Full-scale, near real-time multi-regional input-output table for the global emerging economies (EMERGING)

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Abstract

Multi-regional input-output (MRIO) models are widely used to analyze the economic interdependencies between regions in the context of global trade and environmental research. MRIO tables enable us to teleconnect the sectors in different regions along the supply chain and track both direct and indirect impacts of global production. Yet emerging economies — despite reshaping international trade patterns and playing an increasingly important role in the world economy — are not adequately represented in existing MRIO databases, which lack key detail on countries and sectors. To bridge this gap, our study presents EMERGING: up-to-date and full-scale MRIO tables covering 135 sectors in 245 economies over the period from 2015 to 2019. We describe in detail the steps the development of the database and reconciliation and validation of bilateral trade data and national statistics. The EMERGING database is also designed to incorporate more official and publicly available data from national statistical institutes to ensure a high level of data quality, especially for these economies. We compare both national production-based and consumption-based value added generated from the EMERGING MRIO with the results from four major MRIO databases. Although global value-added accounts are similar across databases, we find some significant discrepancies at the level of individual countries and sectors concerning conflicting benchmark data.

Keywords: Global multi-regional input-output database; Emerging economies; Bilateral trade data; Modularization

1. INTRODUCTION

Emerging economies — low-income, rapid-growth countries (Hoskisson et al., 2000) — play an important role in the world economy, accounting for 70% of global GDP growth (Gail Cohen et al., 2017; Gruss et al., 2018; Hove & Turso, 2019). According to the International Energy Agency (IEA), between 2018 and 2050 global primary energy demand is expected to grow by 50% (IEA, 2020) and emerging economies would contribute 74% of the future increase in global energy demand (Phuc Nguyen et al., 2020; Sadorsky, 2010, 2014). In addition, emerging economies' participation in international trade is growing (Iapadre & Tajoli, 2014). International trade increased more than 50% from 2005 to 2015, and emerging economies contributed 60% of the increase and accounted for 46 percent of world trade in 2015 (Meng et al., 2018). At the same time, these economies face many challenges, among them climate change, population growth and poverty — vulnerabilities that make achieving sustainable development disproportionately important and difficult to achieve (Gunasekaran et al., 2014; Wang & Yang, 2020). More research is thus needed on understanding these economies' role in global supply chains and progress towards sustainable development.

Multi-regional input-output (MRIO) tables reveal the economic and technological links between sectors in different regions, and have proved to be a useful method for describing and understanding supply chains and relationships between consuming and producing sectors (Isard, 1951; Leontief, 1986). The environmentally extended MRIO approach has proven to be an effective tool in analyzing the environmental impacts of global supply chains (Minx et al., 2009; Wiedmann, 2009; Wiedmann et al., 2007).

There have been numerous efforts to model global supply chains and generate MRIO databases. They include the World Input–Output Database (WIOD) (Dietzenbacher et al., 2013; M. Timmer et al., 2015; Timmer et al., 2016), the Global Trade Analysis Project (GTAP) (Peters et al., 2011), Eora (Lenzen et al., 2012a; Lenzen et al., 2012b; Lenzen et al., 2013) and EXIOBASE (Bjelle et al., 2020; Stadler et al., 2018; Tukker et al., 2013a; Tukker et al., 2009). However, these databases do not contain enough detail on emerging economies; as a result, there is less available data on sectors in emerging economies than there is for those in developed ones (Wiedmann et al., 2011). WIOD, for example, is dominated by countries in the Organisation for Economic Co-operation and Development (OECD), and provides MRIO tables for 43 major countries from 2000 to 2014 (Dietzenbacher et al., 2013). GTAP covers more countries (141 in version 10) than WIOD, but its data sources are older: the latest data for 2014 was released in 2019. In comparison, the Eora database has the most country-level detail, but only provides a set of consistent data for 26 sectors for each country or the original format but not harmonized sectors of the tables for each country (Lenzen et al., 2013). The main aim of EXIOBASE, meanwhile, is to provide environmentally relevant accounts for countries in the European Union (EU) and a few other major economies. Hence, its detail on sectors is relatively high (163 sectors), however, its coverage of economies is relatively limited (Stadler et al., 2018).

The information available in existing MRIO databases on sectors and small economies is in some cases not detailed enough. Due to growing heterogeneity of different regions and

sectors, datasets with highly aggregated sectors or regions do not support accurate supply chain analysis, especially for emerging economies. Meanwhile, due to the difficulties of data collection and constraints of data compilation, many existing MRIO databases (Tukker & Dietzenbacher, 2013b) do not release annual MRIO tables. This impedes the capacity to analyze historical data on supply chains and international trade patterns in order to forecast future trends.

To lay out how environmental impacts arise progressively in emerging economies via supply chains, MRIO databases need to fulfil five requirements. They should: (1) be global, and include emerging economics to the extent possible; (2) contain enough detail on sectors to capture structural changes in supply chains and economic developments; (3) cover changes over time; (4) up-to-date representation of changes to allow for timely policy implications; and (5) use modular compilation for timely updates. In this paper, our compilation method is divided into nine modules. There are 3 data modules for storing data and 6 functional modules for data processing (See more detail in Section 3.2).

The EMERGING World Input-Output Database project (EMERGING: Construction and Applications) has been developed to create such an all-encompassing database. The EMERGING-MRIOTs cover 245 economies with 135 sectors, and provide annual MRIO tables running from 2015 to 2019. It is a tool that can provide indicators used by both policymakers and academic researchers that require empirical observations for testing and quantifying policy decisions or theories.

By focusing on emerging economies, we strive to create annual MRIOTs that are highly detailed on economies and sectors. With this database, it is possible to address issues related to the socio-economic aspects (such as the creation of jobs or value added) and environmental aspects of global supply chains such as energy use, emissions and natural resource consumption. It should be emphasized that all data in the EMERGING database are obtained from official sources and are consistent with countries' national statistics. The full database is open access: https://ceads.net/.

2. CURRENT PROGRESS IN MULTI-REGIONAL INPUT-OUTPUT TABLES

Various global multiregional input-output (GMRIO) data sets have been developed (Andrew & Peters, 2013; Lenzen et al., 2012a; Lenzen et al., 2013; Timmer et al., 2015; Tukker et al., 2013a; Tukker & Dietzenbacher, 2013b; Tukker et al., 2009), along with classification systems and methods of analysis (Tukker et al., 2018; Wood et al., 2014). Currently, eight such databases are available, as summarized in Table 1: (1) Eora (Lenzen et al., 2012a; Lenzen et al., 2012b; Lenzen et al., 2013); (2) EXIOBASE (extended version EXIOBASE 3rx (Bjelle et al., 2020; Stadler et al., 2018; Tukker et al., 2013a; Tukker et al., 2009)); (3) WIOD (Dietzenbacher et al., 2013; Timmer et al., 2015; Timmer et al., 2016); (4) GTAP (Aguiar et al., 2019; Carrico, 2020; Chepeliev, 2020; Glen P. Peters et al., 2011); (5) the OECD Input-Output Database (OECD ICIO) (OECD, 2021); (6) Asian Development Bank MRIO Database (ADB) (Dietzenbacher et al., 2013);

(7) The Institute of Developing Economies, Japan External Trade Organization (IDE-JETRO) Asian International Input-Output Tables (AIIOTs) (mainly focusing on the Asian Pacific economies (Meng et al., 2013)); (8) the Full International and Global Accounts for Research in Input-Output Analysis (FIGARO) (mainly focusing on the EU (Rémond-Tiedrez & Rueda-Cantuche, 2018)); and (9) The Global Resource Input-Output Assessment Model (GLORIA) MRIO database (Lenzen et al., 2017; Lenzen et al., 2021).

Given that the information available in existing MRIO tables does not provide sufficient geographic and sectoral detail (Wiedmann et al., 2011), all these databases have specific strengths and weaknesses regarding coverage of these aspects. Few of the databases are kept up to date, even though some of them cover relatively long timeframes. WIOD provides annual time series of MRIO tables from 2000 to 2014, mainly focusing on EU countries (28 EU member countries, plus 15 major economies); its classification of sectors (56) is relatively coarse, particularly within the broader categories of agriculture and energy production. GLOARO provides continuous time series of 1990-2019 and covers 164 regions with 94 sectors. However, in the process of compiling the table, the collected national data is used to mathematically adjust the initial MRIO table rather than completely used as primary inputs, which limits the data quality and accuracy.

The Eora database was the first to use all available country supply-use tables (SUTs) and input-output tables (IOTs). By using these data in their original formats, it avoided the step-wise optimization and harmonization of the former databases. Eora uses a sophisticated, fully automated procedure to calculate highly detailed GMRIO tables covering around 190 countries, with time series in current prices from 1990 to 2015 (Lenzen et al., 2012a). Despite its large and detailed database, however, Eora does have notable limitations. For instance, its detail on sectors is highly variable (ranging from 26 to over 400 sectors), which limits cross-country comparisons for specific sectors and only provides consistent data for 26 sectors across all countries (Lenzen et al., 2013). The OECD ICIO also has limited sectoral detail (OECD, 2021), including just 45 aggregated sectors (Wiebe et al., 2012).

EXIOBASE focuses on environmental accounts, but mainly for EU countries. It has the highest level of sectoral detail in all the countries covered in its database, including 163 sectors in EXIOBASE 3. In EXIOBASE V3.8 the trade and macro-economic data run up to 2022 based on forecasts. However, EXIOBASE 3 (V3.8) only covers 28 EU member countries plus 16 major economies, and 5 rest of the world regions. EXIOBASE 3rx disaggregates to 214 countries, based on EXIOBASE 3. Economic data, such as GDP and output, were mainly collected from databases of the United Nations (UN); the Food and Agriculture Organization of the UN (FAO), which compiles FAOSTAT data on food and agriculture; the International Energy Agency (IEA) database; and national statistics. The input-output structure of the additional countries directly use the region coefficients from EXIOBASE 3 (Bjelle et al., 2020). Moreover, the most recent update of EXIOBASE 3rx was in 2015 (Merciai & Schmidt, 2018; Stadler et al., 2018).

GTAP (Aguiar et al., 2019; Carrico, 2020; Chepeliev, 2020) provides a harmonized database with IOTs and trade data that can be used to construct MRIO tables (Peters et al., 2011). GTAP covers 121 countries and 20 aggregated regions. The GTAP 10 MRIO consists of only 65 sectors

(76 sectors in the GTAP-Power database), which makes adequate assessments of specific sectors difficult, especially highly diverse service sectors. Moreover, GTAP provides MRIO tables only at three- or four-year intervals.

The remaining databases have a geographic focus. ADB and IDE-JETRO mainly cover the Asia Pacific region. ADB expands the WIOD database to cover Asian economies. To address any specific informational and analytical needs associated with this region, the ADB MRIO tables cover 25 Asian emerging economies. The IDE-JETRO (Meng et al., 2012) database also mainly focuses on Asian economies, which limits its usefulness for emerging economies in other world regions. FIGARO is a compilation of inter-country supply-use tables and input-output tables at the EU level (Mahajan et al., 2018; Rémond-Tiedrez & Rueda-Cantuche, 2018; Rémond-Tiedrez & Rueda-Cantuche, 2019).

Analyses of trends in global trade by emerging countries are gaining attention (Amighini & Sanfilippo, 2014; Bloomfield, 2020; Pasquali, 2021), as are growing environmental impacts related to trade between emerging economies (Lin & Xu., 2019; Meng et al., 2018; Wang & Yang, 2020). Pasquali et al., for instance, have shown that global value chains and the global manufacturing factory will gradually move to the South (Pasquali, 2021). Meng et al. found that the CO_2 emissions embodied in South-South trade increased rapidly, and noted that more attention should be paid to smaller, less-developed economies (Meng et al., 2018). However, there is still a lack of MRIO databases with continuous time series without time delay and cover all possible economies and sectors, which are essential for further analysis of global supply chains and environmental impact in emerging economies. This is the key goal of our EMERGING project.

Table 1. Review of the main GMRIO databases

Database name	Countries	Sectors	Time	Approach
Eora	global (187)	Varying across countries (25-500); highly aggregated version with 26 sectors	1990-2015	Creation of initial estimate; collection of raw data in original format; formulation of constraints; detection and judgement of inconsistencies; calculation of balanced global MR SUT/IOT by applying large-scale optimization approaches
WIOD	EU focus (43+ 1RoW region)	56	2000-2014 annually	Construction of time series of national SUTs; creation of bilateral trade database; building international SUTs and RAS to balance; transformation of into symmetric WIOTs
GTAP 10	global (121+20 regions)	65 (76 in GTAP-Power)	2004,2007, 2011,2014	Harmonization of trade; use of IOTs to link trade sets; IOT balanced with trade and macro-economic data
OECD ICIO	OECD focus (66+Row)	45	1995-2018	Use of harmonized OECD IOTs (ignoring differences of products and industries); use of OECD bilateral trade database for trade links
ADB	global (62+Row)	Varying SUT dimensions; harmonized to 35 industries	2000,2007-2018	Use of national SUTs and detailed bilateral international trade statistics to create time series SUTs; transformed into a global IOT
EXIOBASE (v3,3rx, v3.8)	EU focus (44+5RoW: v3, v3.8; 214: 3rx)	220×163	1995-2011 (3) 1995-2015 (3rx) 1995-2022 (3.8)	Creation of SUTs and bilateral trade database; use of trade data to harmonize SUTs; transformation to global multi-regional SUT; RAS to balance
IDE-JETRO	Asia-Pacific (8:1975) (10:1985–2005)	56 × 56 (1975) 78 × 78 (1985–1995) 76 × 76 (2000, 2005)	1975-2005	Harmonization of IOTs based on cross-country survey information; link via trade, using a manual, iterative process to balance and reduce discrepancies
FIGARO	EU focus (45+Row)	64×64	2010–2019	Construction of a full set of national SUTs and IOTs on the basis of national statistics; creation of a balanced bilateral trade database; inter-country SUTs and IOTs based on the ESA 2010 methodology; GRAS to balance

GLORIA	global (160+4 regions)	97	1990-2019	Build an initial table with complete structure as the starting point of data compilation process for the initial year of time series; Collect the data of various countries, such as official national statistical office data and international trade data and use these data as mathematical constraints to adjust the initial table. The output is the final MRIO table for the first year; For the next year in the time series, use the final MRIO of the previous year as the initial estimate, and repeat steps 1-2 for the next year.

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3. DEVELOPMENT OF THE EMERGING-MRIO FRAMEWORK

3.1 Content of EMERGING-MRIOTs

The EMERGING-MRIOTs cover 245 economies and provide annual data from 2015 in current prices (for the period 2015-2019). The economies are listed in Figure S3. They are selected based on the availability and quality of the data. Our MRIOTs have 135 sectors, including 105 commodity sectors and 30 service sectors. There are 98 commodity sectors according to the classification standard of Harmonized System Codes in 2002 (HS 2002; 2-digit code).

To highlight the importance of the energy sector, we further split HS sector 27 (mineral fuels, oils etc.) into energy sectors 99-105, which is based on the HS 2002 sector detailed classification (4-digit code) of sector 27 (Table S8). The service sector is divided into 30 according to Extended Balance of Payments Services Classification in 2010 (EBOPS 2010) and according to the average level of sectoral detail across all economies. All years are provided in the format of 105 goods sectors and 30 service sectors. The industry classifications are given in Table S7 and Table S8, in the supplementary information. All data are downloadable at www.ceads.net

3.2 Overview of the Framework

Two principles underpin our project. The first is coverage of all economies, with a specific focus on emerging economies. To ensure the accuracy of MRIO data, we have collected economic data released by the national statistical offices of 245 economies, of which 111 have their own input-output (IO) data (in the form of national IOTs, SUT tables and social accounting matrices (SAMs).

The second principle is an emphasis on timely updating of MRIO tables. Since the data we use come from a variety of sources, and data availability varies among economies, we divide the MRIO table compilation process into nine modules (see breakdown below) and adopt corresponding compilation procedures according to the data source and the economy. Figure 1 shows the main framework of the EMERGING-MRIO tables compilation.

Constructing the tables is a three-step process: data collection, data compilation, data validation. First, we collect bilateral trade data, macroeconomic data such as IO data, and sectoral output and value added (***Data module***). These data are collected from various sources and constrained by top-level macroeconomic data to ensure consistency between regions and over time.

The second step consists of six modules as listed below and will be described in detail in SI.

Trade module: National economic data for many emerging economies, such as time-series IO data and sectoral output, are very limited, which demands a great deal of labour input. Therefore, the backbone of our compilation process involves a time series of the MRIO tables with high regional resolution, and bilateral trade data (on both export and import), which are both annually updated (Andrew & Peters, 2013; Streicher & Stehre, 2015). We use this module to establish trade ties between economies by building a 3D matrix including 245 economies and 135 sectors per year.

Reconciliation module: To use as much of each country's statistics as possible, we collect original economic data from various sources which have different statistical characteristics. We use the World Bank data to reconcile the range of raw economic data for each economy before compilation (see more details in SI).

Disaggregation module: The trade matrix which we have built into the ***Trade module*** (see more details in Section 4.1) provides bilateral trade flow information about total imports and exports for each product and for all economies, which only meets the data conditions for compiling the national competitive tables. In this module we use bilateral trade data and other economic data to compile the national competitive IOTs for each economy and including 135 consistent sectors (see more details in SI). (1) For economies for which we have complete IO data, we use the ***Disaggregation module*** to compile national competitive IOTs. (2) For economies that have not complete IO data, we use the weighted average sum of the available national IOTs compiled in the corresponding region to get its approximate regional IOT, and store it in **Database 2** by using the ***Region module***. Then, we compile the national competitive IOTs for these economies in the ***Disaggregation module*** by combining the regional IOT built in the ***Region module.***

This module is followed by the ***Transformation module,*** where for each economy we transform competitive IOTs to national non-competitive IOTs. We then use all national non-competitive IOTs to transfer into a complete MRIO table by using the ***Linkage module*** (see more details in SI).

As a final step, we validate the accuracy of EMERGING-MRIO tables to ensure that the EMERGING database is transparent, comparable, freely accessible and verifiable. In the ***Validation module***, we calculate both the production-based and the consumption-based value added. We then compare the results with other databases to scrutinize their accuracy and comparability.

To update data for a specific economy individually and timely, the raw data collected must be stored for each economy in **Database 1**. If we collect the latest released economic data, which is not available in **Database 1**, we update **Database 1** and revise the existing MRIO tables by using the ***Update module***. (See more details of construction methodology in Supplemental Information (SI).)

4. VALUE-ADDED ACCOUNT VALIDATION

We compare both the value added (VA) (Peters et al., 2012; Steen-Olsen et al., 2016) and the CO_2 emission account. In this part of the validation process, we compare VA from both the production and consumption perspectives, as the former reflects the uncertainty of MRIO original data and the latter also combines the Leontief inverse (Steen-Olsen et al., 2016). We compare the VA in 2015 for each economy from EMERGING with the results from EXIOBASE 3rx in 2015, OECD in 2015, Eora in 2015 and GTAP 10 in 2014. (See more details on validation methods in SI.)

4.1 Comparison of global value-added accounts by sector

For the sectoral comparison, we first aggregate all VA accounts across economies, and then pick 12 detailed key sectors. The results are distributed between the 17 aggregated sectors (see Table S10*)*. Figure 2 shows the sectoral comparison results calculated by five MRIO databases.

There are some differences in sectoral distribution among the different databases, especially in service sectors. The overall sectoral distribution in consumption-based global VA accounts is similar across the five databases. Variations in VA results for the 17 aggregated sectors are in the order of 0–15% compared EMERGING with GTAP 10, Eora, OECD and EXIOBASE 3rx. The biggest such gap between EMERGING and the other databases is with GTAP, and amounts to 13.5% in the financial service sector (financial intermediation & business activity); the equivalent gaps between EMERGING and the other databases — Eora, OECD and EXIOBASE 3rx — are 6.2%, 6.1% and 3.7%, respectively. In the public sector (Public administration; education; health; recreation; other services), the gaps between EMERGING, and GTAP and EXIOBASE 3rx, are 7.7% and 3.9%, respectively. When comparing EMERGING to OECD ICIO and Eora, there is only a 0.7% gap.

Regarding the 12 detailed key sectors, Eora has 26 highly aggregated sectors and OECD ICIO has 45 sectors; thus, we can only compare the consumption-based VA of the construction, electrical equipment and motor vehicles and parts sectors in EMERGING with those of these two databases. The variation for VA results of the construction sectors are in the order of 8–30% between EMERGING with GTAP 10 (10%), Eora (8%), OECD (22%) and EXIOBASE 3rx (30%). The biggest difference between EMERGING and GATP is in the mining sectors and the biggest gap between EMERGING and EXIOBASE 3rx is in the transportation sectors.

The relatively large gaps between different sectors in the five MRIO databases is mainly due to the underlying economic data used in these databases, the degree of sectoral aggregation and deviations in dealing with allocation and attribution across different databases.

4.2 Comparison of value-added accounts by economy

We compare VA accounts of domestic production and consumption across countries. Domestic production accounting includes exports to other economies; domestic consumption accounting includes imports from other economies. Although the deviation of global VA is less than 1% across three databases (barring EXIOBASE 3rx, in which the production-based gap is 2.4%, and consumption-based one 11.4%), the comparison of VA accounts per economy (as shown in Figure 3) reveals a different picture: the differences among the five databases are significant, mainly due to the variation in benchmark data used in them.

We analyze the results of 63 OECD economies (a, b) and 181 emerging economies included in EMERGING (c,d). The differences among existing databases vary, so it is not representative to use maximum differences or averages of difference. Thus, we only compared the minimum differences between the results of EMERGING and five other databases.

Across OECD economies, the smallest difference of VA in domestic production varies in the range of -20%-20%; in the consumption-based accounts, the gaps are almost the same, except for those of Malaysia and Cyprus. Even though the trade characteristics of each economy are consistent (net importer or exporter) across all the databases, the benchmark data used and the compilation methods (especially for matrix F and L) for different databases are different, resulting in a large gap in consumption-based accounts.

Among emerging economies, the smallest difference in VA for domestic production is in the range of -60% to 90%; for consumption-based VA the range is -50% to 90%. Moreover, the gap for VA in domestic consumption is larger than that for domestic production. Among the five databases, GTAP 10 generally provides higher estimates. Overall, the level of variation is stable in the VA for production and consumption across almost all economies. Emerging economies exhibit the highest differences across four databases (EXIOBASE 3rx, OECD, Eora and GTAP), largely due to the difference in basic data sources used. And economies highly dependent on trade (such as Cyprus, Hong Kong, Malaysia and Singapore) show the highest difference in consumption-based VA accounts across five databases, largely caused by a difference in treatment of re-exports (Hambÿe et al., 2018) and variations in trade data used across these databases (UN Comtrade and other data sources) (Gehlhar, 2004).

4.3 Structural decomposition analysis

To further clarify the causes of differences between databases, we compare consumption-based VA accounts for these five MRIO databases. We use structural decomposition analysis (SDA) to attribute differences in VA to a set of determinants, such as VA share (sectoral VA/output), the Leontief inverse and final demands (Owen et al., 2014). (See more details of the SDA method in SI)

For the SDA, we aggregate 5 different MRIO databases (EMERGING, EXIOBASE, Eora, GTAP and

OECD) into 5 consistent MRIO tables with 5 regions and 17 sectors (as laid out in the processes described in SI). The consumption-based VA account differences among Oceania, America and Africa are small across the five databases (Figure 4). The main driver for the large gap of Consumption-based VA account between European and Asian countries is the gap of Leontief inverse and there are also great differences in Final demand in Asia. In comparing different databases, the overall difference between EMERGING and GTAP, Eora is small. As for EXIOBASE, the Final demand in the Americas is relatively large. Since there are only 66 individual countries (and one ROW) in the OECD, there will be considerable uncertainty and error in the division and consolidation of five aggregated regions. The main possible explanation of such big differences is the different sectoral classifications across databases, which will lead to sector aggregation uncertainty when using SDA analysis (Owen et al., 2014).

The results of the SDA thus reveal a large gap between EMERGING and OECD in regions with low coverage of OECD individual countries, such as those in Asia, America and Africa.

4.4 Case studies

We select four main developing economies (Vietnam, Brazil, South Africa and Bulgaria) and four small emerging economies (Azerbaijan, Bahrain, Ecuador and Mauritius) in different regions to analyze the economic structure of both domestic production and consumption between EMERGING and three other MRIO databases (GTAP, EXIOBASE and Eora).

As shown in Figure 5, for main developing economies, Vietnam's manufacturing and processing industry and mining industry are the main industrial sectors of Vietnam, accounting for 15.3% and 7.5% of GDP respectively (Trinh & Kobayashi, 2010). With the economic development of Vietnam, the construction industry has achieved significant economic growth, with an average growth of 8% in the past 10 years. At the same time, the growing domestic consumption and the signing of the EU Vietnam free trade agreement have promoted the development of Vietnam's retail trade and the increase of demand. The characteristics of production and demand side are all reflected in the EMERGING and other databases.

In 2017, Brazil's GDP reached US $2.05 billion, of which 63% came from services (Sousa et al., 2015). Therefore, the service shares of Brazil in both production-based and consumption-based perspectives are largely. The economic structure reflected in EMERGING and other databases is roughly consistent.

The economic development of South Africa is mainly driven by the tertiary industry, accounting for about 65% of GDP. Mainly for tourism, ICT, transportation and wholesale and retail trade (Yeo & Grant, 2018). Except for services, the construction demand in South Africa also largely. According to the South African Bureau of statistics, in 2018, the total expenditure on construction projects and related activities exceeded 430.2 billion rand and the employed labors accounted for more than 8%, which are represented in EMERGING and other databases.

In 2017, industry and service accounted for about 28% and 67.4% GDP, separately (Kirilova, 2018). Among it, the fast GDP growth is based on real estate , IT and trade. Compared with

2018, the output of construction increased by 8.3% in 2019. The share of residential construction accounts for 27.3% of the total operating revenue of the construction industry. Foreign direct investment in construction increased by 39.1 million euros over 2018. Employees in the construction industry account for 5.5% of all employees in Bulgaria. The significant contributions of construction and services to both the production and consumption sides are represented in EMERGING and other databases.

For small emerging economies, oil and natural gas play a dominant role in Bahrain's economy. In 2017, some 19% of its GDP was contributed by this sector (Khayati, 2019). The country's banking and financial services have also benefited from the regional boom driven by demand for oil (Alaali & Naser., 2020); the financial sector contributed to almost 17% of the national GDP in 2017 (source: Ministry of Finance, Bahrain). The significant contributions of oil (through the mining and petrochemical sectors) and financial services to both the production and consumption sides are represented in EMERGING and other databases.

Azerbaijan is another economy heavily reliant on oil (Vidadili et al., 2017). In 2019, the World Bank reported that it contributed 21.86 % of the national GDP. According to data from the Asian Development Bank (ADB) (Yoon, 2019), after mining and quarrying (sectors that incorporate oil), the next largest sectors have been construction and transport, storage and communication (7.2% and 8.8% of GDP, respectively), all of which is reflected in the EMERGING, GTAP and EXIOBASE databases.

Mauritius, a small island developing state (SIDS), is a mixed developing economy based on agriculture, exports, financial services and tourism (Cervigni & Scandizzo, 2017). According to the African Development Bank (AFDB)'s report, tourism and hospitality contributes around 24% of GDP and accounts for 22% of employment — both consistent with the economic structure reflected in EMERGING and other databases.

The economy of Ecuador is based on the export of oil, gold, bananas, shrimp and other primary agricultural products (Martínez et al., 2017; Valdivia, 2008). In 2017, remittances constituted 2.7% of the country's GDP and total trade amounted to 98% of GDP. The country is also highly dependent on petroleum resources: oil contributed 6.7% of GDP in 2019. The economic structure reflected in EMERGING and other databases for Ecuador is roughly consistent.

5. DISCUSSIONS

The key principle guiding our method of compilation is to individually represent as many small emerging economies as possible. That recognition as independent economies enables policy-makers to ensure the significant country and sectoral heterogeneity in their economic assessments. Moreover, by focusing on standardization, modularization and timeliness, we have achieved a method for rapid, in-time, high-resolution MRIO tables. And we have ensured that the philosophy behind the EMERGING database is one of comparability, verifiability, openness and transparency. We will disclose the raw data source of each economy for users to evaluate its credibility and what EMERGING-MRIO frameworks can and cannot deliver. The purpose of our paper is to propose a

new, modular compilation framework method for MRIOs. Because not every economy we represent in this work currently possesses high-quality data, the data quality of the MRIO tables for some emerging economies can be poor. However, in the future, we will deploy any available higher-quality national raw data to update the EMERGING database in a timely fashion. At the same time, in the spirit of our open-access, crowdfunded venture, we hope more people will join us in contributing to improving EMERGING.

Looking ahead, due to the huge amount of data in the full EMERGING-MRIO tables, we will develop user-defined functions on our website to allow people to choose the economies and sectors they are interested in, while other economies will be automatically merged into one region, ROW (standing for 'rest of the world'). Moreover, combining data from corresponding environmental and socio-economic accounts, especially carbon-emission inventories and labor inventories, will also be released in the future for analyzing many more studies on the socio-economic and environmental impacts of globalization.

6. CONCLUSIONS

This paper describes the compilation of the EMERGING-MRIOTs: a time series of MRIOTs for 245 economies updating from 2015 to 2019. In contrast to methods used to compile other MRIO databases, we use bilateral trade data from UN Comtrade as the base of our compilation.

There are some uncertainties in the compilation. First of all, the "export proportionality assumption" in the sectoral split of output is used, which is relatively strong due to the limitation of data. Secondly, the proportion of imports used in intermediate and final demand is assumed to be same for each sector, because the data is too limited to build a concordance mapping between products and end-uses, especially for most emerging economies. Thirdly, the weighted average IOTs from the corresponding region is used to construct specific IOTs for economies that lack the necessary data when developing the IOTs and sectoral divisions

Some weaknesses of the approach have been touched upon above, there are also some limitations in the data usage of EMERGING database. (1) We did not consider tariffs in EMERGING compilation. We only use the World Trade Organization bilateral service trade data in the trade matrix construction, which is under reporting for several main economies, without using other data sources, such as the UN and the OECD, as a supplement. (2) As CIF-FOB transformation, we use the total value of national imports in CIF price to scale the trade matrix, which is very simple and ignores the difference between goods and services. (3) Given the different levels of data availability, the data quality varies across economies. For a better understanding and appropriate use of the table, Table S13 in the appendix shows the level of data reliability for 245 economies.

In the future, we will focus on these limitations to improve the reliability of EMERGING-MRIO tables. (Note that as EMERGING-MRIO tables are compiled based on the most recently available data in each economy, they may as a result be released at different times).

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AUTHOR CONTRIBUTIONS

Jingwen Huo and Peipei Chen contributed equally. Jing Meng and Dabo Guan designed the study. Jingwen Huo and Peipei Chen performed the analysis. Jingwen Huo prepared the manuscript. Jingwen Huo, Peipei Chen, Klaus Hubacek, Heran Zheng, Jing Meng and Dabo Guan interpreted the data. All authors participated in writing the manuscript.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The time series of EMERGING-MRIO tables from 2015-2019 are shared on the CEADs website (https://ceads.net/). The original economic data we collected are available from the corresponding authors upon reasonable request. The Matlab code for reproducing the validation analysis and source data for main figures presented in this study are available in Github at: https://github.com/Jingwenhuo/EMERGING_1212.git .

REFERENCES

Aguiar, M., Chepeliev, M., Corong, E. L., McDougall, R., & Mensbrugghe, D. v. d.. (2019). The GTAP Data

Base: Version 10. *Journal of Global Economic Analysis, 4*(1), 1-27. Retrieved from https://www.jgea.org/ojs/index.php/jgea/article/view/77

Alaali, F., & Naser, H.. (2020). Economic development and environmental sustainability: evidence from Bahrain. *Energy, Ecology and Environment, 5*(3), 211-219. doi:10.1007/s40974-019-00143-4

Amighini, A., & Sanfilippo, M.. (2014). Impact of South–South FDI and Trade on the Export Upgrading of African Economies. *World Development, 64*, 1-17. doi:https://doi.org/10.1016/j.worlddev.2014.05.021

Andrew, R. M., & Peters, G. P.. (2013). A MULTI-REGION IN PUT–OUTPUT TABLE BASED ON THE GLOBAL TRADE ANALYSIS PROJECT DATABASE (GTAP-MRIO). *Economic Systems Research, 25*(1), 99-121. doi:10.1080/09535314.2012.761953

Bjelle, E. L., Többen, J., Stadler, K., Kastner, T., Theurl, M. C., Erb, K.-H., . . . Wood, R.. (2020). Adding country resolution to EXIOBASE: impacts on land use embodied in trade. *Journal of Economic Structures, 9*(1), 14. doi:10.1186/s40008-020-0182-y

Bloomfield, M. J.. (2020). South-South trade and sustainable development: The case of Ceylon tea. *Ecological Economics, 167*, 106393. doi:https://doi.org/10.1016/j.ecolecon.2019.106393

Carrico, C., Corong, E. & Mensbrugghe, D. v. d.. (2020). The GTAP version 10A Multi-Region Input Output (MRIO) Data Base. *GTAP Research Memorandum, No. 34. April 2020*(https://gtap.agecon.purdue.edu/resources/download/10043.pdf).

Cervigni, R., & Scandizzo, P. L.. (2017). The Ocean Economy in Mauritius.

Chepeliev, M.. (2020). GTAP-Power Data Base: Version 10. *Journal of Global Economic Analysis, 5*(2), 110-137.

Dietzenbacher, E., Los, B., Stehrer, R., Timmer, M., & De Vries, G.. (2013). The construction of world input–output tables in the WIOD project. *Economic Systems Research, 25*(1), 71-98.

Gail Cohen, J. T. J., Loungani, P., Marto, R.. (2017). Emissions and Growth: Trends and Cycles in a Globalized World. *IMF Working Paper, No. 17/191*, ISBN/ISSN: 9781484316702/9781484311018-9781484315941.

Gehlhar, M.. (2004). Re-export trade for the Netherlands and Singapore. In.

Gruss, B. a. N., Malhar and Poplawski-Ribeiro, Marcos. (2018). Growth Accelerations and Reversals in Emerging Market and Developing Economies: The Role of External Conditions. *IMF Working Paper, No. 18/52*, Available at SSRN: https://ssrn.com/abstract=3157015.

Gunasekaran, A., Jabbour, C. J. C., & Jabbour, A. B. L. d. S.. (2014). Managing organizations for sustainable development in emerging countries: an introduction. *International Journal of Sustainable Development & World Ecology, 21*(3), 195-197. doi:10.1080/13504509.2014.915439

Hambÿe, C., Hertveldt, B., & Michel, B.. (2018). Does consistency with detailed national data matter for calculating carbon footprints with global multi-regional input–output tables? A comparative analysis for Belgium based on a structural decomposition. *Journal of Economic Structures, 7*(1), 11. doi:10.1186/s40008-018-0110-6

Hoskisson, R. E., Eden, L., Lau, C. M., & Wright, M.. (2000). Strategy in Emerging Economies. *Academy of Management Journal, 43*(3), 249-267. doi:10.5465/1556394

Hove, S., & Tursoy, T.. (2019). An investigation of the environmental Kuznets curve in emerging economies. *Journal of Cleaner Production, 236*, 117628. doi:https://doi.org/10.1016/j.jclepro.2019.117628

Iapadre, P. L., & Tajoli, L.. (2014). Emerging countries and trade regionalization. A network analysis. *Journal of Policy Modeling, 36*, S89-S110. doi:https://doi.org/10.1016/j.jpolmod.2013.10.010

IEA. (2020). *World Energy Outlook 2020*. Retrieved from IEA, Paris: https://www.iea.org/reports/world-energy-outlook-2020

Isard, W.. (1951). Interregional and Regional Input-Output Analysis: A Model of a Space-Economy. *The Review of Economics and Statistics, 33*(4), 318-328. doi:10.2307/1926459

Khayati, A.. (2019). The Effects of Oil and Non-oil Exports on Economic Growth in Bahrain. *International Journal of Energy Economics and Policy, 9*(3), 160-164. Retrieved from https://www.proquest.com/scholarly-journals/effects-oil-non-exports-on-economic-growth/docview/2256136657/se-2?accountid=10673

Lenzen, M., Kanemoto, K., Moran, D., & Geschke, A.. (2012a). Mapping the Structure of the World Economy. *Environmental Science & Technology, 46*(15), 8374-8381. doi:10.1021/es300171x

Lenzen, M., Moran, D., Kanemoto, K., Foran, B., Lobefaro, L., & Geschke, A.. (2012b). International trade drives biodiversity threats in developing nations. *Nature, 486*(7401), 109-112. doi:10.1038/nature11145

Lenzen, M., Moran, D., Kanemoto, K., & Geschke, A.. (2013). BUILDING EORA: A GLOBAL MULTI-REGION INPUT–OUTPUT DATABASE AT HIGH COUNTRY AND SECTOR RESOLUTION. *Economic Systems Research, 25*(1), 20-49. doi:10.1080/09535314.2013.769938

Lenzen, M., Geschke, A., Abd Rahman, M. D., Xiao, Y., Fry, J., Reyes, R., Dietzenbacher, E., Inomata, S., Kanemoto, K., Los, B., Moran, D., Schulte in den Bäumen, H., Tukker, A., Walmsley, T., Wiedmann, T., Wood, R., & Yamano, N.. (2017). The Global MRIO Lab – charting the world economy. *Economic Systems Research*, *29*(2), 158-186. https://doi.org/10.1080/09535314.2017.1301887

Lenzen, M., Geschke, A., West, J., Fry, J., Malik, A., Giljum, S., Milà i Canals, L., Piñero, P., Lutter, S., Wiedmann, T., Li, M., Sevenster, M., Potočnik, J., Teixeira, I., Van Voore, M., Nansai, K., & Schandl, H.. (2021). Implementing the material footprint to measure progress towards Sustainable Development Goals 8 and 12. *Nature Sustainability*. https://doi.org/10.1038/s41893-021-00811-6

Leontief, W.. (1986). *Input–Output Economics* (2nd ed ed.). NewYork, Oxford University Press.

Lin, B., & Xu, M.. (2019). Does China become the “pollution heaven” in South-South trade? Evidence from Sino-Russian trade. *Science of The Total Environment, 666*, 964-974. doi:https://doi.org/10.1016/j.scitotenv.2019.02.298

Mahajan, S., Beutel, J., Guerrero, S., Inomata, S., Larsen, S., Moyer, B., . . . Thage, B.. (2018). Handbook on supply, use and input-output tables with extensions and applications. *United States: United Nations Publication*.

Martínez, J., Martí-Herrero, J., Villacís, S., Riofrio, A. J., & Vaca, D.. (2017). Analysis of energy, CO2 emissions and economy of the technological migration for clean cooking in Ecuador. *Energy Policy, 107*, 182-187. doi:https://doi.org/10.1016/j.enpol.2017.04.033

Meng, B., Yaxiong, Z., & Satoshi, I.. (2012). *Compilation, application and challenge of IDE-JETRO's International Input-Output tables*. Retrieved from https://EconPapers.repec.org/RePEc:jet:dpaper:dpaper375

Meng, B., Zhang, Y., & Inomata, S.. (2013). COMPILATION AND APPLICATIONS OF IDE-JETRO'S INTERNATIONAL INPUT–OUTPUT TABLES. *Economic Systems Research, 25*(1), 122-142. doi:10.1080/09535314.2012.761597

Meng, J., Mi, Z., Guan, D., Li, J., Tao, S., Li, Y., . . . Davis, S. J.. (2018). The rise of South–South trade and its effect on global CO2 emissions. *Nature Communications, 9*(1), 1871. doi:10.1038/s41467-

018-04337-y
Merciai, S., & Schmidt, J.. (2018). Methodology for the Construction of Global Multi-Regional Hybrid Supply and Use Tables for the EXIOBASE v3 Database. *Journal of Industrial Ecology, 22*(3), 516-531. doi:https://doi.org/10.1111/jiec.12713
Minx, J. C., Wiedmann, T., Wood, R., Peters, G. P., Lenzen, M., Owen, A., . . . Ackerman, F.. (2009). INPUT–OUTPUT ANALYSIS AND CARBON FOOTPRINTING: AN OVERVIEW OF APPLICATIONS. *Economic Systems Research, 21*(3), 187-216. doi:10.1080/09535310903541298
OECD. (2021). OECD Inter-Country Input-Output Database, http://oe.cd/icio.
Owen, A., Steen-Olsen, K., Barrett, J., Wiedmann, T., & Lenzen, M.. (2014). A STRUCTURAL DECOMPOSITION APPROACH TO COMPARING MRIO DATABASES. *Economic Systems Research, 26*(3), 262-283. doi:10.1080/09535314.2014.935299
Pasquali, G. P.. (2021). When value chains go South: Upgrading in the Kenyan leather sector. *Journal of World Business, 56*(2), 101161. doi:https://doi.org/10.1016/j.jwb.2020.101161
Peters, G. P., Andrew, R., & Lennox, J.. (2011). CONSTRUCTING AN ENVIRONMENTALLY-EXTENDED MULTI-REGIONAL INPUT–OUTPUT TABLE USING THE GTAP DATABASE. *Economic Systems Research, 23*(2), 131-152. doi:10.1080/09535314.2011.563234
Peters, G. P., Davis, S. J., & Andrew, R.. (2012). A synthesis of carbon in international trade. *Biogeosciences, 9*(8), 3247-3276. doi:10.5194/bg-9-3247-2012
Phuc Nguyen, C., Schinckus, C., & Dinh Su, T.. (2020). Economic integration and CO2 emissions: evidence from emerging economies. *Climate and Development, 12*(4), 369-384. doi:10.1080/17565529.2019.1630350
Rémond-Tiedrez, I., & Rueda-Cantuche, J.M.. (2018). The EU Inter-Country Supply, Use and Input-Output Tables (FIGARO Project). *Methodological note. ESTAT & JRC*, https://www.iioa.org/conferences/25th/papers/files/2837_20170511021_FIGARO_UNECE_v20170511026.pdf.
Rémond-Tiedrez, I., & Rueda-Cantuche, J.M.. (2019). *Full international and global accounts for research in input-output analysis (FIGARO)*: Eurostat.
Sadorsky, P.. (2010). The impact of financial development on energy consumption in emerging economies. *Energy Policy, 38*(5), 2528-2535. doi:https://doi.org/10.1016/j.enpol.2009.12.048
Sadorsky, P.. (2014). The effect of urbanization on CO2 emissions in emerging economies. *Energy Economics, 41*, 147-153. doi:https://doi.org/10.1016/j.eneco.2013.11.007
Stadler, K., Wood, R., Bulavskaya, T., Södersten, C.-J., Simas, M., Schmidt, S., . . . Tukker, A.. (2018). EXIOBASE 3: Developing a Time Series of Detailed Environmentally Extended Multi-Regional Input-Output Tables. *Journal of Industrial Ecology, 22*(3), 502-515. doi:https://doi.org/10.1111/jiec.12715
Steen-Olsen, K., Owen, A., Barrett, J., Guan, D., Hertwich, E. G., Lenzen, M., & Wiedmann, T.. (2016). Accounting for value added embodied in trade and consumption: an intercomparison of global multiregional input–output databases. *Economic Systems Research, 28*(1), 78-94. doi:10.1080/09535314.2016.1141751
Streicher, G., & Stehrer, R.. (2015). WHITHER PANAMA? CONSTRUCTING A CONSISTENT AND BALANCED WORLD SUT SYSTEM INCLUDING INTERNATIONAL TRADE AND TRANSPORT MARGINS. *Economic Systems Research, 27*(2), 213-237. doi:10.1080/09535314.2014.991777
Timmer, M., Dietzenbacher, E., Los, B., Stehrer, R., & De Vries, G. J.. (2015). An Illustrated User Guide to the World Input–Output Database: the Case of Global Automotive Production. *Review of*

International Economics, 23(3), 575-605. doi:https://doi.org/10.1111/roie.12178

Timmer, M., Los, B., Stehrer, R., & De Vries, G.. (2016). *An anatomy of the global trade slowdown based on the WIOD 2016 release*.

Tukker, A., De Koning, A., Wood, R., Hawkins, T., Lutter, S., Acosta, J., . . . Kuenen, J.. (2013a). EXIOPOL – DEVELOPMENT AND ILLUSTRATIVE ANALYSES OF A DETAILED GLOBAL MR EE SUT/IOT. *Economic Systems Research, 25*(1), 50-70. doi:10.1080/09535314.2012.761952

Tukker, A., & Dietzenbacher, E.. (2013b). GLOBAL MULTIREGIONAL INPUT–OUTPUT FRAMEWORKS: AN INTRODUCTION AND OUTLOOK. *Economic Systems Research, 25*(1), 1-19. doi:10.1080/09535314.2012.761179

Tukker, A., Giljum, S., & Wood, R.. (2018). Recent Progress in Assessment of Resource Efficiency and Environmental Impacts Embodied in Trade: An Introduction to this Special Issue. *Journal of Industrial Ecology, 22*(3), 489-501. doi:https://doi.org/10.1111/jiec.12736

Tukker, A., Poliakov, E., Heijungs, R., Hawkins, T., Neuwahl, F., Rueda-Cantuche, J. M., . . . Bouwmeester, M.. (2009). Towards a global multi-regional environmentally extended input–output database. *Ecological Economics, 68*(7), 1928-1937. doi:https://doi.org/10.1016/j.ecolecon.2008.11.010

Valdivia, G.. (2008). Governing relations between people and things: Citizenship, territory, and the political economy of petroleum in Ecuador. *Political Geography, 27*(4), 456-477. doi:https://doi.org/10.1016/j.polgeo.2008.03.007

Vidadili, N., Suleymanov, E., Bulut, C., & Mahmudlu, C.. (2017). Transition to renewable energy and sustainable energy development in Azerbaijan. *Renewable and Sustainable Energy Reviews, 80*, 1153-1161. doi:https://doi.org/10.1016/j.rser.2017.05.168

Wang, Q., & Yang, X.. (2020). Imbalance of carbon embodied in South-South trade: Evidence from China-India trade. *Science of The Total Environment, 707*, 134473. doi:https://doi.org/10.1016/j.scitotenv.2019.134473

Wiebe, K. S., Bruckner, M., Giljum, S., & Lutz, C.. (2012). CALCULATING ENERGY-RELATED CO2 EMISSIONS EMBODIED IN INTERNATIONAL TRADE USING A GLOBAL INPUT–OUTPUT MODEL. *Economic Systems Research, 24*(2), 113-139. doi:10.1080/09535314.2011.643293

Wiedmann, T.. (2009). A review of recent multi-region input–output models used for consumption-based emission and resource accounting. *Ecological Economics, 69*(2), 211-222.

Wiedmann, T., Lenzen, M., Turner, K., & Barrett, J.. (2007). Examining the global environmental impact of regional consumption activities — Part 2: Review of input–output models for the assessment of environmental impacts embodied in trade. *Ecological Economics, 61*(1), 15-26. doi:10.1016/j.ecolecon.2006.12.003

Wiedmann, T., Wilting, H. C., Lenzen, M., Lutter, S., & Palm, V.. (2011). Quo Vadis MRIO? Methodological, data and institutional requirements for multi-region input–output analysis. *Ecological Economics, 70*(11), 1937-1945. doi:https://doi.org/10.1016/j.ecolecon.2011.06.014

Wood, R., Hawkins, T. R., Hertwich, E. G., & Tukker, A.. (2014). HARMONISING NATIONAL INPUT—OUTPUT TABLES FOR CONSUMPTION-BASED ACCOUNTING — EXPERIENCES FROM EXIOPOL. *Economic Systems Research, 26*(4), 387-409. doi:10.1080/09535314.2014.960913

Yoon, S.. (2019). Azerbaijan: Country Digital Development Overview.

Trinh, B., & Kobayashi, K.. (2010). Measuring the effective rate of protection in Vietnam's economy with emphasis on the manufacturing industry: an input-output approach. *Depocenwp, series*(2010/12).

Sousa, M., Ferreira, V. d. R. S., Najberg, E., Medeiros, J. J.. (2015). Portraying innovation in the public

service of Brazil: Frameworks, systematization and characterization. *Revista de Administração (São Paulo), 50*, 460-476.

Yeo, B., & Grant, D.. (2018). Predicting service industry performance using decision tree analysis. *International Journal of Information Management, 38*(1), 288-300.

Kirilova, K.. (2018). Challenges to the Administrative Service of Municipalities in Bulgaria. *Nauchni trudove*(4), 229-245.

SUPPORTING INFORMATION

This supporting information includes detail information about the construction methodology for EMERGING.

FIGURE LEGENDS

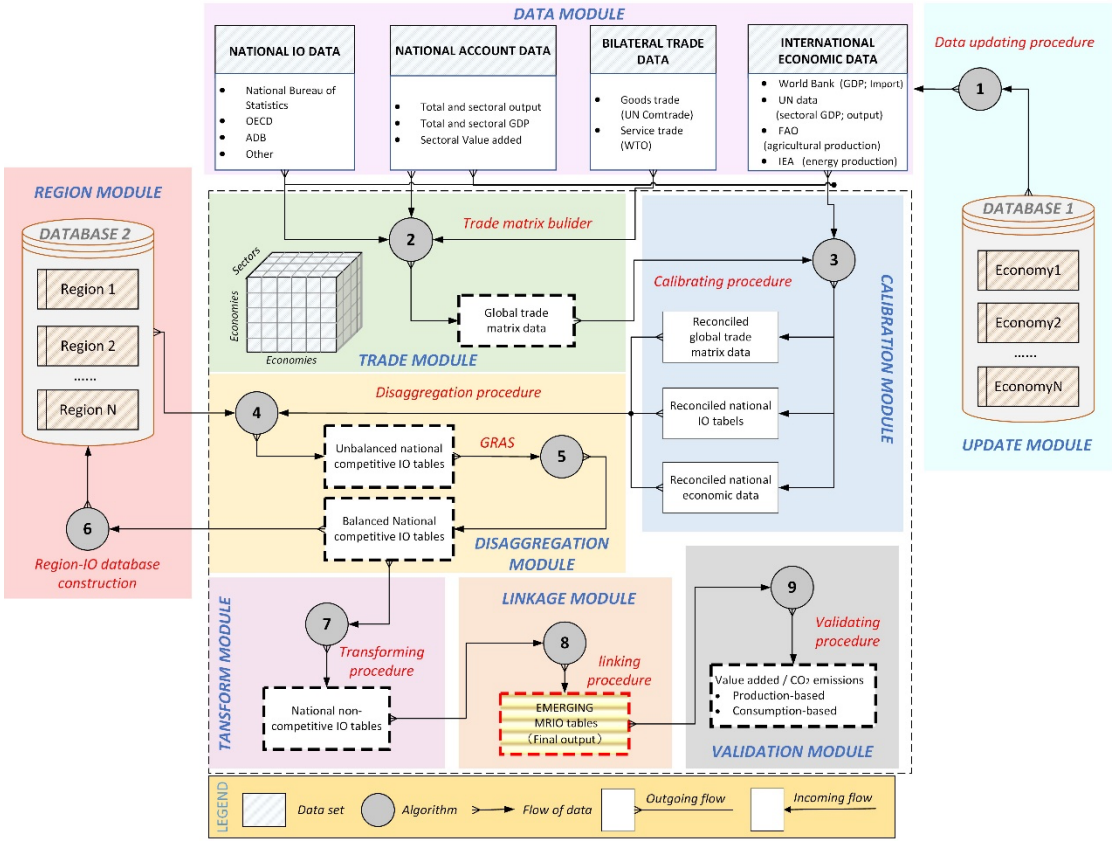
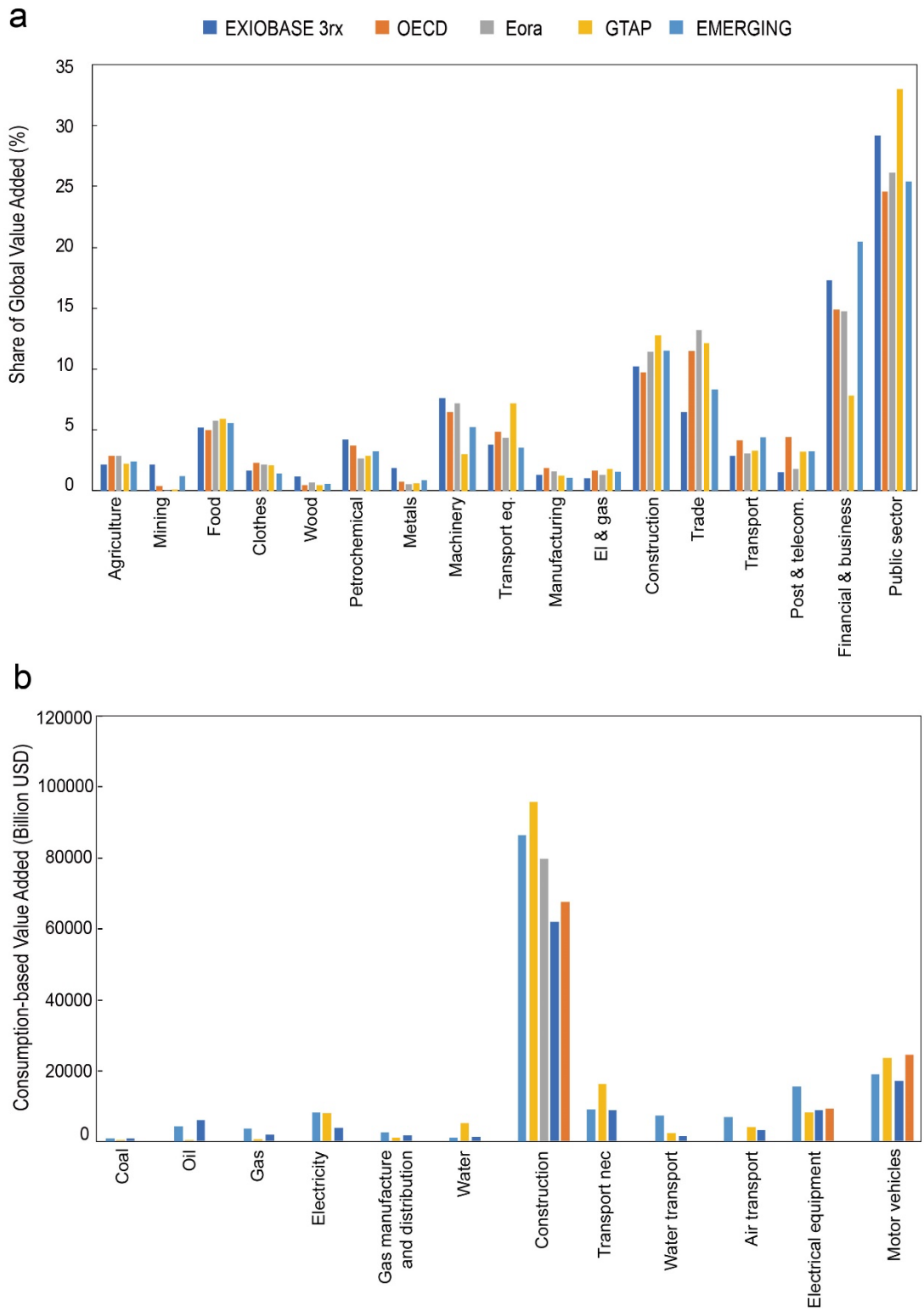
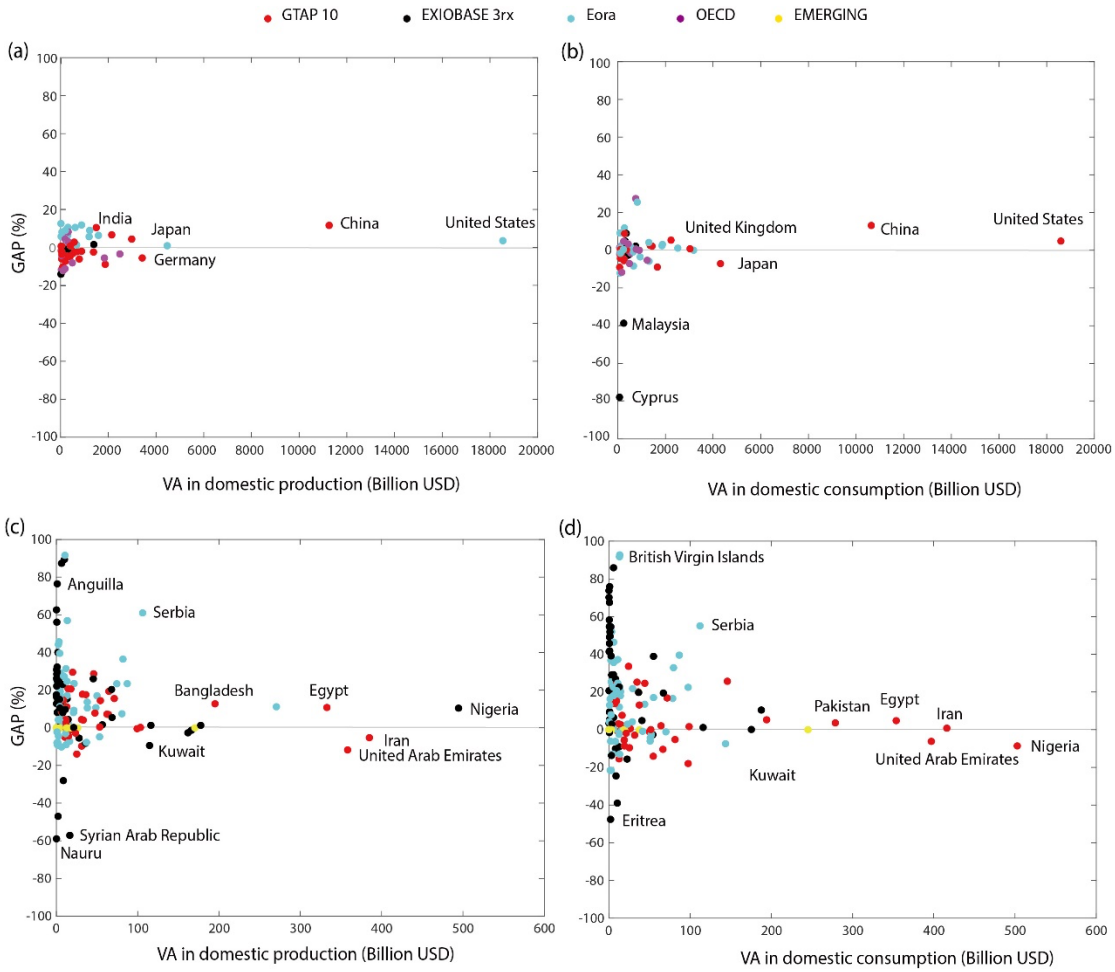


Figure 1. Framework of EMERGING method update database



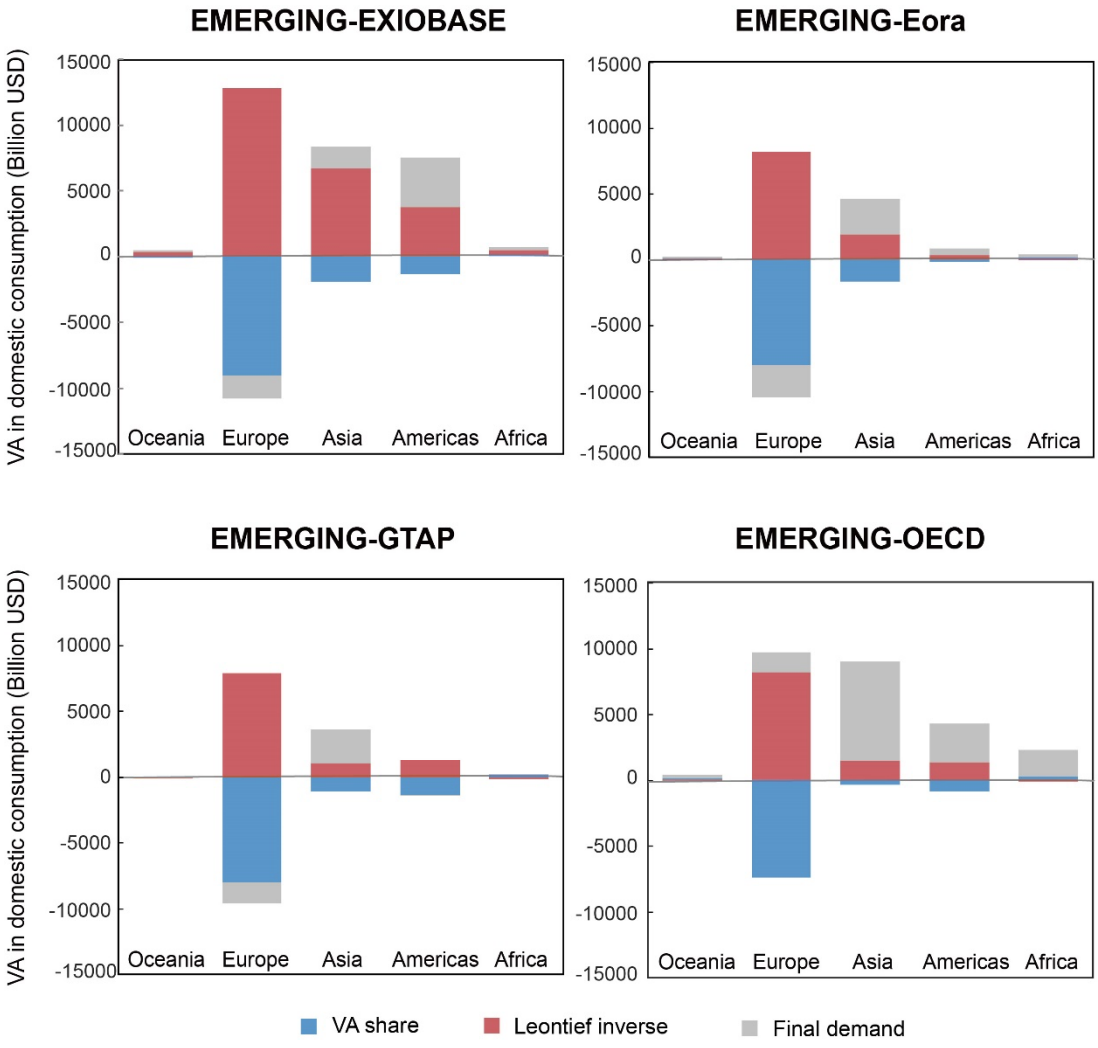
642

643 **Figure 2. Comparison of consumption-based VA accounts between five MRIO databases.** (a)
644 with the 17 aggregated sectors; (b) with the selected 12 detailed key sectors. Underlying data for
645 Figure 2 are available in Github at: https://github.com/Jingwenhuo/EMERGING_1212.git .



646

647 **Figure 3. Smallest differences between the EMERGING database and four other MRIO**
648 **databases in domestic production and consumption estimates.** (a, c) VA of domestic production,
649 (b, d) VA of domestic consumption. The colour represents the database with the smallest gap in
650 comparison to figures for the economies in EMERGING. The VA accounts displayed in the X
651 coordinate is the VA-account result calculated by EMERGING. Underlying data for Figure 3 are
652 available in Github at: https://github.com/Jingwenhuo/EMERGING_1212.git .



653

654 **Figure 4. SDA decompositions of variation in regional consumption-based VA accounting**
655 **between EMERGING and four other databases.** Underlying data for Figure 4 are available in
656 Github at: https://github.com/Jingwenhuo/EMERGING_1212.git .

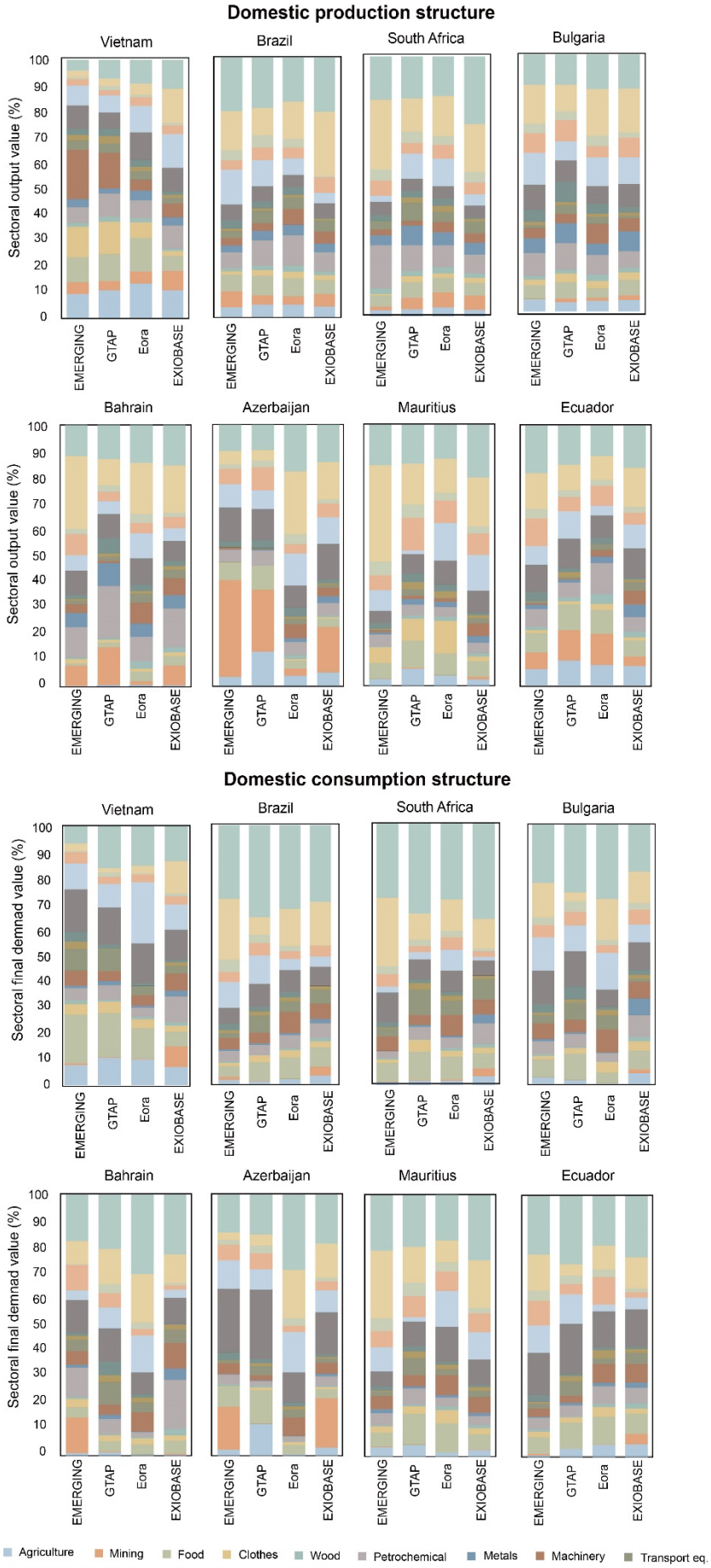

Domestic production structure
Vietnam
Brazil
South Africa
Bulgaria
Bahrain
Azerbaijan
Mauritius
Ecuador
Sectoral output value (%)
0
10
20
30
40
50
60
70
80
90
100
EMERGING
GTAP
Eora
EXIOBASE
Domestic consumption structure
Sectoral final demnad value (%)
Agriculture
Mining
Food
Clothes
Wood
Petrochemical
Metals
Machinery
Transport eq.
Manufacturing
El & gas
Construction
Trade
Transport
Post & telecom.
Financial & business
Public sector

Figure 5. The economic structure of domestic production and domestic consumption of the selected eight emerging economies across four databases. Underlying data for Figure 5 are available in Github at: https://github.com/Jingwenhuo/EMERGING_1212.git .