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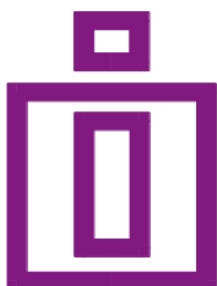
BOOK OF ABSTRACTS
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Table of Contents

Sectoral interlinkages and the role of natural gas sector in India: An intertemporal economic impacts analysis

Topic: Input-output Analysis for Policy Making (2)
Author: Alok ADITYA

This study aims to provide a comprehensive economic assessment of the natural gas sector and its impacts on sectoral output, employment, income, and price level. One of the significant contributions of this study is that it aims to capture the policy dynamics within natural gas and the rest of the economy by incorporating an intertemporal analysis of the effect. It employs the input-output (I-O) method to analyze the sectoral interlinkages and impact of exogenous change in the natural gas sector on the rest of the economy. The findings reveal stronger forward linkages compared to backward ones. The intertemporal dynamics of natural gas show consistent patterns in sectoral linkages, income, and employment impacts, with the strongly linked mining, manufacturing, construction, transportation, and services sectors. This study significantly contributes to sectoral linkage analysis by incorporating both demand-driven and supply-driven input-output frameworks, allowing for a comprehensive exploration of natural gas sector interlinkages. It also examines the intertemporal impact of natural gas allocation on production, value addition, income, and employment, highlighting changes due to different allocation policies. The intertemporal dynamics of natural gas show consistent patterns in sectoral linkages, income, and employment impacts, with the strongly linked mining, manufacturing, construction, transportation, and services sectors. In 2019-20, linkages shifted toward crude Petroleum and services like business, financial, and transport sectors, reflecting policy changes and increased investment in city gas distribution and technology. While income effects slightly increased, employment effects declined, indicating a shift from labour- to capital-intensive production. The findings suggest investment in natural gas upstream sectors to improve its backward linkages while investment in midstream infrastructure to boost the forward linkages. It also suggests formulating gas allocation policies for India based on the sectoral interlinkages of the sector. As India moves toward a balanced energy mix, natural gas will drive growth across sectors. Understanding these linkages is essential for effective policymaking and strategic planning in India's evolving economy.

Trump's climate policy reversal: a dynamic multisectoral analysis for the US

Topic: CGE and Econometric Input-output Modelling (2)
Author: Ludovica ALMONTI
Co-Authors: Stefano DERIU, Francesca SEVERINI

President Trump's announcement regarding the United States' withdrawal from the Paris Agreement places the nation among the countries – Iran, Yemen, and Libya – that refrain from contributing to the global initiative to combat climate change. This decision follows Trump's initial withdrawal from the Agreement during his first term in 2017, and it coincides with a 'national energy emergency' declared by the President, which is aimed at reversing several environmental regulations put forth during the Biden administration. These actions are likely to exacerbate global environmental challenges, particularly in light of the ongoing climate disasters, including droughts, wildfires, and superstorms, that the US is currently facing. Moreover, the Nationally Determined Contribution (NDC) to reduce greenhouse gas (GHG) emissions by 26-28% below 2005 levels by 2025 is thus compromised.
Concurrently, the United States is experiencing an unprecedented surge in fossil fuel production.

Since 2016, there has been a 70% increase in American oil production, and the United States has emerged as the world's leading producer and exporter of oil. A similar trend is evident in the export of liquefied natural gas (LNG), which has grown exponentially from negligible levels in 2016, propelling the United States to the forefront of the global LNG market. The new administration asserts that the President will also put an end to Biden's "Green New Deal", which allocated billions of dollars into clean energy. The actions and intentions of President Trump have the potential to jeopardize the current efforts to transition towards a greener energy and environmentally sustainable production and consumption processes, not only in the United States, but also in all countries involved in the Paris Agreement.

The magnitude, scope, and temporal extent of these decisions require the use of advanced economic instruments, characterized by a high degree of disaggregation and detail, to estimate their effects and delineate the trajectory the country is pursuing. The evaluation of the aggregate, disaggregated, direct, indirect, and induced effects of environmental policies over time can be achieved by developing sophisticated modeling tools that can quantify the impact of the US withdrawal from cleaner energy transition pathways and highlight their implications in terms of social, economic, and environmental sustainability. Dynamic Computable General Equilibrium (CGE) models, calibrated on multisectoral databases, are regarded as a comprehensive numerical framework for estimating the broad socioeconomic impacts of shifting policy directives over time. These models integrate the general equilibrium theory with rigorous microeconomic foundations regarding the optimizing behavior of economic agents and the analysis of equilibrium conditions in the defined time frame. By offering counterfactual ex-ante comparisons in each period, DyCGE models enable the assessment of the tendency of supply-side, demand-side, and distributional effects of policy measures.

The mapping of the transmission mechanisms between the US economy and the environment is performed by constructing the Environmental Social Accounting Matrix (ESAM) for the US, as well as by the development of the DyCGE model based on the ESAM. Indeed, the database and the model can be suitably adapted to accommodate the quantification of the impacts of Trump's anti-climate policy interventions on the full circular flow of income and on key environmental and social variables in disaggregated real and nominal terms. These variables encompass, but are not limited to, emissions associated with sectoral production, natural and energy resources absorbed by production processes as intermediate inputs, private consumption, and welfare. The environmental module involves supplementing the SAM with a set of rows and columns that report GHG emissions by production activity and by commodity for final demand.

The present study proposes a series of simulation scenarios designed to investigate the effects of reforms aimed at dismantling previous environmental protection measures during the duration of Trump's second administration. The ESAM-based DyCGE model for the US is the specific analytical instrument that allows the assessment of the fiscal policies aimed at cutting the climate-oriented public expenditure, triggering changes in production processes and in the composition of final demand over time. The change in production by activity would affect income generation by primary factors and the primary and secondary distribution of income by institutional sectors in each period. This dynamic interplay between production activities has the potential to influence the formation of disposable income for institutional sectors. Furthermore, it may result in varied patterns of allocation of savings and consumption over time, which could have implications for sustainability and economic growth.

Metal footprint and greenhouse gas emissions embodied in South-South trade: a study about the Brazil and China bilateral trade (2000-2019)

Topic: YSI and Development Programme (1) (Discussants: Sanjiv Mahajan and Peipei Tian)
Author: Tiago Ferreira BARCELOS
Co-Authors: Kaio Vital COSTA

The effects of climate change on production and international trade have become a constant concern for policymakers. According to the Intergovernmental Panel on Climate Change (IPCC, 2023), the substantial impacts estimates of climate change on the global economy are the occurrence of the water drawdown, which difficult the food production; the cities and transportation infrastructure, mainly on the cost area, that difficult the economic activity dynamism; and the impact on the health and well-being.

In the last decade, the implementation of policies to mitigate greenhouse gas (GHG) emissions - that is, the greater responsible for the increase in the global average temperature (IPCC, 2018) - has increased, corresponding to the productive decarbonization and energy transition. The Paris Agreement (UN, 2015) has formally attached this compromise through the coalition regime of National Developing Countries (NDC), which aims to reduce emissions and promote more transparency of climate actions. The positive results are observed through the creation of regulatory and economic instruments to increase energy efficiency, the reduction of deforestation levels, and the rapid development of technologies for emissions reduction (IPCC, 2023).

In this sense, countries have implemented strategies to build a low-carbon economy, accelerating the process of energy transition to renewable energy systems. However, as renewable energy is mineral intensive, the process has highlighted the environmental impacts associated with the increase in raw materials and minerals demand (Hund et al., 2020). As each country plays a different role in renewable energy value chains, the growth of renewable power plants has been a another driver of environmentally unequal exchange (Fu er al., 2023).

The environmental extended multiregional input-output (EE MRIO) analysis has been used as an important tool for understanding pollution transfer through trade flows (Steinberger et al., 2012; Grubb et al., 2022) and for the attribution of responsibility (Lenzen, Murray, 2010; Zhang et al., 2020).

Therefore, this paper proposes to use this tool to investigate the pattern of greenhouse gas (GHG) emissions and metal footprint (MF) associated with the bilateral trade pattern between Brazil, China and the Rest of the World (ROW) in the period 2000-2019. Since 2004, China's dynamism has influenced Brazil's export structure, increasing demand for commodities such as mining, livestock, and cereals. On the one hand, Chinese demand contributed to a trade surplus, with export growth averaging 15% since 2010. On the other, this rise in commodity exports led to the "re-commoditization" of Brazil's export structure (Bertola, Ocampo, 2012). Additionally, the growth of Brazilian agriculture has been linked to deforestation, raising GHG emissions through land-use change.

In general, the results show that bilateral trade between Brazil and China follows a North-South pattern, with Brazil being the larger supplier of raw materials and commodities, and China being the larger supplier of industrialized and higher value-added goods and services. The trade pattern is reproduced on the environmental dimension, where agriculture and food production are more CO2e-intensive in Brazil's exports to China, while manufacturing, machinery and equipment are more CO2e-intensive in China's exports to Brazil.

In the total consumption emissions indicator (domestic and foreign) and emissions on international trade (foreign), we observed that Brazil was a greater production-based emissary, while China evolved to a consumption-based with developing economies. In this sense, the results of Net Emissions Carbon demonstrate that Brazil has had a surplus of GHG emissions on

its transactions with China. This result is related to the export volume, the energy efficiency, and the emission intensity of Brazil's export structure.

Finally, in the material footprint analysis, the results indicate that Brazil's role in renewable electricity value chains is in the mining stages, in the categories of bulk and scarce metal ores. On the one hand, these sectors are positively affected by the low-carbon electricity system, which requires more material components than fossil-fuel electricity. On the other hand, the mining sectors generate the largest number of negative environmental externalities.Therefore, based on this analysis and considering the strategic partnership between Brazil and China, we pointed out the principle of shared responsibility (Rodrigues et al., 2006; Zhang et al., 2020) as a reference to design trade policies for these countries.

Compiling time-series of the Dutch input-output table with multinationals and non-multinationals

Topic: Input-Output Accounts and Statistics
Author: Timon I. BOHN
Co-Authors: Robin KONIETZNY, Oscar LEMMERS

This paper discusses ongoing work by Statistics Netherlands on slicing up Dutch IOTs by firm type with a focus on the activities of multinationals (MNEs). Industries in the extended IOTs are broken down into five categories: 1) small non-MNEs, 2) large non-MNEs, 3) small Dutch MNEs, 4) large Dutch MNEs, and 5) foreign MNEs. The analysis provides new insights into the importance of MNEs for the Dutch economy and addresses questions such as: what was the contribution of Dutch MNEs to exports? How many jobs were created by foreign MNEs and how many by small firms? How much capital and labor income was created in small firms due to the exports of foreign MNEs? And to what extent are large firms in the manufacturing sector dependent on small firms in the services sector for their final output?

The method builds upon earlier work on breaking down Dutch IO-tables by multinational status and size class (e.g., see Walhout et al. (2017) and Onat et al. (2018)) and applies it to a more granular level in terms of industries and by constructing a new annual time-series from 2015-2021. The approach uses a short-cut technique implemented by Piacentini and Fortanier (2015) that is based on using shares of different types of firms in trade and production to slice up industries. This is much less demanding in terms of resources as compared to the traditional way of breaking down the supply-use tables themselves. We show that this approach can be used to break down the IOT at a very detailed level while still ensuring a stable time-series. The construction of a stable time-series is crucial yet also an aspect less commonly discussed in the literature on extended IOTs. We ensure that years and results are well-comparable by performing checks and making small adjustments. The paper will describe our experiences, including solutions to several of the problems encountered on the way.

We incorporate a number of different data sources to add this heterogeneity by firm characteristics. Data on firm-level output, value added, and employees (size class) is drawn from Structural Business Statistics, and we make estimations for firms not included in the survey. The data is matched to information on domestic/foreign ownership from the Inward Foreign Affiliates Statistics based on the ultimate controlling institutional unit. It is then matched to information about foreign affiliates yes/no, and together with the ownership information this yields whether a Dutch-owned firm is a multinational or not. Trade data is based on extending the approach of Aerts et al. (2022) by linking firm-level exports and imports at the detailed product level to their multinational status and subsequently matching this to industries in the IOT a way that is fully

consistent with the concept of economic ownership in the National Accounts. In addition, we use firm-level survey data and register data on services trade to provide estimates on this part as well.

One of the particular strengths of the approach is the additional detail present in the underlying data architecture that will pave the way for novel extensions in future work. For example, the firm-level data on multinationals, including matched trade data, can be allocated to the home country of the firm such that the category "foreign MNE" can be further subdivided in the IOT (e.g., into "German MNE" or "French MNE"). Also, the detailed trade data linked to National Account totals is only aggregated away in one of the last steps for the purposes of the current study – i.e., over all firms, products, and destinations for goods and services. We will discuss how we intend to keep this split by product and destination in future work to integrate even more detail into the extended IOT.

The findings show that multinational firms are responsible for about three-quarters of Dutch imports and exports and almost one-third of total value added production, shares that remained remarkably stable over time. Approximately two-thirds of the trade by MNEs is carried out by foreign MNEs and the remainder by (mostly large) Dutch MNEs. The contribution of only foreign MNEs to total output (about a quarter), jobs (12%) and value added (18%) is also substantial. The importance of Dutch multinationals for value-added production has steadily declined since 2015 - both relative to foreign MNEs and as a share of Dutch GDP. We find that when one considers indirect effects, the role of non-MNEs in trade is considerably larger. Well more than half of their earnings from exports is attributable to exports through other firms. This confirms the notion that also these firms participate in trade but do so indirectly via the chain as suppliers of large firms and MNEs rather than via direct exports.

African Inter-Country Input-Output Tables and TiVA Indicators for Enhancing Economic Integration and Policy Analysis in Africa

Topic:
Author: David Gbetongninougbo BOKO
Co-Authors: Clementina IVAN-UNGUREANU, Eleanor Carys Jerram KEEBLE, Leandre NGOGANG WANDJI, Endri RACO, LE WU, Ali YEDAN

African Inter-country input-outputs tables (AfCIOT) and derived TiVA indicators seek to provide critical insights into the domestic and foreign value-added content of exports, facilitating informed policy decisions for the African Continental Free Trade Area (AfCFTA). With these tools, policymakers can better navigate trade and industrialisation policies, foster sustainable economic growth, and enhance regional integration, aligning with the aspirations of African Union Commission's Agenda 2063. AfCIOT and TiVA analysis enable policymakers to understand Africa's participation in global value chains (GVCs), allowing for strategic positioning to maximize value-added exports and enhance economic competitiveness. These tools support the understanding of basic traits in the quest to establish regional value chains and promote intra-African trade and investment by identifying opportunities for cross-border value chains, crucial for AfCFTA's success. Besides, AfCIOT and TiVA indicators are instrumental in supporting industrialization strategies, fostering job creation and sustainable development across Africa. They help policymakers design policies that promote local value-added production, contributing to sustainable economic growth and poverty reduction. By enhancing understanding of intra-African trade dynamics, AfCIOT supports deeper regional integration, aligning with Agenda 2063's vision for a unified and prosperous Africa.

The development of African inter-country input-output tables (AfCIOT) and related TiVA indicators is pivotal for understanding Africa's economic dynamics within global value chains. This initiative, supported by UNECA, OECD, and WTO, addresses the under-representation of African economies in global trade databases.
This paper will primarily focus on presenting the preliminary results for a handful of African pilot countries, providing an analysis of their economic inter-dependencies and TiVA indicators. It will also provide highlights of the methodology for developing AfCIOT which involves using Supply-Use Tables (SUTs), National Accounts, and trade statistics, and addressing data gaps through innovative methods.

The results of compiling EV and its impact on Korean economy

Topic: Special Session: IO Analyses for Electrified Vehicles
Author: Sangdon BU
Co-Authors: Youngho JUNG

The results of compiling EV and its impact on Korean economy

Youngho Jung (Bank of Korea), Sangdon Bu (Bank of Korea)

Electric Vehicle (EV) has been newly created as one of the product sectors from the 2020 benchmark Input-Output tables in Korea. The EV sector was separated from the existing passenger car sector in consideration of the growth potential of the EV industry and the difference in input structure from existing internal combustion engine vehicles. The size of the EV market has been steadily increasing, showing a level of growth that is expected to exceed the sales of non EVs after 2030. Input structure of EV was newly estimated by removing engines and fuel tanks from the input structure of existing car, and by adding batteries, motors, electric converters. The difference in input structure creates a difference in inducement effects on the economy as a whole.

EVs have a greater production inducement effect than conventional cars, but have a lower value added (VA) inducement effect. The EV's production and VA inducement effect can be analyzed by dividing into stages of the value chain. (EV, battery, battery materials)Especially the performance of the battery is the most important component and batteries account for the largest portion of the cost structure. The production inducement effect mainly occurred at the battery stage. The battery accounts for 35.4% of EV's intermediate input, which is why the production inducement effect occurred the most in the battery sector. Meanwhile, the VA inducement effect mainly decreased in the EV and battery material
stages. This is primarily due to the low VA rate of EVs. Because EVs have a small number of parts and a simple assembly process, the labor input is small and the rate of compensation of employees is low. Also, the operating surplus rate is low due to low margins caused by high battery costs. Therefore, the VA created by the EV is low. In addition, as the raw materials of batteries showed high import dependence, the VA that could have been created in Korea was leaked abroad, further reducing the VA inducement effect of EVs.

Recently, the VA overseas outflow on the value chain has changed. Comparing the situation in 2020 and 2023 by stage of the value chain, it can be seen that the amount of imports compared to the output of the battery material is lower, while the amount of imports compared to the output of the battery is higher.This is mainly due to the fact that overseas battery production increases by domestic companies and the batteries are imported to produce EVs in reverse. This

leads to VA outflows. The trend is expected to continue for the time being, given the future investment plans of battery companies.

The VA inducement effect of EVs in the future depends on the conditions at each stage of the value chain. If the VA rate of EVs rises as battery costs are stabilized, domestic production of battery companies expands, and the localization rate of battery materials continues to rise, the VA inducement effect of EVs will rise and vice versa. It seems necessary to pay attention to the impact of changes in the value chain on domestic VA.

Inter-provincial population migration and carbon inequality in China

Topic: Special Session: IO Analysis for Just Transition: Linking Economic Structures and Social Inequality (1)
Author: Yan BU

(1) The research question
This paper focuses on exploring how China's large-scale inter-provincial population migration impacts carbon emissions. In recent years, a large number of people in China have migrated from less-developed regions to developed regions. Meanwhile, the Chinese government has committed to achieving carbon peak by 2030 and carbon neutrality by 2060. Against this backdrop, understanding the influence of population migration on carbon emissions is of great significance. Existing studies have limitations in the mechanism and quantitative assessment of the impact of population migration on carbon emissions. This paper aims to fill this research gap, deeply analyze the impact of population migration on carbon emissions, and provide a basis for formulating regionally coordinated carbon reduction policies.
(2) The method used
The paper adopts an integrated model framework. It utilizes the Geographically Weighted Regression (GWR) model to estimate the marginal effect of population migration on production-based carbon emissions, taking into account factors such as economic development and industrial structure. This model can reflect the spatial heterogeneity of sample marginal effects. The population migration matrix is employed to record population migration information, and the 2017 population migration data is approximated. The Environmentally Extended Multi-Regional Input-Output (EE-MRIO) model is used to calculate carbon emissions driven by consumption and investment, considering the environmental intensity in economic activities. Structural Path Analysis (SPA) is applied to track the embodied carbon emissions in critical supply chains. By comparing the results of factual and counterfactual scenarios, the quantitative impact of population migration on carbon emissions is quantified.
(3) The data used
The research mainly uses data from 2017. The data of independent variables in the GWR model are sourced from the China Statistical Yearbook and China Energy Statistical Yearbook. The population migration data comes from the China Population Statistical Yearbook. The carbon emissions inventory data and the 2017 MRIO table are obtained from China Emission Accounts and Datasets (https://www.ceads.net/). For the convenience of analysis, the carbon emissions inventory data is mapped into the MRIO table, and the 42 sectors in the MRIO table are re-integrated into 30 sectors. The research focuses on the economic linkages among provinces and does not consider import and export factors.
(4) The novelty of the research
The research is innovative in several aspects. Firstly, it innovates in the model framework by integrating the GWR model, population migration matrix, and EE-MRIO model. This integrated

framework comprehensively assesses the impact of population migration on carbon emissions from the perspective of industrial linkages, covering direct carbon emissions driven by consumption and indirect carbon emissions driven by consumption and investment, thus making up for the limitations of previous studies that only focused on residential carbon emissions. Secondly, its research findings are novel. It reveals that although population migration increases the indirect carbon emissions of provinces with net in-migrants, it also transfers more carbon emissions to provinces with net out-migrants, exacerbating carbon emission inequality and increasing the carbon emission reduction barriers of net-out-migrant provinces. It also clarifies the impact of population migration on investment - driven indirect emissions. Thirdly, it has new discoveries at the level of industrial linkages and supply chains. It quantifies the impact of population migration on specific industries, identifies the key industries in net -out-migrant and net-in-migrant provinces where carbon emissions increase due to population migration, and provides a basis for China to formulate hierarchical carbon emission reduction policies.

Keywords: Population migration; Carbon emissions; Multi-regional input-output analysis; Carbon inequality; China

Recent developments in GVCs – evidence from OECD and ADB data in constant prices

Topic: Trade and Global Value Chains Policies (3)
Author: Mattia CAI
Co-Authors: Ricardo CHIAPIN PECHANSKY, Sebastien MIROUDOT, Carmen ZüRCHER

Recent years have been characterized by an intense debate on supply chain restructuring and the reorganization of global value chains (GVCs). The origins of this debate can be traced back to the Great Financial Crisis of 2007-2008, which interrupted a long and unprecedented period of very rapid expansion in international trade. Subsequently, the disruptions associated with the Covid-19 pandemic and a global context of heightened geopolitical tensions brought about widespread preoccupation for supply chain vulnerabilities, as well as increased demand for policies promoting the re-shoring (or friend-shoring) of manufacturing activities.

Against this backdrop, the paper considers three broad empirical questions. First, we assess to what extent the data support the notion that production networks have become less international ('deglobalization') over the past decade or so. Secondly, we examine whether value chains are becoming shorter and more domestic ('re-shoring'). Finally, we look for evidence of value chains being increasingly concentrated within regions ('regionalization').

We look for answers to these questions in global input-output data. Specifically, the analysis relies on two types of input-output indicators: a) the import intensity of production; b) value added embodied in domestic final demand. The import intensity of production reflects the cumulated amount of imported intermediate inputs used in a certain value chain, expressed as a share of its overall gross output. Accordingly, it is a measure of the international fragmentation of production. As such, it places the emphasis on what an economy produces. Conversely, the second type of indicators considered here – which are all based on identifying different sources of value added embodied in a country's final demand – emphasizes what countries consume.

In each case, we use Structural Decomposition Analysis (SDA) to disentangle the effects of different drivers of change. Our SDA exercises focus on two time periods, 2011-2019 and 2019-2023. The former begins after the global economy had recovered from the financial crisis

and ends before the outset the Covid-19 pandemic. The latter covers the subsequent years, which were characterized by various kinds of economic turbulence. The components we seek to isolate relate to composition effects (e.g., the industry mix of an economy's gross output or final demand vector), patterns of outsourcing (as reflected in intermediate-cost-to-output ratios), and intermediate input sourcing (what types of inputs are used and where they are sourced from).

Analyses of this kind call for data to be comparable over time. Specifically, one must be able to separate changes in prices from changes in volumes. This paper draws data from the following two sources: 1) the ADB's Multi-Regional Input-Output database; 2) the OECD's Inter-Country Input-Output database. The former is comprised of a set of tables in constant prices. In the case of the latter, we rely on a yet unpublished dataset in previous year prices which is currently under development at the OECD. While conceptually analogous, the ADB and the OECD databases differ in year and country coverage, as well as in various methodological aspects. Thus, in addition to producing substantive analytical results, the paper seeks to validate the two sets of deflated tables against each other. In this sense, it contributes to ongoing efforts to harmonize the production of global input-output tables across international organizations (e.g. the GIANT initiative).

The preliminary results do not show any evidence of production networks deglobalizing at the world level. In 2022, the import intensity of production reached a historical maximum. The year 2023 marked a decline, but it is still early to tell whether this marks the beginning of a new phase. Although already before the Covid-19 pandemic several large economies had experienced periods in which their import intensity of production declined, SDA suggests this was due to changes in the structure of GVCs (e.g., what they produce, what inputs they use, how much outsourcing they do) rather than to a decline in intermediate trade (where inputs come from).

Similarly, our preliminary findings do not support the notion of value chains becoming more domestic. In the years leading to the Covid-19 pandemic, the foreign content of domestic final demand increased steadily in all advanced economies, driven by changes in consumption patterns (what consumers purchase) and sourcing of both final and intermediate products (where those products come from). Afterwards, the picture becomes more varied, with some countries displaying an increase in domestic content in their final demand. Based on SDA results, however, these changes cannot generally be attributed to changes in the sourcing of intermediate products. Finally, the early results on regionalization are sensitive to the definition of the regions.

Estimating Ownership-Based Bilateral Trade and Its Contribution to World GDP

Topic: Trade and Global Value Chains Policies (4)
Author: Quanrun CHEN
Co-Authors: Hanlin LI, Yuechen WANG

Bilateral trade balance is one of the issues that has garnered significant attention from academia and government. Large trade deficit is often used as a motivation for trade protection policies. However, in the context of the development of foreign direct investment and the expansion of global value chains, countries around the world have been closely interdependent through the establishment of a commercial presence. This has had a subversive impact on the traditional international trade statistics that measure the gains from international trade.

On the one hand, the sales by subsidiaries established in Country B through direct investment

from Country A to the local sectors in Country B are essentially extensions of exports from Country A to Country B. These sales largely reflect the gains of Country A. However, the traditional international trade statistics based on the "rule of residence" do not include these transactions as exports from Country A to Country B. On the other hand, a significant portion of the exports from Country B to Country A are completed by foreign-owned enterprises. However, the ownership of these exports belongs to the foreign enterprises and does not represent the gains of Country B. In addition, to avoid the trade protection in Country A, Country B could establish affiliates in Country C for production and further export to Country A.

Considering the substitutive effect of foreign direct investment on traditional trade, the traditional "rule of residence" for identifying bilateral trade no longer accurately reflects the actual trade benefits of both parties. Academia has been attempting to re-estimate the bilateral trade from the perspective of ownership. Ownership-based trade is identified based on whether the transfer of commodity (service) ownership changes "nationality", rather than whether the commodity (service) is cross-border or not. Therefore, ownership-based trade can be achieved not only through cross-border transactions between resident and non-resident units, but also by establishing a business presence abroad.

This paper attempts to estimate ownership-based bilateral trade and its contribution to world GDP by using the OECD Activity of Multinational Enterprises (AMNE) Database. The novelty includes: i) The "OECD Inter-Country Input-Output table split according to ownership" in the AMNE database distinguishes domestic-owned and foreign-owned firms. We further spilt the foreign-owned firms in these tables according to their parent countries. This provides basic data for estimating ownership-based bilateral trade; ii) We propose a systematic approach to estimating ownership-based bilateral trade by using the "inter-country input-output tables split according to ownership of parent countries"; iii) We evaluate the contribution of ownership-based bilateral trade to world GDP by using inter-country input-output model with hypothetical extraction method and give implications on the potential impact of ownership-based trade protection policies.

The preliminary study finds that horizontal FDI and export platform FDI play a significant role in substituting traditional residence-based trade. Some economies export a large amount of goods and services to its trading partners by establishing affiliates through investments in third countries. For instance, the third-country platforms for U.S. exports to China are mainly distributed in the Asia-Pacific region, including Singapore, Australia, Japan, Malaysia, and South Korea. The gap between China and the United States in terms of FDI has substantially reduced the trade balance between the two sides. The traditional residence-based trade balance seriously distorts trade benefits. Formulating trade policies based on residence-based trade statistics will lead to biases and may even trigger unnecessary trade friction.

Regulating household physical carbon unlocks opportunities for significant and more equitable decarbonization in China: critical insights from multi-regional input-output model for carbon metabolism

Topic: Environmental Input-Output Modelling (1)
Author: Shaoqing CHEN
Co-Authors: Yunwen CHI, Yuhan LIANG

A significant amount of carbon is temporarily stored in products consumed by urban and rural

households, contributing to climate change when released as gaseous emissions through incineration or landfill disposal. Despite the studies of accounting for trade-related physical carbon in product storage, long-term committed GHG emissions from household non-fossil-fuel products remain unexplored. This gap hinders informed and adaptive decisions on optimizing resource efficiency and product end-of-life management to meet the tightening carbon budgets. To address this research gap, we develop a technical framework for quantifying the cross-regional flows of physical carbon and committed greenhouse gas (GHG) emissions based on the multi-regional input-output (MRIO) model. We construct a production-based Physical Carbon Flow Dataset (PCD) that encompasses carbon embedded in five categories of products, including four non-fossil-fuel product categories and fossil fuels, at the provincial level in China, serving as a satellite account for consumption-based physical carbon metabolic modelling. Using this new approach, we track the physical carbon footprint (PCF) of fossil and non-fossil-fuel products driven by consumption in 30 provincial regions of China, quantifying the committed greenhouse gas (GHG) emissions from product end-of-life disposal from 2012 to 2060. Our findings reveal that non-fossil-fuel products accounted for nearly half of China's PCF (406 Mt C) in 2020. Petroleum-derived products and crops collectively contribute 63% to the total non-fossil-fuel committed GHG emissions. Implementing efficient solid waste sorting and landfill gas utilization technologies nationwide could reduce GHG emissions by 75%-86% compared to baseline scenario by 2060 while potentially alleviating interregional carbon inequality. Through linking the carbon metabolic processes with products' life cycles, we develop a system-based approach to quantify the physical carbon in products consumed or temporarily stored in households, as well as the emissions that may result at the end of their service time for the first time.

Economic Vulnerability in the Energy Transition: A Geographical Perspective

Topic: Special Session: Environmental Inequality from a Consumption Perspective
Author: Xiangjie CHEN

Even though the need for a spatially just transition has received increasing attention, little information is known about the detailed geographical distribution of the GDP, employment and wage effect (SDG 8) of the electricity transition required for achieving the Net-Zero goal (SDG 13). This paper provides a novel framework to identify the most vulnerable regions for electricity transition by coupling the state-level GCAM-USA model and the county-level IMPLAN model. Our analysis can guide where the policy interventions should be targeted for achieving a spatially just transition. Moreover, the analytical framework developed in this paper can also be applied to other social goals, such as health (SDG 3), inequality (SDG 11), and poverty (SDG 1).

Risk Propagation and Resilience Analysis in the Global Production Network: A Case Study of the Agricultural Sector under Shock

Topic: YSI and Development Programme (2) (Discussants: Heran ZHENG and Sofía JIMÉNEZ)
Author: Mengyi CHENG
Co-Authors: Rong GUAN, Yifan SUN, Huijuan WANG

This paper takes a global production network perspective and constructs a multilayer network based on the multi-regional input-output data published by the Asian Development Bank (ADB). We use the SIR model to simulate the dynamic propagation process of an initial shock to the agricultural sector within the global economy, and explores the impact of this shock on the

resilience of the global and national economies.

We chose the SIR model as the analytical tool and made innovative improvements to significantly enhance its ability to trace propagation paths. Traditional SIR models, when applied to complex networks, typically report only the number of infected nodes at each time point, without clearly identifying which nodes are infected or revealing the specific infection paths and sources. By incorporating key factors such as node size and edge weight into the propagation process, we further optimized the model's infection rules and propagation mechanisms, enabling precise identification of infection paths and sources and providing a clear depiction of how risks propagate layer by layer in the network. This improvement not only enhances the accuracy of the SIR model in complex network analysis, but also provides a more valuable analytical tool for dynamic risk propagation simulations and network resilience assessments.

First, based on the 2023 multi-regional input-output data, we simulated the initial shock to the agricultural sectors of the United States and Brazil. The results show that fluctuations in the agricultural sector directly transmit to downstream industries that rely on agricultural raw materials. China is significantly affected early on, even before the shock occurs in other countries, due to its heavy dependence on agricultural product imports. The initial shock to the U.S. agricultural sector has a greater impact on the global production network than the shock to the Brazilian agricultural sector. Compared to an initial shock in the computer manufacturing industry, agricultural shocks exhibit faster propagation and stronger diffusion effects. Next, based on input-output data from 2007 to 2023, we conducted a time-series analysis of global economic resilience under the initial shock of U.S. agriculture. We found that the impact of fluctuations in the agricultural sector on global economic resilience is relatively stable. This stability is primarily due to the inherent stability of the agricultural sector itself and the diversified development of the global production network. Furthermore, by decomposing the global production structure and using a counterfactual analysis method, we explored the impact of changes in China's domestic production structure and international trade structure on its economic resilience. The results show that since 2018, the optimization of China's domestic production structure has significantly enhanced economic resilience and shock resistance, while the adjustment of its international trade structure remains insufficient.

The innovations of the research are as follows: (1) We innovatively improved the SIR model by incorporating key factors such as node size and edge weight into the propagation process, optimizing the infection rules and propagation mechanisms. This enhancement allows for the precise identification of infection paths and sources. (2) Based on the simulation results from the SIR model, we developed a comprehensive resilience assessment index, which can be used to measure the overall resilience of the global economy, as well as focus on the resilience of specific countries or industries, providing a new analytical tool for resilience studies. (3) Through counterfactual analysis, we systematically analyzed the impact of the optimization of domestic production structure and the adjustment of international trade structure on the economic resilience of individual countries, revealing key sources of risk and offering a more comprehensive perspective and valuable empirical evidence for designing response mechanisms to external shocks.

Firm subsidies and export: Perspective of supply chains

Topic: International Trade (1)
Author: Wenyin CHENG
Co-Authors: David Tao LIANG, Bo MENG, Hongyong ZHANG

This paper explores the role of industrial subsidies in shaping the export performance of Chinese firms by considering supply chains. By analyzing firm-level subsidy data and inter-provincial input-output tables that include firm ownership information, we distinguish between direct subsidies and indirect subsidies originating from upstream industries. Based on regression models with input-output relationships, the study yields several key insights: (1) Direct subsidies significantly boost both the export engagement and volume of Chinese firms, with a clear positive correlation to investments and R&D spending. (2) Interestingly, upstream subsidies, particularly those from first-tier industries, exert an even stronger influence on export outcomes than direct subsidies, playing a critical role in export expansion. (3) While both domestic firms and foreign-invested enterprises benefit from direct subsidies, the impact of upstream subsidies differs based on the ownership structure of the firm. (4) Both types of subsidies are linked to higher export prices and improved product quality, resulting in a reduced quality-adjusted price. These improvements in export growth and quality are driven by direct subsidies through increased investment and innovation, and by indirect subsidies via enhanced intermediate inputs. Overall, these findings underscore how government support not only fosters export growth but also facilitates quality enhancement, thus bolstering the global competitiveness of Chinese exports. This paper offers new insights into the complex relationship between subsidies and exports, contributing to the broader discourse on industrial policy and government support in the context of global value chains.

Measuring the Impact of Intermediate Import Reduction Using an Input-Output Approach

Topic: International trade (2)
Author: Alena CHEPEL
Co-Authors: Andrey CHERNYAVSKIY

Since February 2022, trade sanctions imposed on Russia have contributed to a reduction in intermediate imports and led to a restructuring of supply chains in the Russian economy. However, the impact of these measures has been less severe than initially anticipated.
In this paper, we calculate the effects of trade sanctions affecting intermediate imports using an input-output approach combined with econometric tools to simulate the output response of certain industries under various import reduction scenarios. The approach used here allows us to obtain relatively moderate estimates compared to those derived from input-output models and published in previous years.
We use Multiregional Input-Output (MRIO) tables provided by the Asian Development Bank for the years 2007–2023 at constant prices. Our analysis focuses on industries most affected by the imposed sanctions, such as electrical and optical equipment, transport equipment, and others. Additionally, we account for the country structure of imports.
We examine how the results depend on whether we distinguish between domestic and imported products as different products or distinguish between products only by their kind. We address this issue in terms of output response similarity. Furthermore, we incorporate output and value-added multiplier calculations to account for interindustry linkage effects. According to our results, under a scenario where intermediate imports used by the machinery sector from sanctioning countries

decline by 10%, the total output decreases by 0.2–0.3%. The proposed method can be easily adapted to other economies and different cases of intermediate import reductions.

Advancing the representation of critical minerals supply chains in the global economic models

Topic: Trade and Global Value Chains Policies (1)
Author: Maksym G. CHEPELIEV
Co-Authors: Ayse Nihal YILMAZ, Dominique VAN DER MENSBRUGGHE

Earlier studies have estimated that achieving ambitious climate mitigation targets will require an unprecedented expansion in renewable infrastructure and technologies, such as wind turbines, solar panels, batteries for electric vehicles, etc., leading to the growing demand for critical minerals and materials, such as nickel, platinum group metals, zinc, rare earths, etc., which are essential inputs for the development of renewable energy systems. Apart from pure supply and logistical constraints, the rising demand for critical minerals and materials is also associated with national security aspects and is prone to generate geopolitical frictions, as mining and processing/refining of many important minerals are concentrated in a limited number of countries. Trade policy interventions are frequent, in particular in the form of export restrictions.

It is important to have the analytical capacity for the assessment of future energy transition scenarios, as well as trade and domestic policies, with an explicit representation of the critical minerals supply chains. The evolution of the latter is impacted by various drivers, including costs of technologies, future changes in incomes and population, the spatial distribution of the minerals' mining and refining capacities, bilateral trade patterns, etc. At the same time, such a level of detail is missing in most global databases and integrated assessment models. In this study, we address this gap by enhancing the Global Trade Analysis Project (GTAP) Database with detailed representations of critical minerals and metals supply chains, including both upstream and downstream activities. GTAP is a global multi-region input-output (MRIO) framework, which is widely used for global and regional economic and environmental modeling.

We start from a refined version of the GTAP 11 circular economy (GTAP-CE) Data Base with the 2017 reference year, which disaggregates the mining and refining of iron, bauxite, copper and other non-ferrous metals ores from a single extraction sector, tracing production and bilateral trade across 160 countries and regions, as well as 99 sectors.

We further disaggregate around 20 additional ores and metals, including lithium, cobalt, rare earth elements, nickel, graphite, manganese, platinum group metals, gallium, silver, phosphorus, chromium, titanium and magnesium, among others. The implemented splits include mining, processing/refining and use stages (downstream sectors, such as magnets, batteries, solar panels, wind turbines, electric vehicles, etc.).

We showcase the application of the newly developed GTAP MRIO Data Base by providing a detailed analysis of the global value chains, tracing the geographical and supply-chain (i.e. across different activities) distribution of the critical minerals, as well as identifying the value-added creation stages in this process. Such estimates would allow to better understand the configuration of these complex value chains and provide important policy insights in the context of import dependency and national security dimensions as the world continues to address climate mitigation challenges.

The next steps of this project will include modeling the wide range of forward-looking climate mitigation scenarios in countries around and analyzing the evolution of critical minerals value chains under alternative policy assumptions.

Implications of the Net Zero Transition Scenarios on SDG Indicators: Linking Global Energy System, CGE and Atmospheric Source-receptor Models

Topic: CGE and Econometric Input-output Modelling (1)
Author: Maksym G. CHEPELIEV
Co-Authors: Amit KANUDIA, Dominique VAN DER MENSBRUGGHE

This study contributes to a better understanding of synergies and trade-offs between climate mitigation and sustainable development goals, covering 17 indicators across various SDGs. Our assessment employs a multi-model framework, which includes a global computable general equilibrium model (ENVISAGE), an energy system model (KINESYS) and an atmospheric source-receptor model (TM5-FASST). This combination of modeling tools allows us to provide a detailed representation of the energy-related SDG indicators while accounting for their interactions with climate mitigation and socio-economic dimensions. We find that out of 17 analyzed SDG indicators, seven experience co-benefits from implementing mitigation efforts (including improved environmental footprints, energy efficiency and clean energy), six SDG indicators are subject to trade-offs (energy and food affordability, economic growth and labor participation), while the remaining four SDG indicators show mixed trends (distributional aspects and energy diversity). The identified trade-offs could be substantially reduced through specific policy solutions. We find that if the revenue collected from carbon pricing is recycled via reductions in factor taxes in selected low-carbon activities, as opposed to lump-sum payments to households, 11 out of 13 SDG dimensions analyzed in this regard would improve—reducing energy prices, increasing the share of renewable energy, improving distributional outcomes and decreasing welfare losses. In addition, we showcase the need for properly capturing interactions across various SDG dimensions by monetizing the co-benefits from improved air quality. We find that such co-benefits outweigh mitigation costs by more than a factor of two, thus changing trade-offs earlier identified for the case of economic growth into synergies. A higher ratio of air quality co-benefits relative to mitigation costs observed for developing countries could also lead to reductions in between-country inequality.

Interregional Input-Output Table for Brazil: A Data-Driven Estimation Using the Brazilian Electronic Invoice System

Topic: Regional Input-output Modelling (2)
Author: Joao Maria DE OLIVEIRA
Co-Authors: Patieene Alves PASSONI

This study aims to estimate an Interregional Input-Output Table (IIOT) for Brazil using a data-driven methodology based on the Brazilian Electronic Invoice System for 2018. The increasing availability of administrative data, such as fiscal records and electronic transactions, enables a more refined and precise approach to estimating these tables, addressing historical limitations related to the scarcity and outdated nature of traditional data sources. Improving input-output table estimation methodologies significantly contributes to the development of more robust economic analyses and evidence-based policymaking.
Originally designed for national applications, Input-Output Models have been applied to subnational geographical units since the second half of the last century. Two specific characteristics of the regional dimension make the distinction between national and regional input-output models essential: the production technology of each region is unique and may be either like or significantly different from that recorded in the national input-output table; and

smaller economies are more dependent on external markets, making imported and exported demand and supply components increasingly relevant. A key advantage of interregional models is their ability to account for spillover effects, which allow for the assessment of how an increase in demand in one region affects others while also considering feedback effects on the region where the initial increase occurred.

This research aligns with the recent trend of producing estimates based on official administrative records, offering a more accurate representation of economic reality. It estimates Brazil's interregional input-output table using data from the Brazilian Electronic Invoice System (NF-e). NF-e data captures most business-to-business transactions, particularly those involving interregional trade, addressing a significant data gap in interregional input-output table estimation. The table was estimated at the States level, ensuring compatibility with the System of National Accounts (SNA) and the System of Regional Accounts (SRA) of the Brazilian Institute of Geography and Statistics (IBGE).

This estimation strategy enables the exploration of key research questions, such as how NF-e data can be used to construct a detailed and accurate interregional input-output table, what is the interregional structure of this table as revealed by NF-e data and how it differs from previous estimates, and what is the input-output table of each of Brazil's 27 states and how it differs from isolated state-level estimations. The methodology involves data cleaning and preprocessing from an extraction of the Brazilian NF-e database for 2018. The study employs product codes from the Mercosur Common Nomenclature (NCM), which aligns with the International Harmonized System (HS), along with seller and buyer sector codes and tax codes that classify transactions. A critical step is applying the Broad Economic Categories (BEC) classification to determine whether products should be classified as intermediate consumption, final consumption (households/government), or gross fixed capital formation.

The key variables include NCM/HS product codes, seller and buyer sector codes, legal classification (public or private), transaction values, product tax information, fiscal classification of the transaction, and geographical data (state of origin and destination). The resulting table is designed for seamless integration with both the SNA and SRA.

As a result, the study presents an IIOT covering 27 states and 68 sectors, capturing also the flow of exports and imports between regions. A version was also estimated considering the 5 Brazilian macro-regions. The novelty of this research lies in the pioneering use of comprehensive and detailed NF-e data to estimate intersectoral and interregional transactions and their economic interactions. Unlike previous interregional input-output table estimations for Brazil, which often relied on national data and approximations, this study uses NF-e data to capture actual interregional trade flows, providing a more accurate representation of economic reality.

The study also discusses the challenges and limitations associated with using administrative data, including data quality issues and classification ambiguities. However, the approach offers a significant advantage by utilizing a data-driven methodology that leverages the detailed and extensive coverage of NF-e data. The research contributes to the advancement of methodologies for regional economic analysis and intersectoral linkages estimation, providing valuable insights for evidence-based policymaking. Potential future research directions include expanding the time series analysis, integrating other data sources for enhanced accuracy, and exploring the dynamic interactions between regions.

Key words: Input-Output Analysis, Electronic Invoices, Brazil, Regional Analysis, Big Data.

Environmental targets and fiscal policies for sustainable growth: a general multisectoral approach

Topic: CGE and Econometric Input-output Modelling (2)
Author: Stefano DERIU
Co-Authors: Claudio SOCCI, Rosita PRETAROLI, Francesca SEVERINI, Giancarlo INFANTINO, Silvia DANDREA, Ludovica ALMONTI

As a member of the European Union (EU), Italy is obligated to adhere to the binding targets established by the EU Effort Sharing Regulation, which aims to reduce the total amount of greenhouse gas emissions by 55% by the year 2030 and to achieve net zero emissions by the year 2050. The Italian-specific commitment entails a reduction of greenhouse gases from designated sectors, including road transport, buildings, agriculture, waste management, and non-energy industries. In this regard, the National Recovery and Resilience Programme (NRRP) and the Integrated National Energy and Climate Plan (PNIEC) have been devised to implement comprehensive structural and sectoral reforms and investments, with the objective of attaining these targets by the year 2030. Despite the notable advancements in terms of reducing greenhouse gas emissions, additional measures are essential to achieve the established targets by the year 2030.

Indeed, the processes of energy and climate transition represent a significant challenge, for which substantial investment will be required, thereby generating considerable tax impacts. The transition will entail a substantial shift in employment between production sectors, and the government will be charged with the implementation of policies to facilitate this structural transformation and protect vulnerable households. In this context, the selection of the most appropriate environmental policy instrument or set of instruments requires an ex-ante assessment of the potential disaggregated economic and environmental impacts of each proposal.

The development of multisectoral general equilibrium models based on national accounts is of particular relevance in this regard, as they are capable of delineating the functioning of economic systems in both aggregated and disaggregated terms. Consequently, they ensure the accurate identification of the transmission mechanisms of policy measures. Dynamic Computable General Equilibrium (DyCGE) models calibrated on Social Accounting Matrices (SAM) are widely applied to inform policy maker decision-making processes across various domains. These models can be extended to evaluate the effectiveness of environmental policies, as they facilitate the incorporation of interactions between environmental and economic variables.

The purpose of this paper is to propose a dynamic extension of the Multisector Applied Computable General Equilibrium Model for Italy (MACGEM-IT) to include the environmental module. The objective of this extension is to provide policymakers with an analytical instrument capable of evaluating the economic and environmental disaggregated direct, indirect and induced impacts of policy measures on the circular flow of income. The environmentally extended dynamic MACGEM-IT model is a SAM-based DyCGE model in which environmental variables are endogenous. These environmental variables are related not only to total production (or consumption) of goods, but also to the abatement capital demanded by production processes to achieve the energy transition target. Indeed, the demand for abatement capital would drive a technological advancement towards less polluting production processes. This can be regarded as a potential avenue for mitigating CO_2 emissions, and by extension, the associated carbon taxes incurred by production activities.

In essence, the model incorporates a mechanism that enables production processes to substitute the utilization of polluting capacity with new capital investment, thereby reducing the burden associated with environmental taxes and enhancing the abatement of emissions. In this regard, the CO_2 emissions would be positively impacted by total production and negatively impacted by

the amount of abatement capital employed in each production process, thus overcoming the supposed trade-off between environmental protection and economic growth. Based on the Italian SAM integrated with environmental flows (E-SAM), the dynamic environmental MACGEM-IT model will be implemented to assess the impacts of hypothetical scenarios of technological transition to greener processes coupled with environmental fiscal policies.

Towards A Resolution of the Capital Conundrums of Trade Theory

Topic: International trade (2)
Author: Neha Shailendra DHANAWADE

Abstract
Four and half decades ago Steedman et.al. (1979) launched a powerful critique of the then, dominant Heckscher-Ohlin-Samuelson (HOS) theory of international trade based on the capital theory debates of the earlier decades and Sraffa's (1960) monograph. The principal theme of their critique was the treatment of capital as a factor of production. They argued that treating capital as an exogenously given endowment (on the same footing as land or labour) is fraught with ambiguities and logical difficulties. The term capital is usually employed in economic theory in a dual sense viz, as a vector of the physical quantities of produced commodities or as the aggregate value of those commodities. In which sense precisely is the term capital meant in HOS theory? If it is considered in the physical sense why are the activities that result in the production of capital goods not spell out in the model? And if the capital endowment is considered in the value sense it implies that quantities and prices of capital goods are predetermined both under condition of autarky and trade. And either way why are capital goods prohibited from trade?
Steedman et. al. (1979) went on to demonstrate that questions of this kind lead to a formal breakdown of the HOS trade theory and raise serious doubts about its ability to explain real world trade. It is true of course that other scholars have from time to time made serious attempts to incorporate intermediate capital goods. Vanek (1963), Sanyal and Jones (1982), and more recently Shiozawa (2017) contain theoretical treatments of the subject. Eaton and Kortum (2002) represent an attempt to incorporate capital goods in the form of a composite capital good, an idea that is now widely employed in the literature. But none of them give explicit treatment to the fact that profits are earned on the value of the heterogenous intermediate (and fixed) capital goods that constitute the capital stocks of the industries. Entirely apart from the purely theoretical drawbacks of HOS theory the late eighties pose new challenges in the form of unprecedented policy initiatives of several nations towards international trade liberalization. Naturally policymakers have been deeply concerned about the consequences of these policies for the economic outcomes in their countries. The HOS apparatus was clearly inadequate for estimating them. Because all that HOS theory concludes is that free trade improves the "welfare" of the trading countries; welfare understood in abstract utility terms. It is unable to translate welfare into objectively measurable economic magnitudes like national income, physical outputs, growth rates, standard of living, etc., which is what policymakers want to know. New methods have therefore been devised relying on the technique of applied and computable general equilibrium theory, which has brought new quantitative trade theory (NQTT) into being.
Method used :
Our quest in this paper is to provide satisfactory treatment of capital and trace its implications for the formulation of trade theory. We propose to achieve this by treating capital in both physical and value senses as unknowns of the system of equations. The system of equations of international general equilibrium include (a) the Sraffa system of prices and income distribution (b) the dual of the Sraffa system to determine the growth rate and the outputs of capital goods (c) fixed share consumption demand equations; (d) Kaldor-Pasinetti model of income distribution

and growth; (e) international market clearing equations for tradable goods and domestic market clearing equations for non-tradable goods.

Data used :

Inferences drawn from the model have been illustrated by extensive secondary literature that has employed GTAP, WIOD, IIOD, EU-KLEMS, UNCTAP, and other databases. Reference may be made here to the empirical studies of Marjit, Basu and Veeramani (2024), Caliendo and Parro (2015) and Walters (2022).

Novelty of Research:

Some of results obtained from the model are as follows:.

1.	Two-country two-commodity trade equilibrium in indeterminate when one or both of the commodities are capital goods.

2.	Trade in capital goods leads to greater rates of growth and profit than trade in consumption goods.

3.	It is perfectly possible for a country to export (import) commodities in adherence to the Heckscher-Ohlin theorem (Leontief paradox) at one and the same time.

4.	Trade invariably benefits capitalists more than workers.

5.	It is quite possible that gains of trade may be negative for workers as measured in terms of prices of exportable and non-tradeables.

6.	It is quit possible that capitalists and workers in one country may gain disproportionately at the expense of capitalists and workers in the other country.

Are we at a watershed? An integrated assessment model for Italy

Topic: Special session: From Basins to Planet: Unraveling Water-economy Interactions across Scales with MRIO Models
Author: Tiziano DISTEFANO
Co-Authors: Raphaël PORCHEROT, Mauro VICCARO, Benedetto ROCCHI, Gino STURLA

As global warming intensifies, the availability of water poses an increasing challenge for countries such as Italy. Italy's socioeconomic structure places significant pressure on domestic and international water resources, especially through imports. In 2014, more than half of Italy's total water footprint (WF, 126,453 Mm³) was sourced from abroad. The agricultural sector is the largest contributor, accounting for 78.6\% of the WF---70.9\% domestically and 83.7\% externally. As climate change concerns grow, efficient water management is crucial, yet research often overlooks the complex interactions between socio-economic factors and water resources.

To address this gap, we extend the EUROGREEN (D'Alessandro et al., 2020; Distefano and D'Alessandro, 2022) model by integrating a new hydrological module that explores the water-economy nexus.

EUROGREEN combines Post-Keynesian macroeconomics and ecological economics into a dynamic macro-simulation model that enables the assessment of various scenarios and public policies regarding their social, economic, and ecological impacts. Among other applications, it has been utilized in France to evaluate the relative merits of green growth, social equity policies (similar to those of the Green New Deal), and degrowth, focusing on the evolution of key variables~\autocite{dalessandro_feasible_2020}. The economy is demand-driven, with factors of production not fully utilized. The investment function depends on the capacity utilization gap, profit rate, depreciation rate, and an autonomous component that does not enhance capacity, which has been identified in the literature as essential for addressing Harrodian instability. The model integrates financial and real sectors through a portfolio model that reflects the demand for financial assets among the population, segmented into 13 groups based on skill levels and

occupational status to analyze the distributional impacts of various public policies. Additionally, the model employs input-output methodology using WIOD tables to disaggregate production across ten sectors, specifically modeling the two industries within the energy sector (fossil fuels; electricity and gas). It incorporates endogenous technical change that influences the technical coefficients of each industry.

The new module evaluates feedback loops and the effects of policy measures on both water and economic outcomes, providing a comprehensive view of their interdependencies. The model introduces an Extended Water Exploitation Index (EWEI), considering variations in water stress by fully accounting for grey water demand and supply constraints. We present initial results from a base scenario and several alternatives, analyzing the impact on agricultural productivity, industrial output, and regional water scarcity.

A sequential scenario strategy is employed in formulating the narratives, facilitating the isolation of impacts attributable to each distinct hypothesis and appraising their cumulative effects. Specifically, each successive scenario is presumed to encompass all preceding hypotheses in addition to introducing a novel singular condition. This methodological approach allows us to isolate the effects of introducing a single new assumption, thereby precluding spurious interpretations. We compare the business as usual, with a scenario with climate damage induced by the RCP 6.0 scenario and another in which the Government invests in adaptation strategies and water efficiency.

The base scenario suggests that endogenous growth and climate change could exacerbate water stress, underscoring the need for integrated water management strategies to ensure socioeconomic stability. However, it appears that similar low EWEI may be induced by climate damage that affects agricultural activities or by a scenario in which damages are recovered by public investments paired with improvement in water efficiency.

Resolving the Fossil Fuel Subsidy Reform Dilemma with Social Protection

Topic: YSI and Development Programme (3) (Discussants: Meng Jing and Richard Wood)
Author: Donghao DUAN
Co-Authors: Xiangjie CHEN

Fossil fuel subsidies, despite their regressive distribution and environmental costs, persist due to concerns over poverty and inequality. This paper uses a Social Accounting Matrix (SAM) model to evaluate the effects of fossil fuel subsidy removal on poverty, inequality, and emissions, and to assess the effectiveness of compensatory policies. A global SAM table is constructed, covering 168 countries, 65 sectors, and 201 expenditure bins, integrating data from the Global Trade Analysis Project (GTAP-v11 for 2017), the World Bank Global Consumption Database (WBGCD), and the Luxembourg Income Study (LIS) data. Unlike previous studies, our compensatory policy scenarios are based on real-world data and offer a cross-country perspective. The model captures household responses to energy price changes, providing deeper insights into subsidy reform's economic and environmental impacts. Our results show that while fossil fuel subsidies are inefficient in supporting low-income households, their abrupt removal without compensatory measures could worsen poverty and inequality. Replacing subsidies with cash-based social protection programs is the most effective approach to support vulnerable populations. However, social assistance policies may partially offset emission reduction benefits, with a more significant impact in emerging economies like China, India, Brazil, Mexico, and Russia. Developing countries, particularly upper-middle-income nations, pose the greatest challenge in phasing out fossil fuel

subsidies. This paper provides a practical framework for subsidy reform that ensures both environmental effectiveness and social protection and emphasizes the need for interdepartmental collaboration in aligning social protection with subsidy reforms.

Water scarcity assessment of provincial energy production in China

Topic: Environmental Input-Output Modelling (7)
Author: Cuiyang FENG
Co-Authors: Ao YU, Lixiao XU

The geographical distribution of energy and water resources in China is reversed, leading to the severe challenge of water shortage in energy production. Some studies have measured the water resource use of energy production through water footprint and virtual water, but they cannot fully reflect the water resource vulnerability of energy production. Based on the input-output analysis method and regional water stress index, this study develops the scarce water footprint assessment model and virtual scarce water trade estimation model to comprehensively assess water scarcity for production activities of different energy types at the provincial level in China. The results show that although the water use for energy production in regions like Ningxia Hui Autonomous Region is not large, its energy production faces a serious water shortage problem due to high water stress. To effectively alleviate the vulnerability of water resources in energy production in the above regions, at the regional level, attention should be focused on virtual scarce water transfer from net outflow areas like Ningxia Hui Autonomous Region to net inflow areas like Shaanxi Province. At the sectoral level, attention should be focused on virtual scarce water transfer from energy industries and agriculture to sectors like petroleum, coking products and nuclear fuel processing products. In addition, the scarce water footprint of different types of energy production varies greatly. It is necessary to develop targeted water management measures for production activities of different energy types. This study calls for incorporating water scarcity into energy production planning in China and strengthening cooperation between energy and water management departments to promote the sustainable development of energy and water resources in China.

Advancing Low Carbon Transition While Reducing Inequality: An Input-Output Modeling Approach to Climate Justice

Topic: Environmental Input-Output Modelling (7)
Author: Kuishuang FENG

Wealth and income are disproportionately distributed across countries and income groups resulting in carbon inequality. UNFCCC aims to keep warming well below 2 degrees Celsius while recognizing developing countries' right to eradicate extreme poverty. Carbon pricing is regarded as an essential tool for curbing carbon emissions and ensuring low carbon transition but can be regressive, in the worst-case increases poverty and moreover lacks universal acceptance among the public and policymakers. Recycling the carbon tax revenue raised to vulnerable households is a promising solution to this issue. Using an Input-Output model, this study investigates the complex interplay between income distribution, consumption, and carbon emissions on an international scale. It specifically addresses the issue of largely divided carbon footprints among various countries and income brackets. In addition, the study addresses the issues associated with the impacts of climate mitigation policies, e.g. carbon taxation, on different household

demographics, with a particular focus on the regressive nature of these policies, as well as proposes strategies to adapt fiscal policies to aid economically disadvantaged communities, thereby promoting equity.

How Does GVC Position Affect CO2 Emissions of Supply Chain Partners?

Topic: Environmental Input-Output Modelling (4)
Author: Xiaoyu FENG
Co-Authors: Yimamu ABASI, Yongming HUANG, Suppakorn KHONKHLONG, xin LI

Global value chains (GVCs) play a crucial role in shaping carbon emissions, as supply chains integrate upstream and downstream firms. Therefore, this study examines the relationship between firms' positions in GVCs and the CO2 emissions of their supply chain partners using a unique dataset of Chinese A-share listed firms, their suppliers, and customers from 2010 to 2014. The findings indicate that: First, firm's GVC position is negatively correlated with CO2 emissions of upstream and downstream firms. Particularly, improved GVC position exerts a stronger impact on CO2 emissions reduction of their suppliers as compare to their customers. Second, mechanism analysis shows that a firm's GVC position influences trade credit within the supply chain and generates positive technological spillovers for both upstream and downstream. These spillover effects are further moderated by green innovative activities of firms. Third, the impact of upgrade in GVC position on CO2 emissions reduction is heterogeneous, varying with the ownership of firms, competition in the industry, participation in processing trade, and their scale. Thus, this study is a significant contribution to literature on the empirical side and establishes new evidence for the role of GVCs in reducing CO2 emissions and classifying crucial mechanisms driving these impacts. These findings suggest actionable insights for policymakers targeting to bring into line global value chains with sustainable development goals.

Macroeconomic Impact of the Next Generation EU Instrument: Analysing Recovery and Resilience Facility Funds by Country, Industry, and Policy Pillars

Topic: CGE and Econometric Input-output Modelling (1)
Author: Valeria FERREIRA
Co-Authors: Luis PEDAUGA, José M. RUEDA-CANTUCHE

The European Commission's Recovery Plan for Europe includes the Next Generation EU (NGEU) funds, which came into effect in 2021. A key component of this initiative is the Recovery and Resilience Facility (RRF), with a total budget of €723.8 billion, comprising both loans and grants. The primary objective of the RRF is to help EU Member States (MS) recover from the pandemic's economic and social impact while promoting a green and digital transition, by supporting six key policy pillars.
Given the limited academic research on RRF's potential impact, this study aims to evaluate its macroeconomic effects across the EU-27 and within each MS. The analysis considers both the direct impact of investments outlined in each MS's Recovery and Resilience Plan (RRP) and the spillover effects of RRF-funded projects in other MS.
To achieve this, the study assesses the economic impact of RRF using the FIDELIO (Fully Interregional Dynamic Econometric Long-term Input-Output) model, which offers a high level of industrial disaggregation across 64 sectors. This enables an in-depth examination of how

investments influence both national economies and the broader EU economic landscape, with particular emphasis on major EU economies such as Germany. To the best of our knowledge, this is the first attempt to capture the direct and spillovers of the RRF with such a disaggregated sectorial level. While studies such as Barbero et al. (2024) have analysed the macroeconomic and distributional impact of the RRF at a regional level, they have done so with a very low level of disaggregation, including only 10 industries. Moreover, the analysis of this study can be disaggregated to consider the impact of the RRF within each European Commission pillar, with a particular focus on the green transition and digital transformation.

The RRF allocates financial resources up to a total value of €655 billion to EU MS, consisting of €364 billion in grant funding and €291 billion in loan assistance. Grants are non-repayable financial contributions that directly boost national economies, whereas loans must be repaid but are offered at favourable terms, including low interest rates and extended repayment periods. The allocation of grants considers the pandemic's economic impact on each country, along with their specific reform and investment needs.

Each MS must develop an RRP detailing how funds will be invested until 2026. This study analyses the distribution of grants and loans by country, sector, and policy pillar, using data from the European Commission's Directorate General for Economic and Financial Affairs (ECFIN). The FIDELIO model, a multi-sector Dynamic General Equilibrium economic model developed by the European Commission's Joint Research Centre, simulates the economic and sectoral effects of RRF investments. Version 4 of FIDELIO has been used, incorporating improvements over previous versions.

As an Input-Output model, FIDELIO is able to capture all sectoral spillover and dependency effects of any policy under analysis due to its granularity in terms of economic sectors and regions. In fact, the model is based on official statistics from Eurostat's FIGARO, with a breakdown of 64 NACE industries and covering 45 countries (EU 27 Member States, its main 18 EU trading partners, and an aggregate region of RoW). The model's granularity in terms of economic sectors, coupled with its capacity to capture sectoral spillover and dependency effects, renders it a valuable asset for conducting policy impact assessments.

The simulation models a demand-driven economic shock of €655 billion from the RRF, allocated across countries and industries between 2020 and 2026, differentiating between grants and loans. The model incorporates a 30-year repayment period for loans, with a seven-year grace period and an interest rate aligned with the European Central Bank's refinancing operations.

The study assesses the impact of RRPs on key economic indicators such as GDP. By examining both direct and spillover effects, the analysis provides insights into how national investment plans contribute to economic recovery and sectoral transformation.

In consideration of the unprecedented and substantial significance of the RRF funds, this analysis is of paramount importance, as it provides scientific evidence of their impact, not only on individual countries but also at the industry level, thanks to the characteristics of the FIGARO database and the FIDELIO model.

Furthermore, it provides insight into both the direct effects and the spillover impacts generated when an investment in one country affects another, due to the linkages between them. The spillover effects of such investments are frequently not immediately apparent, and thus this analysis is instrumental in revealing the true impact of the funds. Additionally, the ability to assess the impact of the funds considering each industry as well as the six policy areas pillars is highly valuable.

Relative Advantage Production Position in the Global Value Chain

Topic: Input-Output Theory and Methodology (1)
Author: Xiang GAO

As the global value chain has become a popular topic in the past couple of decades, the measurement of production position in the global value chain has been a hot and essential issue discussed by researchers. This paper defines a new indicator—the relative advantage production position (abbreviated as RAPP)—which is based on the input-output model and Layer Lemma. The paper also produces an algorithm to calculate RAPP. An industry's RAPP is measured as a certain step in the global value chain. At this step, the industry's relative output is more than that at the step nearby. RAPP not only indicates the position of the industries or economies in the global value chain as other indicators do but also more appropriately answers the question: at which step does a certain industry play an important role in the global value chain? To further examine RAPPs, the paper conducts an empirical analysis based on several national input-output tables and world input-output tables to test the hypotheses drawn from the definition of RAPP. There is also a discussion on the differences between RAPP and two popular indicators and its limitations.

Both mechanisms make PV trade barriers counterproductive in protecting local employment

Topic: Industrial Ecology
Author: Yiying GAO
Co-Authors: Xinzhu ZHENG, Xinzhu ZHENG

One of the original intentions of imposing trade barriers is to protect local employment, but after innovatively coupling the GSIM trade model and the global multi-region input-output table (MRIO) model, we found that both mechanisms have the opposite effect on this protection. One is that employment in the photovoltaic industry does not only occur in the manufacturing process, but installation and operation are also labor-intensive and only occur locally. Affected by this mechanism, although trade barriers do protect manufacturing employment by increasing production, the resulting price increases suppress local demand for photovoltaics, ultimately leading to a reduction in employment opportunities in installation and operation. Taking the trade barrier policy of the United States from 2012 to 2021 as an example, compared to the free trade scenario, the barriers have increased the number of local photovoltaic manufacturing jobs by 10000, but reduced installation and operation by 65000. Another important discount mechanism is that the reduction of photovoltaic output in other countries is transmitted through the industrial chain to impact the export of related industries upstream and downstream, ultimately restraining the reduction of employment opportunities in these industries. Taking the US trade barrier policy as an example, although the US electrical machinery and equipment manufacturing industry gained 12000 job opportunities between 2012 and 2021 due to the increase in photovoltaic output under this policy, the decrease in photovoltaic output in other countries resulted in a loss of 3000 job opportunities in other local industries, resulting in a 25% reduction in employment protection effectiveness. Based on the above two impact mechanisms, trade barriers have had a negative impact on the US job market.

Reexamining Patterns and Competitiveness under the Trade in Factor Income through Global Value Chain

Topic:
Author: Yuning GAO
Co-Authors: Meichen ZHANG, Bo MENG, Xuetian WANG, Jiaxin LI

The current misunderstanding of trade imbalance is mainly caused by the inconsistency between the assumptions of traditional trade statistics and modern trade based on global value chains. While traditional trade statistics are premised on goods crossing their own borders, in the era of global value chains, goods crossing borders is no longer a necessary condition for trade realization. The factory-less manufacturing method of multinational enterprises and the sales method of entering other countries' markets through foreign direct investment have become typical features and prevalent phenomena of global value chain trade. In view of this, this paper follows a new concept of "Trade in Factor Income ", that exports are defined as the exporter's factor income used to meet importer's final demand, based on the characteristics of global value chains. This paper constructs a long series global input-output model based on the OECD's AMNE-ICIO database that takes into account firm heterogeneity and a bilateral FDI stock database covering 20 sectors in 35 countries. It further decomposes factor income in value added formation, forms a new measure of bilateral trade balance accounting, and re-estimates the trade balance and competitiveness of main economies from 2005 to 2018. The scientific measurement of bilateral trade between main economies is important for resolving bilateral trade disputes, comprehensively assessing the true extent to the benefits from trade and promoting bilateral trade cooperation.

GVCs and Embedded Carbon Emission Dynamics: Implications of CBAM for EU Downstream Sectors

Topic: YSI and Development Programme (4) (Discussants: Satoshi INOMATA and Kailan Tian)
Author: Shifali GOYAL
Co-Authors: Debashis CHAKRABORTY

Research Question:
Global Value Chains (GVCs) have transformed international trade by distributing production stages across multiple countries, complicating the attribution of greenhouse gas (GHG) emissions to specific nations. While GVC participation has contributed to economic growth, it has also increased emissions embodied in trade. To prevent carbon leakage and mitigate emissions, the European Union (EU) has implemented the Carbon Border Adjustment Mechanism (CBAM), which imposes a levy on certain carbon-intensive imports. However, its potential consequences for EU manufacturers, particularly downstream sectors reliant on emissions-intensive imports, remain underexplored. This study addresses the following research questions: (1) How have emissions embedded in GVCs evolved across regions and sectors? (2) How have domestic and foreign emissions associated with EU production shifted over time, and what are the possible implications of CBAM for EU manufacturers? (3) How are emissions embedded in EU imports from key developing economies, such as China and India, absorbed within GVCs, particularly in downstream value chains? Are they primarily used for final consumption within the EU or as intermediate inputs for further value addition?

Methodology:
This study employs a Multi-Regional Input-Output (MRIO) model, a widely used framework for

tracing emissions through GVCs. The MRIO model allows for a detailed assessment of how carbon emissions are generated, transferred, and absorbed along GVCs. Using this model, we assess the potential impact of CBAM on production costs and competitiveness of EU downstream industries.

Data:
The analysis utilises World Input-Output Tables (WIOT) from the World Input-Output Database (WIOD). These MRIO tables provide detailed inter-industry and inter-country trade relationships, allowing for an in-depth examination of emissions embedded within GVCs. Carbon emissions accounts are sourced from the Joint Research Centre of the European Commission.

Findings:
The results reveal that the growing integration of developing economies, particularly China and India, into GVCs has led to increased emissions generation in these countries, with increased carbon footprint in developed economies such as the USA and the EU. Consequently, the EU's net imports of embedded carbon emissions have risen, making it more reliant on emissions-intensive imports.
Within CBAM-covered sectors, a significant share of imported emissions is further absorbed in downstream value chains, such as manufacturing industries that process raw materials into higher-value goods. This suggests that CBAM, while addressing carbon leakage, may also increase input costs for EU manufacturers, potentially reducing their global competitiveness. The findings further indicate that as CBAM expands to cover more sectors and free allowances under the EU ETS are phased out, these effects could become more pronounced, requiring policy interventions to mitigate competitiveness risks. The findings suggest that coordinated international climate policies may be required to balance environmental goals with trade and competitiveness concerns.

Novelty of the Research:
This study contributes to the literature by offering a novel analysis of GVCs and environmental policy. It provides insights into the dynamics of emissions embedded in international trade. Unlike prior studies that focus on impacts of CBAM on the EU's trade partners, this research assesses broader implications of CBAM on EU manufacturers within GVCs and offers new insights into the evolving structure of emissions-intensive trade and its policy implications.

Counting the Cost: Short-Term Implications of CBAM and Domestic Carbon Tax in India

Topic: Social Accounting Matrix and its Applications
Author: Shifali GOYAL

Starting in January 2026, the European Union's Carbon Border Adjustment Mechanism (CBAM) will impose a carbon price on imports from high-emission intensive sectors from countries without comparable carbon pricing mechanisms. For India, which currently lacks a carbon pricing mechanism, this policy raises concerns about the competitiveness of its exports, particularly in carbon-intensive sectors such as Iron & Steel and Aluminium, which constitute a significant portion of its trade with the EU. In this context, this study seeks to address two critical research questions: (1) What is the CBAM-equivalent tariff on India's exports to the EU? and (2) What are the short-term economic and environmental impacts of a domestic carbon tax as a potential response to CBAM?
The CBAM-equivalent tariff is estimated using an accounting framework that calculates the additional cost imposed on Indian exports under different emissions coverage scenarios. Our

findings indicate that approximately one-fourth of India's total Iron & Steel and Aluminium exports are destined for the EU, making these sectors particularly vulnerable to CBAM-related trade distortions. Using official export data from the Government of India and emission intensity estimates from the Joint Research Centre of the European Commission, we estimate that the CBAM-equivalent tariff could range from 11.3% to 13.5% for Iron & Steel and from 3.9% to 25.5% for Aluminium, depending on whether only direct emissions or both direct and indirect emissions are considered. These findings underscore the financial implications for Indian exporters, who may face reduced competitiveness in EU markets due to CBAM.

To assess the short-term economic and environmental implications of introducing a domestic carbon tax as a countermeasure, we employ an Environmentally-extended Social Accounting Matrix (ESAM) for India for the year 2021–2022. This approach enables an economy-wide evaluation of the policy's impact across various sectors and household groups. Our analysis considers three policy scenarios, including a scenario where the carbon tax is combined with a reduction in existing indirect taxes, i.e. the Goods and Services Tax (GST).

The results indicate that while a carbon tax is effective in reducing CO_2e emissions, it has a limited but regressive impact on household welfare, potentially exacerbating income inequality. At the macroeconomic level, the broader economic effects remain moderate, with industries experiencing a slight decline in output due to higher production costs. Notably, when the carbon tax is implemented alongside a reduction in indirect taxes, the economic burden on industries and households has reduced.

This study makes a novel contribution to the growing literature on CBAM and domestic carbon pricing strategies. While existing research has examined the potential impact of CBAM on Indian industries, this study is one of the first to assess the economic and environmental trade-offs of a domestic carbon tax combined with targeted tax reductions in a developing country context. By proposing a policy mix that balances trade competitiveness, economic stability, and climate action, this research provides valuable insights for policymakers navigating India's response to CBAM. As India considers its strategic options in light of evolving international carbon pricing regulations, a carefully designed domestic carbon pricing policy could serve as both a trade strategy and a climate mitigation tool. While the immediate economic costs of a carbon tax alone cannot be ignored, integrating such a policy with targeted tax reductions presents a viable pathway to minimize trade disruptions, support vulnerable industries, and advance India's environmental commitments.

Research on regional digitalization effect and its influencing factors in China from the perspective of firm heterogeneity

Topic: Special Session: Digital Input-output Accounting: Methodology and Applications (2)
Author: Xuefan GUO
Co-Authors: Kunfu ZHU

At present, digital transformation has become an important engine to promote China's economic growth under the new development pattern. However, unbalanced development has caused the problem of digital divide, which limits the healthy and sustainable development of economy and society. Based on China's inter-regional input-output model that distinguishes enterprise heterogeneity, this paper constructs a digital accounting framework to quantitatively analyze the characteristic differences of the digital level of enterprises in different regions, industries and ownership in China, explore the "digital divide" problem generated in the process of China's digital development, and further analyze the main driving factors in the process. The basic data used in this paper include the inter-provincial input-output table of China that distinguishes enterprise ownership in 2002, 2007, 2012 and 2017 compiled by Chen et al. (2023), as well as

the digital data published by China E-commerce Research Center and National Bureau of Statistics.

The major contributions are as follows: (1) By dividing the content of embedded factors into digital activities and non-digital activities, a unified digital accounting framework is constructed at the production level, and China's digital level index is defined from the perspective of backward industrial correlation to supplement the research on China's domestic and cross-border digital accounting; (2) Add enterprise ownership information on the basis of region-industry level, measure the current situation and development trend of China's digitalization scale and digitalization level from three dimensions of region-enterprise-industry, and discuss the "regional digital divide" and "enterprise digital divide" generated in the process of China's digitalization development; (3) The time and spatial structure decomposition method is adopted to conduct an in-depth analysis of the factors affecting the change of China's digitalization level, focusing on identifying the key driving forces promoting the growth of China's digitalization level, and interpreting the role of Hong Kong, Macao and Taiwan invested enterprises and other foreign invested enterprises in the differentiated development of digitalization level in China's provinces.

Leveraging Machine Learning in Input-Output Economic Modeling

Topic: Input-Output Theory and Methodology (2)
Author: Kehan HE
Co-Authors: Zhifu MI

The Input-Output (IO) model is instrumental in analyzing economic interdependence by tracking how output from one sector serves as inputs for another. Despite its successful applications, the IO model faces challenges such as time lags and inaccuracies due to the labor-intensive nature of compiling IO tables, which are typically updated only every five years. To address these limitations, this research explores machine learning as a promising alternative for estimating and forecasting economic structures based on the IO model. Machine learning can uncover complex relationships between socio-economic parameters and IO structures without relying on intricate economic theories, offering a cost-effective method for predicting economic changes.

The research assumes that a country's development follows a trajectory defined by socio-economic indicators, such as education level, capital and resource availability, and trade statistics, which in turn determine its economic structure over time. By utilizing publicly available socio-economic data from the annually updated World Bank Development Indicators, the study circumvents the challenges of constructing IO tables through labor-intensive surveys by applying the latest machine learning techniques. Using OECD annual IO tables, the IO tables in this research are aggregated into nine sectors—Food, Chemical, Mining, Transport, Heavy Industry, Manufacturing, Energy Consumption, Construction, and Service—to reduce computational demands. A Random Forest algorithm is employed to predict sector-to-sector production ratios, thereby constructing an IO structure using 829 indicators from the World Bank Development Indicators to train models for each element of a 9x9 IO table for each country.

The results demonstrate the promising potential of this method. When defining relatively accurate predictions as those ranging from 50% to 200% of the true value, 27% of the IO table cell data in the testing set fall within this range. Additionally, the accuracy of predictions varies across different countries and sectors. For example, the service sector shows an accuracy rate of 44%, indicating that its contribution to the economic structure, as described by the IO table, can be more precisely estimated using the World Bank Development Indicators employed in this research.

To further illustrate the model's potential as a viable alternative to complex economic models, a sensitivity analysis was conducted on economic structure changes in response to variations in the

renewable energy ratio for Vietnam. The simulation reveals a nonlinear pattern of economic structure change with an increased renewable energy ratio. For instance, when the renewable energy ratio increased from 15% to the current level in Vietnam, the contribution of the chemical sector to energy consumption decreased by 0.4%, while its contribution to itself increased by 0.5%. If the renewable energy ratio were to rise to 30%, the changes in the chemical sector's contributions to all other sectors would be minimal, limited to less than 0.1%.

Overall, this method shows great potential in economic research and represents a significant advancement in IO modeling by integrating it with the latest developments in data science and machine learning. However, the research was constrained by computational hardware limitations, preventing the inclusion of more parameters and a more detailed breakdown of IO sectors. Future advancements could be achieved by incorporating additional parameters from multiple sources and applying better computational devices to enhance the model's performance.

Unequal distributions of consumer responsibilities in driving grid-level freshwater boundary exceedances

Topic: Special Session: Environmental Inequality from a Consumption Perspective
Author: Siyu HOU
Co-Authors: Xu ZHAO, Huo JINGWEN, Xinxin ZHANG

Freshwater use has exceeded freshwater boundaries in many regions, with site-specific depletion is driven by consumption both within and beyond the regions of production. The consumer responsibilities are unevenly distributed across households, posing risks to both sustainability and equity. This study examines the unequal distribution of consumer responsibilities by attributing regional freshwater boundaries (RFB) exceedances to consumers across different income levels using the multi-regional input-output (MRIO) model. The analysis reveals significant disparities in consumer contributions to RFB exceedance. Populous middle-income countries disproportionately contribute to the global RFB exceedance footprint, while high-income countries exhibit distinct non-agricultural contributions. Low- and middle-income countries show agricultural-dominated RFB exceedance footprints, with marked inequality in middle-income countries. These findings highlight the urgent need to address water inequality to achieve Sustainable Development Goals (SDGs), particularly SDG 6 (Clean Water and Sanitation), SDG 10 (Reduced Inequalities), and SDG 12 (Responsible Consumption and Production). By identifying inequitable consumption patterns, this research provides critical insights for policymakers to promote equitable resource allocation, sustainable freshwater management, thereby ensuring a safe and just society.

An Impact Assessment of the Motorcycle Electronification Policy in Taiwan: From the Economy-Energy-Environment (3E) Perspective

Topic: Special Session: IO Analyses for Electrified Vehicles
Author: Shih-Hsun HSU
Co-Authors: Ching-Cheng CHANG

(1) the research question: As the problem of global warming becomes increasingly serious, countries regard electric vehicles as a key measure to reduce carbon emissions. Asia countries are highly dependent on motorcycles, with Taiwan ranking at the top in terms of motorcycle density (followed by Vietnam, India, Malaysia and Thailand). As of October 2023, there are 620 motorcycles per thousand people, and the number continues to increase. Taiwan government plans to completely ban the sale of fuel-powered motorcycles by 2040 and achieve a 100%

market share of electric motorcycles. It places special emphasis on the localization of the supply chain and fosters the local electric motorcycle industry through subsidies, research and development, etc.

(2) the method used: This paper applies the dynamic computable general equilibrium model (CGE) and the newly released 2021 Taiwan Input-Output Table.

(3) the data used (if any): Due to the data restriction on an aggregated motorcycle sector, the related industry classification in Taiwan consists of motorcycles, electric vehicles, etc. However, in order to explore the development of Taiwan's electric motorcycle industry, the cost structure and distribution flow of electric motorcycles in the original motorcycle sector must be identified and calibrated. It will be separated into another independent sector to facilitate the subsequent appropriate assessment of its impact on industrial development, energy use, environment, etc.

(4) the novelty of the research: This paper analyzes the impacts of Taiwan's motorcycle electronification policy from three perspectives: economy, energy, and environment. We also designed several policy scenarios, such as using subsidy incentives to increase electric motorcycle sales and banning the sale of fuel motorcycles, to explore the impact of different scenarios on the electric motorcycle industry chain. However, these policies will also bring structural shocks to the traditional fuel-powered vehicle market. Therefore, we explore the impact of electric vehicle development policies on the overall economy, industrial development, and changes in employment demand from an economic perspective. In addition, the promotion of electric motorcycles will significantly reduce dependence on petroleum gasoline, help Taiwan's energy structure adjustment, and promote the transition to green energy.

As the proportion of renewable energy increases, Taiwan's electricity carbon emission coefficient will be significantly reduced, further reducing carbon emissions over the entire life cycle of electric motorcycles and laying the foundation for achieving the net zero emissions target by 2050. This process will not only have a positive impact on the environment, but will also promote the joint development of the economy and energy, and promote Taiwan's steady progress in the global green transformation path. Therefore, motorcycle electronification policy is not only an effective means to address climate change, but also a key strategy to achieve sustainable economic growth in Taiwan.

Disaggregating the Steel Sector in MRIO: Global Supply Chain Variations in BF-BOF and EAF Steelmaking

Topic: International Trade (1)
Author: Seiya IMADA

Global crude steel production in 2023 is estimated at approximately 1,900 million tons. SMS Group predicts that iron and steel demand will increase by 24% from 2024 to 2050. Steel is essential to daily life, with 52% of global steel products used in buildings and infrastructure and 12% in automobiles. This indicates the widespread use of iron and steel across industries. In 2023, about 280 million tons of steel were traded through global supply chains (GSCs), representing 15% of total steel usage that year.

However, the iron and steel sector is a major CO2 emitter, with direct emissions estimated at 2.6 billion tons of CO2, accounting for 7% of global CO2 emissions. These emissions arise from domestic final demand, such as household consumption, and global final demand from sectors like construction and automotive. Identifying CO2 emission hotspots in GSCs within the steel

sector is crucial for reducing sector-wide emissions.

Many studies have analyzed CO2 emissions from GSCs using multi-regional input-output (MRIO) tables. However, conventional MRIO frameworks aggregate crude steel production and steel products into a single sector, failing to capture differences in steelmaking processes. The blast furnace-basic oxygen furnace (BF-BOF) and electric arc furnace (EAF) methods differ significantly in raw materials (BF-BOF: coke; EAF: steel scrap) and applications (BF-BOF: structural frames for buildings, infrastructure, and automobile bodies; EAF: rebar and steel plates). These distinctions result in significant differences in environmental impact and supply chain structures.

This study clarifies GSC differences between BF-BOF and EAF and variations in GSCs among countries using the same steelmaking technology. A key contribution of this research is the use of TransitionZero's Global Steel Cost Tracker (GSCT) to disaggregate the steel sector in GLORIA for six countries—China, India, Japan, South Korea, Russia, and the United States—into four subsectors: pig iron, basic oxygen furnace (BOF), electric arc furnace (EAF), and steel products.

This study utilizes 2021 GLORIA MRIO data, covering 164 countries and 120 sectors. To expand the steel sector into four subsectors—pig iron, BOF, EAF, and steel products—the following data sources were used: (1) global steel production data and BF-BOF to EAF ratios from the World Steel Association, (2) country-specific steel production cost data from GSCT, including raw materials (coke, direct reduced iron [DRI], iron ore, scrap), energy (electricity, fuel), labor, and other costs, and (3) Japan's 2015 input-output table, which disaggregates the steel sector similarly.

Our findings highlight key differences in intermediate input structures between BF-BOF and EAF. In the BF-BOF process, iron ore and coke dominate intermediate inputs, accounting for over 70%. In contrast, in the EAF process, electricity and wholesale/retail trade contribute approximately 25%, demonstrating significant structural differences. A comparison of Japan and China's BF sectors shows that China sources about 50% of its iron ore domestically, while Japan imports approximately 96% of its iron ore, underscoring Japan's heavy reliance on imports.

Across countries, BF-BOF consistently depends on iron ore and coke, but EAF input structures vary significantly. In Japan, domestic retail and electricity sectors rank among the top three input sources for EAF. In Russia, domestic gas supply and natural gas extraction are among the largest inputs. These differences likely stem from technological and resource variations. Japan's EAF primarily relies on steel scrap, whereas Russia's EAF incorporates direct reduced iron (DRI) produced with reducing gas, leading to substantial differences in input structures.

These findings emphasize that steelmaking method selection impacts raw material use and that input structures vary significantly across countries, even within the same steelmaking process. By leveraging GSCT data, this study successfully disaggregates the steel sector in GLORIA by steelmaking method, revealing distinct input structures and cross-country differences. The results contribute to a better understanding of GSC-related CO2 emissions and provide insights for policymakers and industry stakeholders seeking to reduce emissions in the steel sector.

Measuring exposure to network concentration risk in global supply chains: Volume versus frequency

Topic: Trade and Global Value Chains Policies (2)
Author: Satoshi INOMATA
Co-Authors: Tesshu HANAKA

In this paper, we present new referential statistics for the degree of supply chain exposure to network concentration risk. The study's contribution rests on the development of a metric that indicates network concentration in terms of the frequency of supply chain engagement with the regions of analytical concern, alongside the traditional approach based on volume measurement of value-added concentration.

Japan, a country with a high propensity to encounter natural hazards, and China, under mounting geopolitical tensions with the United States, were chosen as the target regions for the analysis. The study followed a line of techniques in input-output economics yet with methodological augmentation employing a compatible analytical framework in network theory. Using the multi-country input-output tables constructed by the OECD, the following findings were presented. The supply chains of the selected industrialized economies are generally more concentrated in China than in Japan. For Japan as a target region, Taiwanese industries stand out for being dependent on the country, especially in regard to the share of value-added origins.

Focusing on the ICT equipment industry, the supply chains of Korea and Chinese Taipei are most exposed to concentration risk in China, both in terms of volume and frequency. In contrast, the US supply chains present an interesting case; the low concentration of its value-added origin in China may be a straightforward reflection of the sheer size of the US economy, while its frequent exposure to China's geographic territory is associated with the likelihood of being caught by contingencies in the country.

In general, the two metrics of network concentration in the volume and frequency terms were positively correlated. However, the above US case suggests that only considering the volume side may lead to a significant underestimation of the overall exposure to a country risk in supply chain management.

Finally, the analysis of mutual risk positions for the US and China's supply chains revealed a notable asymmetry in the dependence structure between the two countries, posing a significant concern on the feasibility of the "friend-shoring" strategy by the US government.

Environmental Consequences of Population Concentration in Mega-City Tokyo

Topic: Environmental Input-Output Modelling (5)
Author: KAIRI INOUE
Co-Authors: Shigemi KAGAWA, Sho UEHARA

The concentration in Tokyo refers to the phenomenon that population, industry, and economic activities are excessively concentrated in Tokyo, the capital city in Japan, and its surrounding areas. While the total population of Japan is decreasing, the population of Tokyo is increasing. According to government projections, the population of Tokyo is expected to continue to increase. Therefore, it is anticipated that the population imbalance toward urban cities will

continue to accelerate.

If the concentration of people in Tokyo and other metropolitan areas becomes more severe, serious issues may arise, such as the intensification of the urban heat island effect, leading to higher temperatures in city centers, worsening air pollution, and increased CO2 emissions triggered by excessive electricity consumption and high final demand of goods and services. In response, the Tokyo government has set a goal to achieve a carbon-neutral society by 2050. Therefore, mitigating the over-

concentration of population and resources in Tokyo is a critical issue. To address this, the Japanese government has introduced various policies aimed at reducing population concentration in Tokyo. As a representative the Cabinet Office of Japan Announced "Digital Garden City Nation Initiative", aiming to achieve a net annual population outflow of 10,000 people from the Tokyo metropolitan area to regional areas by 2027.

The purpose of this study is to analyze the environmental impacts of mitigating population concentration in Tokyo. We use input-output table of Tokyo Prefecture in 2015 and migration flow data for each prefecture in Japan. Firstly, to identify the factors contributing to population growth in Tokyo, we conducted a multiple regression analysis. We use migration flows data between Tokyo and other prefectures as the dependent variable and included population density, per capita prefectural income, and employment ratios across primary, secondary, and tertiary industries as the independent variables.

Based on the migration inflows to Tokyo estimated through multiple regression analysis, we projected population changes in Tokyo and its surrounding areas under relevant economic scenarios. We then determined the final demand required for these population changes in Tokyo. Additionally, using environmentally-extended input-output analysis, we evaluated the environmental impacts of migration-induced changes in final demand for Tokyo, quantifying the consumption-based CO2 emission reduction potential associated with the government's policies to mitigate population and resource concentration in Tokyo.

The results indicate that a higher proportion of the population engaged in primary industries and higher per capita prefectural income significantly influence migration flows in each prefecture. The findings also suggest that an additional increase of 94,000 JPY in per capita annual prefectural income across 46 prefectures is required to achieve a net annual outflow of 10,000 people from Tokyo.

Furthermore, we estimated the potential CO_2 emission reductions in Tokyo resulting from the mitigation of population and resource concentration. The CO_2 reduction potential associated with a net outflow of 10,000 people from Tokyo is estimated at 48 kt-CO_2, with significant contributions from the electricity, food, telecommunications, and transportation sectors. Based on these findings, we propose effective policies to mitigate over-concentration in Tokyo and promote a sustainable urban lifestyle, focusing on the key sectors identified in this study.

Efficiency through evolution: Comparing Darwinian and comprehensive approaches in agent-based economic forecast modeling

Topic: Input-output Analysis for Policy Making (1)
Author: Martin JARAIZ

This presentation explores two innovative approaches to agent-based modeling (ABM) in economics: the Darwinian deployment method developed by Jaraiz et al. [1] and the comprehensive simulation approach by Poledna et al. [2]. While both methods successfully model real economies, they represent different philosophies in handling agent populations and computational resources, with significant implications for practical applications.

At the heart of this comparison lies a fundamental question about the relationship between model complexity and predictive power. The Darwinian approach demonstrates that a small population of agents, guided by evolutionary principles, can reproduce macroeconomic patterns accurately. Similarly, the comprehensive approach simulates entire populations with intricate behaviors, offering granular insights into economic interactions.

The technical implementation of these approaches reveals their unique characteristics. The Darwinian method employs a selection mechanism where agents compete and evolve, maintaining representative economic actors. This solution requires only four agents per sector per million active population, allowing the simulation to run on standard hardware. The comprehensive approach models each individual agent, tracking their decisions and balance sheets, utilizing advanced computing resources and multiple Monte Carlo simulations for stable results.

These methodological approaches showcase different paths to economic analysis and forecasting. Both methods successfully integrate national accounts data and input-output tables, achieving comparable accuracy in predicting GDP components and sectoral interactions. Their resource requirements differ, offering flexibility in implementation: the Darwinian approach completes its analysis in a single run on a laptop computer, while the comprehensive method leverages high-performance computing clusters for detailed analysis.

The implications for policy analysis reveal complementary strengths. The Darwinian approach suits rapid assessment and forecasting, making economic modeling more accessible. The comprehensive approach offers insights into agent behaviors and aggregate effects for deeper analysis.

Looking forward, these approaches suggest enriching paths for the evolution of economic modeling. The Darwinian method points toward elegant, efficient solutions that capture essential economic dynamics. The comprehensive approach demonstrates the power of full-scale simulation. Together, they expand our understanding of how to balance model complexity with practical utility in economic analysis.

This research carries broader implications for complex systems modeling beyond economics. The success of the Darwinian approach offers new insights about representing complex systems while maintaining predictive accuracy. The comprehensive approach provides valuable understanding of the full complexity of economic interactions. Both methods contribute unique perspectives to our modeling toolkit.

For the academic and policy-making communities, this exploration offers valuable insights into the future of economic modeling. The presentation will examine how these approaches might be combined or adapted for different contexts, from regional economic analysis to global financial systems. Understanding their respective strengths will help researchers and practitioners choose the most appropriate tools for their specific needs.

The technical achievements of both approaches illustrate the richness of modern economic modeling. The Darwinian method's ability to achieve accurate results with minimal computational resources represents an innovation in efficient modeling, while the comprehensive approach's detailed agent-level simulations provide deep insights into economic interactions. This exploration illuminates the possibilities inherent in economic modeling and suggests new directions for research and application.

In conclusion, besides presenting recent progress in the development of the DEPLOYERS framework, this report will demonstrate how different approaches to agent-based modeling can achieve similar goals through complementary means. By understanding these approaches and their implications, we can better appreciate the diverse tools available for economic analysis and potentially develop new hybrid methods that combine their respective strengths. This knowledge is crucial for advancing the field of economic modeling and its practical applications in policymaking and forecasting.

[1] Jaraiz, M. et al. "DEPLOYERS: An agent-based modeling tool for multi-country real-world data", 30th Conference of the International Input-Output Association, Santiago de Chile, July 2024.
[2] Poledna, S. et al. "Economic forecasting with an agent-based model", European Economic Review, Volume 151, January 2023, 104306.

Characteristics and Drivers of the Household Carbon Footprint: An Age Structure Perspective

Topic: Environmental Input-Output Modelling (5)
Author: Xuemei JIA

The study of driving factors behind residents' carbon footprints aids in identifying starting points for carbon reduction. Research that categorizes results by age can reveal the carbon emission characteristics of different age groups in more detail, providing a scientific basis for the formulation of targeted carbon reduction strategies. This study employs a systematic technique that utilizes the environmental input–output life cycle assessment model (EIO-LCA) and IO-based structural decomposition analysis (IO-SDA). The results show that the carbon footprints of 0-14 year olds are mainly concentrated in the mining and washing of coal, the processing of petroleum, cooking, and the processing of nuclear fuel; those of 15-64 year olds are concentrated in manufacturing; and those of people aged 65 and above show obvious geographical differences. Consumption value and the consumption structure of consumption types are the main drivers that increase the carbon footprint, and changes in the structure of industry can effectively promote carbon emission reduction. The structure of the consumption industry is the main driver of the housing consumption carbon footprint, and changes in the value of housing consumption are conducive to carbon emission reduction. It is recommended that policymakers focus on carbon emissions based on the breakdown of population structure, pay attention to carbon emission reduction from housing consumption, and actively optimize both industrial and consumer structures.

      This study includes the following innovative points: (1) This article examines the carbon

footprint resulting from Chinese residents from the perspective of demographics, which aligns with the current reality of an aging society. (2) This study offers a multidimensional analysis of carbon footprints. Unlike previous studies, which often focus on the consumption carbon footprint of a single age group, this study conducts a systematic and comparative assessment of factors including age structure, consumption types, regional distribution, and industrial composition during the 2015–2020 period. (3) This article provides a quantitative analysis of the socioeconomic drivers of the carbon footprint from Chinese residents and how these factors evolve over time and across different types of consumption.

The role of global value chains and their spatial spillovers in convergence dynamics of EU regions

Topic: Trade and Global Value Chains Policies (4)
Author: Sofía JIMÉNEZ
Co-Authors: Lucía BOLEA, Rosa DUARTE

Since the beginning of globalization, with the increase of international networks and the improvement of technology, economic systems are becoming increasingly interdependent. These global processes have been characterized by an increasing fragmentation of production, being each stage located in different geographical points. In this context, the concept of Global Value Chains (GVCs) emerged, which could be defined as the value added generated in each step of the production outsourced in different locations. The emergence of GVCs has been seen as an opportunity to economic growth for many economies through their economic upgrading. However, different authors point out that positive outcomes are not equally distributed among countries, generating potential disparities among them.

On the other hand, the behavior of economies advancing at different speeds is highly related to the concepts of economic convergence and catch up. One of the clearest examples of the convergence process is the European Union. Since its creation, the promotion of economic growth, the implementation of the common currency or the creation of a single market and common regulations aimed to foster the EU economies to advance at the same pace. This process has been seen as one of the main attractions for potential EU candidate countries. At the regional level, the goal of regional convergence has been declared and committed to in the EU Treaties. However, the level of inequality between regions remains high, and different international institutions and scholars have claimed on the effects of these raising income differences in the observed dissatisfaction level within specific geographical areas and social groups, threatening social cohesion.

GVCs have been, commonly, studied at country level. Nevertheless, recent literature has also paid attention to their regional scale. Existing literature shows that regional economic specialization and the different intersectoral and interregional linkages affect the economic performance of regions. Besides, the latest research has found potential different gains of EU regions position in GVCs and highlights the role of spatial spillovers to determine their performance in the international chains.

Within this framework, the main objective of this paper is to analyze to what extent the configuration of GVCs in Europe, and the way in which the regions have engaged in them, has contributed to the processes of income convergence and catch up in Europe. In this context, some works claim the necessity of incorporating the potential spillovers among regions to capture a more informative picture of regional economic growth, challenges and opportunities in a highly

interconnected and globalized economic environment. Thus, we also aim to check the importance of neighboring regions, both geographically and economically, in explaining these processes.

From an empirical standpoint, we combine an interregional input-output with a spatial econometrics' strategy. Particularly, we use the EUREGIO database, which contains information on 249 NUTS2 EU regions for the period 2000-2010, and EUROSTAT Regional Statistics as main databases. EUREGIO is used to calculate participation and position in GVCs. Participation is calculated using the approach of Los et al., 2015, while the upstreamness measure of Antràs et al., 2012 is used as position. As a measure of catch up we define the ratio between regions value added and the maximum value added achieved among all EU regions. The higher is the ratio, the closer is the region respect the one that best performed. As dependent variable it is included the catch-up variation between 2010 and 2019. As independent variables, we will include participation and position in GVCs in the first year of the period analyzed (2010) and other control variables as people in science and technology, degree of urbanization, specialization in EU trade and a dummy variable that takes value 1 if the region shares a border with a region of another country.

To check the spatial dependence two matrices are used. To account for potential geographical dependence among European regions, a queen weight matrix has been employed. This matrix considers all neighboring regions surrounding each specific region. On the other hand, economic distance is defined as the similarity in the production structure among regions. To build this matrix, we first calculate specialization indices of each region on the basis of the sectoral information provided by EUREGIO. Next, correlation coefficients between specialization indices are used to determine the "economic neighbors". We consider economic neighbors those regions with correlation coefficient greater than 0.7. First results suggest a significant role of participation and position in catch-up variations and reveal the importance of geographical spillovers in these processes.

Assessing the impacts of Scaling up 5G Communication Networks in India: A macro-econometric sub-national framework

Topic: Regional input-output modelling (1)
Author: Surabhi JOSHI
Co-Authors: Kakali MUKHOPADHYAY, Vishnu Sivadasa PRABHU

India's communication technology sector has experienced rapid growth over the past decade, with 812 million broadband subscribers and declining data tariffs. Today, the country boasts the second-largest telecom subscriber base and one of the largest internet user bases globally. Existing technologies like 3G and 4G have already showcased the transformative power of mobile connectivity, improving access to education, healthcare, financial services, and employment, particularly in underdeveloped and rural regions. India now stands at a pivotal juncture, with ambitious policies aimed at increasing the deployment of next generation 5G technology. These advancements promise unprecedented speed and data accessibility for users, driving digital transformation across sectors. However, they also come with substantially higher energy consumption and increased carbon emissions, necessitating proactive strategies to balance technological progress with environmental sustainability.
Objectives
This paper examines sub national economic and environmental impacts of scaling up 5G communication networks across 10 major Indian states (around 80 % of total subscriber base in India). The analysis focusses on:

1.	Estimating the direct and indirect contributions to GDP and employment through infrastructure and digitally enabling sector at state level.
2.	Assessing the energy and environmental implications of rolling out of these technologies with respect to state-level decarbonization trajectory.

Methodology
This paper creates a production block for the 5G communication technology for Indian states. At present the total penetration of 5G network in India is close to 240 million users which will reach 940 million users by 2030. The production block includes both the infrastructural inputs for the communication networks including installation of towers and land procurement and investment in enhanced energy demand from the telecom towers along with contribution from digitally enabling sectors as per the OECD definition. Using E3-India, a macro econometric simulation model the sector and state desegregated direct and indirect GDP and employment effects are estimated for this analysis. Further, the economic and environmental impact of enhanced energy demand are also estimated for the same.
Preliminary results
Preliminary findings suggest that while the nationwide deployment of 5G networks by 2030 will generate substantial economic gains across Indian states, the associated environmental costs are significant. Based on projected subscriber growth, 5G adoption alone is expected to contribute approximately 178 million tons of CO2 emissions. These estimates highlight the need for energy-efficient infrastructure, renewable energy integration, and policy interventions to mitigate the environmental impact of large-scale network expansion while maximizing economic benefits.

Systematic Underreporting in Corporate Scope 3 Disclosure

Topic: Enterprise Input-output Analysis
Author: Keiichiro KANEMOTO
Co-Authors: Xinmeng LI, Yuya KATAFUCHI, Daniel MORAN, Taiki YAMADA, Hidemichi FUJII

Accurately assessing corporate carbon footprints is essential, and this is especially true for the Scope 3 emissions which encompass indirect emissions within a company's value chain. These emissions are crucial for a comprehensive view of corporate climate responsibility. Thus, a precise and transparent quantification method is vital for robust corporate carbon reporting and effective climate mitigation. Existing studies, often reliant on Multi-Regional Input-Output (MRIO) databases, primarily estimate carbon emissions at national and sector levels, lacking granular detail. Here, we quantify Scope 3 emissions of companies using an enterprise-level multi-regional input-output (EMRIO) table with the company reporting direct (Scope 1 and 2) emissions of companies. Using a systematic top-down approach considers corporations as portions of the complete global economy and avoids the issue of incomparable Scope 3 emissions, which can arise when different companies use different inventory data and models as is often the case in conventional bottom-up life-cycle estimates and prior MRIO-based estimates. This study provides two main results: A new assessment and comparison to CDP Scope 3 for 500 companies, and new Scope 3 results for 1,500 companies. We find that, collectively, company self-reported Scope 3 emissions may be underestimated by nearly 50%, or 0.75 Gt C, compared to our estimate using a harmonized approach.

China's contribution to emission reduction in countries along the Belt and Road: a study based on trade-embodied carbon

Topic: Special Session: Emerging Global and Regional IO Modelling
Author: Qingyun KAO
Co-Authors: Dabo GUAN, jingwen HUO, Heran ZHENG

The rapid growth of international trade has significantly increased the transfer of carbon embodied in trade, which has substantial implications for the allocation of emission reduction responsibilities and the achievement of global emission reduction targets. In 2023, the Belt and Road Initiative (BRI) marked its tenth anniversary, a period during which trade between China and BRI countries has flourished. China has increasingly produced export goods to meet the consumption demands of these countries, simultaneously assuming responsibility for the carbon emissions that would otherwise be borne by the importing nations. Understanding the embedded carbon in these exports is crucial for China to assert its climate contributions and carbon entitlements in international negotiations.

We employ the input-output methodology and utilize the global multi-regional input-output table (EMERGING) for the years 2010 and 2015–2019, applying the embodied carbon emissions method to calculate carbon emissions in global trade. The analysis focuses on the carbon embodied in trade between China and 63 countries along the Belt and Road, categorizing the trade into seven representative regions. The study analyzes sectoral contributions to embodied carbon in bilateral trade between China and key countries within these regions and conducts a structural decomposition analysis to identify the driving factors behind the observed patterns of embedded carbon.

We explored China's contribution to emission reduction in international trade from an innovative research perspective and found that the embodied carbon in China's exports to the Belt and Road countries has increased significantly, and the embodied carbon in exports has continued to exceed the embodied carbon in imports, showing a state of embodied carbon surplus. As China continues to export more goods to meet the consumption needs of BRI countries, it simultaneously assumes responsibility for the carbon emissions generated during the production of these goods. Among the seven regions, ASEAN and West Asia emerge as the primary destinations for China's embodied carbon exports, while the five Central Asian countries are the principal importers of embodied carbon.

Sectoral analysis indicates that the metal product manufacturing and machinery manufacturing sectors are the largest contributors to the embodied carbon in China's exports, while the energy extraction sector is the major source of embodied carbon imports. Carbon intensity is identified as the key decelerating factor: by producing and exporting goods with lower carbon intensity, China reduces the additional carbon emissions associated with domestic production in importing countries. This has contributed positively to international emission reduction efforts. Trade volume is identified as the primary driver of the growth in embodied carbon exports, with trade structure also playing a crucial role. The study provides critical insights into the regions, sectors, and underlying drivers of China's embodied carbon in trade with BRI countries. These findings offer valuable guidance for advancing the BRI, optimizing China's trade structure, clarifying international trade emission reduction responsibilities, and fostering regional cooperation on climate action.

Construction of An Enterprise-Level Global Supply Chain Database

Topic: Enterprise Input-output Analysis
Author: Yuya KATAFUCHI
Co-Authors: Xinmeng LI, Daniel MORAN, Taiki YAMADA, Hidemichi FUJII, Keiichiro KANEMOTO

Global supply chain data captured in input-output models represents a foundational resource in economic, regulatory, investment, defense, and environmental applications. Work based on input-output tables has yielded valuable insights on interdependency and supported new types of policy based on "Scope 3" supply chain exposure. However current models suffer from coarse sector resolution which hampers their real-world utility beyond scholarship. To address this we elaborate the construction of an enterprise-level multi-regional input-output (EMRIO) table. We expand conventional MRIO frameworks by merging macro-level national accounts with highly detailed corporate data—collected from consolidated and unconsolidated financial statements, segment disclosures, and trade records (including bills of lading) —and systematically disaggregate sector-based IO data into enterprise-level subsegments. This balanced global input-output table, built by combining official national input-output tables with publicly available firm-level production and transaction data, details flows among the business units at 9,466 companies operating across 86,305 subsegments in 121 countries. By capturing the hidden complexity within conglomerates, EMRIO not only facilitates more refined calculations of Scope 3 greenhouse gas emissions but also provides a robust basis for assessing policy measures on forced labor, deforestation, and other sustainability issues requiring firm-level specificity. The dramatically higher resolution of this resource can improve the accuracy and tractability of all analyses reliant on supply chain information.

Input-Output Analysis for African Economic Growth and Employment amid Trade Wars

Topic: Input-output Analysis for Policy Making (4)
Author: Eleanor Carys Jerram KEEBLE

Abstract: Input-Output Analysis for African Economic Growth and Employment amid Trade Wars
Africa's pursuit of sustainable growth stands at a crossroads of dependence on low value traditional primary products versus diversification in the uncertainties of a fast-changing global economy. This paper employs Input-Output (I-O) analysis to explore the policy options. It examine economic interdependencies across African economies, leveraging backward, and forward linkage assessments to determine optimal industrial strategies.
Traditional orthodoxies about the economic benefits of specialisation have trapped in poverty those African economies dependent on downstream commodities. Given global uncertainties, specialisation in one low value item is especially risky.
This paper assesses Africa's position within global value chains (GVCs) and identifies some of the continent's competitive advantages. It does so using IO models and integrating Trade in Value Added (TiVA) analysis, so that our conclusions are based on robust statistical data. Our findings shed light on the industrial specialisation paradox (Carbonell & Nassè, 2020), in which nations juggle between exporting raw commodities and moving up the value chain through industrial upgrading.
Methodology and Scope
Using I-O tables, we identify sectors with the highest multiplier effects in terms of domestic value-added, employment, and industrial transformation (Ojaleye & Narayanan, 2022). Backward linkage analysis highlights industries that are highly integrated within domestic economies,

fostering local supply chain development, while forward linkage analysis reveals sectors with high export potential. Trade disaggregation by partner country allows us to evaluate Africa's shifting trade patterns in response to US-China trade tensions and increased competition for African resources.

Key Findings and Policy Implications

1. Sectoral prioritisation – Manufacturing and agro-processing emerge as industries with strong linkage effects (Ferraz et al., 2021), that require targeted industrial policies to deepen local supply chains and reduce reliance on imported intermediate goods.

2. Trade resilience amid geopolitical uncertainty – Disruptions to global trade, particularly under a second Trump administration, along with China's expanding presence in Africa, underlines the need for diversified trade partnerships and regional value chain integration.

3. Employment-centric industrialisation – While natural resource exports remain dominant, their limited multiplier effect in terms of local job creation and exposure to commodity price shocks underscore the importance of expanding labour-intensive manufacturing and service sectors (Frankel, 2012).

4. Regional collaboration for added value – The findings indicate that African policy-makers should prioritise regional trade agreements (e.g., AfCFTA) to build intra-African supply chains, mitigating exposure to external trade disruptions (Carbonell & Nassè, 2020).

5. Specialisation vs. diversification – Balancing specialisation (leveraging comparative advantages) and diversification (reducing economic fragilities) is essential (Boschma, 2016) The TiVA analysis provides insights into optimising economic complexity and industrial activities while managing risk exposure (Ferraz et al., 2021).

Conclusion

Africa's optimal growth trajectory lies in strategic specialisation with industrial policy interventions to foster downstream processing, expand employment-intensive industries, and reinforce regional economic networks. In the face of geopolitical shifts and heightened protectionism by traditional partners, Africa must proactively shape its trade and industrial strategies to ensure equitable and sustainable development.

This study provides a robust analytical foundation for policymakers seeking to harness input-output linkages, trade diversification, and industrial upgrading as mechanisms for inclusive growth and employment generation.

The Impact of the China-ASEAN Free Trade Agreement on Trade Patterns and Global Value Chains

Topic: Trade and Global Value Chains Policies (2)
Author: Suppakorn KHONKHLONG
Co-Authors: Yongming HUANG, Imam ABBAS, Chenchen TIAN, Xiaoyu FENG

The China-ASEAN Free Trade Agreement (CAFTA) has significantly shaped trade dynamics and economic integration between China and ASEAN, affecting their participation in global value chains (GVCs) and regional industrial upgrading. This study systematically examines bilateral trade imbalances, total exports, intermediate exports, final goods and services exports, and value-added trade patterns between China-ASEAN, employing a disaggregated accounting method and Input-Output (IO) analysis. The empirical findings highlight three key insights: (1) China has strengthened its role in regional supply chains, particularly in intermediate and final goods production, reinforcing its growing influence in ASEAN trade networks. (2) Shifts in trade imbalances and a notable increase in DVA content in China's exports indicate that it transits toward higher-value-added activities, driven by industrial upgrading and deeper economic integration. (3) The rise in FVA content and fluctuations in returned value-added and

double-counted trade flows underscores the complexity and dynamic nature of GVC participation, reflecting evolving interdependencies within the China-ASEAN economic corridor. Policymakers should implement targeted measures to enhance industrial upgrading, improve supply chain resilience, and optimize trade structures, ensuring long-term competitiveness and sustainable economic growth within the China-ASEAN economic corridor.

Firm Heterogeneity in international trade and extension of 2020 IO Table in Japan

Topic: Enterprise Input-output Analysis
Author: Jiyoung KIM
Co-Authors: Satoru HAGINO

This paper demonstrates main features firm heterogeneity in international trade in Japan using firm-level microdata from the "Basic Survey of Japanese Business Structure and Activities" conducted by Japan's Ministry of Economy, Trade and Industry (METI).
Our previous research, Hagino and Kim (2021)*, examined the usefulness of an extended input–output table (EIOT) incorporating the heterogeneity of Japanese firms based on differences in ratios of imported intermediate goods to total output. Developing Japan's EIOT in 2011 and 2015, we calculated the vertical specialization indicators and found that the EIOT captures the foreign value added more comprehensively.
Based on our former study, we adopt 2020 data for this paper. Our analysis shows the shares in export of foreign-owned firms and domestic-owned firms, large firms and small firms, as well as firms with foreign subsidiaries and firms without foreign subsidiaries. Recognizing that foreign firms are not significant in exports in Japan, we measure the differences in intermediate import ratios between exporting and non-exporting firms, between large and small firms, as well as firms with foreign subsidiaries and firms without foreign subsidiaries to identify which element of firm heterogeneity is relevant in extending Japan's input-output table.
Using the largest gaps in intermediate import ratio, we extend 2020 input-out table particularly focusing on its import table, as well as 2020 supply and use. Also, we will try to extend 2020 supply and use table, which was published in 2024 by Japanese government for the first time. Finally, we examine the impact of such extension in measuring the OECD TiVA indicators, comparing with the results of examining such impact for 2015 input-output table.

*Hagino S. and Kim J. (2021) The usefulness of extended input–output tables incorporating firm heterogeneity, Journal of Economic Structures 10:25, https://doi.org/10.1186/s40008-021-00255-3

Discrepancies in Carbon Emissions Accounting: A Comparative Analysis of GTAP and OECD ICIO Databases within the Context of the CBAM

Topic: Environmental Input-Output Modelling (4)
Author: Yong-Gun KIM
Co-Authors: Eun Young KIM, Jae Eun SHIN

The European Union's Carbon Border Adjustment Mechanism (CBAM) introduces a carbon cost on

imports, necessitating accurate carbon emissions estimation. Previous literature on uncertainties in MRIOTs has traditionally focused on sector-aggregated cross-national discussions, often overlooking the implications of database selection at the sectoral level. This study addresses this gap by comparing discrepancies in emissions estimates from two widely used multi-regional input-output databases: the Global Trade Analysis Project (GTAP) database and the OECD's Inter-Country Input-Output Tables (OECD ICIO).

Our analysis focuses on investigating the variations in emissions embodied in trade for scopes 1, 2, and 3 as defined by the European Commission for implementation of the CBAM. We base our estimations on specific trade flows instead of focusing on emissions from specific regions and/or industries(products). Particularly, we utilize the Emissions Embedded in Bilateral Trade (EEBT) method in calculating scope 3 carbon emissions, with a focus on consumption-based EEBT estimates that account for the full carbon footprint along the entire global value chain, which encompasses all upstream emissions.

Being mindful of the potential pitfalls that may arise from ungrounded aggregation, we perform aggregations of the sectors and regions(countries) in the two databases to be able to draw meaningful conclusions on sectors and regions of interest, as well as to further simplify the computational processing of our estimations. Industry sectors in the databases are aggregated into 11 common aggregate sectors. We aggregated the world into 11 regions to reflect the EU's major trading partners in the metals sector, an industry that expects significant impacts from the CBAM.

Results show significant disparities between the two databases examined, varying considerably by region and scope. Under scope 1, the GTAP database underestimates emissions for most regions, with the most extreme differences occurring for South Korea and Japan. This suggests that major differences exist in how industrial emissions are allocated, even for the simplest direct emissions. Differences are less pronounced in general for scope 3 emissions, but an outlier is found in emissions for imports from Vietnam to the EU, where the GTAP database overestimates by 79%. Given these results, South Korea, Japan, and Vietnam may experience substantial differences tariff burdens depending on which data are used for carbon accounting, and which scope the EU ultimately applies to implement the CBAM.

By industry, the largest discrepancies in carbon accounting for trade to the EU between the GTAP and OECD-ICIO are found in the Fossil Fuel sector. The GTAP database overestimates the emissions embodied in trade of fossil fuels by up to 1708% in scope 3. This explosive increase that we see for fossil fuels in scope 3 can be attributed to the emissions caused by the final consumption of fossil fuels, such as those direct use and emissions in the household, etc. now being accounted for in the GTAP database in the fossil fuels sector instead of the respective sectors that utilize fossil fuels.

These findings highlight the significance of database selection in using carbon accounting for policymaking, emphasizing the need for harmonized methodologies to ensure fair and consistent policy implementation. Gaps in estimation by database impede the monitoring of carbon emissions towards achieving carbon neutrality, as inconsistent data can lead to misguided policy decisions and hinder effective environmental regulation. Additionally, gaps in estimation run the risk of being translated into unjustified economic burdens when implementing policy measures such as the CBAM, potentially placing undue financial stress on certain sectors or countries.

Detailing the structure of carbon footprint focusing on long-term care demand in Japan

Topic: Input-output Analysis for Policy Making (4)
Author: Narumi KIRA
Co-Authors: Yosuke SHIGETOMI

The Research Question
As Planetary Health advocated, the importance of quantifying the carbon footprint (CF) of healthcare supply chains has increased. Despite global studies on the healthcare sector's CF, research on the CF of long-term care services, crucial to human health and welfare, remains insufficient.
Looking at Japan, which has one of the most ageing populations in the world, the number of people certified for long-term care is increasing as the population ages, and is projected to reach 9.77 million by 2045. Such progress in an ageing society and the increase in those people will affect the structure of household consumption. In this sense, Nansai et al. (2020) clarified that the consumption-based greenhouse gas (GHG) emissions (i.e. carbon footprint; CF) derived from long-term care services accounted for 10.1 Mt-CO2eq in 2011. However, it is unclear how much the people who need long-term care contribute to these emissions yet. Shigetomi et al. (2014) estimated that the Japanese household CF will decrease by 4.2 % from 2005 to 2035 as a lower birth rate with an aging population. However, this estimation assumed that the consumption pattern of each bracket of the age of household head in 2005 would be fixed until 2035, not taking account into the change in consumption patterns.
Against this backdrop, we aim at highlighting both the CF of households with people who are certified for long-term care and the impact of the increase in those people on future CF with a focus on Japan.

The Method and Data
To achieve the objective, an environmental input-output analysis based on the Japan input-output table (JIOT) was conducted. Although it is not possible to trace the international flow as precise as a multi-regional input-output table, JIOT is described by about 400 commodity sectors that enables us to analyze the consumption-based environmental pressures on the medical and long-term care sectors. This study therefore employed the input-output inventory on JIOT and could consider "Long-term care services (except facility services)" and "Long-term care services (facility services)" for the long-term care sectors.
 Next, we utilized the domestic household consumption data (National Survey of Family Income and Expenditure; NSFIE) and long-term care insurance data (Survey of Long-term Care Benefit Expenditures) to understand the detailed CF structures across household attributes focusing on those who are identified as needing long-term care. In addition, the CF on long-term care ("Facility services," "In-home services," and seven other categories in total) for the seven certification levels of long-term care were identified.
Finally, we considered a Universal Health Insurance System in Japan, which allows Japanese people to receive medical services with a 10%–30% co-payment depending on their age and income. For this reason, NSFIE includes only the co-payment of medical-consumption expenditures. Therefore, based on household-consumption data, we extended household consumption expenditures for medical commodities to include publicly funded healthcare expenditures in each household's consumption.

The Novelty of the Research
As a result, the CF on long-term care services varied from 117 to 4392 kg-CO2eq per person per year, depending on the level of long-term care required. Besides, it was found that households

with people who are certified for long-term care generated 1.4 times larger CF than households without those people. Regarding the pattern of CF, the largest difference between households with and without people who are certified for long-term care was engendered in the long-term care sector. Additionally, households with people who are certified for long-term care were more likely to generate the CF on goods associated with staying home, such as electricity and gases. The previous studies reported that elderly households would generate lower CF per capita than young and middle-aged households. However, we figured out that the CF would considerably increase regarding both a person who is certified for long-term care in a household and the compensation of long-term care insurance. We also estimated that the CF on long-term care services would reach 22 Mt-CO2eq in 2050 (2% of Japan's total CF in 2020).

 Conclusively, the novelty of this study is to highlight that an increase in people who need more serious long-term care may boost GHG emissions unexpectedly. Our study suggests, in other words, suppressing the number of people who are certified for long-term care is useful for both health and climate-change mitigation. Undoubtedly, the demands of long-term care should not be limited in a top-down manner. Therefore, the government in nations with its ageing population such as Japan, should promote long-term care prevention to reduce the number of people certified for long-term care and develop a GHG mitigation strategy focused on the long-term care sector. For future s

Green Transitions in Coal-Dependent Economies: A Hybrid Computable General Equilibrium Analysis of the Czech National Energy and Climate Plan

Topic: YSI and Development Programme (3) (Discussants: Meng Jing and Richard Wood)
Author: Vedunka KOPECNA
Co-Authors: Iñaki Alberto VERUETE VILLEGAS

Environmental policies play a crucial role in mitigating climate change and improving air quality, yet their macroeconomic and sectoral implications remain a subject of debate, particularly in coal-dependent economies such as the Czech Republic. This paper evaluates the long-term economic and environmental impacts of key climate policies outlined in the updated Czech National Energy and Climate Plan (NECP) within the framework of the EU's Fit-for-55 package. We employ a hybrid recursive-dynamic Computable General Equilibrium (CGE) model, integrating a bottom-up electricity module that disaggregates power generation by technology and a discrete choice module that endogenizes consumer preferences for vehicle technologies. The model is formulated as a mixed complementarity problem (MCP) in GAMS, ensuring the consistent integration of sector-specific technological dynamics within a macroeconomic framework. The electricity module follows a technology-specific zero-profit condition with capacity constraints, while the transport module links consumer choice probabilities to aggregate vehicle stock evolution. The recursive dynamic structure captures investment accumulation, capital stock evolution, and intertemporal adjustments to policy shocks. We assess two scenarios: With Existing Measures (WEM), reflecting the continuation of current climate policies, and With Additional Measures (WAM), incorporating enhanced decarbonization strategies, including coal phase-out, the expansion of renewables, and the introduction of a second Emissions Trading System (ETS2). Our results indicate that while WAM requires higher upfront investments, it leads to a 75\% reduction in power sector CO2 emissions by 2040 and an 80\% market share for battery electric vehicles (BEVs) by 2050. GDP initially benefits from green investments but slows post-2041 due to sectoral shifts, particularly in fossil fuel-related industries. By combining top-down macroeconomic analysis with sector-specific bottom-up technological representation, this study provides a comprehensive framework for assessing the system-wide effects of climate

policy. The findings offer empirical insights for Czech and EU policymakers in designing cost-effective and equitable decarbonization strategies.

Analysis of Spillover Effects of Technological Progress from the Perspective of the Integration of Production and Innovation Networks

Topic: Input-output Modelling and Network Theory
Author: Chuan LI
Co-Authors: Xu JIAN, Jialu SUN, Qi SU, Zhijian JIANG

Technological progress is the core driver of economic growth, and an in-depth analysis of its spillover effects contributes to the optimal deployment of innovation and industrial chains. Existing studies largely explore technological spillover from the perspective of production networks, breaking the assumption of independent technological progress, but often overlook the diffusion of knowledge and information, lacking sufficient focus on innovation networks. This paper proposes a method for measuring the spillover effects of technological progress under the integration of production and innovation networks. By introducing new meanings to the spillover effect matrix from three dimensions—elements, row sums, and column sums—the method provides an intuitive display of the benefits and contributions of each sector in technological progress. It also deepens the understanding of the complex interplay between production and innovation networks into levels that are explainable, decomposable, and measurable. Based on 2.8 million patent citations between enterprises, this paper constructs an innovation network among sectors according to their industrial classification and empirically tests the theoretical model. The findings reveal that: (1) Technological spillover between sectors can be divided into three modes: spillover through the production network, spillover through the innovation network, and spillover through the interaction of both networks. (2) In terms of benefits, the interaction between production and innovation networks contributes significantly more to economic growth across almost all sectors compared to each network's individual impact, although the independent contribution of innovation networks still falls short of the scale benefits of production networks. (3) The spillover and amplification effects of technological progress vary across sectors due to differences in production technology, with the digital economy sector identified as crucial for driving the integration of innovation and industrial chains.

Impact of China's Special Economic Zones Policy on Carbon Emissions based on an input-output perspective

Topic: Environmental Input-Output Modelling (4)
Author: Jiaxin LI
Co-Authors: Yuning GAO, Xuetian WANG

The global economy and environment are facing severe challenges and unprecedented shocks, and numerous countries around the world are seeking strategies aimed at striking a balance between protecting the environment and promoting economic growth. Developing countries have been the largest driver of the growth of total GVC-embodied emissions. Among these, China has undertaken several measures aimed at achieving its carbon reduction targets, one of which is the Special Economic Zones (SEZ) policy, which is viewed as a potential solution for reducing carbon emissions.

In this study, we aim to provide city-level evidence from China on the impact of the SEZ policy on carbon emissions, as well as the underlying mechanisms driving these effects. To achieve this, we first employ the input-output (IO) method to calculate both consumption-based carbon emissions and the emissions embodied in exports, using production-based carbon emissions as the baseline. Next, we apply the time-varying difference-in-difference (DID) method to examine the SEZ policy's impact on carbon emissions over time. In our mechanism analysis, we investigate the mediating role of factors such as foreign direct investment (FDI) in influencing the relationship between SEZ policy and carbon emissions. Furthermore, we explore the heterogeneous effects of the SEZ policy on carbon emissions reduction at different levels, including the SEZ level, city level, pollution level, and product level. Finally, to capture the spatial dimension of these effects, we employ a spatial Durbin model to assess the spatial spillover effects of the SEZ policy on carbon emissions.

To conduct this analysis, we utilize a variety of city-level data indicators. Input-output tables and carbon emissions data were obtained from the Carbon Accounting and Database, while data on SEZs were sourced from the Catalogue of Review Announcement of China Special Economic Zones (2018 Edition), published by the National Development and Reform Commission of China. We identified the years in which 284 prefecture-level cities were first approved for establishing SEZs (including both state-level and provincial-level SEZs).

The results of our study offer not only new insights into environmental protection but also provide further empirical evidence supporting the effectiveness of the SEZ policy. Specifically, our findings contribute to the existing literature in the following ways: First, while previous studies have explored the economic impact of the SEZ policy, few have focused on its environmental impact, particularly in the context of China. Second, we estimate the levels of various types of carbon emissions using the input-output (IO) method and examine how the SEZ policy affects these emissions, offering a new perspective on carbon emissions reduction. Third, the pollutant emissions mechanism related to the agglomeration effect has often been a "black box." In this study, we explore how the SEZ policy reduces carbon emissions through foreign direct investment (FDI). Fourth, we provide evidence regarding the 'zero-sum game' theory in relation to China's SEZ policy through spatial econometric analysis, demonstrating that the effects of the SEZ policy on carbon emissions are not localized. Finally, many prior studies have struggled with potential endogeneity issues arising from omitted variables in panel regression models. We address this problem by adopting a time-varying DID approach, allowing us to more accurately assess the impact of the SEZ policy on carbon emissions.

Construction of high resolution maritime multi-regional input–output table for China's bay areas (BAY-MMRIOT)

Topic: Regional input-output modelling (1)
Author: Man LI
Co-Authors: Kuishuang FENG, Dabo GUAN, jingwen HUO, Heran ZHENG, Honglin ZHONG

The Multi-Regional Marine Economy Input-Output Table (MMRIOT) serves as a powerful analytical tool for capturing the teleconnection between maritime and terrestrial economies in different regions, and assessing its supply chain impacts. China's bay areas—despite holding significant economic importance at both national and global levels—are not adequately represented in existing input-output tables for the marine economy, which lack critical detail on marine sector information at high spatial resolution, failing to capture the heterogeneity among cities within the bay. To fill this gap, we propose a framework based on partial survey data for compiling the

Bay-MMRIOT, which covers major bay areas with 55 sectors (13 marine sectors and 42 non-marine sectors) and spans three years (2012, 2015, and 2017). We provide a detailed description of the database development methodology. The Bay-MMRIOT database aims to incorporate official and publicly available data from multi-sources. Based on this framework,, we utilize the Guangdong-Hong Kong-Macao Greater Bay Area (GBA) as a case study, analyzing the impact of GBA's marine economic development on the national economy's production activities along the supply chain. The results show that from 2012 to 2017, the marine economy of the GBA generated indirect output ranging from 0.67 to 0.92 times its direct output, and the total industry chain output across marine sectors exhibited significant heterogeneity. This framework offers a feasible approach for developing subregional-level marine economic trade analyses and provides a viable solution for studying subregional marine economic trade under limited data conditions

Redistributing Mitigation Burden through a Carbon-Added Pricing Mechanism

Topic: Environmental Input-Output Modelling (6)
Author: Meng LI
Co-Authors: Bo MENG, Yuning GAO, Yu LIU, Gabriele SUDER

Carbon pricing is crucial for decarbonizing global production and preventing carbon leakage; however, in the cross-border context, it often fails to ensure equitable burden distribution, sparking debates on effectiveness versus fairness. Our study shows that conventional carbon tariffs can significantly magnify and distort the burdens due to the complexities of global trade. For instance, a 100 $/ton tariff can translate into an impact exceeding 200 $/ton effect for some participants, with one quarter of carbon tariffs falling on intermediary exporters for upstream emissions. These effects necessitate careful policy design. To alleviate magnification and promote more equitable burden-sharing, we propose a carbon-added economic-adjusted pricing mechanism that accounts for economic development status, reducing tariff burdens on developing economies and encouraging the establishment of carbon pricing schemes. This approach could lower the net tariff burdens of the developing economies. Our findings highlight the limitations of unilateral policies like border adjustments, underscoring the urgent need for collaborative and widely acceptable carbon pricing mechanisms to achieve global climate targets.

Measuring and Optimizing Global Value Chain Risks: an Absorbing Markov Model with Rewards

Topic: Input-Output Theory and Methodology (2)
Author: Meng LI

Global Value Chains are central to our understanding of international trade and economic systems. The dense interdependence that typifies these global networks, a consequence of accelerated globalization, makes them especially susceptible to various disruptions such as geopolitical tensions, energy scarcity shocks, and extreme climatic events. A disturbance in one part of the chain can rapidly lead to cascading effects, resulting in substantial economic impacts that transcend national boundaries. This study develops an Absorbing Markov Model with Rewards to trace the risks in GVCs and to minimize the risks accumulated along GVCs. It employs the input-output table and integrates it with the Absorbing Markov Chain to elucidate the flows within GVCs and a Markov Reward Process to quantify the transmission of risks within these chains. This approach provides a method to quantify how risks accompany the flow of goods and

services, considering both the intensity and the propagation of risk factors. This general method makes it applicable to a wide range of aspects—whether analyzing the flow of value-added, energy, emissions, or other factors and how they pass through different key sectors, or analysing the multi-perspective risks, such as climate change risks, natural resources scarcity risks, geo-political risks, socio-economical risks, and many other aspects.

CEDA-FLAG - A Hybrid Multi-Regional Environmentally-Extended Input-Output Model for Forestry, Land Use and Agriculture (FLAG)

Topic: World Input-output Modelling and Databases
Author: Mo LI
Co-Authors: Andrew DUMIT, Marvin BACHMANN, Cheng LIN, Yohanna MALDONADO, Steven J. DAVIS, Sangwon SUH

Research Question
The Forest, Land, and Agriculture (FLAG) sectors account for approximately one-quarter of global anthropogenic greenhouse gas (GHG) emissions. Despite their significant contribution to global emissions, quantifying FLAG-related emissions remains challenging due to the complexity of global supply chains and the scarcity of emissions factor data. This research addresses the key question: How can we integrate existing models and datasets to develop a more reliable, regionally specific, and comprehensive model for assessing FLAG-related emissions across complex global supply chains?

Method Used
To address this research question, we developed CEDA-FLAG, an innovative hybrid Input-Output model that integrates two state-of-the-art models: Comprehensive Environmental Data Archive (CEDA), a Multi-Regional Environmentally-Extended Input-Output (MR-EEIO) model, and the Comprehensive Accounting of Land-Use Emissions (CALUE) model, which provides country-, process-, and product-specific estimates of agricultural and land-use change emissions. Our method leverages CEDA's strengths of Input-Output (IO) analysis in tracing economic activity and associated emissions across global supply chains and combines it with CALUE's granular, physical emissions data from agricultural and land-use activities. By aligning CEDA and CALUE, we built a unified framework that accommodates both spend- and mass-based emission intensity metrics. This integration involved reconciling regional scopes, sectoral classifications, and to create a coherent model capable of assessing FLAG-related emissions with high precision.

Data Used:
The development of CEDA-FLAG relies on two complementary models:
1. CEDA: A renowned MREEIO model that covers 95% of the global economy and provides spend-based emission factors for 400 economic sectors in 149 countries. CEDA enables comprehensive analysis of multi-regional economic activity and emissions embedded in international supply chains.
2. CALUE: A database offering detailed, region-, process-, and product-specific estimates of agricultural and land-use change emissions for 151 agricultural commodities. The CALUE database captures the environmental impacts of land management practices and land-use changes with high granularity.
Through careful alignment of these models, we achieved a harmonized database that combines monetary (spend-based) and physical (mass-based) emission factors, enabling stakeholders to conduct more accurate, regionally specific assessments of FLAG emissions across multiple dimensions.

Novelty of the Research:

The novelty of CEDA-FLAG lies in its ability to bridge a critical gap in FLAG-related emissions accounting by integrating economic and physical models within a unified IO framework. Unlike traditional approaches that rely exclusively on spend-based or physical data, CEDA-FLAG is the first to combine the strengths of both spend-based and mass-based emissions accounting into a single hybrid framework for FLAG sectors. While IO models have been widely used for assessing emissions in other sectors, this research pioneers the integration of agricultural and land-use change emissions into IO models, providing a more comprehensive picture of FLAG-related emissions.

Key innovations include:

1. Hybrid Approach: The integration of economic and physical activities and emissions within a hybrid MREEIO framework allows for nuanced assessments of FLAG emissions, capturing the impacts of both land management practices and global supply chains.

2. Comprehensive Coverage: By harmonizing CEDA and CALUE, CEDA-FLAG offers regionally specific emissions metrics for 400 economic sectors and 151 agricultural commodities, filling a critical data gap in FLAG emissions accounting.

3. Policy Relevance: The database is explicitly designed to align with emerging reporting frameworks, such as the Science-Based Target Initiative and the GHG Protocol, supporting stakeholders in meeting FLAG-specific reporting requirements.

This research contributes to both the field of Input-Output analysis and the understanding of FLAG emissions, providing new insights into the intersection of economic activity, land-use change, and sustainability. By providing stakeholders with a robust tool to identify emissions hotspots, prioritize mitigation strategies, and evaluate the effectiveness of FLAG-related interventions, CEDA-FLAG supports the transition to more sustainable land-use practices and contributes to global climate goals.

Comparison among EXIOBASE-, GLORIA- and CEDA-based USEEIO model with import emission factors

Topic: Special Session: International Trade in Corporate Carbon Accounting
Author: Mo LI
Co-Authors: Sangwon SUH

The research question, the method used

Accurate representation of import factors is crucial for ensuring the reliability of the U.S. Environmentally Extended Input-Output (USEEIO) model in assessing the environmental impacts of goods and services in global supply chains. Import factors, which account for the environmental impacts of goods and services produced abroad and consumed domestically, are derived from multi-regional Input-Output (MRIO) databases. These import factors play a pivotal role in capturing the trade-related environmental impacts, making them integral to both national-level modeling and corporate-level carbon accounting. However, variations in MRIO data can significantly influence model outcomes, particularly in sectors with high levels of international trade. The research question of this study is how do the three prominent MRIO databases—EXIOBASE, GLORIA, and CEDA—affect the estimation of import factors in USEEIO and what are their implications for MRIO modeling, corporate carbon accounting, and global supply chain GHG management.

Our methodology involved harmonizing these three MRIO databases to the sectoral structure of USEEIO and applying them to generate import factors for key sectors, including electricity,

cement, steel, and agriculture. Harmonization ensured comparability while preserving the unique strengths of each dataset. Through this integration, we systematically analyzed the differences in emission factors across the databases, emphasizing regional variations, sectoral trends, and overall alignment with real-world trade flows. Additionally, we explored how these variations influence the corporate carbon accounting conducted using the USEEIO model.

The data used (if any)
In this study, we systematically compared the USEEIO model with import factors generated from EXIOBASE, GLORIA, and CEDA when integrated into the USEEIO framework. These MRIO databases differ in their regional and sectoral resolutions, data sources, and methodologies for allocating emissions. EXIOBASE provides detailed global environmental extensions and allows assessment of environmental impacts associated with consumption of European and other countries across time series data with a high level of product and industry detail. GLORIA is a database with a homogenous multi-regional supply-use table (MR-SUT) structure, offering harmonized sector labels for both industry and commodity sectors and specializing in resource flow analysis. CEDA offers comprehensive coverage of the U.S. economy and global trade, while maintaining a high resolution for key economic sectors and emission categories, making it well suited for both national and international supply chain assessments.

The novelty of the research
Our findings reveal differences in import factors across the three MRIO databases, driven by variations in their sectoral detail, geographic resolution, and data assumptions, highlighting the trade-offs associated with each MRIO database. We underscore the importance of database selection in ensuring robust environmental modeling outcomes and offer guidance on aligning data choices with specific research or policy objectives. We also offer actionable insights for researchers and policymakers seeking to adopt the USEEIO model and other related tools.
This research contributes to the ongoing discourse on improving the accuracy and transparency of environmental impact assessments within Input-Output modeling frameworks. By bridging methodological gaps and providing clarity on database selection, this study paves the way for enhancing the USEEIO model's applicability to global trade and environmental policy. It also supports more informed decision-making in corporate sustainability reporting, resource management, and climate change mitigation strategies.

Carbon Inequality of Chinese Households

Topic: Special Session: Environmental Inequality from a Consumption Perspective
Author: Mo LI

Demand-side emissions reductions necessitates changes in individual lifestyles and consumption habits. However, high levels of inequality can hinder efforts to implement effective mitigation strategies. The impact of socioeconomic and sociodemographic inequalities on consumption patterns and, consequently, carbon emissions is particularly significant for the middle class in rapidly developing economies. Despite this, the relationship between household-level carbon emissions and inequality in China has not been thoroughly examined. This study employs an environmentally extended input-output model and consumer expenditure survey data (CFPS) to analyze how various social inequalities—such as income level, urbanization, aging, and household size—affect the carbon footprint (CF) of Chinese households.

The findings reveal that, in absolute terms, the carbon footprint of the top 20% income group (6.9 tons, accounting for 38% of the total) is 3.6 times higher than that of the bottom 20% (8% of the

total). The disparity in per capita CF is even more pronounced than that in expenditure. Households with elderly members tend to have a smaller CF, particularly in smaller households. Additionally, the urban-rural divide in China further exacerbates disparities in household CF. The study also highlights how carbon inequality reinforces existing social inequalities, layering it on top of economic inequality. These findings underscore the importance of designing climate policies that address carbon inequality and promote equitable transitions in lifestyles and consumption patterns.

Hit by heatwave: Unforeseen transboundary economic consequences of hydropower shortage

Topic: Energy Input-Output Modelling
Author: Ruoqi LI
Co-Authors: Jun BI, Miaomiao LIU, Yuli SHAN

Extreme heatwaves decrease precipitation and water runoff, sharply diminishing hydropower generation. This hydropower shortage triggers immediate disruptions, as regions facing power rationing struggle to maintain production. However, the consequences extend far beyond these direct impacts. Indirectly, energy shortages disrupt downstream sectors reliant on raw materials from the affected regions, creating an unforeseen ripple effect along the supply chain. Previous research focuses on quantifying the direct impacts of heatwaves on energy shortages, yet less is known about the broader, cascading economic losses. The lack of awareness of indirect effects may further reduce the efficiency of actions to mitigate their consequences due to delayed responses.

In 2022, China experienced its most intense heatwave on record, which also became the hottest globally recorded. The Yangtze River, China's largest, reached its lowest levels since 1865. In this context, we use China's case as an example to demonstrate the estimation of the reduction in hydropower generation triggered by the heatwave, along with the associated direct and indirect economic consequences. The key research questions guiding this study are: What is the extent of the hydropower generation gap caused by the extreme heatwave in China in 2022? How much cascading economic loss will hydropower shortfall cause? Where did these losses occur and how are they transmitted spatially?

To answer these questions, this study develops a counterfactual scenario based on historical hydropower generation and estimates the reduction in hydropower generation caused by the heatwave using the seasonal auto-regressive integrated moving average (ARIMA) model. Then, we quantify the direct economic losses within the interprovincial electricity grid network. We further assess the indirect economic losses using a supply-side input-output model, uncovering the overall cascading impacts across different provinces.

The results show national hydropower generation decreases by 24% (1.5 trillion kWh), which is equivalent to 12% of the total generation for the entire year of 2022. Notably, 78% of the decline in hydropower generation is concentrated in 5 provinces in southwest China.

The reduction in hydropower generation propagates the energy crisis to all provinces in mainland China via the electricity grid network, accounting for approximately 30% of the electricity shortage. Many of these flows are from less developed regions to more developed regions. For example, power generation facilities in Guangdong and Shanghai are unaffected by the extreme heatwave. However, the power rationing they faced ranks among the top 10 due to the

hydropower shortage in the southwest provinces.

The economic consequences of the hydropower shortage are further exacerbated by the interregional trade network. One the one hand, trade expands the spatial spillover of the crisis to more regions and over a wider distance. Up to 62% of the cascading losses are transmitted from other regions via the electricity grid network (30%) and interregional trade (32%). On the other hand, the economic consequences became more severe as trade magnified the total financial losses. These cascading economic losses, resulting from the reduced hydropower generation during the 4-month extreme heatwave in China in 2022, reach 581 billion USD, equivalent to 3.9% of China's GDP for the entire year. This nearly triples the direct economic losses (206 billion USD).

Our results also reveal significant differences between the provinces with the largest cascading economic losses, those with the most substantial reductions in hydropower generation, and those most impacted by electricity restrictions, after considering the impact of the supply chain. For example, the top three provinces with the greatest cascading economic losses—Guangdong, Fujian, and Hunan—account for 35% of the total cascading economic losses, while they only contribute to 6.5% of the hydropower generation decrease in 2022. Provinces such as Henan and Shandong are also especially vulnerable to unforeseen lagging effects along the supply chain, though experiencing fewer direct impacts from the electricity restrictions and production cuts during the heatwave. We conclude the study by depicting the major pathways from the provinces most affected by the hydropower generation shortfall to those facing an energy crisis and, ultimately, to the production provinces along the supply chain and highlighting key sectors.

In summary, the study enhances our understanding of the unforeseen transboundary impact of hydropower shortage caused by extreme heatwave, based on an unprecedently severe case in China. The results here can assist policymakers in proactively assessing the climate change-related economic losses, thereby strengthening regional resilience to potential disruptions and improving preparedness for the economic consequences of extreme

Measuring Regional Specialization in China's Counties: An Upstreamness Perspective

Topic: Trade and Global Value Chains Policies (2)
Author: Wantong LI
Co-Authors: Fang YONGBIAO

Production fragmentation has geographically segmented manufacturing processes across regions, anchoring local economies in specialized stages of value creation. While this spatial reorganization improves resource allocation efficiency, it simultaneously generates regional disparities through uneven value distribution. Crucially, such production networks—emerging from variations in factor endowments, industrial bases, and policy frameworks—operate not only within global value chains (GVCs) but fundamentally reshape domestic division-of-labor patterns. Subnational regions increasingly specialize in differentiated functions like R&D, manufacturing, and services. This regional specialization mirrors the structure of global value chains, potentially generating similar economic effects, including efficiency gaps, agglomeration dynamics, and persistent regional imbalances. However, the lack of systematic metrics for measuring subnational fragmentation limits empirical insights into these spatial-economic dynamics.

Within national production systems, regions position themselves along value chains according to

comparative advantages, shaping both local development trajectories and broader national competitiveness. Despite its significance, precise quantification of regional specialization remains underdeveloped. Existing research predominantly focuses on international production fragmentation, leaving systematic analysis of intra-national spatial heterogeneity—particularly at the county level—largely unexplored. This gap is particularly consequential for China, where vast territorial disparities necessitate a granular understanding of regional specialization to inform development strategies. Addressing this limitation requires a robust framework for identifying and measuring subnational production positioning.

To fill this gap, we introduce the concept of county-level upstreamness as a novel metric for evaluating subnational positions within domestic production networks. Ideally, county-level input-output tables would provide direct insights into regional specialization, yet data constraints necessitate an alternative estimation strategy. We propose a weighted-average approach that integrates national industrial upstreamness indices with county-level sectoral output shares, offering a systematic methodology to infer counties' relative positions in value chains.

Empirically, we leverage China's benchmark input-output tables, multi-regional input-output data, and two micro-level enterprise databases to conduct a comprehensive analysis of county-level upstreamness. First, we compute upstreamness scores for all counties based on national industrial linkages and county-sector output structures. Second, we examine the spatial and temporal evolution of upstreamness across China. Our findings reveal two key trends: (1) since 2000, county-level upstreamness has exhibited an upward trajectory, with significant shifts in positioning and increased dispersion in value chain integration; (2) spatial patterns reveal strong asymmetries—southern counties exhibit relatively even distributions, while northern regions display more pronounced industrial clustering, forming distinct production belts. Finally, we investigate the determinants of county positioning in production networks, constructing an analytical framework incorporating economic development levels, factor endowments, administrative hierarchy, and geographic attributes.

This study makes three key contributions. First, methodologically, we develop a new metric for measuring subnational specialization, addressing gaps in spatial-economic analysis at the county level. Second, theoretically, we extend production network research by integrating intra-national fragmentation into value chain discussions, revealing how domestic specialization structures mirror and diverge from global production systems. Third, from a policy perspective, our findings provide actionable insights for optimizing industrial policies, mitigating regional inequalities, and enhancing the overall resilience of China's production network. By offering a systematic approach to evaluating county-level integration into national value chains, this study provides a foundation for future research on subnational economic development and spatial reconfiguration in emerging economies.

China's Reviving Self-Reliance Policies and Regional Development

Topic: Input-output Analysis for Policy Making (3)
Author: David Tao LIANG
Co-Authors: Kyoji FUKAO

Abstract: In 2018, President Xi Jinping highlighted "self-reliance policies" amidst challenging times marked by China's economic slowdown, the end of the real estate bubble, decoupling from developed economies, and an aging population. Despite a decline in regional income inequality since 2004, China's regional disparity remains significant when compared to the US, Europe, and

Japan. For the "self-reliance policies" to succeed, a key issue is the development of rural China. There remains huge potential for further economic development in less developed regions in China. Since China's present GDP per capita is close to the level of Japan in 1970, when Japan's high growth era ended. Japan accomplished regional convergence during the stable growth period of 1970–1990. Therefore, Japan's experience probably offers valuable insights for China.

Methodologically, we adopt a level growth accounting approach following Caves, Christensen, and Diewert (1982). Using regional input-output tables of China and Japan, industry-level data on productivity by region, and regional and international trade statistics, we analyze regional inequality in China and conduct a China-Japan comparison on this issue.

Our findings reveal that Japan achieved regional convergence through industrial expansion into rural areas between 1970 and 1990, following its high-growth era. However, China faces more pronounced labor productivity disparities across regions, primarily due to variations in total factor productivity. Achieving similar convergence in China through further industrialization in less-developed regions is challenged by the second unbundling phenomenon (Baldwin, 2016) and competition with other developing economies. Addressing these challenges necessitates institutional reforms and enhancements to the business environment to attract private and foreign investment, particularly in less-developed areas.

The Restructuring of Global Supply Chains and Inter-Country Value Transfer

Topic: YSI and Development Programme (4) (Discussants: Satoshi INOMATA and Kailan Tian)
Author: Junshang LIANG

ABSTRACT

1. Research Question

Mainstream trade theories assume that specialization fosters economic convergence, yet divergence remains the norm. These frameworks, relying on a subjective utility-based conception of value, fail to explain the structural mechanisms governing global value distribution. Dependency theory and Global Value Chain (GVC) analysis recognize trade asymmetries but do not differentiate between value produced and value captured, reducing policy solutions to industrial upgrading while overlooking systemic value transfer.

Recent global supply chain restructuring, driven by geopolitical shifts, automation, and regionalization, has intensified these patterns, altering the distribution of production and value capture. This study examines how evolving supply chain structures reshape inter-country value transfer, challenging the assumption that production shifts inherently lead to more equitable trade outcomes.

This paper introduces a Marxian framework to reconceptualize global economic divergence by distinguishing value produced from value captured. Under this approach, value produced is determined by the socially necessary labor time required for production, encompassing both direct and indirect labor. Socially necessary labor is validated through market exchange and recognized by society as essential for a commodity's production. In contrast, the value realized

through the sale of a commodity is influenced by multiple factors, including labor intensity variations across industries, market structures, monopoly power, unproductive activities, and exchange rate dynamics. These factors create deviations between the value produced and the value captured, forming the basis for value transfer across industries and countries through international trade. This study investigates the mechanisms that give rise to these transfers and how recent changes in global supply chain structures have intensified or altered these patterns.

2. Methodology

The Marxian concept of value produced—measured as socially necessary labor time—aligns closely with the OECD's employment-embodied output measure from the Trade in Employment (TiM) database. Thus, the vector of value produced across different commodities is computed by left-multiplying the Leontief Inverse matrix by a row vector of direct labor input requirements. However, three critical adjustments are necessary:

1) Labor input should be measured in labor hours, rather than simply counting employed persons, to reflect the actual labor expended in production.

2) Labor time must be adjusted for complexity, as highly skilled labor should be weighted differently from simple labor in accordance with its contribution to value creation.

3) A standardized international value measure should be derived by eliminating country-specific labor productivity differences, establishing a globally averaged labor standard that reflects international labor intensity and efficiency.

The value captured in the market is then determined by the actual sale price of commodities, converted into labor-hour equivalents under the assumption of value conservation—that is, total value in the system equals total price. The deviation between value produced and value captured forms the foundation for analyzing inter-country value transfer.

3. Data

The study draws on four major datasets to construct the value measures:

1) Inter-Country Input-Output Tables – used to compute the Leontief Inverse.

2) Trade in Employment Database – provides employment data by country and industry, essential for measuring labor input.

3) Trade in Employment by Workforce Characteristics Database – includes skill-level indicators(education and occupation), enabling us to convert complex labor into simple labor equivalents for more precise labor value estimation.

4) Penn World Table – supplies data on annual hours worked per employed person across countries, allowing conversion of employment figures into labor-hour units.

4. Novelty of the Research

This study makes several key contributions to the understanding of global value distribution and trade-driven divergence:

1) Reframing Global Trade through a Marxian Lens: Unlike neoclassical and GVC-based approaches, this study explicitly distinguishes between value produced and value captured. It provides a systematic measure of inter-country value transfer, offering a novel way to assess how production and exchange dynamics shape global inequality.

2) Assessing the Impact of Global Supply Chain Restructuring: This study goes beyond static trade models by analyzing how supply chain realignments—such as reshoring, regionalization, and automation—affect inter-country value transfer.

3) Providing a Structural Explanation for Economic Divergence: Rather than attributing

inequality to low industrial upgrading, this study reveals how systemic valu

The Effect of Industrial Digitalization on the Gender Wage Gap: An Analysis Based on Input-Output Tables and Causal Inference

Topic: Special Session: Digital Input-output Accounting: Methodology and Applications (2)
Author: Wanqing LIAO
Co-Authors: Chunyan SHI, Nan ZHAO

Reasonable wage distribution is a core element in building an efficient and inclusive labor market. However, wage inequality is a widespread phenomenon in labor markets worldwide, with wage disparities between genders being particularly significant. According to the Global Gender Gap Report 2023, in 2022, women globally earned only 62.9% of what men earned for the same positions. It is estimated that it will take 131 years to fully eliminate the gender wage gap. As women's levels of education and work experience continue to improve, traditional human capital differences are no longer sufficient to explain gender wage gap (Blau & Kahn, 2017; Goldin & Mitchell, 2017). Increasingly, scholars have begun to emphasize the roles of technological advancements, family factors, and social norms in identifying new methods to reduce gender wage gap (Giuliano, 2020; Berniell et al., 2023; Zhang et al., 2024).

This study aims to explore the effect of industrial digitalization on the gender wage gap in China. As the most populous country in the world, women in China account for approximately 18% of the global female population , placing significant responsibility on the country to promote gender equality and women's development. Using the provincial input-output tables for 2007, 2012, and 2017 published by the National Bureau of Statistics of China, this study calculates the complete dependency of different industries on the digital industry, to measure industrial digitalization levels. These indicators are then matched with data from the Chinese Household Income Project (CHIP) for 2008, 2013, and 2018 to examine how industrial digitalization affects gender wage gap through causal inference methods.

The findings reveal that industrial digitalization generally contributes to reducing the gender wage gap. Specifically, for every 0.1-unit increase in digitalization dependency, the gender wage gap decreases by an average of 2.76%. The narrowing of the wage gap is primarily driven by the reduction in hourly wage differences, rather than changes in working hours, indicating that the comparative advantage of men and women in the labor market may have shifted. To test this hypothesis, we use occupational skill data from the U.S. O*NET website to explore how digitalization affects the returns to different skills. The results show that industrial digitalization devalues physical skills and increases the value of cognitive skills. Since men are more likely to work in occupations requiring high levels of physical skills, this shift leads to a narrowing of the gender wage gap. Moreover, as industrial digitalization progresses, the devaluation of physical skills becomes more pronounced, resulting in a stronger effect on reducing the wage gap. However, the overall gender wage gap does not consistently decline. Using the Oaxaca-Blinder decomposition to analyze the contribution of different factors to the gender wage gap across various years, we find that the expansion of occupational segregation is the main reason for the increase in the wage gap. Although industry digitalization alters skill premiums, it does not reduce occupational segregation. Heterogeneity analysis suggests that factors such as caregiving responsibilities and work flexibility may be the main obstacles to narrowing the gender wage gap.

This study offers three main contributions to the existing literature. First, it enriches research on the effect of digitalization from an industry perspective. Existing studies on measuring

digitalization mostly focus on the national, provincial, or corporate level, with limited attention given to industries. Considering the different production models and organizational structures across industries, which result in significant variations in technological applications and gender distribution, the industry-level digitalization measurement based on input-output tables in this study can more accurately capture this heterogeneity. Second, this study provides new evidence on how digitalization reduces the gender wage gap. Previous research has mainly explored the effect of digitalization on gender wage gap through changes in labor market participation rates, employment types, and gender norms. This study argues that changes in skill premiums are also an important reason for the narrowing gender wage gap. Finally, this paper finds that although industry digitalization helps to narrow the gender wage gap, the increased occupational segregation and gender discrimination have led to a rebound in the overall gap. This not only provides new evidence for understanding the complex dynamics of gender wage gaps but also offers important insights for policymakers on how to address discrimination, promote gender equality, and achieve sustainable development in the digital era.

Impact and spatial spillover effect of digital industry agglomeration on regional carbon emission intensity: Evidence from China

Topic: Special Session: Technological Innovation Enabling GVC Restructuring
Author: Kexin LIU
Co-Authors: Hongxia ZHANG, Zhaotin GUO

China faces the challenge of balancing economic growth with environmental protection. This paper investigates the impact and spatial spillover effects of digital industry agglomeration on regional carbon emission intensity in China. Based on balanced panel data for 30 provinces from 2007 to 2021, the study reveals an inverted U-shaped relationship between digital industry agglomeration and regional carbon emission intensity, with a turning point value of 1.464, and as of 2021, only a few provinces have reached the carbon-reduction stage of digital industry agglomeration. Furthermore, heterogeneity analysis shows that the carbon-reduction effect is more pronounced in regions with developed digital economies and non-resource-based provinces, while policy pilot areas exhibit varying impacts over time. Additionally, mechanism analysis indicates that digital industry agglomeration promotes regional industrial upgrading and has an inverted U-shaped effect on regional energy intensity, thereby influencing carbon emission intensity. Moreover, using a spatial Durbin model (SDM), this study explores the spatial spillover effects of digital industry agglomeration and finds a positive U-shaped nonlinear spatial spillover effect, where digital industry agglomeration initially suppresses but later enhances the carbon emission intensity of neighboring regions. This study offers several innovations as it incorporates industrial agglomeration into the digital economy-carbon nexus, refines measurements of digital industry agglomeration using data from the Chinese multi-regional input-output table, and comprehensively examines spatial spillover effects. The findings underscore the need for region-specific policies to enhance the positive externalities of digital industry agglomeration while mitigating its adverse spillover effects, providing valuable policy implications for achieving coordinated economic and environmental development.

The biodiversity footprint of urban consumption in China declined by one quarter between 2012 and 2017

Topic: Special Session: IO Analysis for Just Transition: Linking Economic Structures and Social Inequality (2)
Author: XIAOJUAN LIU
Co-Authors: Xia LI, Wei TU, Bingqi XIE

China needs to play a vital role in bending the curve of global biodiversity loss. Big gains could be made by understanding and reducing the biodiversity footprint of consumption in cities, the ultimate source of much environmental harm. Yet there is very little information on how the biodiversity footprint of consumption varies among cities, how this changes over time, and which sectors are responsible, hampering the design of sustainability measures in cities to reduce the footprint.

To fill this gap, we estimated the biodiversity footprint associated with urban consumption in 309 Chinese cities for the years 2012 and 2017 using the environmentally-extended multi-regional input-output (EE-MRIO) model. The data on province-level occurrence of 2873 Chinese species (1520 plant species and 1353 animal species), and the threats to which they are exposed were collected from the International Union for Conservation of Nature (IUCN) Red List of Threatened Species. The city-level MRIO tables for 2012 and 2017 were derived from Carbon Emission Accounts & Datasets, which constructed input-output records with a high level of consistent sectoral economy for a complete product classification of goods and services between cities. We also analyse the driving forces of footprint variation using structural decomposition analysis (SDA). Specially, the final demand was decomposed into sector threat intensity, production structure, consumption level, and urbanized population.

We discover that the city-level biodiversity footprint in China decreased by an average of 24.35% between 2012 and 2017, with declines occurring in 266 out of the 309 cities. This striking reduction is strongly correlated with the degree of technological advancement in urban areas, which appears to have more than compensated for the negative impacts of population growth. Our results show a notable decrease in the contribution of food-related consumption to the overall biodiversity footprint, both in proportional and absolute terms. This suggests that there has been a shift in the primary drivers of biodiversity impact from traditional sectors such as agriculture to other industrial and service sectors. Additionally, we observe that the share of species threats exported to regions beyond a city's home province increased from 34.24% in 2012 to 39.40% in 2017, reflecting an increasingly teleconnected footprint within China.

This study is a systematic assessment of urban consumption-based impacts on biodiversity at the city level. Our findings indicate that sustainability strategies in China, ranging from enhanced industrial practices such as sustainable production to proactive social actions including sustainable consumption, have begun to take effect during the observed five-year period. However, our findings underscore the need for greater efforts in responsibility allocation and technological innovation. Addressing these challenges is critical for urban areas to meet increasing consumption demands while simultaneously limiting biodiversity loss within the planet's ecological boundaries. Such efforts are essential to move closer to achieving the 'No Net Loss' target for biodiversity conservation in China. These findings provide valuable insights into footprint reduction in Chinese cities and offer a methodological framework that can be adapted to other regions with rapid urban growth (e.g., South Africa) in the quest for sustainable development.

Realizing the Global Methane Pledge by 2030 via Key Pathways in Inter-country Production and Consumption Networks

Topic: Special session: Sustainable Strategies for Natural Resources and Environmental Security
Author: Xiuli LIU
Co-Authors: Zijie CHENG, Geoffrey J.D. HEWINGS, Mun Sing HO

(1) The research question.
Methane emissions embedded in global production and consumption follow complex, often obscured pathways, offering significant mitigation opportunities and posing substantial research challenges.

(2) The method used.
We applied input-output analysis, complex network analysis, and a double filtering method (DFM), developed an environmental DFM (EDFM) to identify the network of linkages among leading embedded methane-emitting sectors within EICIO tables annually from 2000 to 2020, defining these as key pathways for embedded methane emissions. We distinguished the emissions into those of embedded in domestic intermediate input (DOE) and imported intermediate inputs (IME). We analyzed network characteristics of the key pathways annually and in four phases, and assessed sources of changes in their embedded methane emissions with structure decomposition analysis (SDA) method. Then we made scenario analysis and found practical ways with the lowest cost to reduce methane emissions through the key pathways to achieve the Global Methane Pledge.

(3) The data used.
The data utilized here come from widely-used databases – the Inter-Country Input-Output (ICIO) Tables from OECD and emissions from EDGAR 2024 GHG published by the IEA. We constructed a correspondence for methane emissions from sector i in region r to sector j in region s and form extended ICIO (EICIO) tables across 76 economies and 14 industries.

(4) The novelty of the research.
We identified the key pathways, just 0.3% of 1,132,096 total linkages, accounted for around 60% of global methane emissions. Our analysis revealed that emission intensity, per capita GDP, and technical coefficients significantly yet variably influenced these pathways' emissions. With scenario analysis, we further identified the specific reduction amounts that can be achieved by 2030 through the selected key linkages by reducing emission intensity with corresponding feasible technologies and estimated their costs US$20.63 billion totally, thereby fulfilling the 2030 Global Methane Reduction Commitment, reducing methane emissions by 30.7% from 2020 levels by 2030.
The emission reduction target under scenario 1 we designed is highly likely to be achieved, for the following reasons. Firstly, the emission intensity of each key linkage's input sector we predicted in 2030 is no less than the corresponding sector's smallest emission intensity value among all economies in the EICIO tables in 2020, such as the lowest emission intensity of primary energy sector, agriculture sector and waste sector in 2020 were 0.0003 in Costa Rica, 0.0010 in Singapore, and 0.0001 in Japan, respectively. This indicates that the predicted emission intensity of key linkages in scenario 1 is attainable. Secondly, in scenario 1, the technologies'TA (technical applicability) that we matched to each key linkage is bigger than or equals to 0.7, which means they have high technological feasibility on emission reduction effectiveness. Thirdly, our distinction between the two components DOE and IME facilitates the implementation of emission reduction measures. The technical emission reduction measures for DOE are primarily implemented within the country's own borders, while those for IME are mainly executed in the

exporting countries and national cooperations. Fourthly, our results provided feasible technologies for each key linkage with the lowest cost in certain countries and sectors to achieve the Global Methane Plague by 2030, and incurring either positive or negative costs. This is a practical reference for the financial and technological investments in international cooperation on global methane emissions reduction.

This study, grounded in available scientific data and rigorous analysis, provided a practical strategy for effective and actionable plans for international cooperation in realizing the Global Methane Pledge by 2030. This facilitates the identification of opportunities and challenges at a granular level, aiding nations and industries in the implementation of methane reduction plans and translating climate goals into tangible policy actions. Additionally, the analysis of the DOE and IME key pathways assists major emitting countries in setting methane reduction actions and targets within their upcoming Nationally Determined Contributions (NDCs). Thus, our study serves as a call to action for policymakers, industry stakeholders, the research community, NGOs and the general public to consider these findings and engage in concerted efforts to realize the Global Methane Pledge by 2030.

Interactions between mitigation policies delay the achievement of carbon neutrality in China

Topic: Special session: Sustainable Strategies for Natural Resources and Environmental Security
Author: Yu LIU

Achieving carbon neutrality in China is crucial for meeting the 1.5°C target outlined in the Paris Agreement, and optimizing emission reduction strategies is key to China's response to climate change. Existing studies propose various carbon neutrality policies, yet this attempt is hampered by poor knowledge on interactions between mitigation policies. To address this gap, this study use a dynamic computable general equilibrium model of China (CEEGE model), tand create a policy portfolio area of 1,295 scenarios covering four major mitigation strategies (carbon pricing, energy efficiency, renewable energy, and electrification of end-uses). We find that reveals the synergistic feedback mechanisms among carbon reduction policies and their impact on achieving carbon neutrality. when the interplays between mitigation policies are considered, the percentage of scenarios achieving carbon neutrality target by 2060 decreases by 84%, with the achieving years of these scenarios delayed by 5-6 years. Only the combinations of renewable energy and electrification of end-uses policies generate synergetic effects in both economic and mitigation impacts. The combinations of carbon pricing and renewable energy policies exhibits the greatest trade-offs, significantly weakening emission reductions and enlarging economic losses. This study highlights the importance of considering policy interactions and provides valuable insights for formulating effective carbon reduction strategies for China and other countries.

Income-Based Inequalities in the Environmental Footprint of Protein Consumption in Asia

Topic: Regional input-output modelling (1)
Author: Yin LONG
Co-Authors: Zhimin SHI

The growing demand for protein, driven by population growth and dietary shifts, presents critical environmental challenges. While global studies have explored protein-related environmental

impacts, the extent to which these burdens vary across income groups in Asia remains insufficiently examined. This study investigates income-based inequalities in the environmental footprint of protein consumption across Asian countries, addressing disparities in resource use and ecological impact. Using an input-output model based on EXIOBASE, we quantify the environmental costs of plant-based and animal-based protein consumption across income groups, assessing four key dimensions: land use, greenhouse gas emissions, water consumption, and biodiversity loss. The analysis reveals stark inequalities, with higher-income groups driving disproportionately higher environmental impacts through greater reliance on animal-based proteins, while lower-income groups bear indirect burdens despite consuming less resource-intensive diets. By integrating income distribution with environmental accounting, this study provides novel insights into the socio-environmental trade-offs of dietary patterns in Asia. The findings inform policies aimed at promoting equitable and sustainable dietary transitions, highlighting the need for income-sensitive strategies in food system transformation.

Exploring the balance between positive and negative effects of global supply chains on freshwater consumption: A global and regional scale perspective.

Topic: Industrial Ecology
Author: Keitaro MAENO
Co-Authors: Masaharu MOTOSHITA, Kamrul ISLAM

The expansion of global supply chains (GSCs) has led to the concentration of demands for freshwater resources in specific regions, creating excessive pressure on local human health and ecosystems through overconsumption of freshwater. At the same time, industrial production activities in each country involved in GSCs generate not only negative effects (e.g., environmental interventions) but also positive effects (e.g., creation of economic value-added) for the local economy. As for these opposing effects in production activities, previous studies have mainly focused on clarifying the decoupling status between positive and negative effects at the national level. However, there is no framework in the existing literature that investigates relationship between these two effects of a specific GSC at the globe and each region involved in the GSCs, and indicates pathways for industries towards GSC structures that balance them.

Focusing on freshwater consumption, this study addresses the following research questions: How are the positive impacts (i.e., economic value added) and negative impacts (i.e., freshwater overconsumption) of specific GSCs interrelated at global and regional scales? What are the key factors for transitioning each GSC toward a sustainable structure? The novelty of this study is to explore the balance between positive and negative effects of specific GSCs on freshwater consumption at both scales.

Through this process, we estimated global water overconsumption data in 2015 using WaterGAP 2.2d model, which are based on the regional carrying capacity of water consumption across 11,000 watersheds to maintain regional human living and ecosystem and integrated it into GLORIA multi-regional input-output database which includes inter-sectoral transactions of 120 sectors in 164 countries. This approach allowed us to assess water overconsumption in each country involved in specific GSCs and compare it with economic value-added generated in those country.

We found that global water overconsumption totaled 240 billion cubic meters (m³) in 2015, with nearly one-quarter of total water consumption exceeding regional carrying capacity. Especially,

production activities in the agriculture sectors, which are highly water-consumption-intensive, played a dominant role in water overconsumption, accounting for 92% of total overconsumption. The industrial GSCs with the highest levels of water overconsumption were located in India (43 billion m³), China (40 billion m³), and the U.S. (37 billion m³). The top 20 industrial GSCs in the relevant countries, including those, accounted for 87% of the global total.

Next, we estimated the regional contribution-weighted value-added and water overconsumption for each GSC. In this estimation, the value-added and water overconsumption volumes of each country which are generated by a specific GSCs were weighted based on their respective contributions to the total of those in each relevant country, indicating water sustainability of the GSCs at a global scale. Our results showed that, for example, the USA's industrial GSCs were economically inefficient in terms of water overconsumption, whereas Indonesia's industrial GSCs were efficient compared with other GSCs worldwide.

In addition, focusing on the gap between the volume and regional contribution of both value-added and overconsumption in the agricultural sectors of each country within each specific GSC, we assessed the economic efficiency of water overconsumption at a local scale. For example, within the USA's industrial GSCs, agricultural production in the U.S. yielded a relatively low contribution to domestic value-added but a high contribution to overconsumption. On the other hand, by involving agricultural production activities in countries such as Honduras and Costa Rica, the USA's industrial GSCs contributed to value-added creation while placing substantial pressure on local water resources, implying the economic inefficiency of water overconsumption of this GSC.

Finally, we decomposed these efficiency factors to 120 sector level for each region within specific GSCs and identified key factors related to the efficiency or inefficiency from both global and local perspectives. Based on these findings, we suggested policy implications to improve efficiency within each GSC, including guidelines for selecting suitable procurement partners.

Using a Business Accounting Matrix for Risk Management of a Tourist Facility

Topic: Social Accounting Matrix and its Applications
Author: Casiano A. MANRIQUE DE LARA PEñATE
Co-Authors: Roberta PELLEGRINO

One of the main aspects for the survival and success of a new-born firm, as well as of an already existing one, is the analysis of risks that the latter may encounter throughout its life. Starting from the second half of the 20th century, a series of studies led to the drafting of a succession of Risk Management phases which, today, allows new businesses to avoid catastrophic risks, to control unavoidable risks and to open the doors to new opportunities, through the identification of their own weaknesses and the enhancement of strengths.

However, nowadays, new analysis models that allow Risk Managers to have an even broader vision of the company and consequently greater speed in the management of problems of all kinds are still being sought. In this regard, the application of Input-Output Analysis makes it possible to know, evaluate and manage in the most appropriate way hypothetical scenarios that could occur following a disruptive external event. These changes can alter the balance of an economic system to a greater or lesser extent, due to the multiplier factors that link the different sectors of the firm itself.

Input-Output Analysis has so far been mostly used for the analysis of socio-economic systems, in particular issues from trade policies and macroeconomic shocks. The use of Input-Output (IO) Analysis for single firms is still little used and under development. A useful tool for the application of Input-Output Analysis to a company is the Business Accounting Matrix (BAM), a matrix that shows the main aggregates of the economic and financial activity of the firm and all the significant economic flows among them in a specific period (Manrique-de-Lara-Peñate et al., 2022). The SAM related structure of the BAM allows one to undertake impact analysis related to changes in final demand and prices. We propose to execute this analysis in two steps. The first step calculates the impact on the main elements of the BAM of changes in final demand, that is tourist arrivals in our case. The second one applies the changes in prices to evaluate the potential impact on the Gross Economic Surplus of the firm assuming different scenarios of prices being passed over to the final consumers.

Starting with available historical data on the arrival of tourists and the prices of the main inputs of the firm, forecast simulations are developed using software capable of producing probability distributions and estimating a measure of the uncertainty that an economic parameter has of falling within a defined range. In our case, the economic variable under scrutiny is the Net Operating Surplus (NOS) of the firm. We create a model of possible outputs taking as input uncertain variables (change in visitors and in prices) in the form of probability distributions such as normal, triangular, uniform etc. It then recalculates the results again and again, each time using a different set of random numbers depending on the distribution selected. For each value of the inputs, we calculate the new NOS. The distribution of these values allows us to measure uncertainty, defining the probability of having a positive Net Operating Surplus value (≥ 0).

We believe this probabilistic approach offers a wide decision dashboard to the Manager of the firm and allows her to implement the right strategies according to possible future scenarios. We also hope this type of analysis makes Enterprise Input-Output more attractive to firm managers.

Manrique-de-Lara-Peñate, C. A., & Déniz-Mayor, J. J. (2022). The business accounting matrix: a proposal with an application. Economic Systems Research, 1-25.

CO2 Emission Reduction Potential in Modal Shifts of Freight Transport in Japan: Multi-regional Input-Output Approach

Topic: Input-output Analysis for Policy Making (2)
Author: Mami MATSUSE
Co-Authors: Shigemi KAGAWA, Ai NAGATA

In 2022, the transportation sector accounted for 18.5% of Japan's total CO2 emissions, with trucks contributing 38.0% of the transportation sector's emissions. The Japanese government has set a target to reduce CO2 emissions from the transportation sector by 35% by 2030, compared to 2013 levels, making urgent measures in the freight transport industry essential. In terms of environmental impact by transport mode, CO2 emissions per ton-kilometer of transport activity were 208 g-CO2/ton-km for commercial trucks, while ships and railways had significantly lower emissions at 43 g-CO2/ton-km and 20 g-CO2/ton-km, respectively. This highlights the potential for modal shift—the transition from road transport to maritime and rail transport—as a key strategy for reducing CO2 emissions.

This study provides new insights in two key aspects. First, we constructed a multi-regional

input-output (MRIO) table for 2015 by extending the single-region input-output (SRIO) tables of Japan's 47 prefectures to estimate transport-derived CO_2 emissions. While Hasegawa et al. (2015) previously estimated an MRIO for the 47 prefectures in 2005 using the RAS method, data limitations led to rough estimations based on the strong assumption of the location quotient method. It is important to note that the location quotient method used for estimating the MRIO table conventionally determines intra- and inter-regional flows of a specific commodity based on the market share of that commodity produced in different regions. If a purchaser of a homogeneous commodity produced in multiple regions is equidistant from those regions, the regional market shares of the commodity play a crucial role in determining the amount of intra- and inter-regional flows. However, this is a very specific case. In reality, the geographical distance between purchasers and producers is a crucial factor in determining intra- and inter-regional commodity flows between them.

In contrast, this study estimated an initial multi-regional input-output table for Japan in 2015 based on intra- and inter-regional trade coefficients of commodities. These coefficients were estimated using the location quotient method and derived from 'actual' intra- and inter-prefectural freight movements by transport mode, thereby improving the estimation accuracy of intra- and inter-prefectural commodity flows provided by the Ministry of Land, Infrastructure, Transport and Tourism's freight flow survey data. The initial multi-regional input-output table was then applied to the GRAS method, resulting in a multi-regional input-output table with a balanced demand and supply of commodities.

Second, our analysis comprehensively estimates CO2 emissions by transport mode across all inter-prefectural freight movements, categorizing emissions by commodity type. Previous studies such as Yun et al. (2005), Wisetjindawat et al. (2015) and Matsuo and Hukuda (1997) primarily targeted specific regions within Japan and did not sufficiently consider constraints on transport mode selection or detailed commodity-specific analyses. Given that dominant transport modes and inter-prefectural trade relationships vary due to geographical factors, and that some commodities require the flexibility of truck transport while others can be efficiently shifted to alternative transport modes, our study identifies commodities with the highest potential for CO2 reduction through modal shift.

Our analysis indicates that Japan's dominant freight transport modes are trucks and ships. If all truck transport over distances of 500 km or more were replaced by maritime transport, CO2 emissions would be reduced by approximately 24%. Specifically, CO2 emissions from truck transport would decrease by around 33%, while emissions from maritime transport would increase by about 27% due to the shift. Analyzing CO2 emissions by inter-prefectural transport corridors, Tokyo, Hokkaido, Saitama, and Fukuoka were identified as key regions where prioritizing modal shift could maximize CO2 reduction.

Further, among the top six commodities accounting for approximately 20% of total freight transport, four categories—daily necessities (such as office supplies and furniture and decorations), chemical products (including petroleum and coal), and other transportation equipment and repairs—were identified as key targets for modal shift. Shifting these commodities from trucks to ships could achieve nearly 60% of the CO2 reduction potential from a complete truck-to-ship modal shift.

As a policy recommendation, we propose providing financial incentives, such as subsidies, to prioritize modal shift in prefectures and for commodities with high CO2 emissions, thereby promoting a more efficient and effective transition toward decarbonization in the transportation sector.

Embodied GHG Emissions in ASEAN: A Multi-Regional Input-Output Analysis

Topic: Energy Input-Output Modelling
Author: Asuka MATSUYAMA
Co-Authors: Shigemi KAGAWA

In the ASEAN region, often referred to as a global growth center, rapid economic expansion and population growth have led to a significant surge in energy demand, raising concerns about the corresponding increase in greenhouse gas (GHG) emissions. The population of ASEAN region has increased fourfold over the past 70 years and is estimated to reach 790 million by 2050.

Against this backdrop, ASEAN member states have committed to achieving carbon neutrality between 2050 and 2065 in alignment with the Paris Agreement. For instance, initiatives aimed at reducing greenhouse gas emissions include the installation of floating solar power plants in Singapore and the improvement of hydropower and wind generation in Laos. However, the region remains heavily reliant on abundant and inexpensive fossil fuels, and the challenges of coordinating efforts among member nations pose significant obstacles to decarbonization.

Fossil fuels are widely utilized across various industries, both as raw materials and as energy sources, directly and indirectly contributing to GHG emissions throughout ASEAN's industrial landscape. Considering the dense interconnectivity of the region's industrial networks, it is crucial to quantitatively evaluate the direct and indirect GHG emissions from domestic industries. Such insights can guide strategies for decarbonization tailored to the unique circumstances and characteristics of each member state.

To quantify the GHG emissions generated in ASEAN countries, this study utilized GLORIA database which provides the 2019 multi-regional input-output table (MRIO) covering 164 countries and 120 industrial sectors. Using the Environmentally-Extended Input-Output Analysis (EEIOA), we estimated direct and indirect GHG emissions for each of the 10 ASEAN countries. Additionally, we calculated GHG emissions per capita using the World Population Prospects data for these 10 countries and compared the results across countries.

The findings reveal that in 2019, the ASEAN-10 countries accounted for approximately 6% of global GHG emissions. Indonesia, the most populous ASEAN nation, recorded the highest total GHG emissions. On a per capita basis, Brunei reported the highest emissions, followed by Singapore, Malaysia, and Thailand. Brunei's significant emissions are attributed to energy conversion processes, such as oil refining and power generation, heavily reliant on abundant petroleum and natural gas resources. In contrast, Cambodia and the Philippines, characterized by either the early stage of development or reliance on renewable energy sources like geothermal and hydropower, exhibited relatively low per capita emissions.

Furthermore, approximately 80% of GHG emissions in the ASEAN-10 are attributed to CO_2, primarily driven by fossil fuel-dependent power generation and transportation. For instance, coal-fired power plants dominate energy supply in Indonesia and Thailand, while rapid industrialization has spurred increased fossil fuel consumption in Malaysia and Vietnam. Although Brunei's low population size contributes to its high per capita emissions, the nation is also in a stage of active industrialization. Mitigating fossil fuel usage in these industrializing nations will be pivotal for ASEAN's decarbonization goals.

The diverse economic structures and stages of development among ASEAN countries necessitate

flexible and country-specific decarbonization policies. Moreover, strengthening regional cooperation will be essential for reducing GHG emissions across ASEAN's supply chains. In particular, reducing GHG emissions from industrializing countries remains an urgent priority, requiring measures such as utilizing foreign technologies to convert CO_2. To achieve this, as seen in Japan's recently proposed AZEC initiatives, ASEAN countries should leverage advanced technologies from Japan and other partner countries within a regional cooperative framework. By sharing the common goal of economic growth in Asia and taking a leadership role in the international community, ASEAN countries should work together to promote decarbonization..

A New Skyline Chat Model for Global Value Chain Analyses

Topic: Structural Change and Dynamics
Author: Bo MENG
Co-Authors: Jiabai YE, Satoshi INOMATA, Jiemin GUO, Jinjun XUE

Over half a century ago, Leontief (1963) introduced the Skyline Chat, an innovative input-output based structural analysis tool designed to analyze and visualize a country's industrial structure, trade dependency, and economic self-sufficiency over time, with explicit consideration of production propagation effects along domestic inter-industrial networks. Since its inception, numerous applications and extensions of Skyline Chat have been utilized for economic structure analyses. However, the rise of global value chains (GVCs) presents significant challenges for traditional Skyline Chat analyses in accurately capturing the complexities of economic globalization.

This paper addresses these challenges by identifying three primary limitations of the conventional Skyline Chat model:

1)   The reliance on gross term measures, which leads to double counting issues due to the treatment of intermediate inputs. For example, conventional Skyline Chat uses output share rather than value-added share by sector to measure industrial structure, and gross term exports and imports rather than trade in value-added to measure trade dependency.
2)   The use of a single national input-output model, which treats exports and imports of intermediates exogenously, thereby failing to capture the full extent of foreign interdependencies through complex GVCs.
3)   The focus on country-sector level analyses, which overlooks the role of multinational enterprises (MNEs) as key organizers and players in GVCs.

To overcome these limitations, this paper proposes a new Skyline Chat model based on the OECD AMNE inter-country input-output tables. This model incorporates trade in value-added measures within the GVCs accounting framework, effectively addressing the double counting problem in assessing industrial structure, trade dependency, and self-sufficiency. Empirical results indicate that the conventional Skyline Chat model over- or under-estimates trade dependency and self-sufficiency for more than half of the 70 economies covered in the OECD data by approximately 10-30%. This discrepancy is particularly pronounced in sectors dominated by MNEs compared to domestically owned firms.

Furthermore, leveraging the dual relationship between value-added and final demands (where a country's total value-added equals its total final demands), this paper extends the trade in value-added based Skyline Chat model to measure final demand structures. Additionally, the dual Skyline Chat models are applied to carbon emissions footprint analysis, offering a novel tool to

visualize production versus consumption-based emissions accounting, while considering a country's energy supply and demand structure, foreign dependency, and self-sufficiency in a consistent manner.

Structural Changes in Global Automotive Supply Chains: The Rise of Electric Vehicles

Topic: Special Session: IO Analyses for Electrified Vehicles
Author: Bo MENG
Co-Authors: Aodong JIAO, Ran WANG, Li XIYUAN, Norihiko YAMANO, Yunfeng YAN, Ming YE, Yang ZHOU

In global automotive supply chains, the impact of CO2 emissions on climate change has become a focal point of international discourse. Concurrently, the widespread adoption of Electric Vehicles (EVs), including Plug-in Hybrid Electric Vehicles (PHEVs) and Battery Electric Vehicles (BEVs), is anticipated to bring about significant structural transformations to the global economy. This study aims to provide valuable insights for policy formulation by analyzing and simulating changes in production- and consumption-based CO2 emissions across countries, as well as changes in global value-added creation and distribution resulting from advancements in EV-related technologies.

We utilize the latest OECD Inter-Country Input-Output (ICIO) tables to develop an extended EV-Inter-Country Input-Output model. This model disaggregates the automotive industry into three subsectors: conventional vehicles (internal combustion engines), EVs, and vehicle parts and components. Differences in the technological input structures between EVs and conventional vehicles are estimated based on sample surveys, interviews with auto companies and technical experts, and relevant customs trade data.

Initially, the study analyzes the structural changes in the international trade network of key components required for EV manufacturing (such as batteries, motors, and controllers), as well as the essential materials needed for producing these components. Furthermore, through structural change analysis and simulation based on the developed EV-ICIO model, the study examines how the proliferation of EVs affects value-added creation and CO2 emission patterns within global supply chains, both upstream and downstream, and assesses the implications for the competitive advantage of various countries.

Our main findings indicate dramatic structural changes in global vehicle supply chains, primarily due to the rise and expansion of EV production and consumption. China's role in global EV supply chains, both upstream and downstream (from key materials, key parts and components, as well as finished vehicles), demonstrates a strong dominance in controlling power, resulting in greater value-added gains. CO2 emissions footprints in the entire production process of EVs do not show significant advantages compared to conventional vehicles. This is because EV batteries are relatively high carbon-intensive products compared to combustion engines. Although very limited CO2 emissions occur during the use of EVs, the emissions friendliness of this process highly depends on the source of electricity generation. Even with the popularization of EVs, economies that heavily rely on coal-based power generation to produce electricity still face challenges in emissions reduction.

Circular economy practices drive climate impacts across international supply chains

Topic: Sustainable Production and Consumption
Author: Jing MENG
Co-Authors: Quanzhi XIA, Heran ZHENG

The circular economy framework is posited as a transformative solution to decouple escalating global material demand from raw resource extraction with constrained natural resources. Central to this model is secondary production, which repurposes waste into critical resources, reducing reliance on primary inputs while addressing resource security. However, emerging evidence reveals a systemic paradox: the global supply chains enabling circularity may inadvertently exacerbate carbon emissions through energy-intensive upstream processes. Recycling, reprocessing, and cross-border transportation—cornerstones of secondary production—often depend on fossil fuel-derived energy in regions with carbon-intensive power systems. As nations increasingly outsource these activities abroad, the climate benefits of circular systems risk being offset by transboundary emissions—a blind spot in current sustainability frameworks.

Here, we investigate how secondary production redistributes carbon emissions globally by analyzing five materials critical to economic development and climate change: plastic products, iron and steel, aluminum, copper, and other metals. Using a multi-region input-output (MRIO) model and the hypothetical extraction method (HEM), we map cradle-to-gate emissions from primary and secondary production for 160 economies worldwide, based on the Global Trade Analysis Project (GTAP) Circular Economy Data Base Version 11. We distinguish between domestic and imported carbon emissions to reveal the asymmetric impacts of secondary production on global supply chains. We explore in which sectors and regions these impacts take place to inform targeted policy design that fosters a circular and low-carbon future for all.

We find that global production of secondary iron and steel leads to 613.9 Mt embodied emissions, followed by aluminum (77.1 Mt), plastic products (70.5 Mt), other metals (62.4 Mt), and copper (45.7 Mt). High and upper-middle-income regions account for most embodied emissions from secondary production due to their significant production scale. A majority of global economies risk increasing at least one of domestic or imported emissions when substituting secondary for primary production, revealing the systemic trade-offs between circular economy strategies and climate mitigation. Over 50% of plastic products, iron and steel, and other metals producers and 40% of aluminum and copper producers create imported carbon trade-offs despite domestic synergies. High-income regions are most likely to drive these imported trade-offs by outsourcing energy-intensive recycling processes to upper-middle-income regions, exacerbating emissions in the latter's energy sectors. More than 20% of iron and steel and other metal producers lead to both domestic and imported emission increases. For example, Japan's secondary iron and steel production generates 33.6% more domestic emissions and 30% more imported emissions than primary production due to increased energy use. By contrast, upper-middle-income regions are most likely to achieve both domestic and imported emission reductions. For instance, China's secondary iron and steel production reduces carbon emissions from not only domestic material sectors but also foreign energy sectors.

By linking circular economy practices to transboundary carbon leakage, this study challenges the assumption that secondary production universally aligns with climate goals. It calls for redefining circularity through a lens of global equity, ensuring that emission reductions in one region do not exacerbate climate injustices elsewhere. Our findings provide actionable insights for policymakers navigating the dual imperatives of sustainable production (SDG 12) and climate

action (SDG 13), emphasizing the need for coordinated international strategies to harmonize circularity with decarbonization.

Assessing the Vulnerability of Global Supply Chains to Cargo Theft: A Multi-Regional Input-Output Approach

Topic: Input-Output Modelling: Disaster Analyses
Author: Haruka MITOMA
Co-Authors: Norihiko YAMANO

This paper presents a new framework for assessing the impact of cargo theft on the global supply chain. Extensive research has been conducted in economic modeling, particularly through the Inoperability Input-Output Model (IIM) and the Computable General Equilibrium (CGE) Model, to estimate the economic consequences of disasters. However, most previous studies have focused on low-probability, high-impact risks such as earthquakes, floods, and terrorism. In contrast, there has been limited research on high-probability, lower-impact risks, such as cargo theft.

Cargo theft continues to pose significant challenges to global supply chains, leading to financial losses, injuries, fatalities, disruptions, and increased costs due to heightened security measures. The economic impact extends beyond direct losses, affecting insurance premiums, supply chain reliability, and consumer trust in global trade networks. Despite growing awareness of resilience strategies and advancements in security technologies, such as real-time monitoring systems, cargo theft incidents are on the rise. In 2023, 156,000 incidents were reported in the Europe, Middle East, and Africa (EMEA) region, resulting in total losses of $585 million (TAPA, 2023). In Asia, 343 incidents led to losses of $200 million (TAPA, 2023). That same year, the United States and Canada experienced a record-high number of cargo thefts, with 2,852 reported incidents and total losses amounting to $331 million (CargoNet, 2025).

The structure of global supply chains is evolving due to the increasing fragmentation of production and the growing awareness of network concentration risks, particularly following shocks such as COVID-19. The target goods of cargo theft are also influenced by global dynamics. Thieves tend to focus on high-value, easily resellable goods, with general inflation and product shortages further contributing to the rise in theft incidents. Frequently targeted commodities include food and beverages, pharmaceuticals, metals, and fuels. During the COVID-19 pandemic, medical supplies such as masks and medicines became particularly vulnerable to theft.

To mitigate the impact of cargo theft on supply chain disruptions and economic losses, stakeholders must understand the evolving risks associated with global trade. In our analysis, we assess the vulnerability of product supply chains to cargo theft over time using the Inter-Country Input-Output Tables published by the OECD and cargo incident data from the Transported Asset Protection Association Incident Information Service (TAPA IIS) database. Given that cargo theft increases transportation costs through heightened security expenditures and rising cargo insurance premiums, we develop a model to examine how the cost pressures are propagated through global supply chains, aiming to identify important stakeholders who are indirectly affected. Specifically, we focus on global supply chains passing through hot spot countries and products that have experienced a rapid increase in cargo theft incidents. Since previous studies have largely focused on localized cargo theft risks—analyzing incidents at the national or city level—our research provides a more comprehensive perspective for global supply chain managers. Furthermore, our analytical framework can help quantify the benefits of mitigation measures aimed at reducing cargo theft. This framework provides valuable insights into improving supply chain resilience while minimizing the financial risks associated with cargo theft.

The Regional Inequality of Mexican Productive Articulation: A Spatial Input-Output Perspective

Topic: YSI and Development Programme (2) (Discussants: Heran ZHENG and Sofía JIMÉNEZ)
Author: Rodrigo MORALES-LóPEZ

Regional inequalities in Mexico have increased since implementing structural adjustment programs and trade liberalization, limiting economic development. The poor performance of the export-led growth model underscores the need for an industrial policy. This paper seeks to answer the following question: What is the magnitude of the regional inequality footprint generated by how the Mexican productive structure is articulated? The research aims to contribute to the design of a regional-focused productive development policy that does not perpetuate inequalities.

The regional inequality footprint in Mexico's productive articulation is estimated using the hypothetical extraction method (Dietzenbacher & Lahr, 2013) and the spatial Gini Index (Rey & Smith, 2013). Various studies have analyzed sectoral and regional productive articulation in Mexico through input-output analysis (Morales-López, 2023; Ayala, Chapa & Treviño, 2015; Dávila, 2015). Additionally, other studies have examined the dynamics of regional economic inequalities with a spatial focus (Valdivia, 2008; Quintana-Romero & Salas, 2023). At the international level, this research aligns with studies exploring the relationship between productive structures and the generation of inequalities (Duan et al., 2022; Alsamawi et al., 2017; Duarte et al., 2022). To the best of the author's knowledge, this work is the first to estimate the degree of regional inequality linked to the articulation pattern of Mexico's productive structure.

The results reveal intra and interregional inequalities, the concentration of productive activity in states with the most significant metropolitan areas, and the presence of spatial externalities in the national productive structure. Technology-intensive manufacturing and service industries contribute significantly to regional inequality at the sector level, while fostering resource-processing manufacturing and its supporting primary sectors may help narrow regional disparities among federal entities.

The Unequal Income Distribution Generated by Mexican Exports: A Structural-Spatial Analysis.

Topic: International Trade (3)
Author: Rodrigo MORALES-LóPEZ

In recent decades, there has been an increase in inequality both between countries and within them. Inequality is a social justice issue that limits the expansion of the domestic market and weakens the potential for economic growth. Additionally, it can jeopardize political and social stability (Blecker, Moreno-Brid & Salat, 2017). In the economic sphere, globalization is considered one factor contributing to increased inequality within countries (Pavcnic, 2011). In Mexico, exports have shown sustained growth in recent years; however, they incorporate low value-added and have limited linkages with the rest of the productive structure (Fujii-Gambero & Cervantes, 2017).

The main objective of this study is to estimate and analyze inequality in the income distribution generated by Mexican exports from a structural and spatial perspective. In the first stage, interregional input-output analysis is applied to Mexico's multi-state input-output matrix. In the second stage, spatial inequality indicators are estimated for the distribution of wages and gross operating surplus across federal entities, both for exports and domestic final demand. Additionally, the share of wages in the value added generated by both types of production is

assessed.

Despite its significance, few studies in Mexico have addressed this issue. González (2007) examines regional inequality linked to trade liberalization using econometric techniques, while Ruiz Nápoles (2021) employs a structural approach to demonstrate that the income generated by Mexican exports is predominantly distributed in favor of capital. This study is the first to disaggregate and analyze inequality in the income distribution associated with exports, both at the sectoral and regional levels, comparing the results with those obtained for domestic final demand.

The findings of this study highlight the need to implement industrial policies that not only seek productive development but also contribute to reducing inequalities. The estimates show that production aimed at the domestic market has a better potential for economic growth, as the income generated exhibits a better regional distribution among federal entities and is more favorable towards workers. A regional-scope productive development policy should aim for simultaneous growth through domestic and external demand.

Beyond Borders: Hidden Effects of US Tariffs on the US-MX's Circular Flow of income. A Bi-regional CGE Model

Topic: CGE and Econometric Input-output Modelling (2)
Author: Eduardo MORENO-REYES
Co-Authors: Claudio SOCCI, Rosita PRETAROLI

In 2025, the new elected government of the United States declared the intention to impose trade tariffs on imports from Mexico. The amount of the measure has not been clearly specified yet; however, the action is meant to reduce the current trade deficit between US and Mexico especially in industries like transportation and electronic equipment. The announcement suggests that the existing trade agreement, USMCA (United States, Mexico and Canada Trade Agreement) will be reviewed in 2026 through intense trade negotiations.

In the worst case, the declared tariffs could reach the 25% of the value of all imported goods from Mexico, with severe implications not only on trade but also on the internal income distribution of the two countries. In this perspective, it becomes extremely important to produce a forecast of the potential impacts of this measure in both countries at aggregated and disaggregated level. Indeed, due to the complex industrial interdependencies between the United States and Mexico, notably in the automotive, electronics, oil, and chemical industries, the pricing consequences of the measure might go beyond the simple raise in import costs and the associated adjustments in the trade deficits. They also might encompass wider ripple effects throughout the "trade in task", that is the trade in intermediate goods and services typical of the offshoring (Grossman & Rossi-Hansberg, 2006).

Mexico's trade patterns implicate that 80% of exports go to the US market, generating a 6.0% GDP trade surplus, despite deficits in petroleum, coal products, and chemicals. Mexico also maintains smaller surpluses with Canada (0.13% GDP) and Latin America (0.71% GDP). However, it faces substantial overall deficit culminating in a -2% GDP (INEGI, 2024) and distributed as follows: -5.0% of GDP with China, -2.6% with other Asian countries, and -2.5% with Europe.

On the other side, the US shows greater trade diversification, with exports distributed to Africa and Oceania (32%), Europe (18%), Canada (15%), Mexico (12%), and China (7%). Imports of goods and services follow a similar pattern: Africa and Oceania (27%), China (19%), Europe (16%), and Canada and Mexico (11% each). While the US experiences trade deficits with major partners, notably China (-1.9% GDP) and Europe (-0.76% GDP), these are partially mitigated by services trade balances (BEA, 2024).

Given this multifaced trade situation, to evaluate the effects of potential new/raised tariffs on

both US and Mexico, it can be very useful to use a multi-regional and multi-sectoral approach, in which the multiple (direct, indirect and induced) effects can be determined.

Since the 1960s, Balassa (1965) and Corden (1966) used the Effective Protection Rates (EPR) to measured tariffs escalation's impact on developing countries by imposing high duties on final goods, but lower rates on raw materials. Diakantoni and Escaith (2012) draw on the EPR to capture the indirect effects of the international inter-industry system proposing a Leontevian approach. Miroudot, et al. (2013) examine the implications of Global Value Chains (GVCs) for trade policy for Canada. Giammetti (2020) studied the impact of Brexit on trade by using the World Input-Output Database (WIOD) (Timmer, et al., 2015), and explored how import substitution policies could reduce economic losses for UK and EU27.

However, Diakantoni and Escaith (2012) argues that maybe CGE models fit better how protectionism might affect the economy, enabling sensitivity analysis of substitution effects on Effective Protection Rates. Recently, these models have been widely used to evaluate the effects of tariffs (Bolarinwa, 2024), since they allow simulating a shock on relative prices (Vellinga & Tanaka, 2024) and quantify the real and nominal impacts.

Following this last approach, this article develops a bi-regional CGE model on a bi-regional Social Accounting Matrix (SAM) which reconstructs all inter-regional and intra-regional income flows between the US and Mexico. The bi-regional US-MEX SAM derives from authors' elaborations on BEA and INEGI databases and shows a disaggregation of 63 commodities and 63 industries, 4 components of value added (Compensation of employments, Gross Operation Surplus, Taxes on products, Taxes of Production) and 6 institutional sectors (Households, Financial and non-financial corporations, Federal and Local Government, Rest of World) for each country. In addition, households from US are divided into 9 groups according to the data from BEA, while households from Mexico are classified by deciles. The construction of such a database is functional to the calibration of the CGE model and the definition of the technical coefficients, shares, implicit tax rates, income distribution quota etc. In this way it io possible to quantify the real and nominal potential effects of tariffs in each phase of income generation, distribution and use at a disaggregated level in both countries The detail

Constructing Demand-Driven Input-Output Models by Direct Introducing Quantity and Price Parameters into the Product Balance Identity

Topic: Input-Output Theory and Methodology (2)
Author: Vladimir MOTORIN

The study starts with the product balance identity according to logical scheme [output 0 = intermediate input 0 + final demand 0] for the base year 0. Formal introducing unknown matrices of quantity and price indices and taking the Hadamar products of them and production matrix 0 and, in turn, intermediate consumption matrix 0 leads to generalized nonlinear input-output model with exogenous final demand. This model comprises an excessive number of unknown quantity and price parameters and is not identifiable itself.

Nevertheless, under simplifying assumption about diagonal form of unknown parameters matrices one can get still nonlinear input-output model with exogenous final demand but written with usual matrix operations and so much more operational. In general, this model could be linearize in four ways: set the matrix of price indices equal to identity matrix (constant prices), allow the quantity parameters matrix being identity matrix (constant levels of production by industries), use price indices for outputs and quantity parameters for intermediate inputs, and, finally, apply quantity indices for outputs and price parameters for intermediates.

Special attention in the study is paid to examining some analytical properties of four linearized

input-output models with various sets of price and quantity parameters. All the models turn out to be strictly identifiable under some technical assumptions not so cumbersome. In particular, it is shown that linear model at constant prices is in exact accordance with the formal pattern of product technology assumption widely known in input-output analysis. Second linear model with exogenous final demand at constant levels of production by industries could be appreciate as almost trivial. Other linear models with combined using price and quantity parameters seem to be out of economic sense, have no any mention in special literature but some of their features are of theoretical interest and deserves further exploration.

Mapping Net Decarbonization Pathways for India's Dairy industry: An Economy-wide evaluation of sustainable livestock management practices

Topic: Input-output Analysis for Policy Making (2)
Author: Kakali MUKHOPADHYAY
Co-Authors: Vishnu Sivadasa PRABHU

Background
India's dairy sector accounts for a substantial contribution to the Indian economy, given that India is the largest milk producer in the world, providing employment for 91 million dairy farmers and further 20 million indirectly. The smallholder farmers in India account for 44% of agricultural land and 75-80% of livestock resources. India is ranked first in livestock population globally. While the dairy sector accounts for 4% of India's GDP, it is responsible for 9.5% of GHG emissions from the agriculture sector, primarily resulting from methane emissions from feed production and enteric fermentation and nitrous oxide from manure management. India recently overtook China to become the most populous nation in the world and is expected to continue to grow till 2035. The rise in demand for milk and milk products will lead to an upward rise in livestock sector emissions, which is detrimental to India's aim of reducing GHG emissions by 1 billion tonnes by 2030. Mapping decarbonization measures for the livestock sector can ensure economic gains across the dairy industry supply chain and simultaneously ensure environmental sustainability aligned with SDG 11.
Research question
The broad objectives of the study are given below:
•   Using a comprehensive Farm-to-Fork Life Cycle Assessment (LCA) approach, the study investigates the economy-wide impact of introducing sustainable animal feed for cattle and buffaloes used in milk production and supply to the dairy industry.
•   To evaluate the scope for economic gains for the smallholder livestock farmers through sustainable growth of dairy production in the country.
•   To estimate the environmental impact by calculating the total GHG and Water footprint in alternative animal feedstock scenarios is assessed.
Methodology and Data Sources
The study adopts an Environmental Input-Output LCA (EIO-LCA) approach by referring to the latest Supply Use Tables published by the Government of India for the year 2019-20. Based on the commodity-wise growth rates estimated using the National Accounts Statistics, between 2019-23, the Input-Output table will be updated to the year 2030. The 'Ration-Balancing Programme (RBP), undertaken by the National Dairy Development Board, focuses on Balanced feed formulation for cattle and buffaloes in order to increase milk yield and reduce feed cost has been referred. The latest survey conducted by the Government of India on the 'Situation Assessment of Agricultural Households and Land Holdings in Rural India 2019' refers to compiling different farmholder category-wise expenses on livestock farming and rearing.

Novelty of research

To the best knowledge of the authors, this is the first-of-its-kind study evaluating an economy-wide decarbonization pathway for the Indian dairy industry. While previous studies have undertaken the direct attributional LCA approach estimating the direct GHG emissions in the dairy industry, this study assesses the economy-wide and environmental impact of not only the dairy industry supply chain but the overarching impact of decarbonization measures in India's livestock sector on rest of the economy.

Preliminary findings

According to the latest household consumer expenditure survey 2022-23, India's urban population consumes on average 197 gms/day of dairy products, compared to the dietary recommendation of 312 gms/day according to the Indian Council of Medical Research. While the current consumption of dairy products remains low, trend analysis shows that India's dietary patterns have been converging to developed countries wherein the expenditure on dairy products is gradually increasing. In the scenario without RBP intervention, the achievement of recommended dairy products intake by 2030 will lead to an increase in Total output, GDP and Employment of 1.7%, 1.1% and 1.3%, respectively with an increase in GHG and Water footprint by 44.4 tCO_2e. and 20.7 thousand cubic meters respectively. However, India's smallholder farmers spend 73.5% of total expenses on animal 'seeds' and animal feed, compared to only 45% by larger farmers. The implementation of RBP recommended diets that reduce feed cost by 11.8% and emission intensity in the primary stage of milk production, leads to minimal difference in macroeconomic indicators, while the GHG emission decreases by 14.7%. In another case of 'detailed RBP', specific accounting for various types of animal feed, such as green fodder, dry fodder and nutrient concentrates as well as optimal water requirement for the cattle and buffaloes is of higher importance for the smallholder farmers, given their larger share of expenses attributed to animal feed procurement. The Benefit Cost Ratio of livestock rearing is expected to increase from 1.38 to 1.56 by following the detailed RBP, leading to further positive economy-wide and environmental multiplier effects, given their larger livestock holdings.

Putting Asian Competitors in the RMG Trade under Fresh Perspectives: Ideas for GVC Ahead of the CSDDD

Topic: International Trade (3)
Author: Kakali MUKHOPADHYAY
Co-Authors: SUVAJIT BANERJEE

1. Introduction

Together, Asian economies account for 70.6% of the global textile and clothing exports in 2022, significantly participated by China, India, Bangladesh, Vietnam, and Indonesia, each exhibiting distinct specializations that appeal to importers. Despite being a major and consistent contributor of approximately 40% of the aggregate value added in global Ready-made Garments (RMG) exports in recent years, China's neoteric emphasis on enhancing the quality and sustainability of its economic growth is prompting a strategic shift away from this sector. This transition entails reallocation of the export prospects for other Asian competitors competing primarily by relying on the low-skill requirements for RMG manufacturing.

However, the newly debated regulatory framework designed by the European Union, known as the Corporate Sustainability Due Diligence Directive (EU-CSDDD), qualifies the trade competition scenario, notably in the RMG sector with additional complexities. This directive emphasizes both environmental sustainability and social responsibility across various industries, including textiles and garments. As a result, compliance with the EU-CSDDD may diminish the cost advantage currently associated with low-skilled RMG manufacturing, posing additional challenges to

regaining competitiveness. Geopolitical resistance to such enforceable commitments might delay the process to set in and buy some time for business and production operations to readjust, however, there will be no escape from the eventual erosion of the comparative advantage naturally accrued through stark social inequality, high unemployment rate, and abundance of low skilled labors.

Consequently, while low labor wages were once a key factor in competitiveness, they will now disrepute the operation of even low-skilled manufacturing, rather productivity may take precedence in the RMG market over the next decade. Countries that adapt more quickly to these regulations will gain a first-mover advantage and are likely to dominate the RMG sector compared to those that move more slowly.

2.   Objectives

o   The study attempts to evaluate the Domestic Value Added and Foreign Value Added contents of increased RMG exports from the four Asian economies, namely – India, Bangladesh, Vietnam, and Indonesia, in recent years and examines the driving forces and potential impacts of FVA on trade.

o   The study intends to determine whether growing global value chains participation may be used as an adaptation strategy for Asian RMG firms to win over mandatory social and environmental compliance and remain relevant in the global trade arena.

3.   Methodology

The study adopts a Multiregional Input-Output Analysis using the ADB-MRIO table. The extracted MRIO tables comprise China, India, Bangladesh, Vietnam, Indonesia, the European Union, and the Rest of the World for the years 2007 to 2023. The study estimates the Forward and Backward GVC participation rates of the RMG sector by individual Asian economies following Borin and Mancini's framework (2019).

The study employs an extensive multiplier analysis to examine both intra-country and inter-competitor relationships regarding the productivity of primary inputs and their participation in GVC. The results derived from this analysis are utilized to simulate variations in productivity resulting from increased compliance costs and a subsequent decline in trade competitiveness. Ultimately, the study provides a comparative assessment of the adaptive capabilities of various economies in response to new regulations that may disproportionately impact competitiveness, particularly in nations characterized by low labor costs.

4.   Novelty

The trade landscape of the RMG sector is likely to undergo substantial transformations in the coming years, influenced by endogenous mutations in the socio-cultural and political environment across Asian competitors and exogenous fluctuations in international market dynamics. This ambiance presents a notable opportunity for trade practitioners and stakeholders to examine the prospects of the RMG sector and to comprehend the interconnections among the determinants that may shape future Global Value Chains. The study examines the vulnerabilities associated with the major shift in the rule of the game determining competitiveness for RMG exports. Suppose the comparative advantage of low-cost labor is diminished due to compliance with social obligations imposed externally. In that case, Asian competitors may close the productivity gap by increasing GVC participation and seizing early market advantages. The study uniquely intends to investigate the preparedness of Asian RMG competitors regarding productivity differences and their implications for employment. The novelty of this study lies in acting as an academic whistle-blower, alerting these low-wage RMG manufacturers and suppliers to their risky reliance on an unbalanced comparative advantage.

Improving the overall economic well-being in Bangladesh through the provision of Safely managed Sanitation and Hygiene services in pursuit of SDG 6 – An Integrated Circular Economy framework

Topic: Special session: Sustainable Strategies for Natural Resources and Environmental Security
Author: Kakali MUKHOPADHYAY

Background
Ensuring access to improved water, sanitation and hygiene facilities is paramount for achieving Sustainable Development Goal (SDG) 6 – Clean Water and Sanitation. Bangladesh has one of the lowest urban sanitation access rates (52%) in South Asia. According to the World Health Organization (WHO), in 2022, 65.5 million people in Bangladesh (two in five) lacked good hygiene at home. Given that more than half of urban residents in Bangladesh, reside in informal settlements, improper faecal sludge disposal significantly impacts human health and the environment. Effective Faecal Sludge Management (FSM) will ensure utilizing treated faecal sludge in organic fertilizer production, thus establishing a circular economy framework. The overarching objective of this study is to ensure that government policies in Bangladesh are aptly aligned to support socio-economically equitable outcomes and the overall well-being of the population, with a focus on the sanitation and hygiene sectors.
Research Objectives
Given this background, the research objectives are presented below:
1)   To study and analyse the impact of sanitation and hygiene sector investments on Output, GDP and Employment, along with the inter-sectoral impacts using an Input-Output (I-O) framework.
2)   To conduct an economic valuation of FSM as a by-product of sanitation and hygiene services to produce organic fertilizers and the resulting environmental benefits through a Circular Economy (CE) framework.
3)Methodology and Data sources
An Input-Output (I-O) framework is used, by adopting the latest Bangladesh I-O table published by the Asian Development Bank. The IOT is modified to separate the sanitation, hygiene and organic fertilizer industries. The Bangladesh National Wash Accounts 2020 report was the key source referred for estimating the expenditure on Sanitation and Hygiene sectors.
4)Research novelty
The earlier studies conducted on the sanitation and hygiene services in Bangladesh are undertaken in a partial equilibrium framework, focusing on the direct impact on the environment and human health and the household's income and expenditure levels at a micro-level. The whole economy (direct and indirect) impacts of various government policies in this sector are yet to be studied. Further, the economic valuation of FSM along with its co-benefits through organic fertilizer production from a macro-perspective has not been conducted. To the best knowledge of the authors, this study develops a first-of-its-kind integrated framework, constituting the sanitation, hygiene and FSM segments to study the overall economic and environmental impacts on the Bangladesh economy, using an Input-Output framework.
5)Results
The advancements in sanitation and hygiene services through investments provide evidence of socio-economic gains. Results indicate that the investment in sanitation and hygiene services could increase GDP per capita between US$1.4 - US$107 by 2030 across various scenarios. The female demographic over the age of 14 is projected to see greater benefits, with GDP per capita increases ranging from US$3.6 – US$287. These effects are accompanied by notable growth in total industrial output, spanning from US$420 million to US$32,003 million, along with an increase in job opportunities that ranges from as few as 18,000 to as many as 3.9 million within the domestic supply chain by 2030. The Construction sector is poised to experience the most

substantial growth due to infrastructure requirements for proper collection of faecal matter for treatment which includes sewerage systems and drainage facilities, such that it does not lead to the spread of infectious diseases. The monetary benefits through positive spillover effects of cumulative expenditure for ensuring safely managed sanitation services from a macro-perspective lead to a benefit-cost ratio (BCR) of 3.33 by 2030. Effective faecal sludge management can boost total industrial production by $153 million and create 18,000 new jobs, while also reducing carbon emissions by 7.2 million tCO2eq, thus providing an opportunity to generate US$4.48 million through carbon credits. By aligning sanitation and hygiene policies towards achieving the aims of SDG 6, this study offers useful insights for policymakers. The outcome and findings of this research provide a potential blueprint for the Global South, aiming to assess the impact of sanitation investments.

Firm-Level Heterogeneity in CO2 Emissions in International Aviation: The Case of Japan

Topic: Industrial Ecology
Author: Sakura MURABE
Co-Authors: Shigemi KAGAWA, Kaoru TSUDA

To address global warming, countries are working on decarbonization across various sectors. According to the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), carbon dioxide (CO_2) emissions from Japan's transportation sector accounted for 18.5% of total emissions in 2022, with the aviation sector contributing 5% of these transportation emissions.

With globalization, the demand for passenger travel continues to rise. Particularly, CO_2 emissions from international flights are expected to increase if no measures are taken, given the expanding global demand for air travel. However, the CO_2 emissions estimated by the MLIT don't include emissions from international flights. To advance decarbonization in the aviation industry, it is essential to estimate CO_2 emissions from both domestic and international flights.

This study estimates the direct CO_2 emissions from international flights operated by Japan's major airlines, Japan Airlines (JAL) and All Nippon Airways (ANA). The objective of this research is to propose effective policies to achieve decarbonization in the aviation industry.

To estimate the direct CO_2 emissions and direct CO_2 emissions per capita from international flights operated by JAL and ANA, we examined the flight distances and fuel efficiency by aircraft type for more than 80,000 direct international flights using international flight schedule data. This study assumed that the aircraft fuel tanks were full, and all seats were occupied. The CO_2 emission factor was sourced from the National Institute for Environmental Studies' 3EID Book for jet fuel, published in 2015. Data on international flight schedules were sourced from the MLIT and the Japan Travel Bureau (JTB), published in 2023. Information on aircraft was obtained from the ANA website. Flight distances were calculated using figures from the International Civil Aviation Organization (ICAO).

The annual number of flights estimated in this study was 44,000 for JAL and 38,000 for ANA in 2023. The annual direct CO_2 emissions from international flights associated with JAL and ANA amounted to 11.4 Mt-CO_2. CO_2 emissions from JAL were 5.69 Mt-CO_2, while emissions from ANA were 5.72 Mt-CO_2. The analysis revealed that despite JAL having more flights than ANA, its CO_2 emissions were lower. In terms of fuel efficiency, JAL achieved 0.100 kilometers per liter (km/L), while ANA achieved 0.096 km/L. This indicates that JAL was using more fuel-efficient aircraft and

operating more efficiently, resulting in lower CO_2 emissions.

Further analysis based on departure regions revealed that the highest number of annual flights was to Asia (48,000 flights), followed by North America (25,000 flights). In terms of annual CO_2 emissions, North America had the highest emissions (5.70 Mt-CO_2), followed by Asia (3.74 Mt-CO_2). Notably, despite having half the number of flights to North America compared to Asia, the CO_2 emissions were 1.5 times higher.

Moreover, the analysis of CO_2 emissions per passenger on a single flight revealed that JAL emitted 0.76 t-CO_2, while ANA emitted 0.81 t-CO_2 across all routes. Further analysis based on departure regions revealed that ANA had higher CO_2 emissions per passenger on flights to and from all regions except Europe. The difference was most significant on flights to and from the Americas, with JAL emitting 1.17 t-CO_2 per passenger and ANA emitting 1.23 t-CO_2. These results indicate that ANA's flights to and from the Americas are a major contributor to its higher CO_2 emissions.

This study estimated the direct CO_2 emissions from international flights operated by major Japanese airlines. The results indicate that ANA's international flights have a greater environmental impact than those of JAL. Additionally, we found that the direct emissions from these two major airline companies accounted for a significant portion of the total direct and indirect CO_2 emissions embodied in the final demand of Japan's aviation service sector. Therefore, key stakeholders should take strong leadership in reducing CO_2 emissions across the relevant supply chains.

To achieve decarbonization in the aviation industry, the government should encourage ANA to improve its operations. Additionally, since flights to North America, which have longer flight distances, produce higher CO_2 emissions, both airlines should actively use more fuel-efficient aircraft and prioritize the introduction of Sustainable Aviation Fuel (SAF).

Application of the Social Accounting Matrix (SAM) in assessing employment impacts within Zambia

Topic: Social Accounting Matrix and its Applications
Author: Besa MUWELE
Co-Authors: Litia SIMBANGALA

This study, explores the application of the Social Accounting Matrix (SAM) in assessing employment impacts within Zambia. The SAM framework, a comprehensive economic accounting system, integrates various data sources to provide a detailed representation of economic transactions and their effects on employment.

The research addresses the following key questions:

1.   How can the SAM be effectively utilized to measure employment changes across different sectors?
2.   What are the specific employment impacts of various economic policies and external shocks in Zambia?

Methodologically, the study employs a SAM-based multiplier analysis to quantify the direct, indirect, and induced employment effects. The data used includes national accounts, household

surveys, and labor statistics, ensuring a robust and comprehensive analysis.

The novelty of this research lies in its application of the SAM framework to a developing country context, providing valuable insights into the employment dynamics and policy implications for Zambia. The findings highlight the critical sectors driving employment and the potential impacts of policy interventions, offering a valuable tool for policymakers and stakeholders in designing effective employment strategies.

Life Cycle CO2 Emission Analysis of Residential Buildings in Japan

Topic: Sustainable Production and Consumption
Author: Ai NAGATA
Co-Authors: Shigemi KAGAWA

Climate change is a major issue for human society, with many governments setting goals of achieving net-zero CO2 emissions The building sector accounts for approximately 30% of global energy consumption, and measures are urgently needed for this sector. In Japan, the turnover of housing stock is relatively high compared to other developed countries, partly due to the short legal lifespan of housing. This results in frequent demolitions and reconstructions, leading to significant CO2 emissions from construction activities.

Understanding the life cycle CO2 emissions of residential buildings is essential for sustainable urban development. To address this issue, efforts to reduce CO2 emissions at the construction stage are also crucial. One such effort is the promotion of wood use in buildings as a strategy to mitigate climate change. Japan has implemented policies to encourage the use of wood in construction, such as the Act on the Promotion of Wood Use in Public Buildings (enacted in 2010 and revised in 2021 as the Act on the Promotion of Wood Use in Buildings for Contributing to the Realization of a Carbon-Free Society), which extends the emphasis on wood utilization to all types of buildings. In response to these trends, several previous studies have analyzed the lifespan of Japanese houses (Kayo & Tonosaki, 2022) and CO2 emissions from wooden houses (Imada et al., 2024).

In Japan, residential buildings that have exceeded their statutory durability period are still traded in the real estate market after undergoing renovations or refurbishments, which extend their lifespan. Extending the lifespan of such older residential buildings through renovations or refurbishments may reduce environmental impact compared to constructing new ones. However, it remains unclear how extending the economic lifespan of residential buildings through renovations or other means affects CO2 emissions throughout their life cycle. Therefore, this study addresses a crucial research question: What role does extending the lifespan through renovation play in reducing the life cycle CO2 emissions of residential buildings?

The novelties of this study are as follows. First, this study is the first attempt to estimate the supply chain CO2 emissions during the construction phase of residential buildings for different construction method. To achieve this, we adopted an Environmentally-Extended Input-Output (EEIO) analysis and calculated direct and indirect CO2 emissions in the construction supply chain of residential buildings in Japan by construction method. This analysis was based on the Japanese Input-Output Tables in 2015 and the Embodied Energy and Emission Intensity Data (3EID) for Japan Using Input-Output Tables provided by the National Institute for Environmental Studies of Japan, and the statistical survey of building starts in 2015 conducted by the Ministry of Land, Infrastructure, Transport and Tourism.

Second, this study analyzed the CO2 emissions from both the construction and use phases of residential buildings in Japan and evaluated the impact of extending their economic lifespan through renovation on their overall life cycle CO2 emissions. Using data on real estate information actually traded in Japan and data on transaction land prices, we estimated the economic value of older residential buildings and the examined the difference in CO2 emissions during the use phase depending on whether or not the housing has been renovated.

As a result, we found that the CO_2 emissions during construction phase per unit of floor area were 195 kg-CO_2/m^2 for wooden houses, 1,109 kg-CO_2/m^2 for steel-reinforced concrete houses, 857 kg-CO_2/m^2 for reinforced concrete houses, and 803 kg-CO_2/m^2 for steel-framed houses. Furthermore, the results indicate that a shorter economic lifespan of residential buildings significantly contributes to higher CO2 emissions, whereas extending their lifespan gradually reduces CO2 emissions.

In conclusion, this study highlights the importance of integrating life cycle CO2 emission considerations into housing policies and urban planning. Renovation and retrofitting emerge as viable solutions to balancing economic and environmental sustainability while extending the functional lifespan of residential buildings. The findings provide valuable insights for policymakers, architects, and urban planners who aim to achieve low-carbon housing in Japan and beyond.

Remote work, real effects: The impact of telework on Brazil's sectoral structure

Topic: Input-output Analysis for Policy Making (1)
Author: Matheus NASCIMENTO
Co-Authors: Pedro LEITE, Fernando Salgueiro PEROBELLI

The growing adoption of teleworking has reshaped labor market dynamics and sectoral interdependencies. This study examines the systemic impact of teleworkers on the Brazilian economy, focusing on their contributions to employment, income flows, and sectoral demand. Using input-output analysis, we estimate type I multipliers to assess the broader economic effects of teleworkers in knowledge-intensive service industries (KIS). In addition, we apply the hypothetical extraction method to assess the role of teleworkers in sectoral structures, comparing telework-intensive industries with key economic sectors. The analysis is based on the Brazilian input-output matrix, estimated from the Resource and Use Tables (TRU) of the System of National Accounts (SCN). Household consumption is included using data from the Household Budget Survey (POF), disaggregated by income level, while household income is derived from the National Continuous Household Sample Survey (PNAD-C), which identifies teleworkers and their income. The results indicate that teleworkers generate positive employment and income spillovers, especially in professional, scientific and technical services. While telework-intensive sectors show higher employment multipliers, technology-driven industries show lower indirect job creation, likely due to productivity-driven processes. The extraction analysis also shows that the consumption effects of teleworkers are more pronounced than their direct labor contributions, with higher-income teleworkers having the largest economic impact. Compared to key economic sectors, telework-intensive industries show greater sensitivity to the removal of teleworkers, reinforcing their dependence on demand-driven interactions. These findings suggest that teleworkers influence economic activity not by driving core production chains, but through their role in revenue flows and service-based transactions. As telework continues to be concentrated in

knowledge-intensive sectors, understanding its implications for sectoral resilience, labor market transformation, and economic policy will be critical to shaping the future of work.
KEYWORDS: Telework. Remote Work. Hypothetical extraction method. Knowledge-intensive services (KIS).

Pathways for Reducing CO2 Emissions Through Decoupling Processes: A Global Multi-Regional Structural Decomposition Analysis

Topic: Structural Change and Dynamics
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Co-Authors: Shigemi KAGAWA

To combat climate change, it is crucial for governments to clarify the process of decoupling economic growth from greenhouse gas (GHG) emissions and to develop effective low-carbon pathways for the economy. Economists have sought to identify factors that influence GHG emissions alongside economic growth, such as changes in emission factors, production technology, consumption volumes, and preferences. While previous studies provide empirical results using structural or index decomposition analysis, they often fail to offer multi-country and multi-period comparisons of decomposition factors or to identify effective low-carbon development pathways for specific countries based on the time trends of decomposition effects observed in reference countries.

It is important to emphasize that a comprehensive and detailed structural decomposition analysis is essential for countries to develop effective decoupling policies. Currently, no studies provide sufficient guidance for global GHG reduction policies with a focus on decoupling processes. In particular, few studies have examined the role of global supply chains as a factor in decoupling economic growth from environmental impacts. This study addresses a wide range of economic factors, including global supply chains, and highlights pathways for reducing GHG emissions through degrowth.

This study employs structural decomposition analysis (SDA) using the Global Multi-Regional Input-Output (MRIO) database (World Input-Output Database) in constant 2014 prices to provide guidelines for reducing global CO2 emissions. The database spans a 15-year period (2000–2014) and includes data for 43 countries and regions. Using this database, we first calculated the annual average change rates of consumption-based CO2 emissions and GDP for each country during the study period. We then estimated decoupling indicators, defined as the ratio of the annual average change rate of a country's CO2 emissions to that of its GDP. Based on the time series of decoupling indicators for the 43 countries and regions, we applied clustering analysis to identify patterns in the decoupling process. Subsequently, we decomposed changes in consumption-based CO2 emissions (i.e., carbon footprint) into six factors: emission factors, production technology, per capita final demand, consumption preferences, the trade structure of intermediate goods, and the trade structure of final goods.

The clustering results revealed eight distinct patterns in the decoupling processes of countries. While some countries reduced their carbon footprints, either relatively or absolutely, alongside economic growth, others increased their carbon footprints despite achieving similar levels of economic growth.

Examining the detailed SDA results for countries with comparable levels of economic growth

during the study period, we identified key factors driving CO2 emission changes. We then compared these factors between countries that achieved decoupling and those that did not. The analysis identified changes in the trade structure of intermediate and final goods (i.e., global supply chains) as a critical factor in reducing a country's carbon footprint while maintaining economic growth.

Conversely, in countries experiencing major economic growth, trade structure changes played a less significant role in achieving decoupling. Instead, changes in consumption preferences and per capita final demand were found to be the primary drivers of decoupling in these cases.

In countries in the de-growth phase, changes in consumption preferences and per capita final demand contributed to emission reductions. However, changes in trade structure and production technology were found to contribute to increased emissions, thereby hindering efficient emission reductions.

The results of this study suggest that changes in trade structure play an important role in achieving decoupling. In order to implement effective policies, it is necessary to consider restructuring global supply chains and providing technical and financial support to countries that specialize in emission-intensive exports.

Global footprints of soil phosphorous from 1970-2017

Topic: Special Session: IO Analysis for Just Transition: Linking Economic Structures and Social Inequality (2)
Author: Kunyu NIU
Co-Authors: Xiangbo XU

Human activities changes Phosphorous(P) balance in agricultural soil with P surplus and deficit widespread, posing environmental and food security challenges. International trade is a key driver of anthropogenic P balances in agricultural soil. Existing P footprint studies, as a well-known way to comprehensively evaluate trade's impact on P cycle, primarily focus on excessive P fertilizer input and its environmental risk, such as eutrophication of water ecosystems. However, P deficits, covering 35% of global agricultural area in 2017 up from 21% in 1970, which could lower crop yields and trigger food insecurity, receive less attention. In this study, we integrate detailed spatial and sectoral information on anthropogenic P balances in soils into a global trade model to capture how trade and consumption drive global soil P surpluses and deficits across 90 countries and regions. In our spatially-explicit global P footprint assessment we find that, from 1970 to 2017, the global anthropogenic P deficit (APD) – largely ignored in previous studies – has more than doubled, far exceeding the 24% growth rate of the global anthropogenic P surplus (APS). Consumption in West Europe and East Asia (excluding China) contributes 73% to global APS and 66% to global APD caused by global trade, respectively. Twenty-four low-income food-deficit countries as categorized by the Food and Agriculture Organization (FAO), exported five times as much APD from cropland as they imported, highlighting the food security risks related to APD implicated in global trade.

The Triple Bottom Line Analysis of the Decline in Foreign Tourist Demand in Japan due to the COVID-19 Pandemic: A Counterfactual Structural Path Decomposition

Topic: Input-Output Modelling: Disaster Analyses
Author: Yusuke OGA

The COVID-19 pandemic brought significant risks to the tourism industry, exemplified by Japan's experience. Japan faced an 87% decline in foreign visitors in 2020 due to lockdown measures. This led to substantial economic losses. While the pandemic has somewhat subsided by 2024, the tourism industry remains vulnerable to potential pandemics and other disasters, such as earthquakes and terrorism, given its reliance on human mobility. Recognizing the importance of the tourism sector, the Japanese government must formulate disaster preparedness policies, considering economic, social, and environmental aspects. This study aims to quantitatively assess the detailed impacts of the COVID-19 pandemic on the tourism industry using Input-Output analysis, and Structural Path Decomposition (SPD) analysis.

To evaluate the economic, social, and environmental repercussions of the COVID-19 pandemic in 2020, two scenarios were defined: one with and one without the pandemic. The 'with-COVID' scenario reflects the actual conditions, incorporating the 2020 foreign visitor numbers to Japan and per capita commodity consumption. Conversely, the 'non-COVID' scenario serves as a counterfactual, estimating foreign visitor numbers and commodity consumption as if the pandemic did not occur. In each scenario, a new consumption-endogenous input-output analysis framework was developed, encompassing a counterfactual model for both pandemic and non-pandemic situations. This allowed for an examination of the direct, indirect, and income-induced economic, social, and environmental effects resulting from the decline in travel consumption by foreign visitors in 2020. Furthermore, a counterfactual SPD framework was applied to identify key supply chains associated with economic, social, and environmental impacts, respectively.

The pandemic caused a loss of 33 million foreign tourists in Japan, leading to economic losses of 3.44 trillion JPY (22.7 billion USD), social losses affecting 869,000 individuals, and environmental benefits equivalent to a reduction of 11.6 Mt-CO_2 emissions. Key sectors impacted included hotels, eating and drinking services, and rail passenger transport. These sectors significantly influence electricity demand and indirectly reduce CO_2 emissions from the electric-supply industry. Decomposition results further showed that hotels are strongly connected with electricity and waste management.

In conclusion, we propose two crucial factors for the development of the most sustainable and efficient countermeasures: (1) the recovery of economic and social losses and (2) the reduction of CO_2 emissions associated with inbound final demand. To address economic and social losses, the government should provide sector-specific stipends based on the magnitude of the losses, and our data can serve as evaluation criteria for distribution. Our analysis encompasses not only the easily recognizable direct effects but also the more challenging-to-estimate and often overlooked indirect and income effects.

To sustain the reduction of CO_2 emissions linked to inbound final demand, we recommend the government integrate a mechanism into counter-COVID-19 measures. This mechanism should determine incentives for in industries to enhance business conditions while simultaneously reducing environmental impact. and This study offers crucial insights for stakeholders to consider in measures implemented by the Japanese government in the event of a future pandemic recurrence or unforeseen disasters.

Multi-regional Input-output Dataset for the UK from 2017 to 2022

Topic: World Input-output Modelling and Databases
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As the sixth largest economy in the world, the United Kingdom plays a pivotal role in global production networks. However, there are long-lasting economic gaps among different regions of the UK. Most of the previous research on the UK's domestic interregional characteristics remains insufficient, lacking industrial resolution. In the face of increasingly frequent challenges and impacts such as Brexit, the COVID-19 pandemic, the refugee waves and the Russo-Ukrainian War, it is essential to construct a detailed regional economic database for the UK for government officials and researchers. The multi-regional input-output (MRIO) model is widely recognized as an ideal tool for tracing regional heterogeneity and the structure of production and supply chain. Unfortunately, existing MRIO databases focus more on the international level, treating the UK as a single economy. One of the pioneers in unraveling the UK's regional details is the EUREGIO database team. They compiled a NUTS 2-level MRIO dataset for all EU countries from 2000 to 2010. Recently, scholars extended this dataset to 2018. However, the latest dataset still relies on outdated trade structure data in 2013 and only includes 10 broad industry categories, which limits its usability.

In this study, we construct a time-series of UK MRIO tables from 2017 to 2022 with 12 International Territorial Level 1 (ITL1) regions, 105 sectors, and 6 final demand categories. To maintain data consistency, we only use publicly available data from the UK Office for National Statistics (ONS), which includes national input-output tables, regional value-added and regional import-export data. We also utilize the latest interregional trade data of 2019 and 2020 released by the ONS in 2025. It contains detailed breakdowns by industries, which shed light on the changes of domestic trade structure before and after Brexit. Our MRIO compilation process features a hybrid entropy-based method. First, we utilize the structural information from the national table to fill in missing values in the regional data and disaggregate them to match the target 105 sectors. Next, 12 single-region input-output tables are constructed by taking national input coefficients as initial values and applying a maximum entropy framework. For each sector and each region, we estimate their local supply, domestic supply to other regions, local demand, and domestic demand for other regions under a series of mathematical constraints. Subsequently, we use the gravity model and the recent ONS domestic trade data to generate the interregional trade matrix. Finally, the trade matrix is integrated with the single-region tables to form the complete MRIO.

Our UK MRIO dataset can reveal the evolution of domestic supply chains during the process of Brexit and the pandemic. With its detailed sectoral classification, it provides a robust foundation for a wide range of in-depth studies on regional inequality, environmental issues, and their spillover effects. Since all underlying data are regularly published by the ONS and the trade data are recent, this dataset also has the advantage of being easily updated in the coming years. It also gives us an intermediate result to compile a more detailed table at UK's ITL2 level or a nested multi-scale MRIO table with the help of mainstream global MRIO databases.

The impact of CBAM on Chinese regional economy

Topic: Special session: Sustainable Strategies for Natural Resources and Environmental Security
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Co-Authors: Shantong LI, Jianwu HE

The European Union's Carbon Border Adjustment Mechanism (CBAM), designed to address carbon leakage, poses significant challenges to carbon-intensive export sectors globally. As China is a major exporter of CBAM-covered products (e.g., steel, aluminum, cement), its regional economies—particularly provinces reliant on high-carbon industries—may face divergent economic risks, including increased trade costs, industrial restructuring pressures, and employment shifts. This study explores the potential heterogeneous impacts of CBAM across Chinese provinces under varying implementation scenarios, with a focus on Gross Regional Product (GRP), employment, and industrial structure. It further evaluates how China's domestic carbon policies could interact with CBAM to shape regional economic outcomes.

Employing a multi-regional input-output (MRIO) model embedding Chinese provinces, and with provincial emission data integrated, this study simulates the following scenarios:

Baseline Scenario: Current economic and carbon emission trends without CBAM.
CBAM Implementation Scenarios:
     Scenario 1: Covers electricity, steel, aluminum, cement, fertilizers, and hydrogen, accounting for direct emissions only.
     Scenario 2: Expands coverage to all EU ETS sectors, with direct emissions.
     Scenario 3: Covers Scenario 1 industries but includes both direct and indirect emissions.
     Scenario 4: Covers Scenario 2 industries with direct and indirect emissions.
Domestic Policy Intervention Scenarios:
     Policy Scenario 1: Integrates CBAM-covered sectors into China's carbon emission trading market.
     Policy Scenario 2: Hybrid policy combining Policy Scenario 1 with a carbon tax mechanism.

We aim to answer three research questions. First, how do different CBAM scenarios affect GRP, employment, and industrial structures across Chinese provinces? Second, what are the spatial disparities in economic impacts, particularly between energy-intensive inland provinces (e.g., Shanxi, Inner Mongolia) and coastal manufacturing hubs (e.g., Guangdong, Jiangsu)? Third, to what extent could China's domestic carbon policies mitigate or reshape these impacts?

This study highlights the urgency of spatially differentiated strategies to address CBAM-induced risks. Potential policy considerations include accelerating regional decarbonization roadmaps, enhancing carbon market linkages, and designing transitional support for vulnerable industries and workforces. The final results will provide empirical evidence to inform China's climate policy design and interprovincial coordination mechanisms in response to CBAM.

Unequal Pollution Flows: Brazil's Role in Global Emission Trade (1995-2018)

Topic: Environmental Input-Output Modelling (2)
Author: Patieene Alves PASSONI
Co-Authors: Raynan ROCHA PORTO, Marcelo Resende TONON, Gilberto Tadeu LIMA, Pedro Romero MARQUES

This study quantifies the net balances of value-added, CO_2 emissions, and employment embedded in Brazilian international trade with the Global South and Global North from 1995 to 2018. It examines the evolution of these balances to assess the applicability of the Environmental Terms of Trade Deterioration Hypothesis to Brazilian trade during the period, particularly in the context of export reprimarization (Alves-Passoni, 2023; Nassif et al., 2020).

A central theoretical framework in this debate is the Pollution Haven Hypothesis (PHH), which posits that, under conditions of free trade, pollution-intensive and resource-heavy industries in developed countries (Global North) relocate to developing countries (Global South) to evade stringent environmental regulations (Copeland & Taylor, 1994). This geographical shift in environmental burdens occurs through both trade in goods and services and foreign direct investment (FDI). As a result, the Global South may experience increased environmental degradation, while the Global North benefits from lower domestic emissions.

In parallel, the Environmental Terms of Trade Deterioration Hypothesis posits that economies specializing in primary products are susceptible to long-term declines in the value of their exports relative to their imports (Pérez-Rincón, 2006; Røpke, 1994). This hypothesis builds on the Terms of Trade Deterioration Theory advanced by Prebisch (1950) and Singer (1950), which argues that developed countries specialize in the export of capital- and knowledge-intensive goods, while developing countries export resource-intensive and low-skilled labor products. Over time, this pattern of specialization leads to a decline in the terms of trade for developing countries, requiring them to export increasing volumes to maintain their import capacity.

To test this hypothesis, the study uses the Pollution Terms of Trade (PTT) metric (Antweiler, 1996) to evaluate whether the environmental cost of Brazil's exports exceeds that of its imports, offering a comprehensive assessment of the sustainability of Brazil's trade patterns.

The analysis employs a multi-regional input-output (MRIO) model to examine the direct and indirect effects of trade flows on value-added, CO_2 emissions, and employment. This approach captures global production network interdependencies, providing a holistic perspective on the environmental and economic implications of international trade.

The empirical analysis utilizes the OECD Inter-Country Input-Output (ICIO) database (November 2021 version), which includes inter-regional input-output tables for 66 countries and the Rest of the World (RoW) category, disaggregated into 45 sectors for the period from 1995 to 2018. By integrating OECD ICIO data with additional sources, the study estimates CO_2 emissions, employment, and value-added embedded in Brazilian trade, categorizing countries into two regions: Global South (developing countries) and Global North (developed economies). Sector-specific impacts on the examined variables are also analyzed.

The study contributes to the literature by providing empirical evidence on the environmental consequences of Brazil's export reprimarization and its implications for environmental terms of trade. It examines the evolving nature of Brazil's international trade and its environmental and economic impacts, offering critical insights for trade and environmental policy debates, and highlighting challenges and opportunities for sustainable development.

The findings reveal that emissions associated with Brazilian exports to the Global South are approaching those directed to the Global North, especially after 2010. Additionally, Brazilian exports to the Global North are consistently more carbon-intensive than those to the Global South, supporting the Environmental Terms of Trade Deterioration Hypothesis. This indicates that

exporting primary products to developed economies results in higher environmental costs per unit of value added.

A central concern is the uneven distribution of environmental impacts, particularly regarding emissions responsibilities. The study emphasizes the ongoing debate on whether emissions burdens should be placed on producing or consuming countries, a critical issue for Brazil given its increasing specialization in primary product exports. This disparity underscores the need for more nuanced discussions about global emissions responsibility and the effectiveness of trade-based emissions accounting methods.

The study concludes by highlighting the significant disparities in emissions between the Global North and Global South, with the Global North consistently having higher average CO_2 emissions. It notes a reversal of emission flows from Brazil to the Global South after 2010, driven by Brazil's growing export specialization in primary products, particularly from resource-intensive sectors such as Agriculture, Forestry, and Fishing.

Lockdowns and Export Growth: The Role of Domestic Production Networks

Topic: International trade (2)
Author: Jiansuo PEI
Co-Authors: Meng ZHANG

Using inter-provincial input-output tables to map domestic production networks, this study empirically examines how COVID-19 lockdowns in upstream and downstream provinces affect local export performance. Leveraging granular customs trade data at the province-partner-product level from January 2018 to December 2020 and applying a generalized difference-in-differences (DID) design, we uncover three key findings: Firstly,
asymmetric impacts: Lockdowns in downstream provinces significantly reduce export growth, whereas upstream lockdowns exhibit negligible effects. Secondly, temporal dynamics: The adverse effects are short-lived, concentrated primarily in the first two quarters of 2020. Thirdly, heterogeneity: The negative consequences are more pronounced for ordinary trade (vs. processing trade), differentiated goods (vs. homogeneous goods), and durable goods (vs. non-durables). Mechanism analysis reveals that disruptions to economies of scale—rather than liquidity constraints—better explain these patterns. Results remain robust to alternative specifications, placebo tests, and instrumental variable strategies addressing potential endogeneity. These findings highlight the critical role of domestic supply chain positioning in shaping regional resilience to external shocks.

Measuring Economic-Environmental consequences of the evolving Dietary Patterns and Nutritional landscape in Urban India

Topic: Environmental Input-Output Modelling (3)
Author: Vishnu Sivadasa PRABHU
Co-Authors: Kakali MUKHOPADHYAY

Background
India's public health status poses an alarming situation. The Non-Communicable Diseases are responsible for 5.87 million deaths annually while India ranks second in number of diabetic patients and around 135 million are affected by obesity. This phenomenon is largely prevalent amongst younger population in urban India with direct link to sedentary lifestyle, consumption of

high calories food intake. The lifestyle-related nutritional disorders are expected to translate to net-economic loss to the country. Along with the economic implications of the changing food consumption pattern, the sustainability of the food systems needs to be ensured. The agriculture sector constitutes 14% of the GHG emissions and 78% of the country's freshwater resources being directed towards agriculture. The urban India's dietary preferences will play a pivotal role in India's pursuit of SDG 2 and 12.

Research Question

Given this backdrop, the objectives of the study are listed below:

i)To assess India's changing dietary patterns over the past decade, between 2011-12 and 2022-23 across different urban income fractile classification.

ii)To measure the gap between actual and required nutritional intake amongst urban population across different age groups and evaluate the economy-wide impact of adopting a healthy dietary guidelines by 2030.

iii)To estimate the environmental footprint – total GHG and water footprint by following the healthy diet guidelines in different scenarios, combining different food habits.

Methodology

To this end, the study adopts a General Equilibrium framework, using the latest Supply Use Table 2019-20, published by the Government of India. The 140 commodity classification of products constitutes among other sectors, 20 foodgrains, cash crops, fruits and vegetables, 4 livestock products, and marine and inland fish. Additionally 14 food processing sectors include meat, fish, fruits and vegetables, dairy, grain mill, sugar, bakery products, tea and coffee. Based on the commodity-wise growth rates estimated using the National Accounts Statistics between 2019-23, the Input-Output (I-O) table is updated to the year 2030. The estimated expenditure, required to bridge the gap between actual and recommended nutritional intake by 2030 will be simulated using the I-O model and the economic and environmental impact (GHG and water footprint) will be measured.

Data construction and sources

The government of India's Household Consumer Expenditure surveys for the year 2011-12 and 2022-23 for different urban fractile classes is used to measure India's evolving dietary pattern. The Indian Council of Medical research (ICMR) 2024 report on 'Dietary Guidelines for Indians' will be used as a reference case to estimate the optimal nutrition intake requirement in Urban India for different age groups. The population forecasts is compiled from the Government's report on 'Population Projections for India and states 2011-2036'.

Novelty of the research

India is already the most populous country in the world with a large 'demographic dividend'. The general status of the public health and societal well-being is paramount for India's aim of becoming $10 trillion economy by 2030. To the best knowledge of the authors, this study proposes for the first time, a comprehensive nexus approach, between nutrition, economic gains and environmental impact, addressing the overall welfare of the country.

Preliminary results

India's dietary preferences are converging towards the developed country consumption patterns, with per capita intake (kcal/day) of 'Meat and Eggs' and 'Dairy products' increasing by 68% and 5%, respectively while 'Cereals and Millets' decreased by 10% on average, between 2011-12 and 2022-23. Contrarily, there is a significant gap of 28.5% in per capita intake between the highest and the lowest income category urban households as per the latest survey and the urban average is 15.8% lower than the recommended 2,010 kcal/day. Comparing scenarios wherein the incremental nutritional intake is met through a) meat and dairy based diet or b) fruits, vegetables, nuts and seeds-based diet, the higher Total output, GDP and Employment increase in the latter case, of 2.5%, 1.8% and 2.7%, respectively, while the total GHG (67,850 kgCO2eq.) and water footprint (22.1 thousand cubic meters) is higher in the case of the former. The age-wise empirical analysis of dietary requirements indicates that the working age group 19-59 which are

the drivers of India's economy will account for 56% of the total population by 2030 and preliminary estimates suggest that in order to meet the required nutritional intake, approximately US$10,536.6/capita/annum expenditure on food items is required led by dairy products, meat and eggs, cereals and millets, while age group 10-18 account for US$11,420/capita/annum that will lead to exponential economic and environment footprint multiplier effect.

Armington Meets Melitz: Introducing Firm Heterogeneity and Export Mode in Trade-A Case Study of Pakistan

Topic: International Trade (1)
Author: Tuba RASHEED

Standard computable general equilibrium models underestimate trade effects from trade liberalization because they neglect the trade measurement along with its extensive margin. This research incorporates firm heterogeneity models with fixed export costs within GTAP while calibrating results with GTAP 10a database information. This study examines the consequences of ending EU, USA, and China tariffs for Pakistani exports by concentrating on three industries and three regions. The analysis shows that free trade systems increase exports while maximizing social welfare by revealing productivity effects and showing scale advantages along with a variety of selection benefits as well as fixed export costs. This research shows that studies of monopolistic competition models relative to perfect competition models expose significant welfare increases due to trade liberalization. Results indicate nations need to implement strategic trade policies focused on productivity growth alongside organizational adaptation to access the best possible outcomes from worldwide trade options.

Downstream impacts complementary to upstream impacts of intermediate sectors

Topic: Environmental Input-Output Modelling (7)
Author: Kajwan RASUL

Environmental impact accounting has become increasingly important for governments and corporations as they strive to meet climate commitments such as the Paris Agreement. While current methodologies allow for the estimation of direct and upstream environmental impacts, indirect downstream impacts remain largely unaccounted for in standard environmentally extended input-output (EEIO) approaches. Governments rely on EEIO models, particularly the Leontief demand model, to calculate upstream impacts and generate consumption-based accounts. However, there is no widely accepted framework for systematically estimating downstream impacts in a complementary and consistent manner, without double counting or introducing subjective allocation principles. This gap is particularly relevant in the context of emerging regulatory frameworks, such as the Corporate Sustainability Reporting Directive (CSRD), which require companies to account for both upstream and downstream environmental impacts of their economic activities.

This paper addresses this methodological shortcoming by developing a framework for downstream impact accounting that is fully compatible with upstream impact accounting. Previously proposed frameworks relied on the simultaneous use of the Leontief demand model and the Ghosh cost-push model, which leads to double counting unless certain allocation principle are introduced. While the Leontief demand model is widely acknowledged as appropriate for

upstream impact (consumption-based) accounting, the use of the Ghosh model has not been used as widely for downstream impact accounting. In the Ghosh model impacts are allocated based on the income of intermediate sectors, rather than final consumption of goods and services as in the Leontief model. Furthermore, there has been a long debate on the economic plausibility of the Ghosh model. Our framework relies solely on the Leontief model and uses the same principles as presented in Table 1 in Lenzen & Murray (2010), but with one crucial difference: "The ultimate responsibility for downstream impacts rests with downstream buyers of final outputs" rather than "...downstream sellers of primary inputs" (1). Thus, both upstream and downstream environmental impacts are allocated using the same responsibility principle.

We present a formal derivation of the downstream environmental impact method, starting from the hypothetical extraction method (HEM). HEM has experienced a minor renaissance in recent years for its usefulness in calculating the upstream environmental impact of a (set of) intermediate sector(s) without double counting or allocating the impacts to the sectors providing the final goods and services to final demand. In the derivation of the HEM method, the equation for the downstream impacts of the extracted sector(s) appears as the natural counterpart to the upstream impacts. The framework does not solve the issue of non-additivity that is inherent in HEM, but we argue non-additivity must logically be present in the impact accounting of intermediate sectors, as well as across national economies in their role as producers, importers, and exporters of environmental goods and services that cause impacts. Although, the framework does ensure additivity of impacts of sectors within the same nation, when all sectors in the nation are extracted simultaneously.

To demonstrate the application of our framework, we conduct two case studies using a global multi-regional input-output model (EXIOBASE). The first case study quantifies both the upstream and downstream greenhouse gas (GHG) emissions of the Norwegian economy, highlighting how the method can be used for national environmental accounting. The second case study focuses specifically on Norway's oil and gas sector, illustrating how the framework can be applied at a sectoral or corporate level.

The results of our analysis demonstrate that downstream environmental impact accounting provides a necessary counterpart to existing upstream approaches, offering a more comprehensive assessment of a sector's or nation's environmental impact. This is especially critical for industries or nations primarily engaged in resource extraction or intermediate production, where environmental burdens are often externalized to other sectors and nations in the consumption-based accounts.
Our study contributes to improving corporate sustainability reporting and regulatory compliance, making it easier for corporations and nations to report the full scope of their environmental impacts. Furthermore, the insights gained from downstream impact accounting can support policymakers in designing more effective environmental regulations that account for the full supply chain impact of economic activities.

(1) Lenzen, M. & Murray, J. Conceptualising environmental responsibility. Ecol. Econ. 70, 261–270 (2010).

Chain Reactions: How China's Environmental Random Inspections Drive Green Innovation Through Industrial Linkages and Regional Spillovers

Topic: Input-output Modelling and Network Theory
Author: Meitong REN

This study examines the impact of China's environmental random check policy on green technology innovation through industrial linkages and regional heterogeneity, employing an integrated framework that combines a multi-regional input-output (MRIO) model with an extended spatial Durbin model. Leveraging panel data from 29 Chinese provinces (2006–2015), including provincial environmental penalty records, sector-level green patents (mapped via IPC-industry classification), MRIO tables, and pollution intensity indicators, we analyze how regulatory enforcement drives innovation diffusion and pollution relocation across supply chains. Methodologically, we innovate by constructing sectoral linkage-based spatial weight matrices to replace conventional geographic or economic distance weights, and we use the matrix to capture inter-sectoral dependencies. Instrumental variables (historical pollution data) and policy simulations (e.g., sector-specific inspection adjustments) address endogeneity and validate robustness.

This study conducts analysis from two perspectives: horizontal and vertical. Horizontal analysis refers to the input-output extension of spatial spillover effects, and quantifies the industrial transfer and technological innovation spillover of random inspection policies among provinces and regions in China. A multi-regional input-output model (MRIO) is constructed, and combined with the results of the spatial Durbin model in existing studies, the direct impact of environmental protection penalties in the eastern region on the acceptance of high-polluting industries in the western region, as well as the inhibitory effect of green technology innovation caused by this, is analyzed. The pollution transfer mechanism is explained through industrial chain linkage, such as the polluting enterprises eliminated in the eastern region drive the expansion of related industries in the western region through the demand for intermediate products, and its long-term impact on regional innovation capabilities is evaluated. Vertical analysis refers to the analysis of environmental regulation effects in the upstream and downstream of the industrial chain, and studies how environmental protection policies affect green technology innovation through the upstream and downstream relationships of the industrial chain. Using input-output tables, high-polluting sectors (such as steel and chemicals) and their upstream and downstream related industries are identified. Green patent data are classified by sector to study the heterogeneous effects of random inspection policies on technological innovation of directly regulated sectors and their related sectors. The "ripple effect" of policies generated through the supply chain is revealed, and the phenomenon that upstream enterprises adopt green technologies and force downstream enterprises to innovate synchronously is found, explaining the transmission mechanism.

It anticipates revealing significant sectoral heterogeneity: high-pollution sectors (e.g., steel, chemicals) are expected to exhibit stronger local green patent growth compared to low-pollution sectors. However, the demand for intermediate products may exacerbate pollution displacement, potentially suppressing innovation in western regions. Industrial linkages are likely to amplify spatial spillovers, with eastern regions' reliance on resource-intensive sectors in the west potentially widening regional innovation gaps. The expectation for simulations are to indicate that targeted inspections in "hub sectors" (e.g., environmental equipment) could enhance supply chain-wide green patent growth while mitigating cross-regional pollution transfer.

Theoretically, this research advances the Porter Hypothesis by proposing a "policy-industry chain-innovation" framework, elucidating how environmental regulation propagates innovation through supply chains. Methodologically, it pioneers embedding input-output networks into spatial econometrics, enabling multidimensional policy evaluation. Practically, it advocates "precision chain-based regulation"—dynamic adjustments of inspection intensity based on sectoral linkages and regional capacities—coupled with cross-regional governance coordination. These findings offer actionable insights for aligning environmental regulation with sustainable development, highlighting the potential of policy synergies (e.g., carbon markets with random checks) to further enhance industrial green transitions.

A model-based analysis of the impact of selected agriculture related scenarios on the Gross Ecosystem Product indicator

Topic: Environmental Input-Output Modelling (6)
Author: Bartlomiej ROKICKI

To date, the impacts of different economic policies have been usually measured by the evolution of Gross Domestic Product (GDP) or employment. Yet, GDP fails to capture fully the contributions of nature to economic activity and human well-being. Consequently, the benefits provided by ecosystem services, such as crop pollination or water purification, are not taken into account in such assessments. This is particularly important in the case of policies with potentially heavy environmental impacts. Hence, Ouyang et al. (2013) proposed and further developed (e.g. Ouyang et al. 2020) the concept of Gross Ecosystem Product (GEP), which summarizes the value that ecosystem services provide to the economy in monetary terms. The Gross Ecosystem Product (GEP) is a measure that quantifies the contribution of final ecosystem goods and services to the economy. GEP highlights the importance of ecosystem services and allows overcoming the current bias in decision-making in favor of GDP growth.

This paper applies the new GEP module in the macroeconomic model MAGNET to assess both, the economic and environmental impacts of a removal of the Common Agricultural Policy (CAP). This scenario is an unlikely policy option as it contradicts the EU Treaty. However, it provides useful insights into the economic, social, and environmental impacts without the policy framework provided by the CAP. MAGNET is a GTAP-based global CGE model used to assess the policy impacts on the economy. MAGNET's endogenous land supply and forestry representation make this model particularly suitable for this task, as does its international dimension. Built upon the INCA database on monetary value of ecosystem services, the new GEP module allows for comparison of the impact of different policies on both GDP and GEP in the European Union. In particular, we apply a forward-looking policy scenario that assumes a complete removal of the Common Agricultural Policy (CAP) in the European Union. The results of preliminary simulations show that a CAP removal would have an almost negligible impact on both GDP and GEP. Although, there exist significant differences between particular ecosystem services.

The Modular Applied GeNeral Equilibrium Tool (MAGNET) is a recursive dynamic, multiregional, multi-commodity CGE model, covering the entire global economy (Woltjer and Kuiper, 2012). As with other CGE models, MAGNET explicitly represents the economic linkages across the sectors of each regional economy. This is particularly important when analysing policy effects in sectors that are vertically linked with each other, such as bioeconomy sectors. It is built upon the GTAP (Global Trade Analysis Project) model (Hertel, 1997) and has been widely used for policy analysis (Nowicki et al., 2009; Woltjer, 2011; Philippidis et al., 2018; Doelman et al., 2019; Kuiper and Cui, 2021; Latka et al., 2021). The MAGNET model is modular in nature and extends the GTAP model through the addition of a number of policy-relevant modules. MAGNET currently uses version 11 of the GTAP database with a coverage of 141 regions, 65 sectors and 8 production factors

including natural resources, oil and gas. In MAGNET, the original GTAP database is further disaggregated to include additional agricultural and bioeconomy sectors. As a result, a complete MAGNET database contains the total of 123 sectors and 144 commodities. For the present study, regions were aggregated to 40, sectors to 46 and commodities to 48. The database includes detailed information on production, gross bilateral trade flows, transport costs and trade protection data for a 2017 benchmark year.

EU trade: understanding deviations in multicountry input-output tables and their implications for trade policy

Topic: Trade and Global Value Chains Policies (5)
Author: José M. RUEDA-CANTUCHE
Co-Authors: Pablo PINERO, Zornitsa KUTLINA-DIMITROVA

Over the past two decades, research institutions worldwide have undertaken numerous projects to develop global multicountry input-output databases. This effort has resulted in the creation of several notable databases, including WIOD, Exiobase, GTAP-MRIO, OECD-ICIO, FIGARO, and Eora. These databases have enabled international organisations and countries to conduct comprehensive assessments of socio-economic, environmental and trade impacts. The trade in value added indicators, in particular, have been widely used and have undergone detailed evaluations to compare the results across different databases.

However, as the compilation of these MCIO tables was experimental, following different assumptions and methodological approaches, (sometimes large) deviations regarding key variables and indicators among those databases were frequent and noticeable. In this respect, little attention has been paid to examine closely the compilation process and underlying trade data of each database as explanatory factors of the differences in the results and their subsequent effects on policy relevant indicators. This paper provides insights into this subject as well as it identifies key drivers in the compilation of the MCIO databases that deserve further scrutiny when comparing differences in indicators, in particular, in the estimation of the domestic and foreign value added and employment content of gross exports. These key elements are:
• the breakdown of exports between intermediate and final uses;
• the breakdown between domestic exports and re-exports;
• the way trade asymmetries are balanced, for goods and services, separately;
• the way confidential values are replaced by guess-estimates; and
• the way the breakdown of products and their geographical allocation is handled when linking the domestic and national concepts in the supply and use tables (e.g. direct purchases abroad).

A key finding of this paper is that the absence of official national supply and use tables can introduce significant discrepancies regarding policy relevant indicators, as demonstrated in the context of EU trade policy.

Urban Green Transformation in India: A CGE Analysis of Policy Impacts on Economic and Environmental Dynamics

Topic: CGE and Econometric Input-output Modelling (3)
Author: PARTHASARATHI SAHU

This study considers the interaction of economic development and environmental quality at the interface of major Indian urban centers, the effect of the currently prevailing environmental regulations (pollution control measures and green building standards) on the urban economic performance. No sophisticated, nameless model appear in this research (quite the contrary it is very complicated); instead, using an adaptive, multi sectoral Computable General Equilibrium (CGE) model, it captures the complicated interrelations between city level economic activities and environmental outcomes. The model's modular design supports the direct integration of policy shocks for a specific environmental policy and evaluation of the direct and indirect economic sector impacts.

Research Gap:
Past studies more or less have examined economic performance and environmental quality in isolation, and there was a large literature gap on integrating economic performance and environmental quality within a unified framework. Most existing models fail to capture the dynamic feedbacks between real improvements in the urban environment and the urban economic performance, such as the health associated productivity gains from lowered SO_2 levels. Furthermore, the lack of use of real time environmental data (pollutant concentration and emission records from Central Pollution Control Board (CPCB), ...) has hampered the accuracy of the impact evaluations for these policies. This paper fills these gaps by incorporating detailed environmental measurement within a CGE framework to refine our understanding of urban sustainability.

Research Question:
What is the economic impact of stringent pollution control and the adoption of green building standards, as far as environmental regulations are concerned, on the performance of major Indian cities over time?

Research Objective:
This research seeks to evaluate trade-offs of urban environmental regulations on economic and environmental levels in India.
Specifically, the study aims to: Try to quantify short-term adjustment costs and long-term benefits of implementing stricter environmental policies and measure the ripple consequences of positive environmental adjustments on work efficiency and general human health.

Methodology and Data:
Cities are simulated in an economic environment using an adaptive multi sectoral CGE model of Delhi, Mumbai and Bangalore. At first, the calibration is done using the data collected from the Ministry of Statistics and Programme Implementation and Census of India on sectoral output, employment rates and household consumption so that the model reflect the current economic conditions. Data related to environmental performance indicators such as the detail of the pollutant concentration and the emission is obtained from the CPCB and the data on urban infrastructures and real estate are obtained from local municipal bodies. First baseline simulations are run to replicate the current situation and then policy shocks that can account for the enhancement of pollution control measures and adoption of green building practices are introduced.

Key Findings and Policy Implications:
This paper's key contribution is in designing a CGE model that allows for easy tailored application to specific environmental data or policy scenarios. This flexibility allows the model to remain a useful tool for future aid and academic research. Based on preliminary simulation results, it is

found that stricter environmental regulations may impose adjustment costs to some certain industrial sectors in a short period, however the longterm benefits resulting from regulatory improves urban public health, labor productivity, and urban sustainability policies always exceed the transitional costs. The analysis demonstrates the main tradeoffs between immediate economic performance and long term environmental sustainability which can guide the decision makers in taking balanced decision regarding the costs and benefits of green urban policies. The results also emphasize the need to use the most current environmental data in such economic models so that future policy evaluations can be better and more timely.

Conclusion:

This research provides a transparent and replicable framework to understand the influence of urban economic growth on environmental sustainability in India by integrating detailed environmental measurements with a dynamic CGE model. In addition, the findings of this study are useful and important to academic literatures and as a valuable resource for the policy makers who are trying to find the sustainable solution of both industrial expansion and urban environmental quality. The model is also modular in its structure, that upon deeper research, it will allow the approach to continue to advance and incorporate with up to date data and new policy scenarios emerging within urban sustainability.

An input-output analysis of CO2 emissions from a regional income perspective: an application to the Brazilian economy

Topic: Environmental Input-Output Modelling (3)
Author: Guilherme Perobelli SALGUEIRO
Co-Authors: Fernando Salgueiro PEROBELLI, Geoffrey J.D. HEWINGS, Eduardo Amaral HADDAD, Edson Paulo DOMINGUES

Using data from SEEG, the climate observatory, Brazil emitted 2.3 billion gross tons of greenhouse gases in 2022, representing an 8% drop compared to the previous year, when 2.5 billion tons were emitted. However, it is a high level of pollution. Deforestation is the main source of greenhouse gas emissions in Brazil; in 2022, the destruction of forests resulted in the emission of 1.12 billion gross tons of carbon dioxide, corresponding to 48% of Brazilian emissions. In the same year, 2022, the amount of greenhouse gases from agriculture grew to 617.2 million tons, an increase of 3.2% compared to 2021 and accounting 27% of the country's total.

While the imbalances in Brazilian regional dependencies in terms of production and income have been documented, little research has been directed to the impact on emissions; are there similar imbalances? To address this question, we develop a multiregional economic network model that integrates spatial (nation, region) and sectoral (industries) dimensions to assess how income variations influence CO_2 emissions. This is achieved by modifying an interregional input-output matrix covering Brazil's 27 states and 68 productive sectors for the base year 2019. Emissions data are sourced from the Greenhouse Gas Emissions and Removals Estimation System (SEEG).

The study explores the spatial, sectoral, and institutional drivers of emissions by analyzing the structure of production, trade, and income formation. A key contribution of this research is its focus on a middle-income country, employing a systemic approach to identify the supply-side impacts, classify sectors and regions, and analyze interregional interdependencies. Through this framework, we aim to identify the key agents responsible for CO_2 emissions, leveraging the concept of embodied emissions to better understand their drivers.

Additionally, a panel data model with fixed effects were estimated, to evaluate the relationship

between CO₂ emissions (dependent variable) and national income across major economic sectors (agriculture, agriculture for exportation, industry, services, trade, and extractive industry). Our findings reveal a trade-off between emissions mitigation and economic growth, as key sectors driving Brazil's development are also major sources of emissions.

The input-output analysis further highlights the role of each sector in CO₂ emissions by categorizing them into quartiles based on their direct and total impacts, establishing a hierarchy for sectoral mitigation strategies. Our results indicate a high degree of heterogeneity in sectoral elasticities, both in direct and total effects.
Dividing the elasticities in two measures (e.g. total and direct) may contribute to a better design of the potential mitigation policies both in spatial and sectorial terms. The spatially aggregate results help to better understand which are the main driver of the emissions, if local – when the direct impact is higher than the total impact or if it is in the rest of the economy – when the total impact is higher than the direct impact.

Spatially aggregated results reveal whether emissions are primarily local (when direct impact exceeds total impact) or driven by interregional linkages (when total impact surpasses direct impact). State of São Paulo, for instance, exhibits a local emissions driver, meaning an increase in its value-added affects emissions nationwide. In contrast, the State of Pará emissions are more sensitive to value-added variations in other states, emphasizing interregional dependencies. Sectoral analysis also shows that emissions from agriculture and livestock are locally driven, whereas wholesale and retail trade emissions are largely influenced by the broader economy.

The results in this paper reinforce the tradeoff between income growth and emissions, the heterogeneity of the results both in sectorial and spatial terms and the necessity to customize the mitigation policies in a country with a spatial production structure with high degree of specialization like Brazil.

Global methane footprints growth and drivers 1990-2023

Topic: Environmental Input-Output Modelling (3)
Author: Yuli SHAN
Co-Authors: Kailan TIAN, Yuru GUAN, Ruoqi LI, Klaus HUBACEK

Methane has been identified as the second-largest contributor to climate change, accounting for approximately 30% of global warming. Countries have established targets and are implementing various measures to curb methane emissions. However, our understanding of the trends in methane emissions and their drivers remains limited, particularly in recent decades when viewed from a consumption perspective (i.e. accounting for all emissions along the entire global supply chain). And many of previous studies lack comprehensive coverage of a wide range of countries and high sectoral resolution.

Aiming to address the research gaps concerning the lack of up-to-date analysis on methane emissions from the perspective of consumption, covering a wide range of countries and with high sectoral resolution, this study uses the latest GLORIA input-output dataset (Global Resource Input-Output Assessment) to examine methane CBE of 164 countries/regions (accounting for 98% of global methane emissions) for the long-term period 1990-2023. We further compare the degree of decoupling of both PBE and CBE from economic growth in each country; reveal the recent changes in trade embodied emissions; and investigate the drivers of changes in CBE with Structure Decomposition Analysis (SDA). We compare our methane emissions results with CO2

emissions and conclude the study with a discussion of solutions to reduce methane emissions.

Our results indicate that there is no foreseeable slowdown in the momentum of global methane emissions growth. Only developed countries have managed to reduce both production- and consumption-based emissions while maintaining economic growth (i.e., strong decoupling) during the observed period (1990-2023). Their decoupling is mainly caused by a decline in their emission coefficient, and to a lesser degree due to outsourcing methane emissions to less developed regions.

Global trade accounts for approximately 30% of global methane emissions, but major trade patterns are shifting from North-North and North-South to South-South, indicating that developing countries are increasingly participating in global supply chains. Also, as sectors across countries differ in technological endowment, production efficiency, emission coefficient of products produced in different countries varies. This provides an opportunity to reduce a sector's methane footprint by supply chain management of upstream production through carefully selecting import partners with low emission coefficient.

The study further reveals the changing drivers of global methane emissions from 1998 to 2023 in five-year intervals. It identifies that the reduction in emission coefficient, reflecting improvements in emission technology, is the main determinant for reducing emissions over the observation period and can offset the increasing effects from growth of final demand. Reducing methane emission coefficient requires targeted strategies across sectors. Changes in demand structure have played a considerable role in the increase of emissions since 2008. We further compared the heterogeneity of each driver between country groups by calculating the SD of the average contribution of the drivers in each group. We find that the emission coefficient, final demand per capita, and demand structure show the greatest differences between groups. We also find the dynamics of emission drivers are fluctuating across periods, similar to the status of decoupling from GDP. Achieving emission reduction in one region/period does not promise long-lasting or stable reduction in the future.

In summary, this study enhances our understanding of the most up to date changes and drivers of methane emission footprints and supports countries in incorporating methane emissions into their climate mitigation strategies.

Income-based carbon emissions of Chinese listed banks

Topic: Environmental Input-Output Modelling (1)
Author: Ling SHAO
Co-Authors: Yunlong PAN, Keyue DAI, Zi WU

Financial institutions not only contribute to carbon emissions through their own business activities but, more importantly, play a crucial role in the transition to a green economy by directing capital flows through their investment and financing activities. Accurately measuring the financed carbon emissions of financial institutions helps assess their impact on climate change and provides valuable insights to guide them toward green investment and sustainable finance.
In the field of carbon emission accounting, there are three parallel principles for allocating carbon responsibility: production-based carbon emissions, consumption-based carbon emissions, and income-based carbon emissions. Among these: production-based carbon emissions of financial institutions are minimal since financial activities do not involve on-site fossil fuel combustion. Consumption-based carbon emissions focus on final products and consumer-side mitigation

strategies, such as green consumption, which have limited relevance to financial institutions. Income-based carbon emissions focus on the enabled downstream carbon emissions of financial institutions, considering them as providers of primary inputs to economic activities. From the above description, income-based carbon emissions are the most relevant for financial institutions because financial institutions indirectly shape the carbon footprint of the industries and projects they fund, making income-based carbon accounting the most appropriate approach to capture their true impact on emissions.

The income-based carbon emissions of financial institutions have attracted widespread attention. Many organizations currently provide methodological guidance for financial institutions to account for carbon emissions. For example, the Partnership for Carbon Accounting Financials (PCAF) has set up separate calculation methods for carbon emissions associated with six different asset classes in 2022. In 2023, the European Central Bank (ECB) released Towards Climate-Related Statistical Indicators, which primarily measures financial institutions' carbon emissions by combining portfolio holdings with corporate emissions or assessing portfolio transition risk. Although current carbon emission measurement methodologies for financial institutions incorporate a life-cycle perspective by attributing the emissions of financed entities to the institutions themselves, they typically stop at primary financing targets, failing to capture these cross-value chain emission transmission effects. Take oilfield exploration financing as an example: while the direct carbon intensity of the exploration phase is relatively low, successful exploration triggers emissions across the entire oil extraction-refining-consumption industrial chain.

While the Leontief inverse, as a demand-driven model, is widely used to analyze complete consumption-based carbon emissions, the Ghosh inverse, as a supply-driven model, is ideally suited for analyzing complete income-based carbon emissions. In the literature, some scholars have already defined and analyzed income-based carbon emissions at the national level using the Ghosh model (Lenzen & Murray, 2010; Marques et al., 2012). In this study, we propose a Ghosh model-based input-output framework to analyze the income-based carbon emissions of financial institutions, filling the gap in existing research and providing a whole perspective on the role of finance in climate change.

As the world's largest carbon dioxide emitter, China pledged in 2020 to peak its carbon emissions before 2030 and achieve carbon neutrality before 2060. Given the central role of banks in financial intermediation and capital allocation, this study measures the income-based carbon emissions of 42 A-share listed banks in China from 2010 to 2022. The Ghosh model and Hypothetical Extraction Method (HEM) are applied, and the data are from annual report of banks, the CSMAR and EXIOBASE databases. Additionally, we conduct structural path analysis to reveal the key financed carbon emission paths of each bank. The main findings are as follows. First, from 2010 to 2022, income-based carbon emissions from Chinese listed banks, including those embedded in their loan portfolios, have shown an overall upward trend. Large state-owned banks account for more than 60% of these emissions, highlighting their continued capital allocation to high-carbon industries. Second, while the carbon emission intensity of bank loans has generally declined, large state-owned banks exhibit significantly higher emission intensity than other types of banks, with the slowest rate of decline. Third, the study reveals that carbon emissions from further-tier financing—previously overlooked in past research—are 2 to 10 times larger than those from tier 1 financing, which has been the primary focus of previous studies or accounting standards. This finding underscores the critical importance of tracing the complete financial chains of financi

Comprehensive Structural Decomposition Analysis of CO2 Emissions from Vessels: Case Study of Japan

Topic: Structural Change and Dynamics
Author: Taiga SHIMOTSUURA

Maritime transport is the backbone of global economy, accounting for more than 80% of world goods trade. However, CO2 emissions from international shipping are increasing, reaching approximately 3% of global anthropogenic emissions. In response to the global need for emission reductions across industries, the International Maritime Organization has set ambitious greenhouse gas reduction targets for international shipping, aiming for a more than 70% reduction by 2040 compared to 2008 levels, and carbon neutrality by 2050. These targets have brought attention to zero-emission vessels, which creates a significant need for comprehensive life cycle assessment (LCA) studies to evaluate their environmental impacts.

While previous studies employed LCA to assess the environmental performance of zero-emission vessels, there is a research gap in evaluating the impacts of lifespan changes with those of other CO2 reduction measures. Specifically, few studies have compared CO2 reduction effects through the lifespan changes with those resulting from other factors, such as fuel efficiency improvements and vessel size optimization.

To address this gap, this study investigates the impact of changes in the average lifespan of vessels on CO2 emissions, using Japanese domestic maritime transport as a case study. Two key analyses were conducted. First, this study estimates CO2 emissions of Japanese domestic maritime transport from 2005 to 2022 under varying vessel lifespans, comprehensively considering the vessel life cycle. This estimation examines the relationship between lifespan changes and emissions, incorporating vessel repair into the estimation model for the first time. Second, this study develops an LCA-specific structural decomposition analysis (SDA) and applies it to the emissions across different lifespan scenarios. This SDA decomposes CO2 emissions into 12 factors across four vessel life cycle stages: production, consumption, repair, and activity. This approach reveals stakeholders' contributions in each vessel life cycle stage to changes in emissions, providing more concrete policy implications for each stakeholder. Furthermore, the SDA identifies the main drivers of emission changes both within and across the different lifespan scenarios, allowing comparisons of environmental impacts of lifespan changes with those of other factors.

The results revealed that extending vessel lifespans by five years led to a cumulative reduction of approximately 1.7 Mt-CO2 compared to the baseline, despite the increased demand for vessel repairs. Additionally, the SDA results under the baseline lifespan scenario demonstrated that supply chain management by shipyards and vessel stock restructuring (i.e., reducing the total number of vessels and travel distances) by shipping companies significantly contributed to the emission reduction. These findings suggest the need for policies that not only target shipyards to improve their supply chain management but also encourage shipping companies to optimize their operations, complementing current policies aimed at enhancing energy efficiency. The comparison of the SDA results across different average lifespan scenarios further indicated that the lifespan changes were the third-largest contributor to CO2 reduction, following reductions in vessel stock and travel distances. Therefore, these findings indicated that the impact of lifespan changes is indeed substantial, suggesting the importance of integrating current CO2 reduction measures with strategies for extending vessel lifespans to achieve greater environmental benefits.

This study made three novel contributions. First, this study incorporated vessel repairs into the CO2 estimation model, shedding light on the environmental trade-offs between extending the average lifespan and subsequently increasing vessel repair demand. Second, this study developed a novel SDA framework capable of comprehensively decomposing the estimated CO2 emissions across vessel life cycle stages. Applying SDA provided deeper insights into stakeholder contributions at each stage of the vessel life cycle. Third, the SDA framework facilitated a quantitative comparison of lifespan changes with other mitigation measures by applying it across various average lifespan scenarios, enhancing discussions on effective CO2 reduction strategies.

CO2 Reduction Potential of Global Supply Chain Networks: An MRIO Approach Incorporating Maritime Network Structures

Topic: Trade and Global Value Chains Policies (5)
Author: Tomomi SHODA
Co-Authors: Shigemi KAGAWA, Keitaro MAENO, Taiga SHIMOTSUURA

The global supply chain (GSC) structure has significantly developed over the past few decades driven by the expansion of international trade. 23% of global CO2 emissions are embodied in traded goods through GSCs, making the reduction of CO2 emissions from GSCs a matter of significant concern for achieving carbon neutrality worldwide. Environmentally Extended Multi-Regional Input-Output (EE-MRIO) models are one of the most powerful tools for tracing GSCs and allocate emissions from production to consumption across countries.

In Input-Output Analysis, Multi-Regional Input-Output (MRIO) tables describe inter- and intra-industry dependencies within and between countries by modeling GSC as a multidimensional space defined by country, commodity, and industry. However, MRIO tables do not provide insights into the domestic and international transportation systems used for these trade flows, as the path through physical space is not explicitly defined.

On the other hand, it is important to note that the development of the GSCs has led to the geographic separation of production areas and consumption areas, which makes the GSC highly dependent on international shipping. To more accurately evaluate the environmental impact of global supply chains, it is essential to develop analytical methods that incorporate physical dimensions. Accordingly, this study aims to establish a new framework for analyzing GSCs by integrating maritime network structures into an MRIO approach.

In this study, we first estimated direct and indirect input (dollar) induced by world final demand in 2019 using Global Environmentally-Extended Multi-Region Input-Output Database (GLORIA). Next, we calculated the ratio (%) of container transport by industry and country based on trade statistics data and estimated Japan's import value (dollar) by container transport using an MRIO approach. Additionally, we utilized big data on international container shipping to calculate offshore CO2 emissions (t-CO2) from container shipping and identified the most effective container shipping routes based on Graph theory to allocate offshore CO2 emissions (t-CO2) to countries. Finally, we calculated offshore CO2 emission intensity (t-CO2/dollar) for international container shipping based on big data and estimated total offshore CO2 emission (t-CO2) based on an MRIO approach.

Results showed that container ships traveling from Europe to Japan typically stop at Amsterdam, the Suez Canal, Singapore, and Hong Kong, while those traveling from the Americas stop at the Panama Canal. These container ships emit more CO2 than those operate within East Asia and

Southeast Asia because of longer distances. Identifying the specific countries where container ships stop is challenging using only the MRIO approach. One of the key contributions of this study is the development of a novel method to allocate offshore CO_2 emissions to countries. This approach highlights that not only import and export countries involved in GSCs but also hub countries where ships make stops (e.g., Singapore, Panama, etc.) should share responsibility for offshore CO_2 emissions. These countries should also consider developing sub-global environmental policies to address the environmental impact of international shipping.

The Role of Agricultural Sector and its Sustainability in the Indian Economy

Topic: Input-output Analysis for Policy Making (3)
Author: Juhi SINGH
Co-Authors: Sushanta Kumar MAHAPATRA

This study investigates the role of the agricultural and allied sectors in India as a driver of sustainable development by analyzing inter-sectoral linkages and multiple multiplier effects over the periods 2011, 2015, and 2019. The study employs the Leontief Input-Output (I-O) Model, a robust analytical tool for examining economic interdependencies. The I-O model, developed by Leontief (1951), captures the flow of goods and services between sectors, allowing for the identification of intersectoral linkages. The study has utilize two secondary data namely, Supply Use Tables and Employment Unemployment Survey from reliable sources such as Ministry of Statistics and Programme Implementation (MoSPI), government of India. Utilizing a comprehensive input–output framework, the research quantifies key metrics such as backward linkages (BL), forward linkages (FL), and their normalized counterparts (NBL and NFL) to assess how agricultural products function both as critical inputs for other sectors and as essential outputs within the economy. In addition, the study examines production-inducing, income-inducing, employment-inducing, and supply shortage effects across six sub-sectors: Cereals, Pulses, Oil Seeds, Commercial Crops, Horticulture, and Allied Activities. The empirical results reveal that primary crop sub-sectors maintain a stable dependence on agricultural inputs, as evidenced by consistently high BL values; however, a decline in FL values suggests a weakening role in supplying raw materials to downstream industries. In contrast, the horticulture sub-sector demonstrates increasing multipliers in both income and production effects, indicating enhanced value addition and processing intensity that have significant implications for rural income generation. Furthermore, while Allied Activities initially exhibit higher multipliers, both their income and employment effects decline over time, pointing to structural shifts and a reduction in inter-industry spillovers. Employment multipliers across primary crop groups also show a downward trend, likely reflecting the impacts of mechanization, technological advancements, and shifts towards higher productivity that reduce labor intensity. The analysis of supply shortage effects further underscores the vulnerability of certain sub-sectors to disruptions, with variations in both direct and indirect impacts highlighting differences in how each product group interacts with the broader economy. These findings underscore the central role of agriculture in sustainable development by linking production efficiency with income generation and employment creation in rural areas. The study offers critical insights for policymakers by identifying areas where strengthening supply chain integration, investing in technological adoption, and enhancing value chain linkages can bolster the sustainability and resilience of the agricultural sector. Ultimately, the research contributes to a deeper understanding of the multifaceted role of agriculture in promoting economic growth and sustainable rural development in India.

Keywords: Agriculture Sector, Sustainable Development, Input Output Model, Inter Sectoral Linkages, Multiplier

Sectoral, spatial and scarcity structure of the Chilean water footprint: a global multi-country input-output analysis.

Topic: Special session: From Basins to Planet: Unraveling Water-economy Interactions across Scales with MRIO Models
Author: Gino STURLA
Co-Authors: Eugenio FIGUEROA, Leonardo LANATA, Benedetto ROCCHI

The water pressures generated by the final consumption of the Chilean economy remain largely unquantified. Despite Chile's modest economic size, characterizing its water footprint is critical for developing internal sustainability policies and assessing the broader impacts of its consumption. This study provides the first estimation of these pressures, identifying their geographic distribution, disaggregating them by economic sectors, and calculating their scarcity content - reflecting the relative water scarcity in the regions where water is extracted to support Chilean consumption. An environmentally extended multi-regional input-output (MRIO-EE) model forms the foundation of this analysis. The model incorporates water data for Chile from diverse national sources, the Aquastat database for other countries, and global input-output tables from the OECD (covering 70 countries). The results reveal that 72% of the water pressures associated with Chilean consumption occur within its national borders, with the mining sector contributing the largest share of the water footprint. However, when adjusted for water scarcity, this figure drops to 43%, as many imported goods and services originate in countries with higher relative water scarcity. These findings offer a global perspective on the Chilean economy's impact on planetary water resources, providing actionable insights for policy development. Recommendations include fostering incentives for cleaner imports, promoting substitution strategies, and implementing targeted policies to reduce the water footprint of domestic and international supply chains, thereby enhancing Chile's contribution to sustainable water resource management.

Valuation of ecosystem services for water provision, purification, and regulation in Chilean regions based on a multiregional input-output model.

Topic: Special session: From Basins to Planet: Unraveling Water-economy Interactions across Scales with MRIO Models
Author: Gino STURLA
Co-Authors: Eugenio FIGUEROA, Leonardo LANATA, Benedetto ROCCHI

Water-related ecosystem services (ES) - including provision, purification, and regulation - are fundamental to regional sustainability but remain economically undervalued in Chile. This study addresses this gap by quantifying the economic value of these services across Chilean regions, employing for the first time an environmentally extended multiregional input-output model (MRIO-EE). The model integrates the economic structure of 15 regions (2014), sectoral water extractions and restitutions from surface and groundwater, and the additional water required for pollutant dilution and assimilation (gray water). Scarcity thresholds (ST) and the extended water exploitation index (EWEI) are calculated to evaluate regional hydroeconomic equilibrium (HEE) and its associated cost (CHEE). The analysis estimates water usage under overexploitation

conditions, linking it to the opportunity cost of reallocating water to its most economically productive use - generating added value. Results indicate that the economic value of water services in overexploited regions ranges from 3 to 50 USD per cubic meter (2014). The total value of provision and purification services is 71.5 billion USD, with groundwater regulation services contributing an additional 10.7 billion USD. These findings highlight the significant regional variability and economic importance of water-related ES in Chile. This study demonstrates that the MRIO-EE model, despite certain limitations, provides a robust framework for quantifying the economic value of water-related ES. The results offer critical insights for designing policies aimed at achieving sustainable and equitable water resource management in regions facing overexploitation.

Integrating an IRIO hydro-economic model with a physically-based hydrological model to characterize water scarcity in sub-basins of Tuscany, Italy.

Topic: Special session: From Basins to Planet: Unraveling Water-economy Interactions across Scales with MRIO Models
Author: Gino STURLA
Co-Authors: Benedetto ROCCHI

Traditional input-output models that link economic activity with water resources often rely on economic units of analysis, overlooking the geographical and hydrological relevance of river basins. However, river basins serve as the fundamental units for evaluating water ecosystems and their interactions with the productive system. This study examines the balance between water supply and demand across five local labor systems (LLS) in the upper Arno River basin, Tuscany, Italy.

Water supply is modeled using the Soil and Water Assessment Tool (SWAT), which simulates key hydrological components such as precipitation, evaporation, surface runoff, and groundwater recharge. On the demand side, the study distinguishes between blue water (withdrawn from surface and groundwater sources), green water (soil moisture available for plant uptake), and gray water (used for pollutant dilution). Demand estimation is conducted using a multiregional input-output hydro-economic model (MRIO), which is fully integrated with SWAT and a water quality mixing model. This integration provides a comprehensive assessment of water flows and their economic implications.

One of the study's critical innovations is its spatial harmonization approach, which aligns sub-basins with their corresponding LLS. This ensures that hydrological and economic analyses are not conducted in isolation but rather within a coherent spatial framework, leading to a more precise assessment of water dynamics.

The integrated modeling framework identifies two key endogenous effects that significantly influence water dynamics:

1.   Adjustments in agricultural water withdrawals based on green water availability, reflecting the ability of crops to rely on soil moisture rather than irrigation.

2.   Changes in industrial gray water requirements due to variations in runoff and groundwater recharge, impacting water availability for pollutant dilution and industrial processes.

By simulating these effects over a 13-year period, the model captures the interannual variability of hydrological components, providing insights into long-term water use trends.

Unlike traditional economic models that lack physical hydrological integration, this approach provides a more accurate representation of green water supply. This, in turn, enables a more precise assessment of agricultural water demand dynamics, as it accounts for seasonal variations and climate-induced fluctuations. A key advantage of this integration is that it allows for a better

understanding of the variability in blue water demand, particularly for the agricultural sector, which is highly sensitive to hydrological conditions.

To quantify water scarcity at the LLS level, the study synthesizes results into multiple indicators, incorporating different demand and supply perspectives. These includes:

- Demand-based approaches: total withdrawals, net demand, and extended demand.
- Supply-based perspectives: natural ecological supply and feasible supply.

By analyzing multiple hydrological years, the study assesses the variability of these indicators, allowing for an evaluation of the risk of exceeding various thresholds suggested in the literature. This long-term perspective is crucial for understanding the resilience of local labor systems to water scarcity risks and for designing adaptive water management strategies.

Beyond water scarcity assessments, the model offers a powerful tool for evaluating the economic impacts of local and regional decision-making on water resources and labor systems. Given its integrated hydro-economic framework, it can inform policy interventions, helping decision-makers assess the trade-offs between economic development and water sustainability.

The results highlight the importance of integrating physical and economic models to develop more effective policies for managing water resources sustainably. In an era of increasing climate variability and water stress, this approach offers a robust framework for ensuring the long-term viability of water-dependent economic activities, while minimizing the risks associated with water scarcity and pollution.

By bridging the gap between hydrology and economics, this study provides a comprehensive approach to water resource management, demonstrating the value of spatially-explicit, physically-grounded economic models in addressing water sustainability challenges.

A New Interregional Input-Output Model with Endogenous Self-sufficiency Rate

Topic: Input-Output Theory and Methodology (1)
Author: Qi SU

Classic input-output models often assume that domestic and imported products are either perfectly substitutable or non-substitutable in measuring the effects of external demand shocks. However, these assumptions do not fully reflect real-world trade patterns. In this paper, we assume that domestic and imported products of the same sector are differentiated products therefore whose elasticity of substitution is non-zero. Based on this assumption, we develop a new interregional input-output model that allows for a constant elasticity of substitution between domestic and imported products by supposing each industry has a Cobb-Douglas production function and intermediate inputs of each industry has a Constant Elasticity of Substitution (CES) aggregator over domestic and imported products. One attractive aspect of our model is that the self-sufficiency rate of intermediate inputs is endogenized by profit maximization of all firms which is determined by both substitution elasticity between domestic and imported products and the international price indices. The new model could provide a more flexible framework to analyze the effects of external demand shocks.

To empirically check the differences in the results of measuring the effects of external demand shocks between our model and the classic Interregional Input-output model, we focus on demand-side shocks which refer to changes in exports from representative industries the between China and the U.S. Operating the new model need to assign values to three types of parameters for: the input coefficient matrix, the relative price level among countries and the elasticity of substitution between countries of each sector. We use the 2014 World Input-Output Database (WIOD) to construct a three-region, 56-sector IRIO table covering China, the United States, and the rest of the world (ROW) to get the input coefficient matrix required. The

information of the relative price level among countries comes from the cross-country price indices of the United Nations International Comparison Program((ICP) and the distribution range of the elasticity of substitution between domestic and imported products from the existing empirical results of the Armington elasticity.

The results indicate that the shocks estimated by the new model have a lower impact on China's value-added compared to the classic model but a higher impact on the U.S.' value-added than the classic estimate. At the sectoral level, the two models identify significantly different sectors as the most affected by trade shocks. To observe the impact of changes in the elasticity of substitution on external demand shocks, we add two scenarios for simulation: a) a high substitutability relationship between domestic and imported products; b) a low substitutability relationship between domestic and imported products. By comparing the simulation results, we find that changes in the elasticity of substitution affect the estimation of the shock's impact, but the classic model consistently provides higher estimates of the impact on China's value-added and lower estimates of the impact on the U.S.' value-added compared to the new model.

Key words: Interregional input-output model; Armington Elasticity; Relative Price Level among Countries; External demand Shock；Self-sufficiency Rate

The implications of re-shoring and increasing US-based production in corporate carbon accounts

Topic: Special Session: International Trade in Corporate Carbon Accounting
Author: Sangwon SUH

The global economic structure is on the verge of a major transformation. Since China's accession to the WTO in 2001, globalization and offshoring have been persistent global trends. For example, global merchandise trade has grown nearly fourfold, with exports increasing from around $6.2 trillion in 2001 to over $25.3 trillion in 2022. Among other trends, developing economies have increased their share of global trade from 33% in 2000 to over 45% by 2022.

The growing participation of developing economies in global value chains has led to the offshoring of GHG emissions to these regions, where technologies and regulations for GHG mitigation are generally less stringent. This phenomenon, often referred to as the "emissions cost of sourcing," contributed approximately 18% of total global CO_2 emissions growth between 1995 and 2007 due to the increased share of foreign production.

However, recent policies, such as higher trade tariffs and the reshoring of major manufacturing bases back to U.S. soil—as seen during the second term of the Trump administration—may significantly alter the structure of global GHG emissions within value chains.

In this panel discussion, we will explore the implications of recent reshoring trends on global greenhouse gas emissions and corporate carbon accounting results. These rapidly changing patterns in international trade may necessitate a reevaluation of how input-output tables, international trade statistics, and GHG accounting data are compiled to ensure they remain up to date. Techniques such as nowcasting, scenario analysis, and model-based data development and compilation may become increasingly important under these circumstances.

During the session, we will hear from experts on the subject and encourage participants to share their thoughts and perspectives. This dialogue will help shed light on the evolving challenges and opportunities in corporate carbon accounting within the context of a shifting global trade landscape.

Errors due to domestic import assumption in corporate carbon accounts

Topic: Special Session: International Trade in Corporate Carbon Accounting
Author: Sangwon SUH
Co-Authors: Steven J. DAVIS, Mo LI, Andrew DUMIT, Yohanna MALDONADO

The research question, the method used

Environmentally-extended input-output models are the dominant source of data for estimating and reporting supply chain greenhouse gas (GHG) emissions by corporations. According to CDP, a UK-based, investor-backed GHG disclosure platform, about 70% of the companies that are reporting their GHG emissions use so-called, 'spend analysis,' which refers to the application of environmentally extended input-output tables. However, the most widely used of such models employ the 'domestic import' assumption, which assumes that the structure of supply chains and the emissions intensity of the products imported to a country match those of the importing country—usually the U.S. or the U.K. The use of domestic import assumption may introduce over- and under-estimation of corporate GHG emissions, depending on the relative GHG intensities of the exporting countries compared to those of the domestic counterparts. Therefore, the research question of this study is: "what are the scale and pattern of emissions that may be missed when using these single-region models?".

We used contribution analysis and sector-specific emissions intensity distribution to analyze the potential for a single-region IO model to mischaracterize the GHG intensities of imported goods under domestic import assumption.

The data used (if any)

We use multiregional and single-region versions of the Comprehensive Environmental Data Archive (CEDA) EEIO model, which was first published in year 2000 and has been regularly updated since, to evaluate differences in sector-specific emissions factors, and then assess the aggregate effect on both the emissions inventories and reduction priorities of various types of companies. Based on publicly available input-output tables and macroeconomic statistics, the CEDA model we use here maintains similar sectoral resolution to the USEEIO model (400 sectors), but adds multiregional resolution of 65 countries and a "rest of world" region (n.b. a condensed version of the full 148 country model). The emissions intensities estimated by the multiregional model are much more consistent with published country- and industry-specific values than a single-region (U.S.) model.

The novelty of the research

We find that the upstream emissions of companies who report to CDP are in the aggregate 2.0 GtCO2e greater when estimated by a multiregional model instead of a U.S.-based single-region model, with especially substantial differences related to manufacturing sectors of moderate emissions intensity (i.e., 0.4-0.8 kgCO2e/$). Although the magnitude of emissions embodied in international trade is well-recognized in the context of national inventories, our results underscore the importance of international differences in emissions for corporate carbon accounting. For example, international supply chains and higher emissions-intensities of production in China lead to much greater emissions in China (+973 MtCO2e), and somewhat lower emissions in areas which rely more heavily on low-carbon sources of energy (e.g., France, Brazil, and the U.K.). High-resolution, multiregional models can both improve the accuracy of

corporate emissions inventories and help companies to prioritize both primary data collection and emissions reduction efforts.

Digital Product Diversity in the Digitization of Global Value Chains: Based on a Supply-Use Table Accounting Framework

Topic: Special Session: Technological Innovation Enabling GVC Restructuring
Author: Yifan SUN
Co-Authors: Shantong LI, Yan XIA, Huijuan WANG

Research question: With the rapid advancement of digital technologies, industrial production structures are undergoing profound transformations. The production of digital products has transcended traditional industrial boundaries, exhibiting cross-sectoral and interdisciplinary characteristics. However, existing literature rarely systematically deconstructs the value-added created by digital products in global value chains from an industry-product dual perspective, particularly overlooking the value contributions of digital products in traditional industries. This study innovatively constructs an industrial product diversity analysis framework and uses it to explore the characteristics of digital transformation in global value chains.

Methodology: This study proposes a novel cross-measurement approach for global value chains based on the dual dimensions of industry and product, systematically extending the existing framework for measuring digital transformation. Building on a supply-use table distinguishing digital and non-digital products, we formulate two equations of product structure and product distribution for industry, establishing a global input-output analysis framework incorporating digital product information. Within this framework, the study decomposes global total value added into digital product demand-driven and non-digital product demand-driven components. Furthermore, we use indicators such as digital product dependency and participation in global value chains, along with their measurement methods, to comprehensively characterize the diversity features of digital products.

Data: We utilize the FIGARO-MRSUT multi-regional supply-use table dataset compiled by Eurostat to quantitatively measure the extent of digital transformation in global value chains and to evaluate the role of digital product diversity in this transformation process.

Novelty: This study innovatively focuses on the diversified production structures of industries and adopts a digital product diversity perspective. We examine the characteristics of digital and non-digital product diversity within both traditional industries and core digital industries. By comparing the production structures of differentiated product diversity across industries, this approach provides a more realistic framework than the traditional assumption of single-product production. In the current context of accelerating digital transformation in traditional industries, the conventional single-product perspective may underestimate the enabling effects of digital product-driven technological innovation in the digital transformation of global value chains. Therefore, introducing an industrial product diversity perspective is both necessary and valuable for analysis.

Structural Transformation and Economic Resilience: The Case of Pakistan

Topic: Structural Change and Dynamics
Author: Farah TASNEEM
Co-Authors: Muhammad Aamir KHAN

Structural transformation, a reallocation towards high-value-added production, is essential for achieving sustainable growth. However, Pakistan's structural transformation has been relatively slow and limited as compared to other Asian economies. This research quantitatively seeks the economic benefits of accelerating structural transformation in Pakistan, primarily focusing on trade liberalization, export-oriented productivity enhancements, and sectoral expansion strategies. By using a Global DynamicComputable General Equilibrium approach calibrated with the GTAP 12 database, the study evaluates the economy-wide impacts of policy changes, including a 10% decrease in bilateral tariffs, a 10% increase intextile and apparel output, and a 10% removal of actionable non-tariff measures (NTMs) on services. The model identifies crucial sectors driving economic growth and transformation in Pakistan, such as "Textile and Wearing Apparel,", "Manufacturing," and "Services." The model results indicate that reducing tariffs and removing NTMs can significantly boost trade flows and GDP, particularly in sectors like textiles and
services, which are vital to Pakistan's export strategy. Moreover, increasing output in the textile sector, a major export industry, leads to substantial gains in exports and overall economic performance. The analysis reveals that structural transformation focused on expanding manufacturing and services, supported by trade and productivity-oriented reforms, positively impacts macroeconomic variables and enhances household welfare in Pakistan. These findings underscore the potential for targeted policy interventions to accelerate structural transformation, fostering inclusive growth and economic development.

Input-output micro-macro twins

Topic: Input-Output Theory and Methodology (2)
Author: Umed TEMURSHO
Co-Authors: Matthias WEITZEL

This paper provides deeper insights into the internal structure and interdependencies of European households' consumption expenditures, and proposes an integrated input-output micro-macro model to assess the impacts of changes in consumer prices, incomes, and other final demand components.

In the first part of the paper, we estimate and analyze EU-wide and country-specific results of intra-budget regressions, which form the foundation of Taylor's (2014) consumer expenditure model. We modify the Taylor framework to account for the income effect when incorporating the household budget constraint and derive closed-form expressions for price and income elasticities.

In the second part, we integrate the modified household expenditure framework with an open input-output quantity model in a multi-regional setting. This integration enables us to capture the circular consumption-production-income multiplier effects. By further investigating the linearized version of the IO micro-macro twins model, we generalize the integrated micro-macro framework to accommodate any demand system. In addition, we provide both theoretical and empirical insights into an array of inter-regional income and consumption multiplier matrices, which show

the corresponding impacts of changes in consumer prices, incomes, and other final demand components. As an empirical application, we analyse the effects of rising consumer prices in the EU, corresponding to a 55% reduction in EU greenhouse gas emissions by 2030 compared to 1990 levels.

How can PFTZs affect firms'GVC positions through supply chains?

Topic: Trade and Global Value Chains Policies (5)
Author: Chenchen TIAN
Co-Authors: Yimamu ABASI, Yongming HUANG, Suppakorn KHONKHLONG, xin LI

Pilot free trade zones (PFTZs) is a national strategy for China's high-quality opening up. This paper analyzes the spillover effect of PFTZs on GVC positions through supply chains in China using a panel of 839 A-share listed firms from 2008 to 2016. The results show that: (1) PFTZs positively affect both upstream and downstream firms in their production line positions; (2) PFTZs improve the positions of upstream and downstream firms in GVCs by boosting productivity and overseas market performance, while also positively influencing FDI inflows to the local market; (3) The spillovers of PFTZs on upstream and downstream differ with firms' ownership, market share and location. Based on these findings, this paper advocates for a stronger focus on supply chain spillovers, including the channels and varied effects across customers, suppliers, and regions.

Digital supply, use, and input-output tables for China from 2000 to 2020

Topic: Special Session: Digital Input-output Accounting: Methodology and Applications (2)
Author: Kailan TIAN
Co-Authors: Kang LIN

Digital technology has profoundly transformed the production and consumption of goods and services worldwide in recent decades. The growing digitalisation—the integration of digital technologies, data, and their interconnections into the economy—is evident, for example, in the automation of tasks previously performed by humans and the increasing reliance on digital tools for communication and professional work. Its expanding impact on businesses and consumption is also apparent in the surge of online purchases. Meanwhile, the rapid growth of the digital economy has brought significant environmental implications. For instance, the carbon footprint of the information and communications technology sector in 2020 was estimated to account for 1.5 to 3.2 percent of global greenhouse gas emissions. Despite these profound influences, the explicit impacts of digitalisation often remain invisible in the conventional national accounts produced by countries. This limits the scope of research on critical economic and environmental issues, such as measuring the contribution of the digital economy to gross domestic product (GDP) and tracing the environmental footprint of digitalisation. To enhance the visibility of digitalisation in macroeconomic statistics and address the growing demand for a useful database for relevant research, we compile a series of digital supply, use, and input-output tables for China, covering the period from 2000 to 2020.
The increasing impact of digitalisation has been picked up by a growing number of international organizations and governments, prompting intensified efforts to delineate and improve its visibility in national accounts and refine methods for measuring the digital economy. However, due to the absence of a standardized framework or a definitive definition of the digital economy, previous work has been conducted on a relatively ad hoc basis, with different organisations and

countries adopting different definitions and methodologies for estimating the digital economy. The United States, Europe, China, Canada, and Australia have all begun measuring the digital economy. These measurements were conducted by identifying certain digital products, such as information and communication technology (ICT) products, and calculating the value-added created from their production. Yet, this approach struggles to fully capture the broader economic impact of digitalisation, particularly the digitalisation of non-digital products. As a result, existing estimates may underestimate the true extent of digital transformation across industries.

To address these challenges, the Organization for Economic Cooperation and Development (OECD) developed digital supply and use table (SUT) as a conceptual framework, providing a more structured method for studying digital economy. Several countries, including Canada and the Netherlands, have begun adopting this framework and conduct experimental research on the compilation of national digital SUTs. To facilitate the measurement of the digital economy and support relevant research and policy making, the National Bureau of Statistics (NBS) of China released the Statistical Classification of Digital Economy and Its Core Industries (2021) in 2021. The classification defines the statistical scope of the digital economy into digital industries and the digitalisation of conventional industries. It also identifies a list of core digital industries. However, despite the urgent need for digital SUTs in China, none have been made available yet.

Based on the OECD framework and the classification from the NBS of China, we make the first attempt to compile digital SUTs for China. The digital SUTs framework offers flexibility in capturing the multidimensional nature of the digital economy. Our approach extends conventional SUTs by introducing both digital products/industries and the digitalisation of conventional sectors. These lead to additional rows and columns in the digital SUTs compared with their conventional counterparts. We propose a novel four-step process to construct the digital SUTs, and subsequently convert them into digital input-output tables (IOTs), which consist of 40 non-digitalised conventional products, 40 digitalised conventional products, and 14 digital products. IOTs are a powerful tool for analyzing interindustry linkages, and heterogeneous IOTs have been developed to capture variations across firm types and trade regimes. However, there are no digital IOTs available for explicitly capturing the impact of digitalisation. To address this gap, we transform the digital SUTs into IOTs and apply them to measure the contribution of the digital economy to China's GDP.

Keeping consumption within planetary boundaries without hurting the poor

Topic: Special Session: Environmental Inequality from a Consumption Perspective
Author: Peipei TIAN
Co-Authors: Honglin ZHONG, Kuishuang FENG, Laixiang SUN, Klaus HUBACEK

The disparity in environmental impacts across different countries has been widely acknowledged. However, ascertaining the specific responsibility within the complex interactions of economies and consumption groups remains a challenging endeavor. Using a comprehensive expenditure database that includes up-to 201 consumption groups across 168 countries, we investigate the global distribution of six environmental footprint indicators and assess the impact of specific consumption expenditures on planetary boundary (PB) transgressions. We show that 31%-67% and 51%-91% of the PB breaching responsibility could be attributed to the global top 10% and 20% of consumers, respectively, from both developed and developing countries. By following the effective mitigation pathway, the global top 20% consumers could adopt the consumption levels and patterns which have the lowest environmental impacts within their quintile, yielding a reduction of 25%-53% in environmental pressure. In this scenario, actions focused solely on the food and services sectors would reduce environmental pressure enough to bring the land system

change and biosphere integrity back within their respective PBs. Our study highlights the critical need to focus on high-expenditure consumers for effectively addressing PB transgressions.

International Competitiveness and the Carbon Footprint of Products

Topic: Input-output Analysis for Policy Making (4)
Author: Haruta TOGASAKI
Co-Authors: Ai NAGATA, Shigemi KAGAWA

To achieve a decarbonized society, it is essential to analyse the environmental impacts of changes in trade and industrial structures. In particular, the automotive industry not only plays a crucial role within the global value chain but also significantly contributes to CO2 emissions across countries through the automobile value chain. For a case study, Tokito (2018) showed that more than 90% of the CO_2 emissions induced by the final demand of transport equipment manufactured in Japan in 2013 were indirectly emitted through its global supply chains, equivalent to 6.8% of Japan''s total emissions then. A critical research question is how the international competitiveness of the automobile sector influences CO2 emissions throughout the automobile value chain.

This study examines the international competitiveness of the automotive industries in 44 countries and regions worldwide from 2000 to 2014, as well as the value added and CO_2 emissions indirectly generated by the final demand for these automotive products. The primary objective is to uncover the impacts of changes in the international competitiveness of the automotive industry on the economy and the environment (i.e., CO_2 emissions) in these countries.

In doing it, the World Input-Output Tables (WIOTs), including 56 industry sectors across 44 countries and regions from 2000 to 2014, are used to determine the annual international competitiveness of each country's automotive industry. Specifically, the revealed comparative advantage (RCA) index is used to calculate the annual international competitiveness of each country's automotive sector.

Subsequently, we estimated the value added and CO_2 emissions indirectly generated across various industries and countries worldwide, associated with the final demand for the automotive industry in each country on an annual basis. These calculations are performed using the Leontief inverse matrix and the relevant factor coefficient vector for 44 countries and regions, specifically the direct sectoral CO_2 emission coefficient vector or the direct sectoral value-added coefficient vector, by year. Additionally, the environmental efficiency of each country's automotive sector is calculated and discussed by dividing the induced CO_2 emissions by the induced value added.

The results show that the top five countries with the highest international competitiveness in the automotive industry in 2014 were Hungary, the Czech Republic, Germany, Japan, and Mexico, in that order. In these countries, automotive production in 2014 generated the largest amounts of value added and CO_2 emissions indirectly within their ''Electricity, Gas, Steam, and Air Conditioning Supply'' sectors.

A simple linear regression analysis between environmental efficiency and RCA from 2000 to 2014 revealed a trend whereby, as a country's international competitiveness in the automotive industry improves, its environmental efficiency (i.e., CO_2 emissions per unit of induced value

added) tends to increase. This trend was particularly pronounced in Europe, where induced CO_2 emissions were not concentrated solely in the country of production but were instead dispersed across supply chains to nations with lower environmental burdens or higher production efficiency.

According to Antweiler et al. (2000), the effects of free trade on the environment can be broadly categorized into three channels: technology, composition, and scale effects. We found that in the European Union (EU), which promotes free trade within its region and enforces stringent environmental regulations, the technology and composition effects have played a particularly significant role in reducing the environmental impact of automotive production. Based on our empirical findings, we propose further promoting free trade to enable each country's automotive industry to distribute production processes to regions with lower environmental burdens and higher production efficiency, thereby contributing to the global reduction of CO_2 emissions. The novelty of this study lies in its global value chain analysis of automotive products, with particular attention to capturing the role of international competitiveness in the world economy and the environment.

Mitigating rebound effects: A CGE model analysis of sustainable consumption and production

Topic: CGE and Econometric Input-output Modelling (3)
Author: Edgar TOWA
Co-Authors: WOUTER M.J. ACHTEN, Jaume FREIRE-GONZáLEZ

The 12th Sustainable Development Goal of the United Nations, "Ensure sustainable consumption and production patterns," promotes combining eco-efficiency in production with consumer efficiency in consumption. Producers can reduce production-driven greenhouse gas (GHG) emissions by enhancing technological efficiency. Consumers can either decrease overall consumption or shift their consumption patterns towards products with lower GHG emissions. However, these actions often lead to the reallocation of resources to other goods and services or to savings, potentially triggering rebound effects (RE). RE can arise from efficiency improvements or changes in consumption patterns that reduce the cost of goods or services, leading to increased demand. There are three main types of RE: direct (re-spending on the same good or service), indirect (re-spending on other goods and services), and macroeconomic (distribution of effects throughout the economy).

Computable General Equilibrium (CGE) models, which account for inter-industry interactions, are widely used for energy and climate policy assessments. These models simulate changes in industry prices and quantities due to policy shocks by including general equilibrium effects. They can incorporate more complex behavioural equations of economic agents than approaches using fixed coefficients, like input-output analysis (IOA). When equipped with energy and environmental information, CGE models allow tracking general equilibrium and inter-industry effects for estimating carbon and energy RE from technological efficiency improvements and shifts in consumption patterns. Previous studies on assessing carbon and energy RE using CGE models often focus on either production or consumption patterns, failing to capture the dual perspective offered by combining both measures. Additionally, previous studies are limited to analysing specific behavioural actions rather than lifestyle changes and provide limited evidence on measures to offset RE.

This study aims to comprehensively evaluate the efficacy of changes in production and consumption patterns in mitigating climate change, considering RE while maintaining economic

stability. A recursive-dynamic CGE model tailored to the Belgian economy is developed to estimate economy-wide energy and carbon RE for various scenarios. Economic instruments, such as carbon taxes needed to counteract the triggered RE, are assessed.

The model integrates 65 economic sectors and commodities, linking economic flows with energy use and carbon emissions through an energy-environmental module. A social accounting matrix constructed from input-output tables and national statistics is used to calibrate the model, providing the foundation for modelling economic interactions among firms, households, government, and foreign trade. Production functions employ a nested constant elasticity substitution structure, where value added, energy, and non-energy inputs are aggregated to represent sectoral outputs. The energy module incorporates data on fossil fuel consumption, electricity use, and renewable energy shares from Belgian statistics and the Belgian energy balance, projecting their growth trajectories. Carbon emissions are estimated through coefficients calibrated with data from the Belgian air emission accounts. Simulations span a 20-year period, capturing the dynamic and long-term impacts of policy strategies. For each scenario, the model quantifies RE by comparing expected energy and emissions reductions from partial equilibrium analysis with general equilibrium outcomes.

The first set of production-based scenarios considers energy efficiency improvements across energy and non-energy sectors. The second set of scenarios pertains to shifts in spending among commodities, distinguishing shifts among main consumption baskets, from energy to non-energy consumption and savings, from energy to individual non-energy commodities, and from individual energy commodities to other types of energy.

Results show the effects of each scenario on GDP, energy use, CO2 emissions, and labour, revealing the performance of production- vs. consumption-based measures and their total effect on the economy. Furthermore, results unveil the magnitude of RE induced by each scenario, explain how RE varies across scenarios, and examine how much a carbon tax could counteract the carbon RE. These findings provide valuable insights for policymakers on effective strategies that integrate production- and consumption-based measures with economic instruments, such as carbon taxes, to mitigate climate change without compromising economic stability. They underscore the necessity for multifaceted approaches that balance production and consumption measures alongside economic instruments to annihilate RE and achieve optimal performance.

Embodied Sugar Consumption in the United States

Topic: International Trade (3)
Author: Kaoru TSUDA
Co-Authors: Shigemi KAGAWA, Yusuke OGA

Excessive food consumption threatens both people's health and the sustainability of the global environment, requiring urgent resolution. Particularly, excessive sugar consumption can reduce diet quality and increase the risk of noncommunicable diseases (World Health Organization (WHO), 2015). The WHO recommends that the daily intake of free sugars for adults and children should be less than 10% of the total energy intake. However, in the United States (the U.S.), sugar consumption exceeds this limit by 5% (Food and Agriculture Organization (FAO), 2023). This highlights the concern over excessive sugar consumption in the U.S. To achieve a healthier diet for Americans, concrete steps must be taken to reduce sugar intake.

To date, few studies have examined this issue in the U.S., leaving the government without

effective solutions. The novelty of this study lies in its estimation of sugar intake embodied in household consumption, with a focus on household characteristics. Based on the results, this study provides policy recommendations for effectively reducing excessive sugar consumption in the U.S.

To estimate the sugar input embodied in household consumption for a specific sector, we first calculated the embodied sugar input per dollar of final consumption (i.e., the sugar consumption unit) using mixed-unit input-output analysis. This analysis was based on the U.S. domestic input-output table, where the 'Sugar and Confectionery' sector (measured in U.S. dollars) was converted into physical quantities (in tons). Importantly, this study estimated per capita sugar intake by incorporating detailed household characteristics—including income, age, and gender—using data from the 2019 Consumer Expenditure Survey (CES). The analysis focused on expenditure data from single-person households. Data on sugar use by each industry was sourced from the United States Department of Agriculture (USDA) for 2019 and the U.S. domestic input-output table from the Bureau of Economic Analysis (BEA), published in 2017.

The results revealed that single-person households in the U.S. consumed 62 grams of sugar per person per day in 2019. The top three sectors for sugar intake were limited-service restaurants (11.0 grams), bread and bakery product manufacturing (10.9 grams), and sugar and confectionery product manufacturing (7.46 grams). These sectors accounted for 47% of total sugar consumption. Furthermore, the analysis found that excessive sugar intake from processed food industries was due to high sugar consumption units, while intake from restaurant industries was driven by high consumer expenditure.

Further analysis, controlling for income, age, and gender, showed that sugar consumption increases as food expenditure rises. Among the six income groups, the group with an income of 70,000 U.S. dollars and more consumed the most sugar (90.3 grams). Similarly, among the six age groups, the group aged 35 to 44 consumed the most sugar (71.3 grams). Households with these characteristics had the highest income and food expenditure compared to other households. The higher expenditure suggests a higher overall food intake, which may also lead to higher sugar intake. As men spent on average 1.13 times more on food than women, men consumed slightly more sugar than women.

To address the problem of excessive sugar consumption, two main strategies are recommended. First, Americans should reduce the frequency of eating out, especially at limited-service restaurants. According to the CES, single-person households spent 965 U.S. dollars annually at limited-service restaurants, accounting for 21% of their food expenditure. Americans frequently opt for limited-service restaurants for lunch due to their affordability and convenience. To reduce sugar intake from limited-service restaurant, the U.S. government should mandate and support the sale of inexpensive and healthy lunch boxes in supermarkets and require all companies to provide employee cafeterias.

Second, the government should introduce a 'sugar tax' on industries producing sugar-containing foods. Foods such as bread and confectionery often contain excessive amounts of sugar. To reduce sugar intake from these foods, it would be most effective to provide industries with incentives to lower sugar usage during production. The government needs to implement policies targeting both producers and consumers, based on the findings of this study, to resolve the issue of excessive sugar consumption in the U.S.

In addition, the government should publish dietary guidelines to improve their unhealthy diets. It is important not only to raise awareness of the dangers of processed and fast food, but also to

warn higher income households.

Integrated Supply Chain Hotspot Analysis Using Forward and Backward Input-Output Unit Structures

Topic: Input-output Analysis for Policy Making (3)
Author: Aoi TSUKIOKA

With the goal of achieving carbon neutrality by 2050, industries that accounted for approximately 25% of Japan's total CO_2 emissions in 2019 are required to reduce their energy-related emissions. At the same time, Japan is experiencing sudden inflation due to rising global prices of imported energy resources and raw materials. Therefore, it is crucial for policymakers to mitigate both the cost burden of energy and material imports and the energy-related CO_2 emissions from industrial activities.

It is important to note that CO_2 emissions and importation costs are inherently linked when considering domestic fossil fuel consumption. Japan relies on imported fossil fuels for over 95% of its primary energy needs. Reducing fossil fuel usage provides industries with dual benefits: alleviating import cost burdens and decreasing CO_2 emissions.

Developing effective policies that emphasize the connection between importation costs and CO_2 emissions is critically important. This leads to a key research question: Which industries are most affected by the combined impacts of these costs and emissions? To address this question, this study introduces a new analytical framework for quantitatively evaluating the comprehensive impacts of importation costs and CO_2 emissions on Japanese industries. This framework integrates two distinct input-output models: the input-output quantity model and the input-output price model.

The novelty of this study is twofold. First, it introduces an innovative input-output analysis framework by utilizing two types of forward and backward unit structure models based on the input-output quantity and price models, respectively (e.g., Kagawa et al., Economic Systems Research, 2013; Tsukioka and Kagawa, Economic Systems Research, 2025). The integrated unit structure analysis framework enables us to assess both the forward price impacts of changes in energy import costs and the backward CO_2 emission impacts of changes in final demand for goods and services.

Second, this study applies supply chain cluster analysis to the integrated unit structures, triggered by changes in both a specific imported energy price and the final demand for a specific commodity. This approach identifies critical supply chain clusters—industrial hotspots—that face the highest energy cost pressures and energy-related CO_2 emissions due to external shocks.

This study utilizes the 2015 input-output tables (IOTs) with the highest sectoral resolution available for Japan. Additionally, it incorporates a time-series dataset on imported energy prices for crude oil, coal, and natural gas to calculate the average rate of price increases for each imported energy resource. Direct sectoral CO_2 emission intensity is also assessed to estimate the CO_2 emissions induced by final demand in domestic industries.

Using the 2015 input-output tables, I identify the iron and steel supply chain as a critical hotspot, significantly affected by coal costs and CO_2 emissions from fossil fuel use. Cluster analysis reveals that the crude steel-related cluster—which includes 'crude steel, with converters,' 'coal

products,' and 'pig iron'—is a major hotspot, heavily impacted by high coal costs. This cluster exhibits significant CO2 emissions, particularly driven by the motor vehicle industry. Additionally, I find that chemical-related clusters, including 'aliphatic intermediates,' 'cyclic intermediates,' and 'methane,' are notably affected by crude oil cost pressures and CO2 emissions.

Based on the supply chain cluster results identified in this study, policymakers should prioritize financial support for industries in critical hotspots facing the highest pressures from importation costs and CO2 emissions. For example, I recommend that the Japanese government increase investments in greener technologies for key hotspots such as the iron and steel industries to reduce reliance on fossil fuels.

Why is asbestos still mined?: Structural path analysis of asbestos mining and manufacturing of asbestos-containing products

Topic: Input-Output Accounts and Statistics
Author: Makiko TSUKUI

Despite causing serious health issues, why has asbestos not yet been banned worldwide? Global Burden of Disease (GBD) data attribute 230,000 deaths in 2021 to occupational asbestos exposure and 6 million deaths total from 1990 to 2021. Although most developed countries have already banned asbestos, around 120 developing and semi-developed countries are still using asbestos.

The reason asbestos is not yet banned universally is that stakeholders who benefit economically from using asbestos differ from those who suffer the health risks. For countries using asbestos, prioritizing their own economic interests, to move toward banning asbestos, it may be effective to clarify the economic disadvantages of continuing asbestos use. In particular, clarifying how many workers are potentially exposed to asbestos health risks and what is driving the mining and use of asbestos should provide important scientific insights supporting banning asbestos. However, little previous asbestos-related research has taken an economic approach, with (to our knowledge) no studies having clarified how mining and use of asbestos are induced through global supply chains.

We expanded the OECD Inter-Country Input-Output tables (OECD-ICIOT) for 2014 for both asbestos mining and production of asbestos-containing products to compile an asbestos extended multi-regional input-output table (AMRIOT). Using this AMRIOT, we then estimated the monetary activities of asbestos-related industries and clarified the global flows of mineral asbestos in tonne. To clarify the contribution of asbestos-banned countries, we then estimated, by country and by industry, the quantity and production value of asbestos that were induced by the final demand of each country. We also estimated the number of workers employed in asbestos-related industries.

In our methodological approach, we divided each original OECD-ICIOT industrial sector that includes asbestos mining and the manufacturing sectors of asbestos-containing products, such as textiles, paper, cement, and auto parts, into an asbestos-related sector and a non-asbestos sector, based on the U.S. Geological Survey (USGS) Minerals yearbook and the UN Comtrade Database. We also estimated the number of workers in each asbestos-related industry sector based on individual country's statistics and United Nations' data. Using the AMRIOT, we estimated how the asbestos production in the major asbestos mining countries, such as Russia, China, Brazil, and Kazakhstan, is induced by the final demand of trading partner countries using a multi-regional input-output analysis (MRIOA) model. In addition, we conducted a structural path analysis (SPA) to clarify the relationship between countries and industries quantitatively. We tried to evaluate the contribution of each country and the final demands on the amount of mineral

asbestos mining, asbestos inputs, and the number of workers employed in asbestos-related industries.

The results showed that 81,406 tonnes of asbestos mining and 807 employees was induced by asbestos-banned countries, accounting for 4% of the total induced in 2014. As an industrial material, asbestos use induced by asbestos-banned countries contributed to the production of cement (40,623 tonnes), textiles (28,182 tonnes), motor parts (6,851 tonnes), and asbestos paper (5,641 tonnes).

Comparing India and China, which use large amounts of asbestos as inputs to their manufacturing sectors, interesting results were obtained. India imported and used 383,475 tonnes of asbestos as inputs for its manufacturing sectors of asbestos-containing products. However, these asbestos-containing product manufacturing industries are strongly connected to domestic industries. Most manufacturing of asbestos-containing products, around 87%, is induced by the final demand for asbestos-containing products in India itself.

Although China is an asbestos-mining country, it imports around 133,125 tonnes from Russia and Kazakhstan. In China, 502,614 tonnes of asbestos were used in the manufacturing sectors of asbestos-containing products, mainly those of motor parts (53%) and the textile industry (32%). Contrary to India, the Chinese manufacturing sectors of asbestos-containing products are induced not only by China but also by many trading partners along complex paths. In particular, the production activities of the asbestos-containing motor parts industry induce a related path through the motor parts industry, land transportation, and machinery industry via global supply chains. The construction industry also contributed significantly to production in the asbestos cement industry in China.

The results of this study provide scientific knowledge that will support international cooperation to ban asbestos by introducing an economic approach to the field of asbestos research. The method used in the present study can also be applied to estimating hazardous raw materials other than asbestos to clarify their global flows and effects.

Efficient Management of Eco-Feed Production from Food Waste in Japan

Topic: Environmental Input-Output Modelling (2)
Author: Junji TSURU
Co-Authors: Daigo USHIJIMA, Tomoaki NAKAISHI, Shigemi KAGAWA

In 2022, global food waste amounted to 1.05 billion tons (631 million tons from households and 419 million tons from businesses), translating to an average of 79 kilograms of food waste per person annually, or roughly 1.3 meals per day for those suffering from hunger. Food waste is also a significant issue in Japan, where 24 million tons of food waste were generated in 2021 (16.7 million tons from businesses and 7.3 million tons from households). To address this, 76% (9 million tons) of business sector food waste is recycled into animal feed (eco-feed), promoting the expansion of eco-feed use. This also contributes to improving Japan's low feed self-sufficiency rate.

This research analyzes the production efficiency of 45 eco-feed plants in Japan using Data Envelopment Analysis (DEA). These plants include 28 using the dry production method, 11 using the liquid production method, and 6 using the fermentation production method. While Nakaishi and Takayabu (2022) identified inefficient plants in Japan, they did not differentiate between eco-feed production technologies. Therefore, Nakaishi and Takayabu (2022) failed to establish a reference Eco-feed production frontier for a specific Eco-feed production technology (e.g., dry production method analyzed in this study). The novelty of this study is twofold. First, this study is

the first attempt to examine the production efficiency with a focus on a specific Eco-feed production technology. Second, we revealed the increase potential in eco-feed sales, categorized by production method and each plant, as well as the GHG reduction potential based on the efficiency estimated by DEA.

A comprehensive input-output database was compiled for the 45 plants, including inputs such as maintenance fees (JPY) and food waste delivered (t), and the output, which is the amount of Eco-feed produced. The study calculated normalized efficiency scores between 0 and 1 for each plant via DEA, with scores closer to 1 indicating higher efficiency.

Two types of DEA models considering Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS) were used in this study. These models helped assess three efficiency types: Overall Technical Efficiency (OTE), Pure Technical Efficiency (PTE), and Scale Efficiency (SE), allowing for the identification of inefficiencies due to production technology or scale.

The results showed that average OTE scores were 0.44 for the dry method, 0.49 for the liquid method, and 0.47 for the fermentation method, with 37 plants scoring below 1, suggesting significant room for improvement. Average PTE scores were 0.55, 0.68, and 0.59, while average SE scores were 0.82, 0.78, and 0.85, respectively, indicating higher SE than PTE.

This suggests that PTE contributes more to the decrease in OTE than SE, highlighting disparities in production technologies between plants. These disparities lead to variations in maintenance costs and eco-feed production per unit of food waste, causing significant differences in PTE and OTE across plants.

Moreover, the potential increase in eco-feed production per plant was 3,433 tonnes for the dry method, 12,981 tonnes for the liquid method, and 335 tonnes for the fermentation method. Additionally, based on these potential increases, the estimated sales increase per plant for eco-feed was approximately 100 million JPY for the dry method, 120 million JPY for the liquid method, and 9.3 million JPY for the fermentation method. Improving efficiency could further enhance eco-feed production and sales.

This study revealed the increase potential for the eco-feed production and its sales in inefficient plants. We also offered guidelines on whether to enhance production technology or production scale to improve the productivity of inefficient plants. Consequently, inefficient plants should seek inspiration from efficient reference plants and make improvements in either production technology or scale to boost production efficiency. This, in turn, could contribute to increasing an elevation in Japan's feed self-sufficiency rate and a further reduction of food waste.

The Hidden Structure of ICT Value Chains: Integrating Firm Size and Export Status in Japan-Taiwan Production Networks

Topic: Trade and Global Value Chains Policies (3)
Author: Yoko UCHIDA

Research on Global Value Chains (GVCs) has made significant progress in recent years; however, the production network structure in East Asia, characterized by close collaboration between large enterprises and SMEs, has not been sufficiently analyzed. This study uses originally constructed Japan-Taiwan international Input-Output tables with 87 sectors and three specialized 22-sector tables: (1) firm size-specific tables, (2) export/non-export sector-specific tables, and (3) combined

tables integrating both firm size and export status dimensions (all for 2016). Through these multi-dimensional tables, we analyze the GVC participation structure of the ICT industry in Japan and Taiwan from the perspectives of value-added trade and employment structure. The objective is to comprehensively understand how different types of firms participate in GVCs and their respective economic and employment impacts, providing insights that cannot be obtained through conventional analysis.

In this study, we leverage three extended types of 22-sector input-output tables—by firm size, by export status, and by their combination—alongside the detailed 87-sector Japan-Taiwan international Input-Output tables and employment data to conduct the following analyses:
1.   Elucidation of value-added trade structures by firm size in the ICT industry
2.   Analysis of the relationship between value-added and employment: international comparison of labor productivity by firm size and evaluation of employment creation efficiency
3.   Relationship between GVCs and employment structure: examination of differences in firm size-specific employment structures between export-oriented and domestic-oriented sectors
4.   Cross-analysis of firm size and export status: analysis of value-added creation patterns and productivity gaps across four categories—exporting SMEs, non-exporting SMEs, exporting large enterprises, and non-exporting large enterprises

The table disaggregation for both Japan and Taiwan was implemented using official census data from both economies, providing a robust statistical foundation for our multi-dimensional analysis. The detailed 87-sector classification tables are used to understand the fine-grained structure of ICT-related industries, while the three extended 22-sector tables allow for direct analysis of specific dimensions: the firm size-specific tables reveal interactions between large enterprises and SMEs; the export/non-export tables highlight differences between internationally engaged and domestically focused sectors; and the combined tables enable the four-category analysis that simultaneously considers both firm size and export orientation. In particular, we apply Koopman et al. (2014)'s value-added trade decomposition framework across these multiple dimensions to clarify differences in value-added creation and employment contribution based on firm characteristics. This multi-table approach allows for a comprehensive examination of how different types of firms participate in GVCs and contribute to employment generation.

The originality of this research lies in its multi-dimensional analysis utilizing three distinct but interconnected specialized Input-Output tables that capture firm size differences, export orientation, and their combined effects. This methodological innovation allows for a comprehensive analysis of GVC participation impacts on both value-added creation and employment generation. By evaluating the value-added creation patterns and employment impacts through these multiple lenses—which cannot be captured by the OECD's ICIO tables or AAMNE database—we can develop a more three-dimensional understanding of the economic and social impacts of GVC participation. In particular, the combined firm size and export status tables enable us to clarify the characteristics of exporting SMEs versus non-exporting SMEs, as well as their relationships with large enterprises, providing concrete policy implications for strengthening the international competitiveness of SMEs.

The Impact of a Carbon Tax on CO2 Emission Transfers: Evidence from Japan

Topic: Environmental Input-Output Modelling (1)
Author: Sho UEHARA
Co-Authors: Shigemi KAGAWA, Aoi TSUKIOKA

The Japanese government plans to introduce a carbon tax in 2028. A carbon tax puts a price on CO_2 emissions, providing an incentive to reduce CO_2 emissions. However, there are some

concerns about introduction of carbon tax. When a carbon tax is introduced in one country, while the amount of CO2 emissions in that country would be reduced, there is a risk of carbon leakage. Carbon leakage occurs when the production site of carbon intensive products (e.g., iron and steel) shifts from countries which have strict carbon tax regulations to other countries which have weaker regulations and it result in increasing of CO2 emission in countries with weaker regulations. Therefore, in regard to the implementation of the carbon tax in Japan, it is crucial to investigate the impact of the carbon tax on CO2 emission, taking into account the potential of the carbon leakage to foreign countries in order to clarify the effect of carbon tax.

This study aims to qualify the amount of change of CO2 emission in Japan and in foreign countries after carbon tax introduction in Japan. The novelty of this study is that we analyze the environmental impact of carbon tax introduction comprehensively, including carbon leakage. We use the multi-regional input-output table (GLORIA), which is composed of data from 120 industries and 164 countries and armington elasticity which denotes the elasticity of substitution between product of domestic country and foreign countries. This allows for a detailed quantification of the changes in CO2 emissions in foreign countries and industries resulting from carbon tax introduction in Japan, and the identification of countries and industries most significantly affected.

In this study, we conducted the analysis following four steps outlined below. First, based on the amount of fossil fuels imported to Japan, we estimate the carbon tax imposed on the domestic industries (upstream industries) which import fossil fuels. Carbon tax implementation on upstream industries will raise the production costs and prices of products produced by those industries. This cost increase pressure will affect the midstream industries (e.g., iron and steel) and eventually the downstream industries (e.g., automobile manufacturing) through the supply chain networks. As a result, not only the price of upstream products such as fossil fuels, but also the prices of intermediate products such as materials and components, and even the domestic prices of final products purchased by consumers, will increase.

Next, we calculate the price increase rate of 120 domestic industries due to the carbon tax implementation. Assuming that the prices of domestic industries increase while the prices of foreign industries remain unchanged, it can be expected that a demand change will occur, with a decrease in demand for domestic industries and an increase in demand for foreign industries, in regard to both intermediate and final demand.

Subsequently, we estimate the demand changes from each industry as the intermediate demand and from final consumers as the final demand for both domestic and foreign industries after the price increase of the domestic industries. As demand for foreign industries increase, the production of products exported to Japan will increase, and it will cause CO2 emissions in foreign countries to increase (carbon leakage).

Finally, we calculate the amount of CO2 emission in Japan and in foreign countries after the introduction of carbon tax in Japan.

From the result, we found that, when the carbon tax at a rate of 30 USD per ton of CO2 emissions is introduced in Japan, total CO2 emissions in the world caused by final demand in Japan would be reduced by approximately 1.2%. In this case, CO2 emissions in Japan required to meet final demand in Japan would be reduced by 3.2%, while CO2 emissions abroad increase by 2.7% due to carbon leakage. It is also revealed that, after carbon tax introduction in Japan, CO2 emissions increase in China, Qatar and the United States will account for a large proportion of total CO2 emission increase outside of Japan.

Furthermore, it is noteworthy that this study shows that if Japanese government providing economic protection to specific industries with carbon tax implementation, CO_2 emissions increase outside of Japan could be reduced compared to the case of a typical carbon tax implementation. Therefore, to mitigate carbon leakage, it is crucial to implement policies that provide subsidies to specific industries shown in this study such as construction and civil engineering industries in order to encourage them to input products produced in Japan, and policies that suppress the price increases of final products shown in this study such as machinery and electronic equipment.

Assessing the Macroeconomic Impacts of Disasters: An Updated Multi-Regional Impact Assessment (MRIA) model

Topic:
Author: Surender Raj VANNIYA PERUMAL
Co-Authors: Elco Eduard KOKS, Mark THISSEN

This paper presents a Multi-Regional Impact Assessment model (MRIA) designed to estimate the macroeconomic consequences of disasters. MRIA is a linear optimization model based on the supply-and-use framework, explicitly incorporating post-disaster adaptive response measures, including (i) constrained overproduction by alternative suppliers, (ii) rationing of final goods, and (iii) post-disaster trade between regions to compensate for lost production. The model is applied to assess the nationwide impacts of manufacturing disruptions in Zuid-Holland, Netherlands. Our findings indicate that regions exporting to the disaster-affected area experience positive spillover effects, while those heavily dependent on disrupted sectors incur losses. Furthermore, overproduction provides only marginal benefits unless post-disaster trade channels remain accessible. Finally, we propose a simplified MRIA-based methodology to identify critical sectors in the Dutch economy, with scalability to larger economic systems.

- Research goals, Methods, and Dataset section are uploaded as PDF. Results and Discussion sections are currently in review with co-authors. A full paper will be uploaded before the deadline

Interregional capital flow tables for Brazil: A data-driven approach using electronic invoices

Topic: Input-Output Accounts and Statistics
Author: Lucas Ferraz VASCONCELOS
Co-Authors: Joao Maria DE OLIVEIRA

Investment dynamics is a cornerstone of economic activity and growth analysis. Capital flow tables, which detail purchases of capital goods by industry, provide crucial insights into the structure of investment, showing its sectoral patterns while allowing more accurate simulations of alternative policies to stimulate investment, promote sustainable growth, and improve the productive structure.

These tables, conceived by Wassily Leontief as an integral part of the input-output framework but not implemented by him, have often lagged behind standard input-output tables in development due to data constraints. The scarcity of prior studies estimating and analyzing capital flow tables for Brazil, which have relied on harmonizing diverse and often limited data sources, further

confirms these data limitations.

This research addresses a significant gap by developing an interregional capital flow table for Brazil, disaggregated by Brazilian states and consistent with the System of National Accounts. It builds on a recent trend of producing estimates based on official administrative records, which provide a more accurate representation of economic reality. The research pioneers a novel approach by using the comprehensive data from Brazil's electronic invoices (Nota Fiscal Eletrônica, NF-e).

The NF-e system captures the majority of business-to-business transactions, offering unparalleled granularity. This allows us to address key research questions: How can NF-e data be used to construct a detailed and accurate capital flow table? What is the structure of industry capital flows in Brazil, as revealed by the NF-e data, and how does it differ from previous estimations? How can this table be integrated into the Brazilian SNA for a more complete picture of investment? And, what is the distribution of capital goods in terms of sales and purchases among the 27 Brazilian states?

Our methodology involves cleaning and adapting a comprehensive extraction of the NF-e database for 2018. Although standardized, the NF-e requires some data cleaning and pre-processing to ensure data quality. We then used the Mercosur Common Nomenclature (NCM) product code, which is compatible with the International Harmonized System (HS), along with seller and buyer sector codes derived from the International Standard Industrial Classification (ISIC), and a tax code of the operation to classify transactions. A critical step is to use the Broad Economic Categories (BEC) classification to determine which products should be categorized as gross fixed capital formation and, in some cases, in what proportions. The data were then used to construct a capital flow matrix, which represents the flow of capital goods from producing to investment-consuming activities. This matrix is disaggregated by industry and by the 27 Brazilian states, providing a regional dimension. The resulting table is designed for seamless integration into the Brazilian System of National Accounts.

The primary data source is an extraction of the Brazilian NF-e database for the year 2018. Key variables include NCM/HS product codes, seller and buyer sector codes, legal classification (public and private), transaction values, product tax information, fiscal classification of the transaction, and geographic information (origin and destination states).

This research offers several key contributions. It provides an unprecedented level of granularity compared to previous studies, enabling a finer-grained analysis of capital flows. The NF-e system allows for potentially more frequent updates than survey-based methods, facilitating timely analysis. The regional disaggregation provides insights into regional disparities. Furthermore, this research develops a new methodology for constructing capital flow tables from electronic invoice data, potentially applicable to other countries with similar systems.

The research will provide a comprehensive and detailed picture of capital flows in Brazil, revealing intricate inter-industry and inter-regional relationships. We will compare the findings with existing estimates to assess the impact of using the more granular NF-e data. The resulting capital flow table will be a valuable resource for researchers and policymakers, offering a powerful tool for analyzing investment, economic growth, and structural change, and supporting evidence-based decision-making in economic development, industrial policy, and the reduction of regional disparities. We will also discuss challenges, limitations, and potential future research directions.

Re-estimating Total Factor Productivity with Consumption Based Energy Depletion and Carbon Damage: A Time Series Multi–regional Input–output Analysis of China

Topic: Special Session: IO Analysis for Just Transition: Linking Economic Structures and Social Inequality (1)

Author: Qingchun WANG
Co-Authors: Yuning GAO

Value-added tax (VAT) plays an essential in role in the economic development and the performance of government. The horizontal distribution mechanism for VAT is vital for motivations of economic growth and promoting the balanced development of regional economy and equitable access to public services. Currently, China's VAT is allocated among local governments based on the origin principle, which means that the VAT revenue is submitted to the producers' tax authority. However, this approach leads to issues such as tax transfer and exacerbates fiscal disparities between regions. It also causes local governments to prioritize production over consumption, potentially worsening China's overcapacity problem. China's industrial overcapacity causes resource misallocation, environmental degradation, corporate debt risks, and delayed industrial upgrades, undermining sustainable economic growth. Globally, it has triggered significant global trade tensions due to dumping of cheap exports, distorting markets and straining international relations. Some scholars have argued that the destination principle, namely that the VAT revenue is submitted to the consumers' tax authority, can help transfer to a new pattern of coordinated development among regions and avoid over-investment and duplicated construction. Therefore, the research on the shift of the VAT horizontal distribution mechanism and China's industrial overcapacity has great theoretical and policy significance.

This study proposes a new approach to estimate consumption by regions and detailed sectors, taking provincial inflow and outflow and international trade into account. This study uses the time-series China's multi-regional input-output tables, from 2000 to 2017, to calculate the regional and sectoral consumption data. Thus, this study simulates the VAT allocation situations under both the origin principle and the destination principle. This allows for the measurement of the VAT distortion across regions and sectors between two allocation mechanisms.

The findings indicate that: (1) Compared to the destination principle, the origin principle results in significant tax inflows to economically developed eastern regions, while underdeveloped central and western regions, as well as sectors with a large agricultural share, suffer severe tax losses. (2) The distortion in the VAT allocation exacerbates China's overcapacity issue significantly, particularly in state-owned enterprises, large firms, and saturated industries, where rigid structures and policy biases hinder efficient resource reallocation. (3) The distortion in the VAT allocation hinders enterprises' participation in the domestic value chains, increases transaction costs and inter-provincial trade friction, leading to overcapacity and market fragmentation, thereby obstructing the development of the "dual circulation strategy".

This study makes the following three main contributions. First, to our knowledge, this study is the first to use the multi-year interprovincial input-output tables to simulate and compare province-industry-level VAT allocations under the origin principle and the destination principle, quantifying systemic interregional VAT distortions. Second, this study is the first to provide the empirical evidence linking VAT distortions to industrial overcapacity, demonstrating how tax-driven incentives for output maximization directly exacerbate resource misallocation. Third, this study uncovers mechanisms exacerbating China's overcapacity issue. The origin principle

hinders domestic value chain participation by rewarding local embeddedness over specialization. Meanwhile, the origin principle intensifies interregional trade barriers as provinces prioritize tax retention over comparative advantages. These findings critically inform China's fiscal decentralization reforms and global debates on tax design's unintended industrial consequences.

Urbanization is an opportunity to lower China's livestock antimicrobial footprints

Topic: Sustainable Production and Consumption
Author: Qingling WANG
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The overuse of veterinary antimicrobials has exacerbated the spread of antimicrobial resistance, posing significant threats to global public health. Livestock production is a key contributor to antimicrobial use (AMU) in China, the world's largest producer and consumer of veterinary antimicrobials. However, responsibilities of various food consumer groups in this regard remain poorly understood. In this study, we employed a Multi-regional Input-Output (MRIO) model, the EXIOBASE database integrated with a global antimicrobial use inventory (covering chickens, cattle, and pigs), and individual consumption survey data, to quantify the antimicrobial footprints attributable to different income groups in urban and rural China from 2010 to 2020. We also quantified the footprint inequalities using the Gini coefficient and revealed contributions of different socio-economic driving factors underlying these disparities using the logarithmic mean Divisia index (LMDI) method. Results show that total antimicrobial footprints in rural China decreased by ~65% (10.8 kt) from 2010 to 2020, compared to a ~43% reduction (8.1 kt) in urban areas. Pork was the dominant contributor to antimicrobial footprints across all population groups, accounting for 64-67% in 2010 and 56-69% in 2020. The decline in antimicrobial use intensity was identified as the primary driver contributing to the observed footprint reduction. Inequality in per capita antimicrobial footprints generally decreased by ~29%, with urban-rural inequality being greater than that across income groups. Notably, population size and rising per capita demand contributed to widening the urban-rural footprint gap, while the consumption share of pork had a mitigating effect. We emphasize that urbanization is not just a demographic process (an increase in the urban share of the total population) but is also closely associated with dynamic shifts in consumer's diet components. This shift could provide an opportunity for reducing China's future antimicrobial use. Further scenario analysis reveals that replacing excessive pork consumption with fish or chicken could lead to an overall footprint reduction of 47-72%. The study stresses the significant potential of urbanization and consumer-side behavioral changes in driving down China's antimicrobial use in livestock production.

Measuring the Employment Structure Effect and Growth Potential of Digital Consumption

Topic: Special Session: Digital IO Accounting: Methodology and Applications (1)
Author: Rui WANG
Co-Authors: YING LONG, Yu-Meng XUE

This study focuses on the emerging modes and distinctive characteristics of digital consumption development. It elucidates the creation effect, substitution effect, scale effect, and structural effect of digital consumption on employment. By constructing an input-output model of the digital economy for employment expansion, this study systematically measures the employment effects

of both digital and non-digital consumption in 2020. Furthermore, it quantifies the employment effects of changes in digital consumption during the 14th Five-Year Plan period by designing three distinct development pathways, aligned with economic development goals and the expansion trajectory of digital consumption.

The contributions of this study are primarily reflected in the following three aspects: First, it conducts an in-depth analysis of digital consumption patterns and characteristics, proposing a conceptual and statistical framework for digital consumption that aligns with both economic definitions and statistical measurement standards. Building on this foundation, the study integrates digital technology, digital consumption, and employment into a unified research framework, clarifying the theoretical mechanisms through which digital consumption drives employment. This approach addresses and expands upon the limitations of existing research on digital consumption. Second, against the dual backdrop of expanding domestic demand and promoting high-quality full employment, the study employs an input-output model of the digital economy with employment expansion to systematically quantify the number of jobs driven by digital and non-digital consumption. It provides a comparative analysis of the employment effects of these two types of consumption, focusing on aspects such as the structure of digital consumption, the educational levels of the employed, and age demographics. Third, the study explores trends in digital consumption changes and shifts in industry employment levels, simulating and characterizing the structural changes in employment triggered by digital consumption. It also investigates effective pathways for digital consumption-driven employment.

The findings of this study reveal that the employment creation effect of digital consumption significantly outweighs its substitution effect. Although the employment dividend of digital consumption has not yet been fully realized, its rapid development has created extensive opportunities for employment and entrepreneurship in the labor market. The scale effect of digital consumption is particularly pronounced in categories such as food and clothing, while developmental and experiential consumption exhibit substantial potential for employment growth. Additionally, digital consumption demonstrates a structural effect on employment, with varying impacts on workers of different educational levels. Notably, its positive influence on employment among the elderly population is significant and should not be overlooked. Sustaining the continued expansion of digital consumption is identified as the optimal pathway to achieving high-quality full employment.

Developing global multi-regional input–output table for emerging economies for 2018

Topic: Special Session: Emerging Global and Regional IO Modelling
Author: Wenqiang WANG
Co-Authors: Heran ZHENG

Emerging economies have become major contributors to global economic growth, contributing 70 % of global GDP growth and accounting 35% of global GDP in 2023 (17% in 2003). It is associated with the recent shifting of global values chains (GVCs) towards emerging economies, due to their cheap labor and raw materials. Despite of increasing importance of emerging economies in global value chains, most of the emerging economies face the scarcity of supply chain data due to expensive labour and statistical costs. This results in the ambiguity of how these emerging economies participate in the global value chains and how their participation contributes to economic growth.
Multi-regional input-output (MRIO) accounting serves as an indispensable statistical system for

describing national production networks and as a key tool for quantify inter-country supply chains. There are 9 MRIO databases compiled by different institutions (see SI). However, the existing MRIO databases have paid insufficient attention to these emerging economies to describe their specific details in the global production network. Most emerging economies are conventionally aggregated into regions in these MRIO databases. Among them, Eora, GLORIA, and GTAP11 cover the largest number of countries (Eora: 187 countries, GLORIA: 160 countries, GTAP11: 141 countries). In contrast, WIOD and FIGARO, which primarily focus on EU countries, provide data for only 43 and 45 countries, respectively. Although EXIOBASE3rx once offered detailed data for 214 countries, this service was unfortunately discontinued in 2015. Meanwhile, MRIO datasets with relatively higher coverage of emerging economies are limited with the sector resolutions. The Eora database includes 26 highly aggregated sectors, while GTAP11 offers data for 65 sectors (with GTAP-power extending to 76 sectors).

Compiling MRIO database is challenging, requiring multi-source data and solving conflicts. This is particularly true in emerging economies whose data is often confronted with over-aggregated sectors, irregular reporting, and inconsistency. To bridge the data gap, EMERGING dataset was developed with 245 economies and 134 sectors in our previous work (EMERGING v1.0) with the entropy-based construction framework. However, the presumption of trade estimation by sectors is to aggregate and split the original input-output tables by customs data (or single constrained export data). This is not applicable to a few sectors whose products are non-tradable internationally, such as electricity or transportation. The export-constrained method might lead to errors in output and value-added when balancing the table. Here, this paper introduces bottom-up sectoral data to avoid the irrationality of presumption. To resolve conflicts between multiple sources of data, we introduce a new version of EMERGING with a new doubly-constrained compilation framework which constrains the trade data and value-added simultaneously. Apart from the compilation method, the improvement also lies in higher underlining data at sector level collected from these emerging economies. Compared to our previous version, the local data has increased from 89 to 125, which represents a better quality of the new MRIO dataset.

This paper presents a detailed compilation procedure of EMERGING MRIO data for 2018, from raw data collection, data cleaning, optimization to the MRIO table compilation. We also demonstrate the application of the table with carbon footprints for emerging countries in 2018, and show the improvement in comparison with the footprint used by the previous dataset. In the discussion, we highlight the limitation remain in the new MRIO dataset and describe further ongoing improvements for EMERGING dataset.

How Digital Trade Restrictions Affect China's Employment: The Role of Regulatory Gaps with the EU

Topic: Trade and Global Value Chains Policies (3)
Author: Xiaolin WANG
Co-Authors: Cuihong YANG, Su ZHANG

The increasing diversification of digital trade restrictions has widened the regulatory gap between China and most European Union members. Such regulatory divergence can significantly impact trade-related labor demand in China. Based on the OECD Digital Services Trade Restrictiveness Index (DSTRI) and Inter-Country Input-Output tables (ICIO), we quantify the net employment effects of increasing digital trade regulatory divergence between China and EU members from 2014 to 2020 through a combination of gravity models and input-output analysis. We find that more diverse regulations have reduced employment related to exports, with the most significant job losses occurring in services. Meanwhile, this divergence has increased employment by substituting previous imported goods and services, with the replacement of imported goods

generating a more substantial employment effect. By comparing the impact of digital trade restrictions on export- and import-related employment, we find that the widening regulatory gap between China and EU members has led to an overall decline in net labor demand. Furthermore, we examine the specific regulation gap between China and the EU, observing that gaps in infrastructure and connectivity regulations have the most negative effect on trade-related labor demand in China. This paper highlights the importance of maintaining moderate openness in China's digital trade regulations and promoting infrastructure connectivity between China and the EU.

China's Digitalized Industry Chains: Value Scale and Network Structure

Topic: Special Session: Digital IO Accounting: Methodology and Applications (1)
Author: Yafei WANG
Co-Authors: Yanyun GAO, Bing LU, Tao WANG, Lixiao XU, Xun ZHANG

Digitalized industry chains are crucial to the deep integration of the digital and real economies in China's New Era and play a significant role in the global advancement of digital technologies. A robust accounting framework supported by comprehensive data—namely, the digital economy input-output table—is essential for understanding the systematic development and future trends of digitalized industry chains worldwide. This paper undertakes two key tasks: first, the construction of China's digital economy input-output tables for 2018 and 2020, and second, the application of these tables to analyze digitalized industry chains.

Building on the overarching framework of the digital economy, we propose a systematic approach for compiling the digital economy input-output table, grounded in theoretical accounting principles, foundational compilation processes, and methodological considerations. The sector classification and structure of China's digital economy input-output table are aligned with the Statistical Classification of the Digital Economy and Its Core Industries (2021) and the sector-setting rules of China's input-output table. The datasets integrate both micro- and macro-level data from diverse sources, including the 2018 Economic Census of China, national input-output tables, and various Statistical Yearbooks. A critical step involves disaggregating industrial sectors into digital and non-digital components using digitalized share coefficients, which are mainly derived from Economic Census data, Industrial Statistics, and Fixed Asset Investment Statistics. By reconciling sectoral classifications and balancing the tables for 2018 and 2020, we ensure the accuracy and reliability of our data. A comparative analysis of the value-added contributions of core digital economy industries and industrial digitalization structures with existing research confirms that this compilation approach represents a meaningful step forward in improving China's digital economy statistical accounting.

This paper further conducts an in-depth analysis of the structural characteristics of digital industry chains related to both digital industrialization and industrial digitalization. We categorize the digital industry chain into two types: the digital product industry chain and the digital-empowered industry chain. By examining the substitutive and synergistic characteristics of digital technologies, we explore the mechanisms driving value creation and structural formation within industry chains. Furthermore, we develop an industry chain network model and adaptively enhance input-output modeling and complex network methods for digital industry chain accounting. The evaluation of China's digital industry chains is conducted from two perspectives: value-added scale and industry network structure. The findings reveal that from 2018 to 2020, the average annual growth rate of value added in China's digital industry chains was 9.54%. By

2020, this figure had reached 13.86 trillion CNY, representing 13.63% of the total annual value added by China's industry chains. The industrial digitalization process emerges as the primary driver of this expansion, with the service sector being the primary area of penetration. In 2020, digital sector participation in China's industry chains stood at 10.05%—not yet dominant but exhibiting an evident upward trend. Moreover, the enabling factors of digital sectors were highly diverse and dispersed across upstream, midstream, and downstream segments. The findings also highlight notable disparities in participation levels, positional distributions among digital sectors, and significant structural differences between the two types of digital industry chains.

Paving the Way: Investigating the Impact of High-Speed Rail Connectivity and Information Connectivity on Industrial Transfer Between Cities from A Perspective of Multiple Factor Flows

Topic: Regional Input-output Modelling (2)
Author: Shan WEI
Co-Authors: Xiuting LI, Shuqin LIU

Abstract: Under the strategy of building a strong transportation nation, infrastructure exemplified by the high-speed rail (HSR) network has emerged as a fundamental component of physical connectivity between urban centers. Furthermore, advancements in digital technology and the widespread adoption of the Internet have facilitated virtual connections among cities, enabling a significant transition from "delayed" to "real-time" information exchange. As essential conduits for intercity connectivity, both high-speed rail (HSR) and information networks play a crucial role in overcoming spatiotemporal barriers to the flow of factors. This, in turn, facilitates efficient industrial transfer in the digital age.

This study aims to investigate the impact of high-speed rail connectivity and information connectivity on industrial transfer between cities from a perspective of multiple factor flows. Based on the intercity input-output tables of China, socio-economic data, and Baidu search data of prefecture-level cities from 2012, 2015, and 2017, this study employs network analysis methods to measure the strength of HSR connectivity (traditional factors) and information connectivity (new factors) between cities. Furthermore, it identifies the spatiotemporal characteristics of intercity industrial transfer based on intercity input-output data. A panel model is subsequently employed to examine the driving effects and mechanisms associated with multiple factor interactions influencing intercity industrial transfer.

The findings reveal that industrial transfer has exhibited new characteristics such as diversified directions, high-end orientations, interconnected patterns, and integrated collaboration. Intercity connectivity, whether enabled by HSR or information networks, can enhance the scale of intercity industrial transfers. HSR connectivity facilitates smoother channels for factor flows, thereby enabling the cross-regional transfer of factors such as labor and capital. This dynamic makes the transfer of capital-intensive and labor-intensive industries between cities more active. Furthermore, information connectivity optimizes the mechanism for factor sharing and promotes the cross-regional co-creation of technological resources, thus facilitating the transfer of technology-intensive industries among cities, a process further enhanced by advancements in the digital economy. The interplay between HSR connectivity and information connectivity can improve resource allocation efficiency while generating a synergistic effect on intercity industrial transfers. Further research categorizing industrial transfer into two patterns, "polarization" and "diffusion", based on the industrial gradient advantages of each city, indicates that the driving effects of high-speed rail (HSR) connectivity and network connectivity on industrial transfers vary with industry type, transfer pattern, and the spatial relationships between cities.

Unlike previous studies that primarily focus on the single-type connectivity, single-factor flow

mechanisms and unidirectional industrial transfers between cities, this study adopts a perspective of multiple factor flows that encompasses both traditional and emerging factors to analyze the economic effects of intercity connectivity within the framework of domestic circulation. It investigates the synergistic effects of traffic connectivity and information connectivity, distinguishing between two types of factor flows: "transfer-based" and "shared." Furthermore, it identifies bidirectional industrial transfers among cities and categorizes them into two patterns, "polarization" and "diffusion", from the standpoint of industrial gradient advantages. This study deepens our understanding of the economic implications of intercity connectivity as well as the collaborative mechanisms underlying industrial transfer.

Moreover, this study offers a solid theoretical basis for building the "enclave economy" pattern, clarifies the feasibility and potential advantages of this pattern across varying levels of intercity connectivity, and provides scientific guidance for the cross-regional cooperation between the industrial transfer-out and transfer-in areas. By thoroughly analyzing the mechanism of multiple factor flows driving intercity industrial transfer, the study provides theoretical support for improving the orderly transfer and collaboration mechanism within industries, contributing to breaking regional barriers and achieving optimal resource allocation. Meanwhile, the study also provides a scientific basis for optimizing the industrial layout, helping policy makers to formulate more reasonable industrial layout plans based on the characteristics of intercity factor flows, and promoting coordinated regional economic development.

Keywords: Intercity connectivity; High-speed rail connectivity; Information connectivity; Industrial transfer; Factor flows; Input-output analysis

Disaggregating multi-regional input-output tables

Topic: Input-Output Theory and Methodology (1)
Author: Jan WEINZETTEL
Co-Authors: Birte EWERS, Karl SCHOER, Richard WOOD

Product detail is often seen as a limiting factor in the precision of the results of the input-output analysis as different types of products are aggregated into one group and treated as identical in the production recipe and sales structure. As the disaggregation of MRIOT can be seen as a computationally, data and time-demanding procedure, we aim to answer the research question: How can multi-regional input-output tables (MRIOT) be disaggregated to increase the product or sectoral detail efficiently regarding time and computational capacity?

In this contribution, we present a novel method to disaggregate MRIOT to increase the product detail and make the results more reliable. Before starting the disaggregation, we harmonize the input data on total output, detailed country-by-country international trade, and the original MRIOT. We prepare a set of input coefficients for the disaggregated product groups derived or estimated from existing data. The MRIOT is disaggregated country by country, always taking the block of columns for each country at once. The procedure is taken in the following steps for each country separately: first, the regions of origin (the rows) are aggregated, resulting in the total IOT for each country. An initial estimate of the disaggregated total IOT with the required product detail is obtained from the total output and input coefficients for the detailed product groups. A GRAS algorithm is applied to balance the initial estimate to meet the constraints of row and column totals and the original IOT. Afterward, the product's origin is added, assuming an identical sales structure for the same product originating from different countries. We see this as an important limitation of this approach. Next, the resulting matrix is balanced again using the same balancing algorithm, resulting in a column block of one country's disaggregated part of the MRIO,

which complies with the data on detailed international trade, the original MRIOT, and the detailed total output. This procedure is repeated for all countries, resulting in a disaggregated MRIOT.

We successfully applied this procedure to disaggregate the EU part of the Figaro MRIOT from the level of 64 product groups to 182 product groups consistent with the Eurostat RME model to calculate the material footprint of the EU. However, we note that this type of disaggregation is not precise. We performed a test in which we aggregated the Figaro MRIOT from 64 product groups to 10 product groups and then applied our method to disaggregate it back to the level of 64 product groups. This allows us to analyze whether this disaggregation procedure with limited information improves the results of the MRIO analysis. This test proved that our disaggregation method improves the precision of the Leontief inverse matrix.

Research question: How can multi-regional input-output tables (MRIOT) be disaggregated to efficiently increase the product or sectoral detail regarding time and computational capacity?

Method used: We developed a novel procedure for MRIOT disaggregation. We use the existing procedures of creating the initial estimate from the input coefficients and total output and the GRAS algorithm to balance the initial estimate to the three constraints: row total, column total, and the original IOT, allowing negative entries in the column of changes in inventories and valuables.

Limitation: We assume an identical sales structure for the same product originating from different countries.

Data used: We applied this procedure to disaggregate the EU part of the Figaro MRIOT from 64 product groups to 182 product groups.

Novelty: The novelty is in harmonizing the input data before the disaggregation and disaggregating the MRIOT country by country, which significantly reduces the computational requirements.

Technology change to stay within the Planetary Boundaries.

Topic: Environmental Input-Output Modelling (5)
Author: Richard WOOD

This presentation provides insight into the updates to the global multi-regional input-output (MRIO) database EXIOBASE (v3.10) and results are presented for consumption-based accounts of nations relative to the planetary boundaries (PBs). The analysis is framed in a scenario perspective in order to answer what level of decoupling is needed to stay with planetary boundaries.

The v3.10 update to EXIOBASE includes a new time series of input-output tables and a range of environmental extensions relevant for PB analysis, with emission, pressure and extractive accounts and their links to biodiversity metrics.

PBs form science-based limits to environmental pressures, from which downscaling can be performed to set limits for national, corporate, or household impacts. MRIO approaches allow for the connection between PBs, interpreted as supply-side limits, and the demand-side pressure of consumption by households or industry.

Specifically, a range of scenarios of population and affluence are presented relative to the current projections in order to determine what level of technological progress is needed to stay within the boundaries by the mid-term policy horizon (2050). A discussion of scenario approaches follows, in order to further model the possibility of technology and efficiency improvements until 2050.

The Impact of Green Technology Innovation on the Global Value Chain Posittion of China 's Manufacturing Industry

Topic: Trade and Global Value Chains Policies (1)
Author: Kaiyao WU
Co-Authors: Yonghui LIU, Li YAN

(1) The research questions.
Green technology is a new type of technology committed to reducing environmental negative impacts and promoting sustainable development. Does green technological innovation, and if so, how does it affect the global value chain (GVC) position of China's manufacturing industry? In the current academic circles, there are two main viewpoints on the impact of green technological innovation on the manufacturing value chain. Yuan and Dai (2017) found that green technological innovation has a positive promoting effect on the GVC position of the manufacturing industry. Li et al. (2022) and Song et al. (2021) suggest that the impact of green technological innovation on manufacturing GVCs is not a simple linear relationship but may involve complex non-linear effects.

There are two reasons that may account for the divergence in research conclusions. One is the measurement indicators. These studies employ methods such as SFA (Stochastic Frontier Analysis), DEA (Data Envelopment Analysis), or single measurement indicators to gauge green technological innovation. However, these indicators are characterized by a lack of directness and clarity, as well as a low correlation with policies and technologies. Meanwhile, there is a lack of consideration and measurement of forward and backward participation in GVCs based on the share of value added in the measurement of GVC position indicators. Second, the non-linear relationship between green technological innovation and GVC position revealed by empirical analyses may be the result of the existence of certain moderating effects.

In view of the above differences, this paper conducts a thorough analysis of the impact of green technological innovation on GVC position.
(2) The data used.
OECD national input output tables (IOTs)
OECD Inter-Country Input-Output (ICIO) Tables
OECD Trade in value-added (TiVA)
UIBE GVC Database
CNRDS PSID Database
EPS Database
China Statistical Yearbook on Environment
China Industry Economy Statistical Yearbook
(3) The method used.
a. This paper reconstructs the measurement method of green technology innovation by combining PCT data and OECD's search strategy to account for green patent applications. Based on input-output value-added accounting, a GVC position index that includes forward and backward participation in the global value chain is constructed.
b. Taking environmental regulation and absorption capacity as moderating variables into the research framework of the impact of green technology innovation on the GVC position of China 's

manufacturing industry, this paper analyzes the possible impact directions and mechanisms of green technology innovation as a whole and its moderating variables on GVC upgrading, and proposes research hypotheses of the overall impact, moderating effects and impact mechanism of green technology innovation on GVC upgrading.

c. Use panel regression method to conduct rigorous verification of the above assumptions such as benchmark model, endogeneity test, robustness test and heterology analysis. Finally, we analyze the moderating effects of environmental regulation and absorption capacity on the impact of green technological innovation on the GVC position of China's manufacturing industry through mechanism tests.

(4) The novelty of the research.

a. This paper reconstructs the measurement method of green technology innovation by combining PCT data and OECD's search strategy to account for green patent applications. Based on input-output value-added accounting, a GVC position index that includes forward and backward participation in the global value chain is constructed.

b. By incorporating environmental regulation and absorptive capacity as moderating variables into the research framework of the impact of green technological innovation on the GVC position of China's manufacturing industry, we offer a more comprehensive exploration of the non-linear effects of green technological innovation on the GVC position under varying levels of absorptive capacity and environmental regulation. This facilitates the formulation of targeted policy measures.

Framework for disaggregating multi-region input-output tables with an application to critical minerals

Topic: Special Session: Emerging Global and Regional IO Modelling
Author: Quanzhi XIA
Co-Authors: Heran ZHENG, Jing MENG

Multi-region input-output (MRIO) tables serve as a powerful analytical tool to model interregional supply chains and explore associated socio-economic and environmental issues. However, the lack of sectoral granularity in existing MRIO tables makes it challenging to analyze numerous emerging topics. Furthermore, the absence of a systematic methodology framework for MRIO disaggregation has hindered progress in refining these datasets. Here, we present a novel, comprehensive framework for disaggregating MRIO tables. Our approach strikes a balance between incorporating detailed, bottom-up information about specific sectors of interest and maintaining consistency with the original MRIO system. The framework adheres to a principle of minimal disturbance, such that only the sectors in focus undergo refinement while all others remain unchanged. Moreover, our method embraces flexibility in reconciling information inconsistencies based on bi- and tri-dimensional matrix balancing techniques.

The proposed framework aims to leverage bottom-up, techno-economic data of sectors under study to disaggregate top-down, MRIO tables. One of the most widely used methods to compile a MRIO table is to link national input-output tables through international trade. Thus, the disaggregation process starts with splitting the inputs and outputs of national input-output tables, followed by reconciling competitive and non-competitive input-output structures towards harmonized, disaggregated international trade flows, and ends with coupling all disaggregated national tables into a new global MRIO system with improved granularity. To deal with discrepancies between bottom-up and top-down information, data reconciliation strategies are tailored for each stage, based on entropy-based nonlinear programing approaches. The proposed framework establishes a methodology benchmark for sectoral disaggregation in MRIO tables and

can be extended to regional and temporal disaggregation, enabling timely response to rapidly evolving global challenges.

We demonstrate the framework by incorporating granular, bottom-up critical mineral details into a time series of global MRIO tables. Critical mineral supply chains have been an increasingly important focus in the context of clean energy transitions. However, there is a lack of representation of critical minerals in existing MRIO tables, where mineral sectors are lump into a small number of highly aggregated sectors, making it impossible to capture the detailed nuances of critical mineral supply chains. As countries ramp up efforts to deploy clean energy technologies, it is important to have the analytical capacity for modeling worldwide critical mineral supply chains.

Addressing this gap, we split the single aggregated mineral sector in the GTAP Power database into 38 distinct mineral sectors. The resultant mineral-focused MRIO tables offer granular details for minerals that are central to clean energy technologies, including lithium, nickel, cobalt, and rare earth elements, among others. To achieve this high-resolution dataset, we draw on a diverse array of data sources. In addition to national input-output tables and international trade metrics from the GTAP database, we incorporate production values, input structures, and output structures from the UNIDO database and official input-output tables for representative countries; production quantities and price data from WBMS, S&P Global, USGS, and BGS databases; and mineral trade flows from the BACI database. This refined dataset equips researchers, policymakers, and stakeholders around the world to investigate the socio-economic and environmental impacts along critical mineral supply chains, enabling more informed decision-making in the pursuit of sustainable and secure energy transitions.

Chinese agriculture-focused provincial multi-region input-output database

Topic: Regional Input-output Modelling (2)
Author: Quanzhi XIA
Co-Authors: Jing MENG, Heran ZHENG

Agriculture plays a pivotal role in food security, poverty alleviation, and economic development. Beyond its socio-economic importance, agriculture also exerts profound environmental pressures, contributing to greenhouse gas emissions, deforestation, soil degradation, and excessive water consumption. China is the world's most populous country and a major agricultural powerhouse. With limited arable land and growing food demand, China faces the challenge of balancing agricultural productivity with environmental sustainability. A detailed understanding of China's agricultural sector is crucial for formulating effective policies that support sustainable agricultural development. However, existing Chinese provincial multi-region input-output (MRIO) models often lack the necessary resolution to capture the full complexity of agricultural supply chains. The aggregation of multiple agricultural activities into a single sector masks crucial differences in resource use, productivity, and environmental impacts across agricultural sub-sectors.

In this context, we introduce Chinese agriculture-focused MRIO tables that cover 91 economic sectors for 31 provinces in 2012, 2015, and 2017. This dataset splits the single aggregated agriculture sector in previous Chinese MRIO tables into 50 new sectors, including granular information on 27 agriculture sectors, 3 forestry sectors, 10 animal husbandry sectors, 9 fishery sectors, and 1 agriculture-related service sector. This refined MRIO framework provides the necessary granularity to identify region- and sector-specific economic trends, trade

dependencies, and environmental footprints within China's agricultural system.

We disaggregate all the underlying single-region input-output tables and interregional trade matrices to reach a disaggregated MRIO table. Our disaggregation process begins by splitting the inputs and outputs of these regional tables. We then reconcile competitive and non-competitive input-output structures to achieve harmonized, disaggregated interregional trade flows, ultimately merging all refined tables into a new MRIO system with enhanced granularity. To resolve mismatches between bottom-up and top-down information, we apply tailored reconciliation strategies built on entropy-based nonlinear programming methods. Information for the new sectors is collected from multiple sources. These include Chinese statistical yearbooks, cost-benefit compilations for various agricultural products, the China Health and Nutrition Survey, and product-level trade statistics from China Customs. Our study not only enhances the understanding of China's agricultural economy but also provides reference for improving sectoral disaggregation in MRIO models worldwide, enabling more precise and effective policy interventions for sustainable agriculture.

This agriculture-focused MRIO dataset, featuring unprecedented detail in agricultural sub-sector delineation, has broad applicability for socio-economic research on regional agricultural development in China. Policymakers and researcher can rely on this dataset to simulate policy scenarios related to China's agricultural transition, such as shifts in subsidy allocations or technological upgrades. The expanded resolution supports more precise assessments of production efficiency, labor distribution, and regional trade dependencies, thereby providing critical insights into areas for targeted intervention. Furthermore, these data can serve as a foundational baseline for generating extensive satellite accounts, facilitating in-depth studies of environmental footprints. This includes the analysis of greenhouse gas emissions, air pollutants, land-use changes, and biodiversity loss stemming from interprovincial agricultural supply chains. Our dataset significantly enhances the capacity of researchers and decision-makers to examine and address the complex interplay of economic, social, and environmental factors within China's agricultural sector.

Construction of China's Green GDP Input-Output Model

Topic: YSI and Development Programme (1) (Discussants: Sanjiv Mahajan and Peipei Tian)
Author: Jiaqing XIAN

The global economy is undergoing rapid development. As a prominent developing country, China possesses a substantial economic scale, with its GDP steadily increasing year by year. However, such rapid economic growth has often come at the expense of natural resources and environmental integrity. To ensure that the national economic accounting system accurately and comprehensively reflects economic growth, it is imperative to incorporate resource and environmental factors into its framework. Practical experience in economic and social development demonstrates that the current System of National Accounts (SNA), rooted in traditional value-determination theory, inadequately captures the intricate relationships among resources, the environment, economic growth, and social development. Moreover, it largely overlooks the significant costs incurred by resource depletion and environmental degradation in pursuit of economic progress.

In recent years, the United Nations has introduced successive versions of the System of Environmental Economic Accounting (SEEA) to supplement the SNA, encouraging nations to account for resource depletion and environmental degradation alongside conventional economic

metrics. Building on this foundation, and utilizing input-output analysis, this study develops a theoretical framework integrating economy, resources, and environment. It establishes a green GDP input-output model designed to transcend the limitations of traditional GDP accounting, which focuses solely on economic dimensions. The proposed model aims to quantify and account for the value of resources and the environment, enabling a more accurate assessment of green development.

The approach modifies the traditional input-output table by incorporating resource depletion and environmental degradation into the column input section, reflecting the environmental costs associated with economic activities. The row output section remains largely unchanged, except for the inclusion of adjustment items in the final use category to balance the table and account for resource and environmental expenditures.

Existing literature includes studies on China's green GDP competitive input-output tables, yet the green GDP non-competitive input-output table proposed here represents a novel contribution. Although prior research has explored green input-output accounting, these studies typically focus on quantifying resource depletion and environmental degradation without effectively integrating these factors into GDP calculations. By contrast, this study not only captures the value of resource depletion and environmental degradation within the green GDP input-output table but also calculates green GDP using the production, income, and expenditure approaches. This comprehensive methodology elevates green GDP from a supplementary indicator to a central metric in economic assessment.

Furthermore, the study includes an empirical application of the model. China's annual input-output tables, regularly published by the National Bureau of Statistics, serve as the foundational dataset. To compile the green GDP input-output table, it is necessary to calculate the values associated with resource depletion and environmental degradation and integrate these adjustments into the dataset. Using available data, this study estimates the impacts of selected economic activities on resource depletion and environmental degradation. The data used are derived from statistical yearbooks and official government bulletins issued by the National Bureau of Statistics, ensuring reliability and credibility.

In summary, this study addresses a critical gap in green GDP accounting by integrating resource depletion and environmental degradation into the input-output framework. The proposed model not only highlights the economic costs of environmental and resource impacts but also facilitates the calculation of green GDP using multiple accounting methods. This advancement enables green GDP to transition from a secondary status to a core indicator, fostering a more balanced and sustainable approach to economic development.

Structure decomposition analysis of China's digital economy on economic growth

Topic: Special Session: Digital IO Accounting: Methodology and Applications (1)
Author: Lixiao XU
Co-Authors: Cuiyang FENG, GUAN HUIJUAN, Nan ZHAO

The digital economy is a new economic form that has emerged with the extensive integration and deep penetration of digital technology into various industries of the national economy. Measuring the effect of the digital economy on the entire economy could provide insights to facilitate economic development. This study tries to split the production chain into three parts: traditional

cycle indicating economic links between traditional industries in the production chain, digital cycle indicating links between digital sectors, and digital-traditional integrated cycle indicating links between traditional sectors and digital sectors. According to the macro-data and national digital industry classification published by National Bureau of Statistics, we try to construct national digital input-output tables which have 174 sectors, including 129 traditional sectors and 45 digital sectors. Then, we quantify the contributions of these three cycles during 2012-2020 in China combining three cycles and the extended input-output model, and identify the critical impact factors referring to the digitization of economic growth through the structural decomposition analysis (SDA) which considers the correlation of value-added intensity and direct consumption coefficient.

The results show that China's economy is gradually characterized by an integration economy. The value added driven by digital cycle increased from 5.18 percent in 2012 to 6.56 percent in 2020. A similar ascending trend could be observed in the digital-traditional integrated cycle, which was from 2.97% to 3.75% from 2012 to 2020. In terms of digital industries, the digital product manufacturing declined while the digital technological application climbed. It indicates that digitalization is gradually significant in China's economy and the digital technological application should be noticed. The structural decomposition analysis shows that the positive pulling effect of final demand on China's economic growth has significantly weakened. In the production structure, the negative restraining effect of non-digital inputs has been significantly strengthened and has become the biggest obstacle restricting China's economic growth at present. The positive promoting effect of digital inputs on economic growth is gradually increasing. Stabilizing China's economic growth requires simultaneous efforts from both the demand side and the production side, especially the urgent need for digital transformation to optimize the production structure.

Are quantitative models for disaster impact analysis accurate? A measurement framework and a validation case

Topic: Input-Output Modelling: Disaster Analyses
Author: Ran XU
Co-Authors: Xiang GAO

Quantitative models are widely employed to assess disaster impacts, yet their accuracy remains under-examined due to scarce verifiable validation cases. This study addresses this gap by proposing a novel measurement framework for disaster impact analysis and rigorously testing its accuracy through a real-world validation case: the 2022 Shanghai COVID-19 lockdown. The specificity and short-lived nature of this event—a city-wide sealing policy with minimal confounding factors—provides a unique opportunity to benchmark model performance against actual economic data.

Our framework integrated a multi-regional input-output (MRIO) model with two critical innovations. First, on the production side, it quantified both upstream losses from disrupted supply chains and downstream losses via raw material inventory constraints. Second, on the consumption side, it captured immediate non-rigid spending reductions and long-term demand contractions caused by income loss, offering a dual-perspective analysis. Applied to Shanghai's lockdown, the model estimates a GDP loss of 153.8 billion yuan for Q2 2022, deviating by only 3.6% from official statistics. This close alignment demonstrates the framework's precision in retrospective impact assessment.

Beyond validation, the framework's flexibility is showcased through ex-ante simulations of

hypothetical disasters across Chinese regions, revealing differentiated economic vulnerabilities. Policy simulations further illustrate how adjusting mitigation strategies—such as inventory buffers or household income support—can reduce losses by 12–18%, providing actionable insights for decision-makers.

The study's primary contribution lies in delivering a validated, transparent methodology for disaster impact analysis, supported by empirical evidence of its accuracy. By bridging the gap between modeled and observed outcomes, this framework advances the credibility of economic impact models. Its adaptability to diverse scenarios—from regional disruptions to global crises—positions it as a critical tool for evidence-based risk management and policy design.

Economic and Environmental Impacts of Sports League Transitions: A Case Study of the J.League

Topic: Input-output Analysis for Policy Making (1)
Author: Ryosuke YAMASHITA
Co-Authors: Shigemi KAGAWA, Haruka TODA

In recent years, as Japan grapples with economic decline in its regional areas, the J.League, Japan's professional soccer league, has actively engaged in community-based initiatives. These efforts have significantly contributed to local and regional economies by increasing spectator attendance and promoting tourism. However, the environmental impact of travel and energy consumption associated with match events has become a pressing issue. This study aims to quantitatively analyze the effects of league transitions on regional economies and the environment, clarify the developmental potential of the soccer industry alongside its environmental challenges, and propose sustainable practices for league management.

As a case study, this research focuses on 'Avispa Fukuoka,' a club that competed in the second-tier J2 League in 2015 and was promoted to the top-tier J1 League in 2016. The J.League consists of three tiers, from J1 at the top to J3 at the bottom, with promotion and relegation based on season results. Using the 2015 regional input-output table for Fukuoka Prefecture, we estimated the economic ripple effects and CO_2 emissions associated with game spectatorship. This study focuses on tourism-related expenditures by spectators, specifically in the food and beverage, transportation, and accommodation sectors. Based on these data, we constructed a tourism consumption vector. Spectators were categorized into home and away supporters for a more detailed analysis. Data sources included the J.League data site, Fukuoka Prefecture's 2015 input-output table, Fukuoka Prefecture's Tourism Statistics, and the Environmental Load Data (3EID) Book from the National Institute for Environmental Studies.

To the best of our knowledge, this is the first comprehensive study to evaluate the economic ripple effects and CO_2 emissions resulting from league transitions between different tiers, focusing on a soccer club. This study represents a pioneering effort to shed light on the contributions of the sports industry to a sustainable regional society.

First, the total annual number of spectators at Avispa Fukuoka's main stadium was 182,540 in 2015 and 218,576 in 2016. Although the number of matches differed—21 in 2015 and 17 in 2016—the average number of spectators per match increased by approximately 50% from 2015 to 2016.

In terms of economic ripple effects, the impact generated by home spectators in 2015 was

approximately ¥1.67 billion, while that of away spectators reached ¥2.60 billion, totaling ¥4.27 billion. In 2016, home spectators contributed ¥1.83 billion, and away spectators ¥3.16 billion, bringing the total to ¥4.99 billion—a year-on-year increase of approximately ¥720 million (16.9%). Notably, away spectators had a significantly higher economic impact, with an average per-capita effect of ¥70,974 compared to ¥10,530 for home spectators, nearly seven times higher.

Regarding CO_2 emissions induced by spectator consumption, total emissions were 7,977 tons in 2015 and 9,063 tons in 2016, marking an increase of 1,086 tons (+13.6%). In 2015, home spectators accounted for approximately 3,700 tons, while away spectators accounted for 4,260 tons. In 2016, these figures rose to 4,000 tons and 5,100 tons, respectively, with away spectators comprising about 56% of total emissions, indicating a high environmental burden. A breakdown reveals that the energy, transportation, and accommodation sectors accounted for a large share, with transportation alone responsible for about 45% of total CO_2 emissions. The per-capita CO_2 emissions for home spectators was 0.02 t-CO_2, while for away spectators, it was 0.11 t-CO_2, nearly five times higher.

These results highlight that while league promotion in the J.League generates significant economic benefits, it also leads to a considerable increase in CO_2 emissions. Emissions related to transportation are particularly severe and represent a key area of concern. Addressing these trade-offs is crucial for sustainable league management.

Towards a Low-Carbon Future for China's Power Supply Chain: Critical Sectors Identification and Scenario Analysis

Topic: Environmental Input-Output Modelling (2)
Author: Jin YANG
Co-Authors: Lin TANG

In recent years, China has witnessed a noteworthy increase in its carbon emissions, even amidst the COVID-19 epidemic. Increasing coal use in the electricity sector is the major contributor to China's CO2 emissions, accounting for 60% of the increase in emissions. Considering the substantial carbon emissions from the power sector, a new low-carbon electricity system with solar and wind as its primary energy sources was proposed at the ninth meeting of the Central Finance Committee in March 2021. It should be noted, however, that China's rapidly expanding renewable energy capacity in recent years has not kept pace with the constantly growing electricity demand. A certain number of thermal power installations are still required to guarantee the energy supply security. The total new capacity of coal-fired units is estimated to be 316 GW during the 14th Five-Year Plan (FYP) period even though the entry thresholds for new coal-fired plants are raised by the Chinese government. In light of China's high proportion of coal power installations, achieving a low-carbon transformation of the power structure has become an urgent topic.

Changes in the electricity mix will not only have an impact on direct carbon emissions, but also on indirect carbon emissions from the upstream sector due to the substantial differences in the supply chains associated with the various generation technologies. The indirect emissions should thereby be fully considered in the low-carbon transition of the electricity mix. Moreover, to achieve a low-carbon energy mix from a supply-chain perspective, special attention should be paid to identifying the key upstream sectors of different power generation technologies that have the highest carbon reduction potential. It is therefore necessary to reduce indirect CO2 emissions resulting from the growth of electricity supply and the restructuring of the electricity sector by

identifying the critical sectors of different power technologies and implementing effective strategies.

In this study, a multi-regional input-output model based on disaggregation of power sectors was firstly used to assess the embodied carbon intensity of different power technology sectors in 30 provinces in China and identified major upstream carbon emitters and transmission nodes in the electricity supply chain. Further, scenario analysis based on provincial 14th Five-Year Plans and the Implementation Plan for Transforming and Upgrading Coal-Fired Power Plants was conducted. The results indicate that the solar power sector brings the highest carbon reduction benefits, with an average embodied carbon intensity of 1.25 t/10000 yuan, and significant differences in low-carbon technologies exist across provinces. Critical carbon emitting sectors along the power supply chain are concentrated in the energy sector and energy-intensive sectors, while the electrical machinery and equipment sector is also essential to alleviate environmental pressures as an important carbon transmission sector. Besides, the implementation of the "Replacing Small Generation Units with Large Ones" policy at the provincial level, especially in Western China, and "Further Enhancing the Supply Capacity of Clean Energy" can effectively promote the emission reduction of the whole supply chain in the power sector. The results presented in this paper may provide a reference for the provincial government to rationally plan future low-carbon transformation paths of the power sector.

This study makes the following contributions: (i) From a provincial rather than a national perspective, the power sector was disaggregated in provincial input-output tables according to power technology, and its direct and embodied emission intensity were accounted for to reveal the different levels of power generation technology in each province; (ii) The provincial carbon emissions inventories of different power generation technologies in the power sector were compiled based on point source data of coal-fired units, which served as the basis of this study to improve the accuracy of the division of the coal-fired power generation sector in the input-output table; (iii) To our knowledge, this is the first systematic identification of the critical upstream carbon sectors of different electricity technologies from both a consumption perspective and a betweenness perspective.

Assessing the impacts of fertility and retirement policies on China's carbon emissions

Topic: Special Session: IO Analysis for Just Transition: Linking Economic Structures and Social Inequality (2)
Author: Junai YANG
Co-Authors: Kehan HE, Zhifu MI

Mitigating climate change and coping with population aging are both critical goals for China in achieving sustainable development. As the world's largest carbon emitter, China aims to have a carbon emissions peak before 2030 and achieve carbon neutrality by 2060. Currently, China is turning toward more sustainable development, as evidenced by the deceleration in annual carbon emissions growth from 10% (2000-2010) to 2% (2010-2020). However, China remains an important driver of global carbon emissions due to its large population and growing household consumption over the past two decades. Moreover, China is one of the most populous countries in the world, with a population that is nearing its peak and aging rapidly. In 2020, China's total fertility rate was only 1.3 births per woman, which is far below the replacement level (2.1) needed for a stable population. At the same time, China is aging rapidly, with the proportion aged 65 years and above doubling from 7% in 2000 to 14% in 2020. To address these challenges, China has implemented national strategies such as relaxing fertility policies and delaying retirement age.

The gradual adjustment of fertility and retirement policies in China has social benefits in terms of coping with population aging. However, the environmental consequences of these policies remain ambiguous. While numerous studies have estimated the impact of population aging on carbon emissions in China, few have assessed the impacts of policies that address population aging—including fertility (particularly the three-child policy) and retirement policies—on carbon emissions or household carbon footprints. Thus, we aim to address this gap in the literature. In this study, we investigate age-based household carbon footprints in China and its provinces by using a global multiregional input-output (MRIO) table and employing a large-scale household survey (China Family Panel Studies, CFPS). We then estimate the population of China and its 31 provinces up to 2060 by age (0-100+) and sex (male and female) under different fertility policies: previous two-child policy, the latest three-child policy, and the assumed "replacement-level" policy (with fertility rate reaching the replacement level of 2.1). Finally, we explore the potential effect of these fertility policies and their combination with retirement delay policies on the household carbon footprints.

We find that Chinese young people have relatively higher household carbon footprints than their older counterparts due to differences in income by age group. Relaxing fertility policies and delaying retirement age are associated with an increase in population (and labour supply) and thus increases in household carbon footprints, with a majority of these increases from the fertility side. Our result provides evidence of interactions between the policies targeting population aging and climate change, highlighting the importance of synergising these two types of policies. In addition, although fertility and retirement policies may pose a challenge to China's carbon emission mitigation, these policies (particularly those for retirement delay) can considerably lower the dependency ratio and thus improve the demographic dividend. In sum, our results add to the literature on climate change and population, which has typically evaluated the effect of demographic structure on emissions without considering the independent effect of population policy (especially in China) that contributes to bringing about the change in demographic structure in the first place. Our results also offer insights for developing countries undergoing economic and demographic transformation for more sustainable development.

Unequal Environmental Burdens of Food Loss and Waste in global food supply chain

Topic: Special Session: Technological Innovation Enabling GVC Restructuring
Author: Ziyan YANG
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Research question: Global food trade drives economic growth but also exacerbates food loss and waste (FLW) and environmental burdens, challenging the achievement of sustainable development goals. Existing studies primarily focus on the total volume of FLW and its environmental impact, with limited attention to its unequal distribution across income groups. We explored the disparities in FLW and it environmental burdens within the global food supply chain and proposes policy recommendations that balance equity and sustainability.
Methodology: We constructed a global agri-food trade matrix covering 98 agri-food products and five utilization categories across 49 countries/regions to estimate FLW embedded in the global food supply chain and quantify its direct and indirect environmental impacts based on satellite accounts and the matrix we constructed. Furthermore, we applied structural decomposition analysis (SDA) and counterfactual simulations to examine its driving factors and trade effects. Finally, we developed an inequality index to assess the unequal distribution of environmental

burdens associated with FLW in global food supply chain.

Data: We constructed an agri-food matrix based on FAOSTAT food balance sheets and Exiobase input-output data and developed the FSC-FLW database for the 49 countries/regions based on the FAO Food Loss and Waste Database and existing literature on FLW rates.

Novelty: We developed a novel and comprehensive modeling framework and constructed a global food trade matrix to estimate the FLW embedded in different stages of the global food supply chain. By integrating structural decomposition analysis (SDA) and counterfactual simulations, we extended the analysis to identify the key drivers of food loss and its trade-related impacts. Based on this framework, we developed an inequality index to explore the hidden disparities in environmental burdens within the global food supply chain, providing a novel perspective distinct from previous research.

Energy Engel Coefficient: A New Indicator for Measuring Poverty

Topic:
Author: Tatsuto YUKIHARA
Co-Authors: SUN QIAN

☐☐We propose a new Energy Engel Coefficient (EEC) indicator to measure poverty as the proportion of energy used for cooking.

☐☐Compared to monetary-based indicators, the EEC better fits Engel's Law, which holds that poorer households spend a greater proportion of their income on food.

☐☐Chinese Residential Energy Consumption Survey (CRECS) dataset

☐☐EEC can capture behavioral information and changes in household welfare☐EEC can complement traditional indicators to identify poverty that is otherwise ignored.

Flood footprint assessment: assessing impact of external assistance on post-disaster economic recovery

Topic: Input-Output Modelling: Disaster Analyses
Author: ZHAO ZENG
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Mitigating the risks posed by natural disasters has become a pressing public concern due to their increasingly frequent and intense occurrences, which threaten human lives and socio-economic development. External assistance (EA), as a common form of support for post-disaster reconstruction, has been recognized as significant in several studies. However, the lack of an assessment method has made it unclear to what extent economic recovery can be affected by external assistance. This study aims to investigate the impact of EA on economic recovery following natural disasters from an economic system perspective. To address this issue, we propose a novel approach called EA-FFM that can effectively quantify the effect of EA on both industrial and regional levels using the EIF indicator (EIF is defined as an indicator to show the economic impact of EA on affected economy). The approach also allows us to apply the EA selection principle, which focuses on mitigating indirect economic loss by selecting the most appropriate EA scheme from among all available options.

To address this problem, we adopt the flood footprint as an indicator and improve the Flood Footprint Model by combining it with the consideration of EA. The Flood Footprint Model, which builds upon previous ARIO models, can provide a dynamic modeling process of post-disaster

recovery by considering productivity constraints, demand adaptation, and supply bottlenecks before and after a natural disaster, and it can quantify economic loss. The 2013 Super Typhoon Haiyan serves as a case study for conducting scenario analysis on alternative external assistance schemes. The devastation caused by Super Typhoon Haiyan in Hainan on November 9th, 2013 resulted in a total economic loss of 4.93 billion Chinese Yuan (CNY), equivalent to 1.57% of Hainan's GDP in 2013.

Our findings reveal that EA has a definite positive effect on economic risk reduction, and its influence on the economy is complex. In the Typhoon Haiyan case, we found that EA, which accounted for 2.4% of direct economic losses, resulted in a 7.31% reduction of indirect economic losses in Hainan. Furthermore, through scenario analysis on alternative EA schemes, we discuss that the ration scheme is a significant factor in determining EA's impact. Various distribution ways of the same EA value can result in different sectoral and regional EIFs. The proper EA scheme can be determined by adopting the EA selection principle, which minimizes indirect economic loss. The significance of the EA's impact at the industrial and regional levels is largely determined by factors such as total values of EA, rationing scheme, and even the 'key sectors' of EA, damage level of industrial productivity, inter-linkages of sectors, and the relationship of suppliers and consumers. The EA-FFM's high feasibility and flexibility have been validated through our successful application of it to the Typhoon Haiyan case study.

This study offers fresh perspectives on policy implications that pertain to natural disaster management and risk reduction. Specifically, the analysis emphasizes that the impact of EA should be assessed from an overall economic view. While some sectors may suffer high visible economic losses due to natural disasters, such as Typhoon Haiyan, the potential indirect risks faced by these sectors depend greatly on industrial resilience and interdependence within the economy. Directly affected sectors may potentially play a less significant role in supply chains. Accordingly, the Manufacturing sector, which experienced the largest indirect economic loss in the Typhoon Haiyan case, should receive greater attention and investment from related departments in order to reduce risk. Policy decision-makers must also consider the allocation scheme for EA as well as its total amount. There is no one-size-fits-all rationing scheme for EA that applies to all natural disasters, so it's necessary to analyze each case uniquely. Moreover, the aim of EA must be established, considering differences in its effects across sectors and regions. If the priority is to target the entire economy, then the analysis of regional effects among available EA plans is more important. Alternatively, if certain sectors are prioritized, the industrial effects of EA should be compared.

The Good, the Bad: How digital technology shapes welfare for formal and flexible workers

Topic: Special Session: Technological Innovation Enabling GVC Restructuring
Author: Su ZHANG
Co-Authors: Xiang GAO, Feng ZHANG

Digital technology has a profound impact on China's labor market. How does the welfare inequality between formal and flexible workers change under the influence of digital technology? In this paper, theoretical and empirical studies are carried out respectively. In theory, the welfare effect of individual dimension is considered based on building a general equilibrium model including market production sector and household production sector; In the empirical aspect, the pooled four-wave data from the China Family Panel Studies (CFPS) from 2014 to 2020 are used to test the effects of digital technology on the welfare inequality between the formal and flexible

workers. The study found that digital technology widened the wage disparity and non-wage benefits inequality between the formal and flexible workers, and the sub-industries found that digital technology mainly significantly expanded the wage disparity between the formal and flexible workers in the high-digitalization sectors and the non-wage benefits inequality between the formal and flexible workers in the low-digitalization sectors. The mechanism analysis shows that the substitution effect and the productivity effect have negative effects on the wage disparity between the formal and flexible workers, while the creation effect and the flexibility of flexible workers have positive effects on that. The digital skills difference caused by digital technology has a negative effect on the non-wage benefits inequality between the formal and flexible workers, while the legal efficiency and regulatory quality have a positive effect on that. In addition, the wage disparity and non-wage benefits inequality between the formal and flexible workers caused by digital technology are significantly different in different education levels, gender and time intervals.

The challenge of global carbon emissions will be unbearable if India undertakes industrial relocation from China

Topic: Special Session: IO Analysis for Just Transition: Linking Economic Structures and Social Inequality (1)
Author: Xiaoxu ZHANG
Co-Authors: Kang LIN, Kunfu ZHU

With the rise of labor costs in China, constraints on resources and environment, and ongoing geopolitical conflicts, India has emerged as the most likely candidate to undertake China's industrial relocation. This shift could undermine global efforts to cut carbon emissions. However, ex ante measurement of the environmental effects of such industrial relocation is poorly understood. Here we show that shifting the iPhone production from China to India doubles the production's carbon footprint. Overall, India's undertaking of China's industrial relocation will lead to increased carbon emissions and reduced global economic growth. The carbon burden surpasses the emission reductions achieved by the EU since the Copenhagen Climate Conference. At the sector level, the computer, basic metals, electronic equipment, and automotive sectors are the largest sources of incremental carbon emissions, ensuring these sectors are not substituted by India and promoting technological progress in developing countries are essential to offset the extra emissions.

The New Wave of Global Industrial relocation: Measurement, Trends, and Economic Impacts

Topic: World Input-output Modelling and Databases
Author: Yu ZHANG

Abstract: A new wave of industry relocation has been set off around the world since the global financial crisis of 2008, due to trade protectionism, geopolitical conflicts, the COVID-19 and the new technological revolution. This study innovatively constructs a novel global industry relocation measurement model based on the input-output framework. Using the newly published 2007-2023 global multi-regional input-output table of Asian Development Bank, this study measures the specific scale and path of global industry relocation and evaluates the economic impact of the new global industry relocation on different regions of the world.
This study's main conclusions are as follows. First, from 2007 to 2023, China is the main

destination of the global industry relocation, while the United States (US), the European Union (EU) and Japan are the main sources of the global industry relocation. From the perspective of dynamic evolution, the US, the EU and Japan have continuously reduced industry relocation to China, mainly focusing on technology-intensive industries, labor-intensive industries, capital-intensive industries and producer services. Meanwhile, the US has significantly increased its industry relocation to Mexico, Canada, ASEAN, and the EU. The EU has significantly increased its industry relocation to itself, the UK, and India. Japan has significantly increased its industry relocation to the US, EU, ASEAN, and India. Second, although the US and Japan try to reduce their economic ties with China through industrial relocation, China's position as a key node in the global supply chains remains indispensable due to its comprehensive industrial ecosystem and advanced technological capabilities. Specifically, industries moving to ASEAN, Mexico, and India continue to rely heavily on intermediate goods and core components sourced from China, leading these recipient economies to simultaneously increase their industrial relocation to China. Third, China's value-added benefits from global industry relocation are gradually decreasing, while ASEAN, Mexico, and India are gradually increasing their value-added benefits from global industry relocation.

This study's main contribution is: (1) A new quantitative measurement model for industry relocation is constructed, and a quantitative indicator that simultaneously reflects both the scale and direction of industry relocation is proposed, overcoming the limitations of current industry relocation measurement. (2) This study measures the absolute scale and specific path of global industry relocation from 2007 to 2023, filling the empirical gap in related fields and providing detailed data support for grasping the current global industry relocation. (3) Under the global value chain accounting system, a quantitative evaluation framework for the economic impact of global industry relocation has been constructed. This study assesses the economic impact of the new round of industry relocation on different regions around the world, providing reference and warning for a comprehensive understanding of the economic impact of industry relocation.

Keywords: industry relocation, global production network, global multi-regional input-output table

Livestock antimicrobial use embodied in global supply chains

Topic: Environmental Input-Output Modelling (6)
Author: Heran ZHENG

Global demand for protein has surged over the past decades, due to the booming population and increasing affluence. As the key protein source, the demand of animal protein has more than tripled over past decades from 70 to 350 million tons, and it is expected to grow another 12% between 2019 and 2029. The growth hotspots of the meat production are mostly concentrated in developing countries due to population and income. The growth was especially alarming in Asia, Africa, and South America over the past 20 years. However, the massive increase in meat production cannot be achieved without the excessive use of antimicrobials for the growth promotion and mass prophylaxis of the livestock. Today, antimicrobial use in animals represented 73% of all antimicrobials used worldwide, significantly contributing to antimicrobial resistance which has become a global concern, linking with an annual death toll of 700,000 and is projected to increase to up to 10 million fatalities worldwide by 2050.

However, animal products are not only driven by local demands but also significantly by the demands overseas. For example, global trade of animal products accounts for roughly 10% of total merchandise trade and keeps rising. Animal products can be beyond the global food system. By-products of animals are essential for industrial use, such as skin for apparel industry and fat

for the chemical industry. This indicates the antimicrobial use is highly related to the manufactured goods and embodied in the international trade of both food and manufactured products, referring to a spillover effects along the global supply chain. As the new type of challenges, the global antimicrobial governance establishment requires a comprehensive accounting framework from primary use to final consumption via global supply chains. Therefore, we call for more academic efforts, public awareness, and international coordination to address the emerging global antimicrobial overuse issue.

In this study, we link antimicrobial estimates in livestock production with a global multi-regional input–output (MRIO) model, enabling us to quantify the antimicrobial footprint via global supply chains from 2010 to 2020. The footprints encompass both direct and indirect antimicrobial use throughout the production stages of food and non-food products. For example, the antimicrobial footprint of beef includes direct use in feeding cattle and indirect use in services supporting husbandry. We estimate global antimicrobial use in chicken, cattle, and pigs across 16 antimicrobial types for each country/region using Bayesian regression (6), based on official data from 43 countries and product-level data from the UN Food and Agriculture Organization (FAO). We then utilized the EXIOBASE model to quantify antimicrobial use embodied in global supply chains. We further examined the socioeconomic drivers behind trends in antimicrobial use for each country/region using structural decomposition analysis. Our study provides a novel perspective by linking on-site antimicrobial use with final demand via international trade, shedding light on the often-overlooked spillover effects of antimicrobial use in global supply chains. By shifting the focus from on-site to off-site responsibility, we aim to reshape the understanding of how responsibility for AMR should be shared between producers and consumers globally. This research lays the groundwork for more comprehensive strategies to address AMR, emphasizing the need for coordinated international efforts to mitigate this critical global health threat.

The energy system transition pathway towards carbon reduction using a model-coupling approach

Topic: Energy Input-Output Modelling
Author: Jiali ZHENG
Co-Authors: Shouyang WANG, Xiaoqing HOU, Yihan WANG

Energy system transition is widely regarded as an important strategy to achieve carbon reduction and is aligned with the commitment to reach peak carbon emissions by 2030. However, most modelling approaches in the existing literature do not pay sufficient attention to inter-sectoral dynamics. By using a model-coupling approach, this paper aims to study inter-sectoral energy consumption flows from 2000-2021 and to explore energy system transition pathways at the national and city levels.

Existing studies, commonly employing models including input-output (IO) analysis, integrated assessment models (IAMs), etc., discuss the impact of energy transition policies on energy consumption and emissions. Taking the IO model as a case in point, most of the existing studies based on the IO models use national data for research at the city or regional levels, which are rather homogeneous in scope. Moreover, these models are generally used only for short-term simulations to assess the effects of emission reduction policies and are not suitable for studies on the long-term impacts of emission reduction policies. The IAMs provide an integrated assessment of policies through the construction of large-scale simulation models. The long-range energy alternatives planning system (LEAP) model, for example, is used to simulate energy demand, generation mix, carbon emissions, and total costs under different scenarios at the city level.

However, IAMs omit details of interdependencies between sectors and the indirect impacts on the energy system supply chain. And interactions among sectors should be further explored, as recent research has argued that inadequate treatment of intersectoral interdependencies in current modelling approaches substantially understates the challenges of meeting existing climate targets and is a major shortcoming.

In order to address the limitations of a single model, including a single scope of study and unclear trends in changing industrial structure, model coupling combines IO and IAMs models to systematically study the impacts of energy transition on energy consumption and climate change. Research on coupling IO with IAMs models mainly focuses on improving one model using the results of the other. The macro-analysis of IO models is enhanced by the detailed technical outputs of IAMs. By soft-linking top-down IO analysis to bottom-up IAMs with rich technology details, such coupling model can be used to assess the evolution of the electricity mix under energy regime scenarios and apply future energy scenarios to IO analysis. The results provided by IO analysis can be used to improve the evaluation of the economic-social module of IAMs.

In this study, we use sectoral data from 20 sectors and consumption data from 16 cities to explore the energy system transition pathway towards carbon reduction, by developing a model-coupling approach. At the national level, we study inter-sectoral energy consumption flows using a IO-LEAP model and then use scenario analysis to suggest sectoral-level specific strategies from 2000-2030 and city-specific strategies from 2019-2030. This paper makes the following contributions. We propose model-coupling of IAM and IO modelling to address the limitations of existing approaches. The coupling model tracks energy consumption, production and transition across sectors of an economy. Despite the widespread recognition of importance of energy transitions, IAMs underestimate the indirect effects of changing energy mix and effects of intersectoral interdependencies. Recent studies attempt to solve this problem; however, they generally limit to a specific industry or urban setting. We propose a multi-industry and multi-city perspective.

The results show that historically heavy industries have consistently maintained a high share of energy consumption and emissions accounting for 49.9% and 60.7% respectively by 2021, mainly caused by direct energy-resource inputs rather than post-processing inputs. In the scenario analyses, compared to the baseline scenario, the national EES scenario can reduce energy consumption by 6.7% and emissions by 24.6% in 2030, while the EES_CCS scenario can further reduce emissions by 48.4%. Furthermore, the energy consumption and carbon emissions across cities are influenced by the industrial structure, the degree of electrification, and the amount of new energy installed.

Key Drivers of China's Renewable Energy Adoption: Constructing and Analyzing a Time Series of Energy Use between 1997 and 2021

Topic:
Author: Lingxiu ZHU
Co-Authors: Erik DIETZENBACHER, Cuihong YANG

Energy transition involves the shift from fossil fuels to renewable and sustainable alternatives. Although annual data on energy use for China exist, they show two important shortcomings. First, energy use matrices (that list energy use by sector and by energy product) are lacking. Second, the total energy consumption by sector is overestimated in the data reported in the China Energy Statistical Yearbook. A primary contribution of this paper is therefore the construction of a time series of China's sectoral energy use matrices from 1997 to 2021. The data addresses the overestimation issue and provides information on China's annual energy use for 47 sectors (including 46 industries and households) and 30 energy products. The data is then applied

through an energy input-output model and Structural Decomposition Analysis (SDA) to identify the key drivers behind the growth of renewable energy (RE) use. The findings highlight the critical role of the transition in electricity generation, electrification, and energy efficiency improvements in driving the adoption of renewable energy across industries.

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