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Title: Addressing technical issues in the compilation of the AfCIOT and TiVA indicators in Africa

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ABSTRACT

This paper addresses the technical issues encountered while compiling the African Continental Input-Output Table (AfCIOT) and the calculation of Trade in Value Added (TiVA) indicators in Africa. The AfCIOT, developed by the United Nations Economic Commission for Africa (ECA), is a significant tool for supporting the African Continental Free Trade Area (AfCFTA). The paper details the methodologies adopted, including the standardization of national classifications, balancing of Supply-Use Tables (SUTs), and the creation of inter-country tables. Challenges such as data gaps and the use of machine learning for classification are discussed, alongside strategies for data dissemination. This study emphasizes the AfCIOT's potential to enhance statistical capacity and inform policymaking for regional integration in Africa.

Introduction

This paper describes the technical compilation process of the first African regional Input-Output table, entitled the African Continental Input-Output Table (AfCIOT), led by the United Nations Economic Commission for Africa (ECA). The main objective of this tool is to support the implementation of the African Continental Free Trade Area (AfCFTA) through the calculation of Trade in Value Added (TiVA), carbon embodied in trade, and employment indicators for African countries. Such indicators will allow for an in-depth understanding of countries' positioning in regional and global value chains that will empower governments, development partners, and other policymakers to make informed decisions for regional integration. The research responds to the question: How to develop a regional input-output table to promote regional integration in a data-constrained environment?

The defining feature of the AfCIOT is the detailed representation of African countries through a "bottom-up" approach based on the country's Supply-Use Tables (SUTs), National Accounts (NAs), and trade statistics. It generates indicators for these countries and other foreign countries originating from OECD's Inter-Country Input Output (ICIO). The process of building the AfCIOT is a tool for the statistical capacity development of African countries. It allows the identification of data gaps that, in turn, foments interactions with Member States.

The development of AfCIOT follows the OECD's methodology as closely as possible, allowing for the data limitations of the region. The steps are 1) standardization to international classifications; 2) balancing and updating of national SUTs based on their NAs; 3) conversion from purchasers' to basic prices and from SUT to IOT; 4) separation of the use table into domestic and import matrices; 5) construction and balancing of the inter-country use table (ICUT) and inter-country supply table (ICST); 6) conversion to IO table; and 7) production of indicators. This paper highlights the adaptation of these methods to the African context.

Key to the AfCIOT's compilation is the matching of national product and industry descriptions with international standards CPC and ISIC 4 codes at a two-digit level. These codes are used by AfCIOT to enable integration with the OECD's ICIO. To perform this task, an expert system for semi-automated classification was developed. This module involved tests with machine learning, Large Language Models (LLMs), text mining, and expert assessment.

The technical compilation also involves several balancing steps using RAS-based methods. These steps are performed both at the individual country data level to harmonize with country NAs and at the aggregated level to balance international trade flows. Where key indicators are missing for the required year and country, cluster analysis alongside econometric regression provides estimations. These estimations shall be replaced with country data as direct discussions with Member States progress. Countries not explicitly represented are incorporated into the "Rest of the World".

Data dissemination is also a key aspect, with the development of an interactive platform using the R programming language. R's shiny package provides users with a user-friendly interface for visualization of the indicators and download of the underlying data. A country profile, with key visualizations and descriptive text, can also be exported from the interface. This platform supports a multilingual interface to cater to a diverse user base, enhancing accessibility and engagement.

In conclusion, this paper will detail not only the technical processes behind the AfCIOT but also explore its dissemination strategy; underscoring its potential to drive informed policymaking and foster regional integration in Africa amidst data constraints.

Methodology

The development of the AfCIOT closely follows the OECD's methodology, with adaptations to accommodate the data limitations of the African region. The key steps involved are:

1. **Standardization of International Classifications**: Aligning products and industries with international standards such as CPC and ISIC 4 codes.

2. **Balancing and Harmonization of National SUTs**: Ensuring consistency with national accounts.

3. **Conversion from Purchasers to Basic Prices and from SUT to IOT**: Adjusting for trade margins, transport costs, taxes, and subsidies.

4. **Separation of the Use Table into Domestic and Import Matrices**: Distinguishing between locally produced and imported goods and services.

5. **Construction and Balancing of the Inter-Country Use Table (ICUT) and Inter-Country Supply Table (ICST)**: Integrating and aligning data across countries.

6. **Conversion to Input-Output Table (IOT):** Transforming the data into a comprehensive IOT format.

7. **Production of Indicators**: Generating Trade in Value Added (TiVA), carbon embodied in trade, and employment indicators for analysis and policymaking.

These steps ensure the AfCIOT is robust, comparable, and useful for analyzing economic activities within Africa and with the rest of the world.

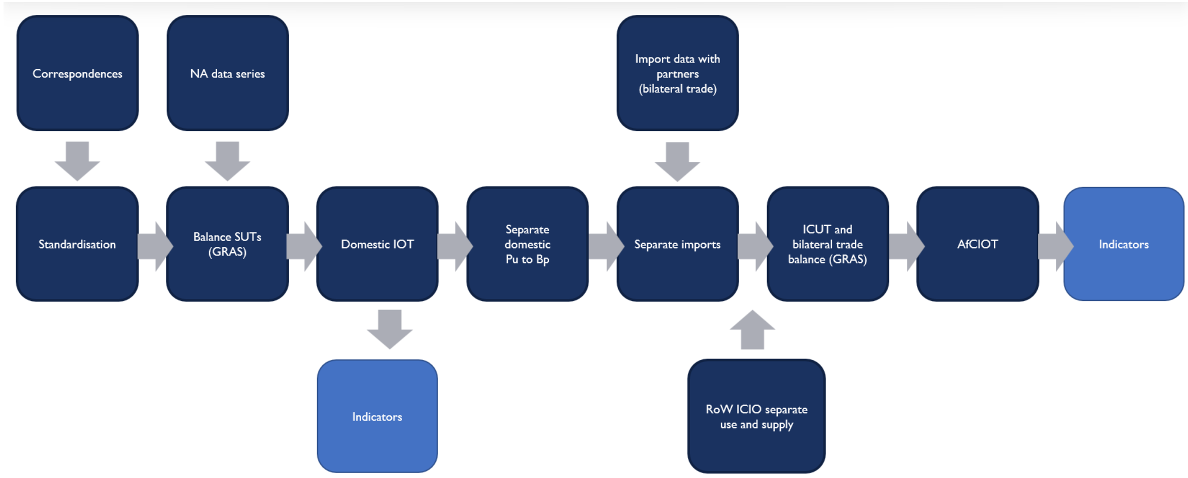

Figure 1: Schematic of the AfCIOT methodology.

DATA INPUTS

Classification

The classification task aims to convert national product and industry classifications to the standard ones used in AfCIOT. For products, AfCIOT uses 87 categories, originating from CPA 2.1 at the two-digit level. The table below provides this classification.

For industries, it uses the 45 industries adopted by ICIO. However, at this classification stage, matches are made between local industries and two-digit level ISIC rev 4 initially and then matched to the ICIO category.

Table 1: List of industries and products used in AfCIOT.

Code (ICIO)	Industry (OECD's ICIO aggregation)	Industry (ISIC) / Products (CPA)
D01T02	Agriculture, hunting, forestry	01, 02
D03	Fishing and aquaculture	3
D05T06	Mining and quarrying, energy-producing products	05, 06
D07T08	Mining and quarrying, non-energy producing products	07, 08
D09	Mining support service activities	9
D10T12	Food products, beverages, and tobacco	10, 11, 12
D13T15	Textiles, textile products, leather and footwear	13, 14, 15
D16	Wood and products of wood and cork	16
D17T18	Paper products and printing	17, 18
D19	Coke and refined petroleum products	19
D20	Chemical and chemical products	20
D21	Pharmaceuticals, medicinal chemicals, and botanical products	21
D22	Rubber and plastic products	22
D23	Other non-metallic mineral products	23
D24	Basic metals	24
D25	Fabricated metal products	25
D26	Computer, electronic, and optical equipment	26
D27	Electrical equipment	27

Code (ICIO)	Industry (OECD's ICIO aggregation)	Industry (ISIC) / Products (CPA)
D28	Machinery and equipment, nec	28
D29	Motor vehicles, trailers and semi-trailers	29
D30	Other transport equipment	30
D31T33	Manufacturing nec; repair and installation of machinery and equipment	31, 32, 33
D35	Electricity, gas, steam, and air conditioning supply	35
D36T39	Water supply; sewerage, waste management, and remediation activities	36, 37, 38, 39
D41T43	Construction	41, 42, 43
D45T47	Wholesale and retail trade; repair of motor vehicles	45, 46, 47
D49	Land transport and transport via pipelines	49
D50	Water transport	50
D51	Air transport	51
D52	Warehousing and support activities for transportation	52
D53	Postal and courier activities	53
D55T56	Accommodation and food service activities	55, 56
D58T60	Publishing, audiovisual, and broadcasting activities	58, 59, 60
D61	Telecommunications	61
D62T63	IT and other information services	62, 63
D64T66	Financial and insurance activities	64, 65, 66
D68	Real estate activities	68
D69T75	Professional, scientific, and technical activities	69, 70, 71, 72, 73, 74, 75
D77T82	Administrative and support services	77, 78, 79, 80, 81, 82
D84	Public administration and defense; compulsory social security	84
D85	Education	85
D86T88	Human health and social work activities	86, 87, 88
D90T93	Arts, entertainment, and recreation	90, 91, 92, 93
D94T96	Other service activities	94, 95, 96
D97T98	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	97, 98

An application (also called “Expert system for semi-automated classification”) was developed in R Shiny to provide a semi-automated correspondence among the national classifications and the ones used in AfCIOT.

The application was developed based on data from seven countries, as described in the table below. The countries have different numbers of product and industry classifications and three different languages.

Table 2: Countries with descriptions to be classified.

Country	Language	# Categories
Guinea	fr	19
Kenya	en	154
Mali	fr	38
Mauritania	fr	26

Mauritius	en	59
Mozambique	pt	175
Rwanda	en	80

Data preparation

This step includes the preparation of an Excel file with two columns, the first the national code and the second the national description. Then the app is fed with existing correspondences between the standards used in AfCIOT and a broader collection of international standards, including different versions and languages. Both the standards codes and descriptions and the correspondences files were downloaded from https://unstats.un.org/unsd/classifications/Econ or the {concordance} R package. The third aspect of data preparation is the Lemmatization, by which the words in the text description of the standard categories are broken down into their dictionary form, or lemma. This is done with the support of the {udpipe} package. The process removes different stop words for each specific language {tidytext} and {tm}.

For the implementation of the algorithm to work, it is necessary to have:

- A table with all the standards and their correspondence with the target standard.
- A table with the new codes and descriptions. The country and the language should also be provided as columns.
- A table with the lemmatization of all the standard category names.
- The lemmatization code for the languages used.

In simple words, for each new national category, the algorithm will look for exact matchings on the target standard and on the non-target standards first. Then it will tokenize and lemmatize the new description; remove the customized stop words; and compute the number of those lemmas that are in the lemmas of each standard. Then, it will compute the distance between lemmas and choose the code of the closest correspondence. Afterward, it will expand or reduce the matching to n-digits classification, being the target number of digits.

The figure below shows a screenshot of the app after running the matching algorithm.

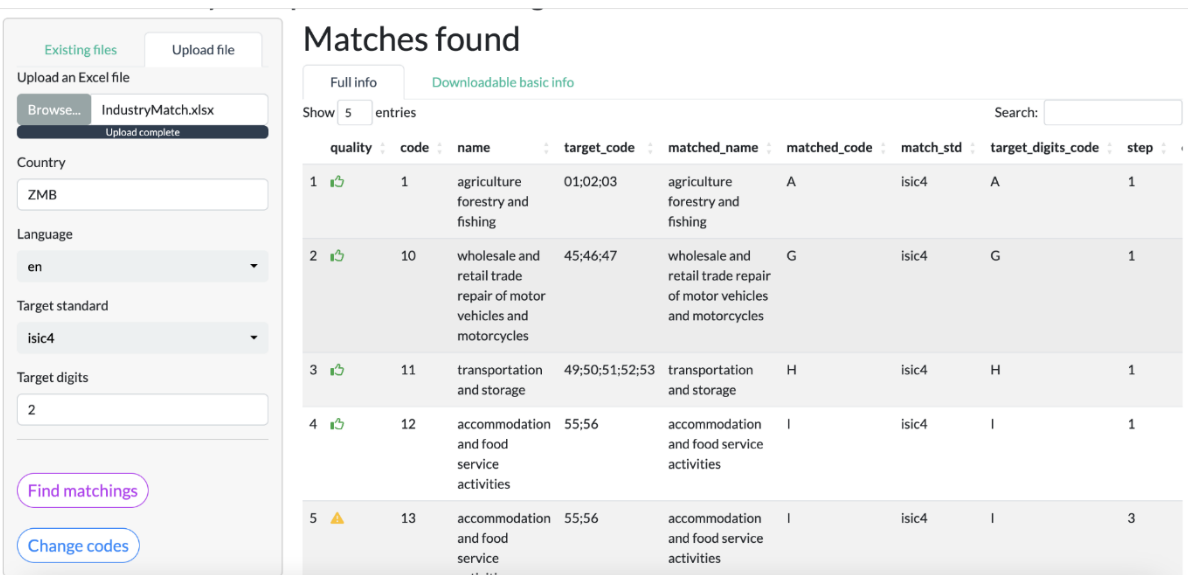

Figure 2: Screenshot of the app after running the matching algorithm.

Previous attempts

The first attempt to deliver this classification task applied distance in strings, also called the Similarity Approach and was based on an expert manual classification previously made for sixteen countries. This approach was not sufficient.

A machine learning approach using supervised classification was initially foreseen. That worked very well for small datasets and one-digit classification. However, it did not work for the large number of two-digit classifications and the large number of possible words in the new data to classify. In particular, random forests and Support Vector Machines were modeled with poor results.
Estimations: approach to estimate missing data as a placeholder for country data

We utilize National Accounts data, national Supply-Use Tables, and disaggregated trade data to construct the AfCIOT. The indicators required for the balancing and updating of SUTs are detailed in the table below.

Table 3: Indicators required for balancing and updating of SUTs.

Indicator	Indicator description
B.1*g	Value added at basic prices
B1_GE	GDP expenditure approach of national accounts
P1	output
P3	Final consumption
P31S14_P31S15	Final consumption of households, government and NPISH
P31S14	Final consumption expenditure of households
P31S15	Final consumption expenditure of non-profit institutions serving households
P3S13	Final consumption expenditure of general government
P5	Capital formation
P51	Gross fixed capital formation
P52	Changes in inventories
P6	Total exports
P61	Exports of goods
P62CB	Cross-border exports of services
P34	Final consumption expenditure of non-resident households on the territory
P7	Total imports
P71	Imports of goods
P72CB	Cross-border imports of services
P33	Final consumption expenditure of resident households abroad

Within these datasets, we encounter instances of missing data, prompting us to employ estimation techniques to bridge these gaps. This section elucidates our approach to estimating missing data.

The primary data sources from the national accounts are drawn from UNSD National account data, specifically from "National Accounts Estimates of Main Aggregates" and "National Accounts Official Country Data."[1] These datasets originate directly from the respective countries' National Statistics Offices. To address missing data, we employ the following methods:

- Utilization of algebraic identities within National Accounts.
- Incorporation of supplementary data from alternative sources.

[1] http://data.un.org/Explorer.aspx?d=SNAAMA

- Application of time series imputation (TS) utilizing a Kalman filter.
- Utilization of econometric modeling techniques.
- Median imputation based on data from neighboring and similar countries.

First step: Utilization of algebraic identities within National Accounts

When confronted with incomplete national accounts data for a country each year, we resort to leveraging the algebraic identities inherent in National Accounts, such as the GDP Expenditure Approach and the value-added approach.

For instance, suppose we possess data on GDP, investment, government expenditure, exports, and imports, yet lack information on consumption. By employing the GDP Expenditure Approach, which asserts that GDP equals the sum of final consumption (C), investment (I), government expenditure (G), and net exports (exports minus imports) — GDP = C + I + G + (X - M) — we can deduce the final consumption component through subtraction. This identity enables us to estimate missing data by branch and product.

While Gross Fixed Capital Formation (P51) constitutes a complete series and requires no estimation, the series on Changes in Inventories (P52) necessitates estimation. Estimating changes in inventories proves challenging due to its volatility, which can yield positive or negative values. Additionally, P52, combined with the Statistical Discrepancy, serves to balance the GDP expenditure approach equation. Although the series P5 is comprehensive in the UNSD dataset, it solely represents the sum of available items, meaning that if P52 is absent, it cannot be straightforwardly derived via subtraction (P52 = P5 - P51).

Second step: Incorporation of supplementary data from alternative sources

In instances where data is absent from the UNSD National Account data, including "National Accounts Estimates of Main Aggregates" and "National Accounts Official Country Data," we initially turn to the Balance of Payments (BOP) data sourced from the International Monetary Fund (IMF).[2] Subsequently, we consult the World Economic Outlook provided by the IMF, along with other datasets such as those from the International Labor Organization (ILO) for variables of employment. To mitigate currency-related discrepancies (e.g., current prices, base year), we normalize the data into ratio form.

The compensation of employee's series frequently encounters numerous missing values. To supplement employment information, we incorporate a series from the ILO. The ILO indicators utilized include:

- Employment by sex and age (thousands)
- Labor force participation rate by sex and age – ILO modeled estimates, Nov. 2022 (%)
- SDG indicator 10.4.1 - Labor income share as a percent of GDP (%)

Third step: Application of time series imputation (TS) utilizing a Kalman filter.

When a series for a country contains at least three values, we employ time series imputation (TS) utilizing a Kalman filter to interpolate the missing data across the entire timeline. As outlined by Kim and Bang (2018), the Kalman filter algorithm furnishes estimates of unknown variables based on

[2] https://data.imf.org/?sk=7A51304B-6426-40C0-83DD-CA473CA1FD52

observed measurements over time. The authors highlight the utility of Kalman filters across diverse applications, underscoring their effectiveness in data imputation.

Fourth step: Utilization of econometric modeling techniques.

We proceed with econometric modeling of the ratios of national accounts items (about GDP or sub-items), drawing upon expert knowledge, extensive literature, and thorough exploratory analysis to ensure the validity and reliability of our estimations.

For example, an econometric model may be employed to estimate the ratio of Final Consumption Expenditure of Households (P31S14) to Final Consumption Expenditure (P3). The ratio of Final Consumption Expenditure of NPISH is derived through subtraction from the combined item. Similarly, an econometric model is applied to estimate the ratio of Changes in Inventories to GDP (P52/GDP). Independent variables are meticulously selected following various tests, including regional dummies, the ratio of sectoral value added in "Accommodation and Food Services Activities" and "Electricity, Gas, Steam, and Air Conditioning Supply" to total value added, and the openness ratio.

At the national level, missing values are observed for output at basic prices (P1) and intermediate inputs at purchaser's prices (P2). Following time series imputation of output at basic prices (P1), an econometric model utilizing the sectoral breakdown of Value Added at Basic Prices (B1G) is employed to estimate output at basic prices (P1) in ratio form (P1/B1G). Given that B1G = P1 - P2, with B1G and estimated P1 in hand, intermediate inputs at the purchaser's prices (P2) are easily derived through subtraction (P1 - B1G).

Fifth step: Median imputation based on data from neighboring and similar countries.

In cases where no value is available, Median Imputation by neighboring and similar countries is considered for a National Accounts data item ratio, utilizing regional or subregional medians where applicable.

Following a time series estimation, econometric modeling is conducted using ratios derived from the sectoral breakdown of value-added, alongside variables from the International Labor Organization (ILO), such as labor force participation and labor income share. Subsequently, for any remaining missing values, median imputation of the ratio of Compensation of Employees (D1) over Value Added at Basic Prices (D1/B1G) is applied on a country-by-country basis, then by year and region, ensuring that the imputed data does not surpass a ratio of 0.6.

Throughout each step of imputing missing National Accounts data, visual inspections and summary statistics are generated to verify that the imputation does not significantly alter the median and standard deviation. Furthermore, it is imperative to preserve the algebraic identities of National Accounts from the second to the third steps. The first step may be reiterated after each subsequent step to address any remaining gaps.

STANDARDIZATION

Standardization to international classifications

Standardization is an essential process necessary for integrating African Supply-Use Tables (SUTs) into the African Continental Input Output Table (AfCIOT). Standardization is critical for ensuring consistency across diverse data streams from various African nations, enabling effective comparison and analysis on a continental scale.

The core objective of standardization is to ensure that all SUTs are comparable: it's akin to the concept of comparing "apples to apples." This means bringing data from different countries, which often have divergent approaches to economic structures, base years, and pricing systems, into one shared system. For example, if country A's SUT is valued in 2010's currency A for 20 industries and 10 products, and country B's SUT is in 2015's currency B for 15 industries and 20 products, standardization involves recalibrating both SUTs to a common year (e.g., 2018) and currency (e.g., USD), with a uniform classification of industries and products. Additionally, the inherent discrepancies in valuation methods within SUTs—such as supply valued at basic prices, use at purchasers' prices, imports at CIF, and exports at FOB—need alignment to basic prices (FOB) to ensure uniformity across all tables.

This next section sets out a comprehensive approach to the standardization of SUTs, which includes the following key steps (in order):

- Standardization of Products and Industries: Aligning local classifications to international standards to ensure compatibility across countries.
- Harmonization of Base Year: Updating all SUTs to a common reference year to eliminate temporal discrepancies.
- Currency Conversion: Converting all economic values to a common currency, facilitating direct comparisons.
- Price Level Adjustments: Transforming data from purchasers' prices to basic prices to standardize valuation bases.
- Separation of Domestic and Import Uses: Distinguishing between domestic production and imports within the SUTs to accurately reflect economic activities.
- Conversion from SUT to IOT: Transforming the standardized SUTs into a format suitable for input-output analysis, enhancing their utility for economic modeling and analysis.

Data inputs

The starting point for the standardization process is the national SUT, along with the National Account indicators compiled as set out in the previous section. Further on in this process, this data is combined with international trade sources from Comtrade, WTO and OECD, to allow for separation of imports by trade partners. One key difference between AfCIOT and other TiVA databases is the entrance requirement for being included in the database. AfCIOT requires the minimum national input that still allows for TiVA analysis, allowing for the inclusion of countries within Africa. However, the production of National SUTs varies in quality, structure, and size between countries reflecting the different economic structures and statistical systems of the countries. Currently, the dates of the SUTs in the database range between 2010 and 2020, with the number of products and industries varying between X and Y.

Table 4: Summary information about SUTs in AfCIOT.

Code	Country	Year	SNA year	# Products	# Industries	Industry Classification	Products Classification
AGO	Angola	2009	2008	77	34	ISIC Rev 4	CPC 2.0
BDI	Burundi	2014	1993	22	22	NAEMA (National Versions)	NOPEMA (National Versions)

BEN	Benin	2015	2008	24	24	ISIC Rev 4/NAEMA Rev 1	NOPEMA Rev 1
BWA	Botswana	-	-	0	0	-	-
CIV	Cote d'Ivoire	1996 - 2016	1993	44	44	ISIC rev 3.1/NAEMA	CPC 1.1/NOPEMA
CMR	Cameroon	2014 - 2017	2008	45	45	ISIC Rev 4/NAEMA Rev 1	NOPEMA Rev 1
DJI	Djibouti	2013	2008	26	26	NAEMA Rev 1	NOPEMA Rev 1
DRC	DR-Congo	2015	1993	32	32	NAEMA Rev 1	NOPEMA Rev 1
EGY	Egypt	2008/09, 2010/11, 2012/13	1993/2008	79	84	ISIC Rev 4	CPC 1.1
GHA	Ghana	2004, 2013	2008	101	58	ISIC Rev 4	CPC 2.1
KEN	Kenya	2009, 2016	2008	152	87	ISIC Rev 4	CPC 2.1
MAR	Morocco	2016, 2020	2008	41	42	ISIC Rev 4	CPC 2.0
MLI	Mali	2014	1993	24	24	NAEMA	NOPEMA
MOZ	Mozambique	2016	1993/2008	169	18	ISIC Rev 4	CPC 2.0
MRT	Mauritania	2014, 2015	2008	20	20	ISIC Rev 4	NOPEMA Rev 1
NGA	Nigeria	2010	2008	342	46	ISIC Rev 4	CPC 2.0
SEN	Senegal	2014 - 2020	2008	28	28	NAEMA Rev 1	NOPEMA Rev 1
SWZ	Eswatini	-	-	0	0	-	-
TCD	Chad	2016	2008	35	34	NAEMA	NOPEMA
TZA	Tanzania	2007	1993	252	59	ISIC Rev 4	CPC 2.0
UGA	Uganda	2009/10	2008	161	161	ISIC Rev 4	CPC 2.1
ZAF	South Africa	1993 - 2015	2008	200	200	ISIC Rev 3.1	CPC 2.0
ZMB	Zambia	2010	2008	63	24	ISIC Rev 4	CPC 2.1

In Africa, the diversity in classification is particularly evident. This is often a reflection of the strong reliance of the continent's national economies on agriculture—a sector that is underrepresented in international classification systems. For instance, African SUTs frequently feature detailed breakdowns for agricultural products like coffee, bananas, and cassava, while often consolidating various manufacturing activities into broader categories. This tailored approach helps in capturing the nuanced economic activities that are significant locally but may not be aligned with global categorization.

Adopted Classifications

For AfCIOT's classification of products, the Classification of Products by Activity (CPA) has been adopted. For industries, the International Standard Industrial Classification (ISIC) has been adopted as an intermediate step and, as a final step, the industries adopted by OECD's Inter-Country Input Output (ICIO) table were adopted to facilitate the incorporation of non-African countries originating from ICIO into AfCIOT.

Correspondence Tables

Each country's national codes thus need to be matched to the international classification. This task is initially handled by an automated system that maps local categories to CPA and ISIC based on predefined rules, as previously explained. However, due to local nuances and unique local economic activities, manual verification and adjustments are also necessary. This two-step approach ensures accuracy in aligning classifications.

Once the correspondence tables are complete, one can understand the nature of the relationship between the national and international classifications, vital for determining the treatment of the data. The first case is where a national category exactly matches an international one (1:1), for example, "crude oil" in a national classification directly matches "crude petroleum" in the CPA. In this case, no manipulation needs to take place and the values can remain as is. The next case is a many-to-one case (M:1), where several national categories fit into one international category: for example, the breakdown of vegetables into plantain, cassava, and other vegetables, all fit into the "fresh vegetable" CPA. In this case, the multiple categories are simply aggregated – this is relatively straightforward and generally does not introduce discrepancies. Finally, the trickiest situation is where there is a one-to-many relationship (1:M), where a single national category splits into multiple international categories. This division is more complex and typically requires assumptions about distribution ratios, which may not accurately reflect real-world proportions but are necessary for initial estimations. For example, a single category of "manufacturing" might need to be divided into "metal manufacturing," "plastic manufacturing," and "furniture manufacturing" in ISIC.

Table 5: Relationships in the construction of correspondence tables.

Match	Description	Example	Treatment
m:1	many to one: where many national products fit into one category of the international standard.	In Africa, it is common to separate key agricultural products such as cassava, banana, cocoa, and coffee. These all fit into CPA 01 Agricultural products.	Aggregate.
1:m	one to many: where one national product fits into many international products.	For example, many African countries group all types of manufacturing into one Manufacturing industry, whereas in ISIC there are 24 types of manufacturing at the two-digit level.	Divide by several categories matched with (for example by 24 in the case of manufacturing).
1:1	one to one: where there is an exact match between the national and international classification	This is common for mining categories (coal, gas, quarrying, and support services), as well as some service categories such as education and health.	No change.

Processing steps

Once the relationship between national and international categories has been identified for each product and industry, the SUT can be processed. First, the products are approached, aligning according to the relationships identified, where M:1 relationships are summed, 1:M relationships are divided equally among the matched international categories, and 1:1 relationships remain unchanged. After products, the process is mirrored for industries, ensuring that industry classifications also align with international standards. There are specific categories each for the supply and use table that also need to be adjusted accordingly. In the use table, components such as value added are treated as products, and final demand components are treated as industries. In the supply table, primary inputs (P1) are considered products, while imports and margin categories are treated as industries.

Quality Assurance and Checks

After the standardization is performed, the following checks are conducted to assess whether the standardization was accurate:

- **Economic Identities:** Check that each total of the standardized SUT aligns with the original SUT, and verify key economic identities such as:
    - Input (Value Added + Intermediate Consumption) = Output (by industry)
    - Total Supply at Purchasers' Prices = Total Use at Purchasers' Prices (by-product)
- **Sectoral Analysis:** Ensuring that sector-specific data such as services or agriculture are accurately captured and reflect the economic significance within the national context.
- **Temporal Consistency:** Checking data over time to ensure that changes in classifications or economic conditions do not introduce anomalies.
- **International Comparison:** Comparing the standardized data with similar economies to check for outliers or significant deviations that might indicate issues in data collection or classification.

Balancing and harmonization of national SUTs based on their Nas

Once all country SUTs are following the international categories, they can be updated and balanced to a common year, such as the base year 2018. This is done using publicly available national account data for 2018 which forms the boundary, or totals, with which to align the information inside the SUT.

Boundary Development and Application

The SUT updated totals that are required are twofold: the row totals, or the total supply at purchasers' prices, which is equal to the total use at purchasers' prices by-product, as a key identity of the SUT; and the column totals, which is the output by industry in the case of the supply table, and the intermediate consumption in the case of the use table.

These are taken from indicators in the national accounts. The first step is to fix the value added by each sector; value added is fixed first due to its critical nature as an economic indicator, and to its often more reliable estimation. In the second step, the output by each sector is established, ensuring it aligns with the economic data. While some data exists on industry breakdowns of these indicators, currently the implemented approach is to break down totals by the 45 ICIO industries using underlying standardized SUTs.

For calculating supply, the relevant figures are the trade, transport, and tax margins; for sure they are the final expenditure indicators and capital formation. Most of this data exists, where it does not exist at an itemized level, it can be found at an aggregated level which can then be broken down into more detailed components through econometric analyses of similar countries.

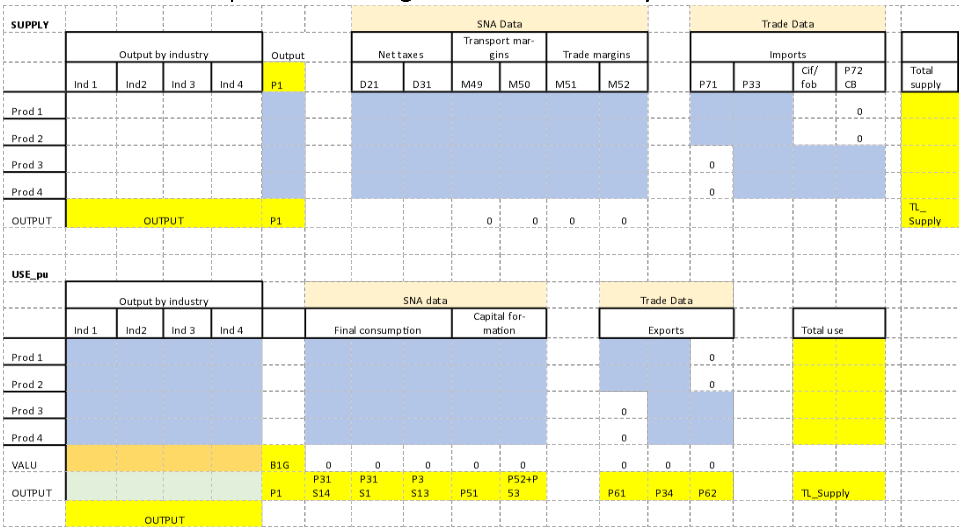

Figure 3: Illustration of how the data blocks of national accounts and trade statistics are coupled to the SUT framework.

GRAS Method for Balancing SUTs

The Generalized RAS (GRAS) method is an iterative technique used to balance and update the SUT according to the boundaries described above. It uses "correct" boundaries to re-estimate the internal part of the matrix such that the row and column totals are aligned to these correct totals. It does this in a step-by-step procedure: first adjusting the row (row normalization) whereby rows of the matrix are adjusted to match the total known row margin, ensuring that each row aligns with the actual economic data; followed by a column adjustment (column normalization) where columns are then adjusted to ensure that their totals align with the known column margin totals. This is the start of an iterative process in which row and column adjustments are alternated until the internal entries of the matrix converge to match the known margin totals closely. This iterative adjustment ensures that the entries within the SUT are consistent and reliable, reflecting the actual economic transactions accurately.

Applying GRAS and Setting Boundaries

The GRAS procedure is applied to four parts of the SUT. The supply table is balanced first. The "final demand" component of the supply table is balanced using the total supply at purchasers' prices and updated output and net tax indicators from the SNA as shown in Balance 1 of the diagram. Once this is balanced, the output column (P1 by-product) provides the row total or boundary for the make matrix (the intermediate part of the supply table), along with the output estimated by industry which makes the column totals as shown in Balance 2 of the diagram. This balances the supply table. The use table is then balanced. First, the final demand component of the table is balanced. The row total boundary is used to balance the supply table to maintain the supply equals demand identity of SUTs. The column total boundaries are total intermediate consumption, final consumption and capital formation as shown in Balance 3 of the diagram. Again, the intermediate consumption column from the balanced final demand component forms the row total boundary for the next stage. To balance the intermediate consumption, the intermediate consumption estimated by industry from the boundary development is used (see Balance 4 of the diagram). This then balances both tables, updating to 2018 and harmonizing with the SNA.

Balance 1: "Final demand" of supply table

Table 6: implementation of balancing "final" demand of supply table in AfCIOT.

Product / Industry	Total output (P1)	Imports of goods (P71)	Imports of services cross border (P72CB)	Direct purchases of residents abroad (P33)	Trade margins (M45M47)	Transport margins (M49M52)	Net taxes (D21_D31)	Total supply (TL_SUP)
87 CPA Products	Original SUT data	Original SUT data	Original SUT data	Original SUT data	Original SUT data	Original SUT data	Original SUT data	TL_SUP by SUT proportions
Total	National Account 2018 data	National Account 2018 data	National Account 2018 data	National Account 2018 data	0	0	National Account 2018 data	TL_SUP = rowSums

Balance 2: "Intermediate" supply table

Table 7: "Intermediate" supply table.

Product/ Industry	45 ICIO industries	Total output (P1)
87 CPA Products	Original SUT data	P1 by product from Step 1
Total	Total decomposed by SUT proportions	Total from National Accounts 2018

Balance 3: Final demand of use table

Table 8: Final demand of use table.

Product/ Industry	Total intermediate consumption (IC)	Exports of goods (P61)	Exports of services cross border (P62CB)	Direct purchases of non-residents in territory (P34)	Final demand (FD) units	Total use (TL_USE)
CPA Products 2 digit	Original SUT data	Original SUT data	Original SUT data	Original SUT data	Original SUT data	TL_SUP from supply table
Total	Total IC from SNA P1 – SNA B1	BoP IMF – SNA estimation	BoP IMF – SNA estimation	BoP IMF – SNA estimation	2018 National Accounts	Total supply = Total use from 2018 national accounts

Balance 4: Intermediate consumption

Table 9: Intermediate consumption.

Product/ Industry	ICIO industries	Total Intermediate consumption
CPA Products 2 digit	Original SUT boundary	Intermediate Consumption by Product from Step 3
Total	Estimated B1 by 45 ICIO industries– estimated P1 by ICIO	From Step 3

Quality Checks and Adjustments

This process also helps to ensure some of the basic requirements for SUTs and key identities hold. Firstly, it ensures that supply at purchasers' prices is equal to use at purchasers' prices for every product. This check ensures that all recorded transactions are balanced within the table, reflecting accurate tracking of economic flows. In addition to this there must be consistency in the calculation of Gross Value Added (GVA) across the three primary estimation techniques—production, expenditure, and income approaches. We also then put in place some additional checks to ensure key economic identities such as value added plus intermediate consumption equals output hold true across the balanced tables.

The application of these balancing techniques and quality checks ensures that the SUTs used in the AfCIOT are both accurate and harmonized, providing a reliable basis for economic analysis and decision-making across Africa.

CONVERSION FROM PURCHASERS TO BASIC PRICES

Conversion Principles

The conversion from purchasers' prices to basic prices involves removing valuation matrices; i.e. adjusting for trade margins, transport costs, taxes, and subsidies that are included in the purchasers' prices but not in the basic prices. This adjustment is necessary to isolate the producers' costs and revenues directly associated with the production process to return to the basic price as is recorded in the supply table.

Valuation Matrices

Valuation matrices play a key role in this conversion process. They account for the various additions and subtractions required to move from purchasers to basic prices: trade and transport margins are removed as they represent costs added after the production process, such as distribution and retailing; and adjustments are made to remove taxes levied on products and include subsidies provided on the production.

Step-by-Step Conversion

In an ideal world, the basic prices would be estimated through reverse engineering. Achieving price conversion through this methodology would require possession of separate domestic and import use tables, as the costs associated with these can differ significantly, particularly in terms of transport and tariffs. The trade and transport margins are reassigned to the relevant rows of the domestic production; for example, if an apple cost $1 at purchaser's prices but this includes a 10% trade and transport margin, then the basic price is $0.9 and the $0.1 gets added to the trade and transport industries. Finally, taxes such as VAT, excise duties, and import tariffs are removed from the respective table prices, while subsidies that directly affect production costs are added to the basic prices.

Practical Implementation in AfCIOT

Due to varying levels of detail in national SUTs, the conversion process often relies on generalized assumptions. Margin and tax matrices are constructed based on the available data. Where detailed data are lacking, the matrices use the columns provided by the supply table and average proportions derived from the underlying SUT. Then, as most countries do not have a separate domestic and import use table, the import proportionality assumption is applied, which assumes that imports are utilized in similar proportions across all industry inputs and final uses, with adjustments made based on the specific economic sector and known trade patterns.

The conversion process can be broken down into three major steps:

1. **Margin Matrices:** Calculate and apply adjustments for trade and transport margins based on their proportion in the total costs associated with each product.
2. **Tax Matrices:** Adjust for taxes and subsidies using proportionality to reflect their impact on the price. This results in the use table at basic prices.
3. **Import Adjustment:** Apply the import proportionality assumption to separate the imports and domestic use tables at basic prices.

Balanced Updated Supply Table

Product/ii	D01T02	D03	D05	P1	D21_D31	M45M52	P71_P72CI	cif/fob ad	P33	TL_SUP
01	21	21	0	41	0.0	0.5	9.7		0.0	52
02	21	21	0	41	0.0	0.5	9.7		0.0	52
03	12	12	170	194	-1.0	-1.0	20.6		3.0	215
04	0	0	23	23	0.0	0.0	0.0		0.0	23
Total (P1)	54	54	193	300	-1	0	40		3	342

Balanced Updated Use Table (Purchasers' Prices)

Product/ii	D01T02	D03	D05	TIC	P31S14_P3	P5	TL_USE
01	3	3	16	22	18	0	40
02	3	3	16	22	18	0	40
03	32	29	73	134	52	3	189
04	5	5	11	22	0	0	22
Total (IC)	44	40	116	200	88	3	
VA	10	14	77				
				100			

Trade and Transport Margins

Product/ii	D01T02	D03	D05	TIC			Total
01	-0.50	0.00	0.00	-0.50			-0.5
02	0.00	-0.50	0.00	-0.50			-0.5
03	0.50	0.50	0.00	1.00			1.0
04	0.00	0.00	0.00	0.00			0.0
Total (IC)							

Margin proportions

Product/ii	D01T02	D03	D05	TIC			1/s
01							2%
02							2%
03	100%	100%	100%	100%			0%
04							4%

Revised Use Table

Product/ii	D01T02	D03	D05	TIC	P31S14_P3	P5	Total
01	3.72	2.96	15.95	22.64	17.72	0.00	40.4
02	3.22	3.46	15.95	22.64	17.72	0.00	40.4
03	31.18	28.63	73.20	133.01	52.27	3.00	188.3
04	5.45	5.01	11.25	21.71	0.00	0.00	21.7
Total (IC)							

Revised Use Table Proportions

Product/ii	D01T02	D03	D05	TIC	P31S14_P3	P5	TL_USE
01	9%	7%	40%	56%	44%	0%	1
02	8%	9%	40%	56%	44%	0%	1
03	17%	15%	39%	71%	28%	2%	1
04	25%	23%	52%	100%	0%	0%	1

Figure 4: Step 1.

Net Tax Margins

Product/ii	D01T02	D03	D05	TIC	P31S14_P3	P5	Total
01	0.00	0.00	0.00	0.00	0.00	0.00	0.0
02	0.00	0.00	0.00	0.00	0.00	0.00	0.0
03	-0.17	-0.15	-0.39	-0.71	-0.28	-0.02	-1.0
04	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Total (IC)							

Use Table at Basic Prices

Product/ii	D01T02	D03	D05	TIC	P31S14_P3	P5	Total
01	3.72	2.96	15.95	22.64	17.72	0.00	40.4
02	3.22	3.46	15.95	22.64	17.72	0.00	40.4
03	31.34	28.78	73.59	133.72	52.55	3.02	189.3
04	5.45	5.01	11.25	21.71	0.00	0.00	21.7
Total (IC)							

Use Table Proportions v3

Product/ii	D01T02	D03	D05	TIC	P31S14_P3	P5	TL_USE
01	9%	7%	40%	56%	44%	0%	1
02	8%	9%	40%	56%	44%	0%	1
03	17%	15%	39%	71%	28%	2%	1
04	25%	23%	52%	100%	0%	0%	1

Figure 5: Step 2.

Use Table at Basic Prices

Product/ir	D01T02	D03	D05	TIC	P31S14_P:	P5	Total
01	3.72	2.96	15.95	22.64	17.72	0.00	40.4
02	3.22	3.46	15.95	22.64	17.72	0.00	40.4
03	31.34	28.78	73.59	133.72	52.55	3.02	189.3
04	5.45	5.01	11.25	21.71	0.00	0.00	21.7
Total (IC)							

Use Table Proportions v3

Product/ir	D01T02	D03	D05	TIC	P31S14_P:	P5	TL_USE
01	9%	7%	40%	56%	44%	0%	1
02	8%	9%	40%	56%	44%	0%	1
03	17%	15%	39%	71%	28%	2%	1
04	25%	23%	52%	100%	0%	0%	1

Imports table

Product/ir	D01T02	D03	D05	TIC	P31S14_P:	P5	Total
01	0.70	0.56	3.00	4.25	3.33	0.00	7.6
02	0.61	0.65	3.00	4.25	3.33	0.00	7.6
03	2.99	2.75	7.03	12.78	5.02	0.29	18.1
04	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Total (IC)							

Import proportions

Product/ir	D01T02	D03	D05	TIC	P31S14_P:	P5	Total
01	0.19	0.19	0.19	0.19	0.19	0.19	0.4
02	0.19	0.19	0.19	0.19	0.19	0.19	0.4
03	0.10	0.10	0.10	0.10	0.10	0.10	0.2
04	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Total (IC)							

Domestic Use Table

Product/ir	D01T02	D03	D05	TIC	P31S14_P:	P5	Total
01	3.02	2.41	12.96	18.39	14.39	0.00	32.8
02	2.62	2.81	12.96	18.39	14.39	0.00	32.8
03	28.35	26.03	66.56	120.94	47.53	2.73	171.2
04	5.45	5.01	11.25	21.71	0.00	0.00	21.7
Total (IC)							

Figure 6: Step 3.

Challenges and Limitations

The main challenges in this conversion arise from incomplete data and the need to make assumptions about the distribution of costs and margins. These challenges are addressed currently by applying the SUT proportions for distributing these margins. However, by not having the breakdown of types of taxes, all taxes are applied in the same way to both domestic and import use tables. Similarly, as separate import use tables are not available, the same trade and transport margins are also applied to both domestic and import products.

CONVERSION FROM SUT TO IOT

The conversion of Supply-Use Tables into Input-Output Tables is a key stage in creating an analytical framework that supports economic analysis and policymaking. This step is also used as a check on the conversions made up to this stage. Furthermore, the consideration of forward and backward linkages and multiplier coefficients and their comparison with those produced by the economy's original IOT (when available) or similar economies, enables the identification of errors in the process. The UN Handbook details four sets of assumptions (or models) for the conversion of SUTs into IOTs. Models A and B convert the SUT to product-by-product tables, whereas Models C and D convert to industry-by-industry tables. In practice, Models A and D are commonly utilized by national statistics offices because of their practical applicability. Model D is notably popular as it simplifies the transformation process and avoids the potential for negative outputs that can occur in Models A and C. This fixed product sales assumption (Model D) posits that each product has a specific sales structure across different industries. This model is favored for industry-by-industry IOTs and is particularly used in policy-making due to its straightforward application and relevance.

Implementation of Model D

To convert the SUTs now at basic prices into IOTs, AfCIOT applies Model D. The four steps involved in implementing Model D are:

1. **Constructing the Market Share Matrix (T):** Begin by constructing the market share matrix where each cell of the supply table is divided by the total output of the row. This matrix represents the proportion of each product's total output that each industry contributes.
2. **Transposing the Market Share Matrix:** Transpose this matrix to align industries to products, resulting in a matrix dimension of ni×np (industries by-products).

3. **Matrix Multiplication:** Multiply the transposed market share matrix by the use table converted to basic prices. This multiplication integrates both the intermediate consumption and final demand components, producing an IOT of industries by industries (ni×ni)
4. **Normalization:** Finally, normalize each column in the IOT by the total production of the industry. This normalization yields the technical coefficient matrix (A), essential for further economic analysis using Leontief's model.

Analytical Applications

Once the IOT is established, significant economic analysis can be performed, including calculations of economic output, value-added multipliers, labor outcomes, and environmental impacts. These analyses are pivotal in understanding the economic interdependencies of different policy strands and assisting in effective policy formulation.

INTEGRATION

Introduction

Integrating standardized national economy Supply-use Tables (SUTs) for the African Continental Input-Output Table (AfCIOT) with each other requires the separation of imports by a partner. This task involves separating and classifying imports from AfCIOT countries, and non-AfCIOT countries, and addressing the remaining balance, also known as the Rest of the World (RoW).
This section of the paper will methodically detail the theory of integration through imports through three distinct steps:

- Step 1: Separation of AfCIOT Countries' Imports
- Step 2: Separation of Non-AfCIOT Countries' Imports
- Step 3: RoW (remaining balance)

A mixture of theoretical discussion, methodological exposition, and practical examples support each of these steps, illustrating the complexities involved in handling international trade data within a unified economic modeling framework.

Purpose and Integration with ICIO

The table below represents how the standardized African countries are integrated, and the OECD's ICIO. This step requires deconstructing the OECD's ICIO tables and integrating its countries as trade partners with AfCIOT countries. On the diagonal, there are the domestic Input-Output tables of each country. On the off-diagonal, there are the imports of each country from the country indicated on the left-hand side, i.e. the yellow highlighted cell indicates what ICIO's Country 1 imports from ICIO Country n.

So far in the integration, we have effectively produced the domestic IO for the AfCIOT countries (22 currently). We have also developed an import use table of the total imports of each AfCIOT country from the World. As a first step, we have to break this into each of the import countries represented in the model, i.e. the 21 other AfCIOT countries, the ICIO countries, and the remaining balance (Rest of the World). This column (column 3) represents all matrices estimated from the underlying SUTs of the African countries combined with trade data. These countries, except the African countries explicitly in the ICIO model, all form part of the RoW in the OECD's model. Thus, the creation of this column effectively split up the ICIO's RoW into the AfCIOT countries and the "remaining balance". At the same time the AfCIOT countries also split the ICIO's RoW into two; using trade data we can estimate the imports of the ICIO country from each African country and estimate a revised RoW on the remaining balance.

		1	2	3	4
		ICIO Country 1	ICIO Country n	RoW 1 (AfCIOT Country 1)	RoW 2 (Remaining)
1	ICIO Country 1	ICIO A (IO)	ICIO B	AfCIOT	ICIO E
2	ICIO Country n	ICIO B	ICIO A (IO)	AfCIOT	ICIO E
3	RoW 1 (AfCIOT Country 1)	ICIO C	ICIO C	AfCIOT (IO)	ICIO F
4	RoW 2 (Remaining)	ICIO D	ICIO D	AfCIOT	ICIO G (IO)

Figure 7: Illustration of AfCIOT.

Step 1: Separation of AfCIOT Countries' Imports

The first step is to separate AfCIOT countries' imports. This approach is different from that taken for non-AfCIOT countries as we are working with the underlying SUTs. As an African-focused model, our focus is on receiving data from African NSOs and estimating data gaps sufficient for global integration. We then merge these with IOTs already processed into the OECD global database.

The methodology for this integration is centered around the import proportionality assumption, a key concept in the African input-output model designed to estimate the distribution of imported goods and services across various industries and final use categories. This assumption was previously used to separate domestic and import use tables for production of domestic national IOTs, we now apply the imports by partner.

Purpose and Data Requirements

This Component requires both the standardized supply and use table and the trade boundaries. The trade boundaries are produced by taking data from Comtrade for trade in goods, and WTO/OECD's BaTIS database for trade in services, which separate trade by partner. A conversion from the database's used classification (Harmonized System – HS – for Comtrade and EBOPS for BaTIS) to the 87 CPA products is carried out.

The partners here include AfCIOT countries and those in the OECD's Inter-Country Input Output (ICIO) model that we will be incorporating. It also produces boundaries for each country's RoW (i.e. the remaining amount after removing AfCIOT and ICIO countries from total imports).

Methodology Overview

The import proportionality assumption posits that imports are utilized in similar proportions across all industry inputs and final uses, except exports and re-exports. To implement this, the ratio of imports by each partner to domestic supply for each product is determined first. This ratio is then used to proportionally allocate the imports across each product used by industries as intermediate inputs and by final use categories, excluding exports. For example, if 50% of semiconductors are imported from Country B, it is assumed that each industry using semiconductors also imports 50% of its semiconductor needs from Country B. This approach ensures a uniform distribution of imports across different uses, highlighting the significance of detailed product categorization in the SNA for achieving accuracy.

Implementation Process

The implementation involves first taking the proportion of partners' imports by CPA as per the trade boundaries and producing a proportion out of the total supply. This proportion is then applied to the use table at basic prices. The mathematical expression for this is provided below, where mp are the partner imports, sbp is the supply table at basic prices, Ubp is the use table at basic prices, and Ux- is the intermediate consumption and Uf is the final demand.

This then provides us with the imports for each country by partner.

Evaluation and Adjustment

After applying the proportionality assumption, it is crucial to evaluate the results for reasonableness and make necessary adjustments based on the specific operations of each economy. This method not only aids in correcting imbalances in GDP calculations and the distribution of Gross Value Added (GVA) by industry but also addresses challenges in allocating imports for changing inventories, necessitating careful handling of negative values.

Step 2&3: Integration with OECD's ICIO

Methodology for Integrating Non-AfCIOT Imports

The key challenge in integrating the ICIO lies in redefining what constitutes the Rest of the World (RoW) for the OECD, separating it into African countries now part of the AfCIOT and the remaining RoW. This separation is crucial as it impacts how imports are accounted for within the AfCIOT framework. The steps include:

- Component A (Domestic IO ICIO Tables)
- Component B (Imports between ICIO Countries)
- Component C (Estimating ICIO's Imports from Africa)
- Component D: Re-calculating ICIO's Remaining Imports from RoW
- Component E: Estimating RoW's Imports from ICIO Countries
- Component F: Estimating RoW's Imports from AfCIOT Countries

		ICIO Country 1		ICIO Country n		RoW		
		A	B	A	B	A	B	Total
ICIO Country 1	A	0	10	1	9	49	31	100
	B	10	0	9	1	31	49	100
ICIO Country n	A	7	3	2	2	41	45	100
	B	3	7	8	8	39	35	100
RoW	A	23	57	49	37	10	24	200
	B	57	23	31	43	30	16	200
	Total	100	100	100	100	200	200	

Figure 8: Example of OECD's ICIO.

Step 2: Separation of Non-AfCIOT Countries' Imports

Step 2 of the paper, focusing on the separation of Non-African/Non-AfCIOT Countries' Imports, extends the analysis to encompass imports originating from countries outside of the AfCIOT. This inclusion is crucial for a comprehensive integration of global trade dynamics within the AfCIOT framework. In particular, for Africa, where the majority of imports and exports are still outside of the continent, the dynamics of these relationships are important to incorporate.

Methodology

Component A (Domestic IO ICIO Tables): This involves segregating the countries from the integrated matrix into their separate parts, which is achieved by selecting the column of a specific country, transposing, and then re-selecting the country to isolate its domestic input-output table.

		ICIO Country 1	
		A	B
ICIO Country 1	A	0	10
	B	10	0
ICIO Country n	A	7	3
	B	3	7
RoW	A	23	57
	B	57	23
	Total	100	100

Figure 9: Select Country 1.

		ICIO Country 1	
		A	B
ICIO Country 1	A	0	10
	B	10	0

Figure 10: Transpose and select Country 1.

Component B (Imports between ICIO Countries): Each of the other ICIO countries is then selected one by one to define the imports input-output matrix and the final demand components for each country.

		ICIO Country 1	
		A	B
ICIO Country n	A	7	3
	B	3	7

Figure 11: Imports between ICIO countries.

Component C (Estimating ICIO's Imports from Africa): This step estimates the trade matrices between each ICIO country, and each African partner included in the AfCIOT model using the trade boundaries estimated. These boundaries are converted from CPA classification to ICIO classification, and then applied to generate the import use table by the African partner.

ICIO Country 1's imports

ICIO industry	AfCIOT Country 1	RoW
A	3	20
B	2	10

Figure 12: Trade boundaries data.

Each country in the ICIO model has a RoW import matrix. We thus use the proportions of the RoW imports in use table and assume this is representative of the distribution for each country in AfCIOT. We apply these import use table proportions to the trade boundary by the ICIO industry to produce the import use table by an African partner.

Figure 7: RoW proportions for ICIO Country 1

		ICIO Country 1	
RoW	A	29%	71%
	B	71%	29%

Figure 13: RoW proportions for ICIO Country 1.

For each ICIO country, we then need to estimate the imports IO tables for African countries which are not yet estimated in OECD’s model, but rather form part of the RoW grouping. The usual method to calculate this we apply the import proportionality assumption; first use the imports by product and partner, calculate the ratio of imports to supply; and then apply these proportions to the use table. However, we do not have the country’s supply table – rather we have the IO table. The adjusted methodology, therefore, is to use the proportions of imports from RoW (according to the IO of the RoW in the OECD model) as representative of African countries. The proportions then apply to the trade by the ICIO industry and African partners and are distributed according to these IO proportions.

ICIO imports from Africa		ICIO Country 1	
		A	B
AfCIOT 1	A	0.9	2.1
	B	1.4	0.6

Figure 14: Estimated import matrix between ICIO Country 1 and AfCIOT Country 1.

Addressing Non-AfCIOT Imports in SUTs

The methodology discussed also highlights how imports from non-African/non-AfCIOT countries are differentiated from African imports in the SUTs and the implications this has for economic analysis within the AfCIOT framework.

Step 3: RoW (Remaining Balance)

Step 3 of the paper addresses the Rest of the World (RoW) category, which encapsulates all other global economic interactions not previously covered in the integration of African and non-African/non-AfCIOT countries' imports within the AfCIOT framework. This step is crucial for ensuring that the economic activities of non-participating regions are accurately and coherently represented in the AfCIOT.

Defining the RoW Category

Purpose: Reconstructing the OECD's Rest of the World (RoW) category by removing African countries now included in the AfCIOT.

The RoW category within the context of AfCIOT SUTs includes all countries and regions not explicitly categorized under AfCIOT or non-AfCIOT entities. This comprehensive grouping ensures that global interactions impacting the African continent are considered, even if they originate from countries outside of the direct trade data networks of AfCIOT and ICIO (Inter-Country Input-Output) participants.

Methodology for Estimating RoW Imports

The process of recalculating and integrating RoW imports is segmented into several key components:

Component D: Re-calculating ICIO's Remaining Imports from RoW: This component focuses on adjusting the ICIO's RoW IO in the OECD model by removing the aggregated imports attributed to the newly included African countries within AfCIOT. This recalibration is essential to accurately reflect the remaining RoW's economic interactions after accounting for direct African engagements.

ICIO imports from RoW

		ICIO Country 1	
RoW	A	22.1	54.9
	B	55.6	22.4

Figure 15: ICIO's "remaining" imports from RoW.

Component E: Estimating RoW's Imports from ICIO Countries: RoW's imports from ICIO countries are recalculated by subtracting the African countries' imports from the total ICIO imports, using established trade boundaries that summarize trade across all non-AfCIOT and non-ICIO countries by the 45 ICIO industries.

RoW imports			
	African Country 1	ICIO Country 1	ICIO Country n
A	15	30	20
B	35	10	15

Figure 16: Trade boundaries for RoW.

The trade proportions of RoW with each ICIO country are then applied to distribute these revised trade boundaries, providing updated estimates of RoW's import matrices from each ICIO country.

RoW's import proportions from ICIO Country 1

		RoW	
		A	B
ICIO Country 1	A	61%	39%
	B	39%	61%

RoW's import proportions from ICIO Country n

		RoW	
		A	B
ICIO Country 1	A	48%	52%
	B	53%	47%

Figure 17: RoW proportions of imports from ICIO Country 1 and Country n.

RoW's imports from ICIO		RoW	
		A	B
ICIO Country 1	A	18	12
	B	4	6

RoW's imports from ICIO		RoW	
		A	B
ICIO Country 1	A	10	10
	B	8	7

Figure 18: Applying these proportions to the trade data provides us with estimates of the import matrix of RoW imports from each ICIO country.

Component F: Estimating RoW's Imports from AfCIOT Countries: To calculate RoW's imports from AfCIOT countries, trade boundary data, which provide the estimated imports of RoW from these countries, are utilized.

RoW proportions		RoW	
		A	B
ICIO Country 1	A	29%	71%
	B	65%	35%

Figure 19: RoW IOT proportions.

The distribution of these imports across industries follows the structure of RoW's existing IOT, assuming similar industry distribution patterns as those observed within AfCIOT.

RoW's imports from Africa		RoW	
		A	B
AfCIOT Country 1	A	4	11
	B	23	12

Figure 20: Estimation of RoW imports from Africa.

Component G: Domestic RoW Input-Output Table: The final step involves adjusting the RoW's IO table in the OECD's ICIO model by subtracting the IO tables of each AfCIOT country. This adjustment reflects the revised economic interactions of the RoW after accounting for direct engagements with AfCIOT countries.

		African Country 1	
		A	B
African Country 1	A	3	2
	B	2	3

Figure 21: IOT from AfCIOT for AfCIOT Country 1.

		RoW	
		A	B
RoW	A	7	22

	B	28	13

Figure 22: Revised RoW IOT.

The key check here is that the total world balance, the sum of all columns and rows, should remain the same. So, the total output and input of Product A should be equal, and the same as the world production of Product A. By leaving the Rest of the World as a remaining balance this ensures this condition is met. Each country's RoW should still be checked for accuracy along with all other estimated matrices.

Future improvements

Specific Product Considerations: Certain products like crude oil or food items have straightforward allocations due to their limited use in the domestic economy. The import proportionality assumption may also utilize the Broad Economic Categories (BEC) classification, which categorizes imports into intermediate, consumer, and capital goods. Although this method is resource-intensive, particularly during initial setup, it is essential for generating detailed allocation ratios and percentages for each import category and accommodates secondary outputs where products are used in non-typical industries.

Non-AfCIOT country integration: Currently the integration of ICIO bases on Input-Output tables, assuming a diagonal supply table, and applying the import proportionality assumption. It would be better to move to a system of integration with supply and use tables.

DISSEMINATION

Dissemination Tool

The AfCIOT App is an innovative, interactive visualization tool for exploring and getting insights from the different indicators calculated by the AfCIOT model. It was developed in R Shiny and contains several features. Below is the description of the main ones.

- **Map:** The map on the landing page shows the countries that are included in the current version of the app.
- **Multilingual:** The UN has six official languages, being two (English and French) considered working languages. Therefore, to better address the needs of Member States, the app was developed to be multilingual. The package xx
- **Availability and metadata of indicators.**
    - Indicator code, name, units, and dimensions.
    - Insights on policy simulation
    - Groupings (RECs, subregions, world zones etc).
    - Indicators: descriptions and units in English and French.
    - Dimensions: Dimensions of the TiVA indicators.
    - Industries: Industry code and description by language.
    - Geographical data: Geographical information for the indicators. There are different geographical levels, i.e.: a country, a region (composed of several countries), the World (WLD), or the rest of something, e.g., ROW for the rest of the World, ROA for the rest of Africa, and so on.
    - Country profile
    - Data visualization for analysis
    - Time series
    - Ranking

- Matrix

Dissemination strategy

The AfCIOT could inform policymakers and foster regional integration, including the implementation of AfCFTA, in Africa in several ways. Beyond merely intra-trade information, the AfCIOT offers insights into the intricate interactions among various intra-country and inter-country branches through its continental Input-Output Table. This data is indispensable for comprehending the depth of economic and regional integration. For instance, it delineates Kenya's financial sector exports utilized in Tanzania's transport infrastructure, and reciprocally, Tunisia's agricultural sector exports employed in Algeria's catering industry. Such cross-border exchanges underscore the interconnectedness of regional economies and emphasize the importance of collaborative policy initiatives.

The AfCIOT offers insights into various trade-in-value-added indicators, including Domestic Value Added, Indirect Domestic Value Added, Foreign Value Added, Backward Participation, Forward Participation, and Global Value Chain. Domestic Value Added in Gross Exports estimates the value added by an economy in producing goods and services for export. It is calculated as the difference between gross output at basic prices and intermediate consumption at purchasers' prices, according to OECD (2013). Foreign Value Added in Exports measures the value added in exports whose inputs are sourced from foreign industries.

The Indirect Domestic Value Added in exports refers to the value added embodied in the exports of other countries, representing the upstream contributions of domestic value added from other industries. This is also termed as Domestic Value Added sent to third economies. The proportions of Foreign Value Added and Indirect Domestic Value Added in gross exports signify backward and forward participation or linkages, respectively. These components enable the estimation of Global Value Chain Participation, which is the aggregate of backward and forward participation. This metric illustrates the extent to which a country or sector is integrated into the global or regional value chain.

These indicators are pivotal for assessing the efficacy of regional and continental free trade agreements and gauging the level of economic integration. Domestic value added between African countries signifies the economic contribution of a product whose inputs are sourced domestically within the context of export partnerships. Consequently, smoother conditions for free trade facilitate easier product exchange and higher levels of domestic value added. In analyzing the benefits of Global Value Chains (GVCs) for domestic economies, CEPR (2015) proposed that engagement with global production networks can enhance productivity and lead to spillover effects for the domestic economy. This assertion is supported by examples such as the successful integration of the Czech Republic and South Korea into global value chains. Kummritz et al. (2017) demonstrated, through a literature review and empirical modeling, that participation in Global Value Chains facilitates Economic Upgrading. They observed that global value chain integration increases domestic value added, particularly on the selling side, a trend consistent across all income levels. UNCTAD (2013) identified a correlation between growth in GVC participation and GDP per capita, noting a stronger correlation in developed countries compared to developing ones and in years post-2000 compared to pre-2000.

Regional economic and trade integration assumes greater significance in analyzing Foreign Value Added and Indirect Domestic Value Added, which contribute to backward and forward participation, respectively, as these indicators entail the involvement of at least three countries. Significant values at the continental level signify a profound degree of regional integration. For example, the foreign value added of Ghana's electrical equipment can shed light on the value added of the Ghanaian economy regarding its exports of electrical equipment to Nigeria, which sources inputs from Senegal.

Similarly, the Indirect Domestic Value Added of Burkina Faso's telecommunications sector could illuminate the value added in Burkina Faso's economy concerning its exports to Cameroon, which are then embodied in Cameroon's exports to Gabon. Thus, understanding these values provides insight to countries regarding the benefits they can derive from regional and continental integrations, including the AfCFTA. Llop (2024) demonstrated that economic interdependencies could influence the value added of exports. Additionally, Kummritz et al. (2017) suggested that a diverse range of policy measures at the national level can contribute to economic upgrading through global value chains, by focusing on aspects such as global value chain integration, and the quality and conditions of input and output factors. Ibrahim and Vo (2020) discovered that increased economic integration stimulates sectoral value added, particularly impacting the industrial sector in Sub-Saharan Africa. They concluded that this effect persists, albeit unevenly, when economic integration is analyzed across different forms, with the impact of trade integration consistently outweighing that of financial integration.

Indicators also reveal the contributions of countries' industries to the production of goods and services in other countries. For instance, they demonstrate how one country's energy sector supports another country's agricultural sector, or how a country's manufacturing sector benefits from another country's financial sector. These diverse examples underscore the significance of trade-in-value-added indicators in assessing the effectiveness of various trade and regional integration agreements. Jangam (2022) presented compelling evidence of a robust relationship between global value chain linkages and domestic value-added content at the sector level, as demonstrated through empirical analysis.

In addition to economic implications, global value chains also have a positive impact on social factors such as education, health, and inequality. Durongkaveroj (2023) discovered that increased integration into global value chains could serve as a policy tool to bolster recovery from ongoing health and economic crises, as evidenced by findings from Thailand.

CONCLUSION

The main focus of this paper was to elucidate the intricate process involved in compiling the African Continental Input-Output Table (AfCIOT), the first of its kind for the African region. This table, aimed at overcoming technical challenges in compiling AfCIOT and TiVA indicators in Africa, represents a significant stride towards fostering regional integration within a data-constrained environment. Its development constitutes a vital contribution to the realization of the African Continental Free Trade Area (AfCFTA).

The construction of the AfCIOT relies on data from various sources, primarily Supply-Use Tables (SUTs), National Accounts (NAs), and international trade statistics from individual countries. The primary data sources from national accounts are drawn from UNSD National Account data, specifically from "National Accounts Estimates of Main Aggregates" and "National Accounts Official Country Data," obtained directly from the respective countries' National Statistics Offices.

Encountering instances of missing data prompted the adoption of several methods to address these gaps:

- Utilization of algebraic identities within National Accounts.

- Incorporation of supplementary data from alternative sources.
- Application of time series imputation (TS) utilizing a Kalman filter.
- Utilization of econometric modeling techniques.
- Median imputation based on data from neighboring and similar countries.

As Supply-Use Tables (SUTs) are not produced annually, the SUTs utilized are typically the most recent ones available close to the base years. Established balancing methods, such as the GRAS method, have been employed to align the SUTs with the National Accounts of the base years. The GRAS procedure is applied across four components of the SUT, encompassing: (1) The "final demand" component of the supply table, (2) industry-estimated output within the supply table, (3) the final demand component of the use table, and (4) industry-estimated intermediate consumption within the use table.

For the AfCIOT, aggregated international trade statistics by product, service, and trade partners were utilized to the fullest extent. Correspondence tables were employed to harmonize classifications, such as transitioning from CPA to CPC, from HS to CPA for goods, and from EBOPS to CPC for services. Additionally, OECD's ICIO data for non-African countries complemented the AfCIOT. Exchange rate information was also employed to convert values from local currency to USD.

The development of the AfCIOT adhered to the OECD's methodology while considering African contexts regarding data limitations, data quality, classifications used, and the integration of new statistical methods such as machine learning and Large Language Models (LLMs). The AfCIOT encompasses 87 product categories originating from CPA 2.1 at the two-digit level and 45 industries, aligning local industries with ISIC rev 4.

The initial step in building the AfCIOT methodology involved standardization to international classifications, which encompassed the following key steps in order:

- Standardization of Products and Industries.
- Harmonization of Base Year.
- Currency Conversion.
- Price Level Adjustments.
- Separation of Domestic and Import Uses.
- Conversion from SUT to IOT.

The methodology also encompasses the conversion from purchasers to basic prices, which involves adjusting for trade margins, transport costs, taxes, and subsidies included in purchasers' prices but not in basic prices. A crucial step in building the AfCIOT is the conversion of Supply-Use Tables into Input-Output Tables, a pivotal stage in creating an analytical framework supporting economic analysis and policymaking. Bilateral trade flows are essential for constructing and balancing the inter-country input-output table and elaborating the rest of the world block.

The AfCIOT carries significant implications both statistically and in terms of economic policy. On the statistical side, the AfCIOT App stands as an innovative, interactive visualization tool for exploring and gaining insights from the various indicators calculated by the AfCIOT model. Features include the AfCIOT tool itself, a map on the landing page illustrating countries included in the current version of the app, multilingual options, indicator availability and metadata, country profiles, and data visualization tools for analysis.

In terms of policy, the AfCIOT holds the potential to inform policymakers and promote regional integration in Africa, particularly by facilitating the implementation of the AfCFTA and providing intra-trade information. It also offers insights into trade-in-value-added indicators, including Domestic Value Added, Indirect Domestic Value Added, Foreign Value Added, Backward Participation, Forward Participation, and Global Value Chain. Beyond economic implications, global value chains have positive impacts on social factors such as education, health, and inequality, underscoring the significance of the AfCIOT.

Future Improvements and Recommendations

The African Continental Input Out Table is a crucial tool for analyzing, and more importantly, building up African economies. Future improvements are essential to overcome current limitations and enhance the robustness and applicability of this pioneering economic tool. These measures include:

- **Coverage of SUTs:** Improving the database of Supply-Use Tables (SUTs) by engaging with African governments and national statistical offices (NSOs) to ensure access to the most up-to-date tables and collaborating on establishing accurate national accounts boundary data.

- **Country-specific correspondence tables:** Developing country-specific correspondence tables and refining allocation shares between local classifications and their international counterparts to further enhance data accuracy and usability.

- **Accuracy of valuation matrices:** Improving the availability and accuracy of valuation matrices, particularly those used in estimating basic prices for the import use table, which will enable more precise conversions and calculations.

- **Econometric techniques:** Integration of more sophisticated econometric models and advanced data integration techniques, to address the existing gaps in data, methodology, and technology. This progression will not only refine the standardization and balancing methods but also expand the analytical capabilities of the AfCIOT, making it a more effective instrument for economic analysis and policy formulation across Africa.

In conclusion, the main findings underscore the necessity of a standardized and balanced AfCIOT for sound economic analysis, which can significantly influence economic policy and research across the continent. By ensuring that the AfCIOT is accurate, comprehensive, and reflective of the diverse economic environments across Africa, policymakers and researchers can better understand economic dynamics and craft policies that foster sustainable growth and development.

Appendix I

Balancing: description of balancing methodologies and existing challenges; discussion on the construction of boundaries

Although countries routinely produce National Accounts data on an annual basis, the collection of Supply and Use Tables (SUTs) is infrequent. Stanger (2018) emphasizes that SUTs entail a substantial amount of data and that numerous countries do not consistently possess such detailed information. The author highlights that crafting a thorough and accurate SUT demands considerable time, complicates the compilation process, and requires additional expertise to prevent subjective or biased adjustments. Due to resource constraints in many nations, SUTs are typically assembled only every few years, presenting a notable challenge.

In several African countries, the most recent SUT data predates 2015. For instance, according to Table 1 of the Progress report on the implementation of the 2008 System of National Accounts and related statistical systems in Africa at the eighth meeting of the Economic Commission for Africa Statistical Commission for Africa (United Nations, 2022), Angola and Seychelles have SUTs data from 2014, Ghana from 2013, Zimbabwe from 2012, Nigeria and Zambia from 2010, and Liberia from 2008. Additionally, the report indicates that other African nations, including Eritrea, Lesotho, Libya, Namibia, Sierra Leone, Somalia, South Sudan, and Sudan, lack available SUTs.

To construct IO Tables, having SUTs for the base years is crucial. However, in the absence of SUTs for these years, balancing methods are employed to estimate them. For example, although Kenya's last available SUT is from 2016, if we aim to develop our AfCIOT for the years 2017, 2018, and later 2022, balancing methods enable us to approximate SUTs for these years while maintaining the original SUT's structure and preserving the values of the National Accounts for the respective years.

Eurostat (2019) emphasizes that Balancing serves not only to ensure consistency between supply and use for each product and between output and input for each industry but also to identify discrepancies in fundamental data and estimation methods. Moreover, it is advantageous to balance the supply and use system at both current and constant prices simultaneously to ensure the accuracy and reliability of the data.

Even when SUTs are generated for base years, discrepancies with National Accounts values can arise due to various factors: differences in methodology, levels of aggregation, classifications used, or statistical errors. The methodology used to estimate values for national accounts differs from that used for SUTs; the latter involves more intricate and disaggregated methodologies, necessitating the determination of interactions among different sectors, whereas national accounts primarily deal with aggregate values. Stanger (2018) highlights those differences in methodologies, survey errors, classification inconsistencies, and varying levels of aggregation contribute to such discrepancies.

Consider the example of household wheat production discussed by Eurostat (2019). Eurostat (2019) thought that a discrepancy was attributed to the assumption that all household-produced wheat was consumed by households for their use, without changes in inventory or involvement in trade activity. This discrepancy was interpreted as representing household wheat production, with its value serving as the balancing item.

The standard procedure for mechanical adjustment involves the proportional distribution of discrepancies. To illustrate, consider a simple scenario with three branches, three products, and a single sector (household) for final use, as depicted in Table 1 below.

Table 10: Example of production and use.

	Intermediate Use			Final use			
	Agriculture	**Industry**	**Services**	**Household**	**Total row**	**Output**	**Balancing**
Crops	25	15	12	40	92	100	8
Factories	7	20	5	20	52	58	6
Services	10	17	30	30	87	90	3

Balancing entails ensuring that the sum of the rows equals the outputs while maintaining consistent proportions. To achieve this, each element in the first row is multiplied by 100 and divided by 92, each element in the second row is multiplied by 58 and divided by 52, and each element in the third row is multiplied by 90 and divided by 87, resulting in Table 2.

Table 11: Balancing the Total rows.

	Intermediate Use			Final use			
	Agriculture	**Industry**	**Services**	**Household**	**Total row**	**Output**	**Balancing**
Crops	27.17	16.30	13.04	43.48	100	100	0
Factories	7.81	22.31	5.58	22.31	58	58	0
Services	10.34	17.59	31.03	31.03	90	90	0

The primary challenge of proportion distribution arises when you need to balance both the total row and the total column simultaneously. Let's consider the example of an array representing the availability of intermediate requests by branch, where discrepancies exist with the total column.

Table 12: Example of production and use.

	Intermediate Use			Final use			
	Agriculture	**Industry**	**Services**	**Household**	**Total row**	**Output**	**Balancing**
Crops	25	15	12	40	92	100	8
Factories	7	20	5	20	52	58	6
Services	10	17	30	30	87	90	3
Total column	42	52	47	90			
Intermediary demand	40	60	50	90			
Balancing	-2	8	3	0			

By using the proportion method to balance total rows, Table 4 is obtained, resulting in adjustments to the discrepancies in the total columns.

Table 13: Balancing the Total rows.

	Intermediate Use			Final use			
	Agriculture	**Industry**	**Services**	**Household**	**Total row**	**Output**	**Balancing**
Crops	27.17	16.30	13.04	43.48	100	100	0
Factories	7.81	22.31	5.58	22.31	58	58	0
Services	10.34	17.59	31.03	31.03	90	90	0
Total column	45.33	56.20	49.65	96.82			
Intermediary demand	40	60	50	90			
Balancing	-5.33	3.80	0.35	-6.82			

Now, we will balance the total column using the proportion method.

Table 14: Balancing the total Columns.

	Intermediate Use			Final use			
	Agriculture	**Industry**	**Services**	**Household**	**Total row**	**Output**	**Balancing**
Crops	23.98	17.41	13.13	40.42	94.94	100	5.06
Factories	6.89	23.82	5.62	20.74	57.06	58	0.94
Services	9.13	18.78	31.25	28.85	88.00	90	2.00
Total column	40.00	60.00	50.00	90.00			
Intermediary demand	40	60	50	90			
Balancing	0.00	0.00	0.00	0.00			

Thus, when balancing the total columns, the total rows become unbalanced, and vice versa if we start by balancing the row columns before the row total. Each time one of the total rows or columns is balanced, the other becomes unbalanced. Automatic methods have been developed to iteratively address this issue until both total rows and columns are balanced. For instance, the RAS method is widely recognized and commonly used for balancing Supply-Use Tables and Input-Output Tables, as noted by Trinh and Phong (2013). They mention that with the assistance of software, this procedure becomes efficient and rapid, regardless of whether the iteration is performed seven times or seven million times.

The Generalized RAS (GRAS) function serves as an automated mechanism to compile all iterations until balancing both dimensions. According to Temurshoev (2013), the GRAS function is a commonly employed bi-proportional technique for balancing/updating Input-Output (IO) matrices, accommodating both positive and negative elements. One of the notable features of the GRAS method is the availability of its analytical solution, facilitating its straightforward utilization in iterative procedures.

While attempting to balance Table 4 by total columns, the previously balanced total rows became unbalanced, yet the degree of discrepancies is lower compared to those in the former table (Table 3). Thus, with each iteration, the degree of discrepancies decreases relative to their previous levels when the other dimension is balanced. After several iterations, both total rows and columns may become balanced. However, in some cases, instead of the discrepancies decreasing with each iteration, they may increase after a certain point. These discrepancies may not converge to zero but diverge, even when using the GRAS function.

For instance, in constructing the AfCIOT, many countries have faced challenges where the GRAS function could not balance all four parts of the SUTs. In some countries, only one part of the SUT has been balanced using the GRAS function, while in others, two or three parts have been balanced. These issues often arise due to significant disparities between the SUTs and the National Accounts or simply because of algebraic problems in the iterative process.

Given these limitations in balancing using the GRAS function, alternative methods have been developed to balance SUTs and IOTs with National Accounts. For example, Stanger (2018) introduced the Supply and Use Table Balancing tool (SUTB), using the Cholette-Dagum regression-based reconciliation method. This approach involves least squares techniques of simultaneous equations, enabling multidimensional non-iterative distribution of discrepancies. In the construction of the AfCIOT, the proportion method was utilized in cases where convergence with the GRAS function was not achieved.

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