
# The GTAP 10A Multi-Region Input Output (MRIO) Data Base

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Research Memorandum No. 34
April 2020

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**Abstract**

This memorandum describes the GTAP version 10A Multi-Region Input Output (GTAP-MRIO) Data Base. GTAP-MRIO extends the standard GTAP Data Base (Aguiar et al., 2019) by additionally distinguishing bilateral trade and tariff flows by agents or so-called end-users, namely: firms, private household, government and investors. In constructing GTAP-MRIO, we employ the methodology in Carrico (2017) and update it in four ways. First, an updated concordance table is used—i.e., the United Nations Statistics Division (UNSD) 6-digit Harmonized System 2012 to Broad Economic Categories concordances revision 4 to System of National Accounts end-use framework (HStoBECtoSNA). Second, the International Trade Centre (ITC) Market Access Map (MAcMap) data is directly used in lieu of the TASTE utility (Horridge and Laborde, 2008) which is also based on MAcMap. Third, the optimization programs are updated to take advantage of grid facility in GAMS, thereby reducing MRIO data build time by 90 percent and easing MRIO data construction at the full dimensionality of GTAP data—i.e., 65-sectors and 141-regions for version 10A. Fourth, accompanying GTAPAgg2 (Horridge, 2019) and FlexAgg packages (Villoria and McDougall, 2012) are provided to aid researchers aggregate the GTAP-MRIO data.

**JEL Codes:** E01, E16, F13, F15
**Keywords:** MRIO, ICIO, International trade, Tariffs, Global value chains

**Suggested citation:** Carrico, C., E. Corong, and D. van der Mensbrugghe. 2020. "The GTAP version 10A Multi-Region Input Output (MRIO) Data Base". GTAP Memorandum 34. Center for Global Trade Analysis, Purdue University.

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# 1 Introduction

The global economy is increasingly organized along value chains which involve production stages being performed in different countries, with intermediate inputs crossing borders multiple times (Koopman et al., 2014). This global fragmentation of production[1] along with deepening economic integration efforts since the 1990s, resulted in 70% of current global trade being associated with value chains (OECD, 2020).

Understanding the economic and trade implications of global value chains (GVCs) has become an important research agenda since the early 2000s (Hummels et al. (2001); Baldwin (2011); Baldwin and Venables (2013); Backer and Miroudot (2013); (Koopman et al., 2014); Kowalski et al. (2015); Blanchard et al. (2016)).[2] The preferred method for GVC analysis relies on multi-regional input-output (MRIO) frameworks. An MRIO harmonizes input-output (IO) tables for multiple regions and links trade flows directly from producers or firms in each region to importing firms (hence, GVCs) and consumers in other regions. Earlier versions of MRIO produced at the GTAP Center include Walmsley et al. (2014) and Carrico (2017).

This memorandum describes the GTAP version 10A Multi-Region Input Output (GTAP-MRIO) Data Base. GTAP-MRIO extends the standard GTAP Data Base (Aguiar et al., 2019) by additionally distinguishing bilateral trade and tariff flows by agents or so-called end-users, namely: firms, private household, government and investors. In constructing GTAP-MRIO, we employ the methodology in Carrico (2017) and update it in four ways. First, an updated concordance table is used—i.e., the United Nations Statistics Division (UNSD) 6-digit Harmonized System (HS) 2012 to Broad Economic Categories (BEC) concordances revision 4 to System of National Accounts (SNA) end-use framework (HStoBECtoSNA). Second, the International Trade Centre (ITC) Market Access Map (MAcMap) data is directly used in lieu of the TASTE utility (Horridge and Laborde, 2008) which is also based on MAcMap. Third, the optimization programs are updated to take advantage of grid facility in GAMS, thereby reducing MRIO data build time by 90 percent and easing MRIO data construction at the full dimensionality of GTAP data—i.e., 65-sectors and 141-regions for version 10A. Fourth, accompanying GTAPAgg2 (Horridge, 2019) and FlexAgg (Villoria and McDougall, 2012) packages are provided to aid researchers aggregate the GTAP-MRIO data.

In summary, we construct GTAP-MRIO by first incorporating UNSD's HStoBECtoSNA and the GTAP Center's HS to GTAP concordances into MAcMap. We then aggregate over GTAP commodities, the trade and tariff data by end-users in MAcMap and consequently use these information to disaggregate their associated flows in the standard GTAP Data Base. Finally, we employ constrained optimization procedures to ensure that the GTAP-MRIO trade and tariff flows, when summed over end-users, aggregate back to the standard GTAP Data Base.

This memorandum is organized as follows. Section 2 summarizes the GTAP-MRIO data construction procedure (see Carrico (2017) for an extensive documentation). Section 3 provides bilateral tariff analyses at the economy-wide and end-user levels using a 10-region and 10-sector aggregate of GTAP-MRIO. Finally, Section 4 concludes and lists potential updates for the next, GTAP-MRIO version 11 Data Base.

[1] Baldwin (2011) traces the development of value chains to falling communication and co-ordination costs in the mid-1980s, which facilitated spatial separation of manufacturing stages.

[2] See also OECD global value chain webpage at https://www.oecd.org/sti/ind/global-value-chains.htm.

## 2 GTAP-MRIO Data

MRIOs are constructed from IO tables of different countries complemented by trade databases which contain bilateral trade flows by end-users, namely: firms, consumers, and investors. Figure 1 illustrates trade in an MRIO framework, by which producers in source region $s$ export commodity $c$, classified by end-use, to corresponding agents (producers, investors, and consumers) in importing region $d$.

There are three principal methods of MRIO construction. All methods rely on similar data requirements such as Input-Output (IO) tables, national accounts and bilateral trade data. However, the methods differ by which supplementary information is used in the construction of the final database. The simplest method relies only on IO data and trade flows, and assumes proportional sourcing of imports for all agents. A more complex method builds on the first method by using concordances which map between products and end-uses to differentiate between sourcing of imports across agents. Carrico (2017) goes one step further by additionally differentiating tariff rates across end-users.[3]

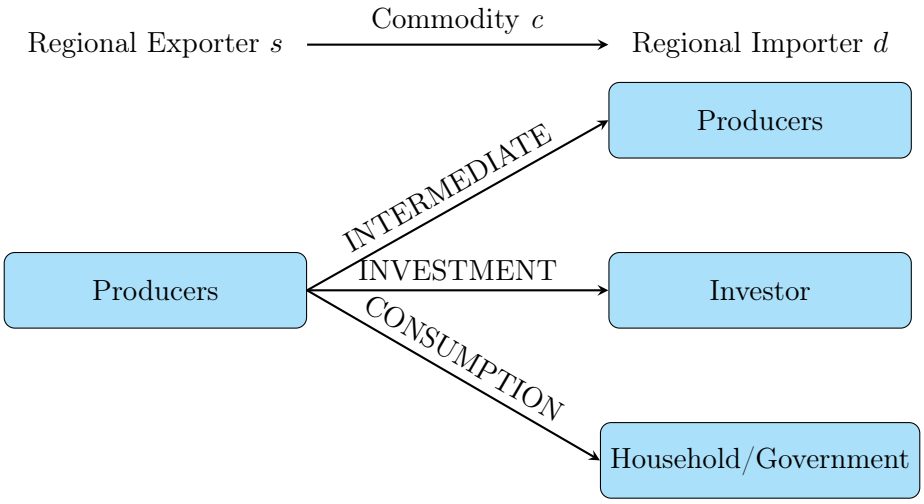



Figure 1: **The MRIO Framework**

IO tables show commodity demands for intermediate use by firms and for final use by private households, investors, and the government. In bilateral trade data like the GTAP Data Base or the UN COMTRADE database, country sourcing information is available for each commodity. However, neither GTAP nor COMTRADE contain information on whether a bilaterally traded commodity is intended for intermediate use or final consumption. Further, the distribution of demand for imports of intermediate products across industries remains unknown in both GTAP and UN COMTRADE data. In order to capitalize on the information available in detailed trade data like COMTRADE, the MRIO literature uses a system of concordances from UNSD. This system is depicted in Figure 2, which shows a mapping between HS product lines to Broad Economic Categories (BEC) and, in turn, to the end-use categories of the System of National Accounts (SNA) framework: capital goods, intermediate goods, and consumption goods.

MRIO methodologies which use the HStoBECtoSNA concordances (Figure 2) include the World Input-Output Database (WIOD) by Timmer et al. (2012) and MRIOs developed from the GTAP

[3] Corong et al. (2009) also differentiate tariff rates across end-users in their GTAP-based MRIO data.

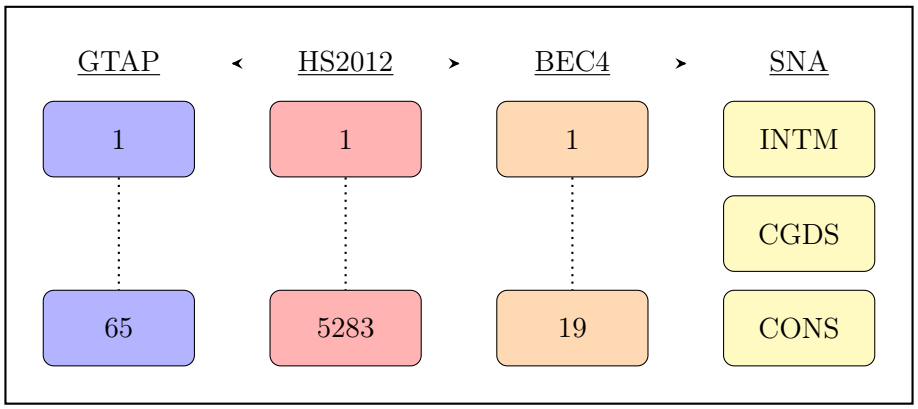



Figure 2: **HS to GTAP, HS to BEC to SNA Concordances**

data by Corong et al. (2009) and Tsigas et al. (2012), and MRIOs produced at the GTAP Center by Walmsley et al. (2014) and Carrico (2017). The WIOD team developed their own HS-BEC concordance by using a system of weights so that trade at each HS line would map to all three end-use categories, based on the HS to BEC concordance. Tsigas et al. (2012) initially used the UNSD HS-BEC concordance in Koopman et al. (2014), but later switched to using the WIOD HS-BEC concordance.

## 2.1 Towards an MRIO from the GTAP Data Base

To construct the GTAP-MRIO, we first incorporate into the MAcMap dataset, UNSD's 6-digit HS2012 to BEC revision 4 to SNA concordances. This allows us to map 5,204 unique HS codes to 19 BEC categories and in turn to 3 end-use categories shown in Table 1. This concordance shows a single direct mapping for 16 of the 19 BEC categories. For three BEC categories, namely: 32, 51 and 7, the UNSD indicates "not classified" which is a mix of end-uses. Therefore, we make simplifying assumptions. For BEC 32, we equally allocate trade values into intermediate and consumption goods, while we equally allocate trade values into consumption and investment for BEC 51. Finally, for BEC 7, we assume intermediate, final consumption and investment each account for one-third of trade values.

Next, we apply the GTAP-HS concordance, which is a one-to-many mapping between the 6-digit HS into 45 GTAP commodity sectors.[4] The process of reformatting the trade data begins with aggregation of the value of imports indexed on the HS line $h$, GTAP sectors $c$, BEC code $b$, SNA end-use categories $u$, source country $s$, and importing or destination country $d$ ($TVW_{h,c,b,u,s,d}$). We then aggregate the trade and tariff values over all HS lines by GTAP commodities and by SNA end-use category. This gives the value of imports indexed on GTAP commodity $c$, SNA end-use category $u$, source country $s$, and importing country $d$ ($TVW_{c,u,s,d}$) and value of tariff revenue for the same dimensions $TVM_{c,u,s,d}$.

[4]The 5,204 commodities only map to 45 commodities out of 65 GTAP sectors, since the other 20 GTAP sectors encompass services.

Table 1: **BEC to SNA Concordance**

| BEC[a] | BEC Description | SNA[b] |
|---|---|---|
| 111 | Primary food/bev for industry | INT |
| 112 | Primary food/bev for cons | CONS |
| 121 | Processed food/bev for industry | INT |
| 122 | Processed food/bev for cons | CONS |
| 21 | Primary industrial supplies n.e.s. | INT |
| 22 | Processed industrial supplies n.e.s. | INT |
| 31 | Primary fuels and lubricants | INT |
| 32 | Processed fuels and lubricants - motor spirit | INT, CONS |
| 322 | Processed fuels and lubricants - other | INT |
| 41 | Capital goods (except transport equipment) | CGDS |
| 42 | Capital goods - parts and accessories | INT |
| 51 | Transport equipment - passenger motor cars | CONS, CGDS |
| 521 | Transport equipment - other industrial | CGDS |
| 522 | Transport equipment - other non-industrial | CONS |
| 53 | Transport equipment - parts and accessories | INT |
| 61 | Durable consumer goods n.e.s | CONS |
| 62 | Semidurable consumer goods n.e.s | CONS |
| 63 | Nondurable consumer goods n.e.s | CONS |
| 7 | Goods n.e.s. | INT, CONS, CGDS |

*Notes:* [a] Broad Economic Categories (BEC). [b]System of National Accounts (SNA).

*Source:* Authors' compilation based on UNSD (2003).

## 2.2 Shares of Trade Value by End-Use

With tariff-inclusive trade values $TVM_{c,u,s,d}$ and tariff-exclusive trade values $TVW_{c,u,s,d}$, we calculate the shares of trade value by end-use for use in estimating the MRIO trade data. First, the share of bilateral trade value of a given commodity designated for a particular use, at market (tariff-inclusive) prices and world (cif) prices are computed as:

$$SHRM_{c,u,s,d} = \frac{TVM_{c,u,s,d}}{\sum_u TVM_{c,u,s,d}}$$
$$SHRW_{c,u,s,d} = \frac{TVW_{c,u,s,d}}{\sum_u TVW_{c,u,s,d}} \tag{1}$$

Specifically, $SHRM_{c,u,s,d}$ is the share of tariff-inclusive trade value of commodity $c$ from source $s$ for end-use $u$ in importing region $d$. Likewise, $SHRW_{c,u,s,d}$ is the share of tariff-exclusive (cif) trade value. We apply these two shares from MAcMap to the bilateral trade data ($VIMS^0_{c,s,d}$ and $VIWS^0_{c,s,d}$) in the standard GTAP Data Base to obtain initial estimates of the GTAP-MRIO tariff-inclusive trade $VIUMS^0_{c,u,s,d}$ and tariff-exclusive trade $VIUWS^0_{c,u,s,d}$.

$$VIUMS^0_{c,u,s,d} = SHRM_{c,u,s,d} VIMS^0_{c,s,d}$$
$$VIUWS^0_{c,u,s,d} = SHRW_{c,u,s,d} VIWS^0_{c,s,d} \tag{2}$$

Note that this process only covers goods trade and excludes services trade. In the absence of

information, we split services proportionately among the three end-use categories. This means that one third of each bilateral flow of services trade is imported by firms, investors, and consumers, respectively.

### 2.3 Optimization to Maintain Standard GTAP Bilateral Trade Data Base

End-uses are defined more broadly than agent flows in the standard GTAP Data Base. End-use, indexed by $u$, only consists of the three aforementioned categories of intermediate, investment, and consumption goods whereas there are 68 agents in the standard GTAP Data Base, consisting of 65 activities/industries, investors, government, and the private household. We assign agents to end-uses as follows: all 65 activities demand intermediate goods, investors demand investment goods, and both government and the private household demand consumption goods.

With this mapping between end-uses and GTAP agents, we specify the aggregation of agent-indexed trade flows to use-indexed trade flows. A new coefficient is defined, the value of trade at market (tariff-inclusive) prices distinguished by dimensions of commodity $c$, end-use $u$, and destination country $d$, as $VIUM^0_{c,u,d}$.

$$
\begin{aligned}
VIUM^0_{c,"intm",d} &= \sum_{j=1}^{65} VIFM^0_{c,a,d} \neq \sum_s VIUMS^0_{c,"intm",s,d} \\
VIUM^0_{c,"cgds",d} &= VIFM^0_{c,"cgds",d} \neq \sum_s VIUMS^0_{c,"cgds",s,d} \\
VIUM^0_{c,"cons",d} &= VIGM^0_{c,d} + VIPM^0_{c,d} \neq \sum_s VIUMS^0_{c,"cons",s,d}
\end{aligned}
\tag{3}
$$

Use-specific imports for intermediates, $u = "intm"$, aggregate over imports across the 65 standard GTAP activities, specified as $VIFM^0_{c,a,d}$, where the index $a$ refers to activities or firms. Use-specific imports for investment, $u = "cgds"$, equals standard GTAP investment import flow, $VIFM^0_{c,"cgds",d}$. Use-specific imports for consumption goods, $u = "cons"$, aggregate over imports for government $VIGM^0_{c,d}$ and the private household $VIPM^0_{c,d}$. Ideally, the original estimates of tariff-inclusive trade value, $VIUMS^0_{c,u,s,d}$, would aggregate to $VIUM^0_{c,u,d}$. However, there is a discrepancy between the import values aggregated across agents to use from the GTAP Data Base and the BEC-based use- and source-specific import values aggregated across sources. To address this, the BEC-based initial estimated use-specific trade flows are adjusted in order to preserve the aggregate import values in the original GTAP Data Base. To achieve this, an optimization procedure is employed to estimate a new use- and source-specific tariff-inclusive trade value, $VIUMS^1_{c,u,s,d}$, subject to the constraint that $VIUMS^1_{c,u,s,d}$ aggregates to the original trade flows of the standard GTAP Data Base, along both source ($VIMS^0_{c,s,d}$) and end-use ($VIUM^0_{c,u,d}$) dimension.

$$\underset{VIUMS^1_{c,u,s,d}}{\text{minimize}} \quad \sum_u \sum_s \left\{ VIUMS^1_{c,u,s,d} \log \left( \frac{VIUMS^1_{c,u,s,d}}{VIUMS^0_{c,u,s,d}} \right) \right\} \qquad \forall (c,d)$$

subject to:

$$\sum_s VIUMS^1_{c,u,s,d} = VIUM^0_{c,u,d} \tag{4}$$

$$\sum_u VIUMS^1_{c,u,s,d} = VIMS^0_{c,s,d}$$

## 2.4 Differentiated Composite Tariffs

As discussed above, end-use shares for tariff-inclusive vs tariff-exclusive imports are used to compute the initial estimates of the MRIO trade data ($VIUMS^0_{c,u,s,d}$ and $VIUWS^0_{c,u,s,d}$). From these, the initial power of the tariff is estimated as

$$VPOT^0_{c,u,s,d} = \frac{VIUMS^0_{c,u,s,d}}{VIUWS^0_{c,u,s,d}} \tag{5}$$

Multiplying the inverse of the power of the tariff ($VPOT^0_{c,u,s,d}$), allows us to compute a first estimate of the tariff-exclusive, use-specific import value ($VIUWS^p_{c,u,s,d}$).

$$VIUWS^p_{c,u,s,d} = \frac{VIUMS^1_{c,u,s,d}}{VPOT^0_{c,u,s,d}} \tag{6}$$

Prior to optimization, this first estimate is used to decompose the original bilateral import values at world (cif) prices ($VIWS^0_{c,s,d}$) from the GTAP Data Base by end-use.

$$VIUWS^s_{c,u,s,d} = VIWS^0_{c,s,d} * \frac{VIUWS^p_{c,u,s,d}}{\sum_u VIUWS^p_{c,u,s,d}} \tag{7}$$

Because of the first optimization procedure, the distribution of market priced (tariff-inclusive) imports across agents in $VIUMS^1_{c,u,s,d}$ differs from $VIUMS^0_{c,u,s,d}$. As such, the new ratio of market-priced (tariff-inclusive) to world-priced (cif) bilateral trade by agent ($\frac{VIUMS^1_{c,u,s,d}}{VIUWS^s_{c,u,s,d}}$) is not always greater than or equal to one, hence indicating there are cases where the market (tariff-inclusive) priced trade is less than the world (cif) priced trade, or the presence of a "false" subsidy. To correct for these "false" subsidies, a second optimization procedure is implemented.

For this procedure, an optimization to fit world-priced (tariff-exclusive) trade values to the standard GTAP Data Base is implemented while ensuring that all tariffs by end-use are positive. Mechanically, the procedure works via the same log-scaling mechanism as the first optimization.

$$\underset{VIUWS^1_{c,u,s,d}}{\text{minimize}} \quad \sum_u \sum_s \left\{ VIUWS^1_{c,u,s,d} \log \left( \frac{VIUWS^1_{c,u,s,d}}{VIUWS^s_{c,u,s,d}} \right) \right\} \qquad \forall (c,s,d)$$

subject to:

$$\sum_u VIUWS^1_{c,u,s,d} = VIWS^0_{c,s,d} \tag{8}$$

$$VIUWS^1_{c,u,s,d} \leq VIUMS^1_{c,u,s,d}$$

By this optimization procedure, a new tariff-exclusive value of trade $VIUWS^1_{c,u,s,d}$ is estimated. The first constraint ensures that $VIUWS^1_{c,u,s,d}$ aggregates along the end-use dimension $u$ to the original world-priced trade flows in the standard GTAP Data Base ($VIWS^0_{c,s,d}$). The second constraint ensures that all tariff revenue is non-negative by enforcing the condition that tariff-exclusive trade flows ($VIUWS^1_{c,u,s,d}$) must be less than tariff-inclusive trade flows ($VIUMS^1_{c,u,s,d}$). This is particularly clear when the second constraint is rearranged as $\frac{VIUMS^1_{c,u,s,d}}{VIUWS^1_{c,u,s,d}} - 1 \geq 0$.[5] The optimized value $VIUWS^1_{c,u,s,d}$ is classified by three dimensions, commodity $c$, source country $s$, and destination country $d$, and the optimization procedure itself occurs only along one dimension, end-use $u$, so that changes in allocation of trade value only shift within the three end-use categories.

## 2.5 Agent values at world (cif) prices

Bilateral import values by end-use are likewise disaggregated. To disaggregate across firms, the share of imports of good $c$ for production in activity $a$ out of total imports aggregated across all activities, $\left(\frac{VIFM^0_{c,a,d}}{\sum_{j=1}^{65} VIFM^0_{c,a,d}}\right)$, is applied to the bilateral value of tariff-exclusive intermediate imports ($VIUWS^1_{c,"intm",s,d}$). This application distributes the bilateral trade value across importing firms.

$$VIFWS_{c,a,s,d} = VIUWS^1_{c,"intm",s,d}\left(\frac{VIFM^0_{cad}}{\sum_{j=1}^{65} VIFM^0_{c,a,d}}\right) \quad \forall\, a \tag{9}$$

For investment (CGDS) goods, the agent and the end-use are the same, so there is no need for further disaggregation. With these bilateral import values distributed across industries and the investor, a new coefficient $VIFWS_{c,a,s,d}$ is defined, being tariff-exclusive bilateral imports across firms and the investor.

$$VIFWS_{c,"cgds",s,d} = VIUWS^1_{c,"cgds",s,d} \tag{10}$$

Similarly, bilateral imports for consumption are disaggregated into imports for government and for the private household using government and household import shares. New coefficients are defined for tariff-exclusive bilateral import values for the government ($VIGWS_{c,s,d}$) and private household ($VIPWS_{c,s,d}$).

$$VIGWS_{c,s,d} = VIUWS^1_{c,"cons",s,d}\left(\frac{VIGM^0_{c,d}}{VIGM^0_{c,d} + VIPM^0_{c,d}}\right) \tag{11}$$

$$VIPWS_{c,s,d} = VIUWS^1_{c,"cons",s,d}\left(\frac{VIPM^0_{c,d}}{VIGM^0_{c,d} + VIPM^0_{c,d}}\right) \tag{12}$$

## 2.6 Agent values at market (tariff-inclusive) prices

To disaggregate use-specific market-priced import values across agents, we can implement either sourcing shares to agent-specific trade flows or agent shares to bilateral trade flows. These are mathematically equivalent as $VIUMS^1_{c,u,s,d}$ was optimized to satisfy the constraint $\sum_s VIUMS^1_{c,u,s,d} = VIUM^0_{c,u,d}$. This ensures that summing the use-specific bilateral import value across sources is equal to the agent-specific import values from the standard GTAP Data Base aggregated to use level. For

[5] While the optimization solves with optimal and feasible solutions, the outcome retains a small margin of error. As such, any remaining insignificant discrepancies are systematically eliminated.

firm imports, we either apply source shares to activity-specific imports ($VIFM_{c,a,d}$) or disaggregate the bilateral value of intermediate imports ($VIUMS^1_{c,"intm",s,d}$) by activity import shares.

$$\begin{aligned} VIFMS_{c,a,s,d} &= VIFM^0_{c,a,d}\left(\frac{VIUMS^1_{c,"intm",s,d}}{\sum_s VIUMS^1_{c,"intm",s,d}}\right) \quad \forall\, a \\ VIFMS_{c,a,s,d} &= VIUMS^1_{c,"intm",s,d}\left(\frac{VIFM^0_{c,a,d}}{\sum_{j=1}^{65} VIFM^0_{c,a,d}}\right) \quad \forall\, a \end{aligned} \tag{13}$$

Imports for investment ($VIFM^0_{c,"cgds",d}$) can be distributed across sources, though this is equal to the bilateral value of imports for investment ($VIUMS^1_{c,"cgds",s,d}$). From these distributions across industries and investment, we define $VIFMS_{c,"cgds",s,d}$ as the tariff-inclusive value of bilateral imports across firms and the investor.

$$VIFMS_{c,"cgds",s,d} = VIFM^0_{c,"cgds",d}\left(\frac{VIUMS^1_{c,"cgds",s,d}}{\sum_s VIUMS^1_{c,"cgds",s,d}}\right) = VIUMS^1_{c,"cgds",s,d} \tag{14}$$

Likewise, for the government and private household, we can either apply sourcing shares to government- or household-specific import demands ($VIGM^0_{c,d}$ or $VIPM^0_{c,d}$) or agent-shares to bilateral consumption imports ($VIUMS^1_{c,"cons",s,d}$).

$$\begin{aligned} VIGMS_{c,s,d} &= VIGM^0_{c,d}\left(\frac{VIUMS^1_{c,"cons",s,d}}{\sum_s VIUMS^1_{c,"cons",s,d}}\right) \\ VIGMS_{c,s,d} &= VIUMS^1_{c,"cons",s,d}\left(\frac{VIGM^0_{c,d}}{VIGM^0_{c,d} + VIPM^0_{c,d}}\right) \end{aligned} \tag{15}$$

From these computations, we create new coefficients for tariff-inclusive bilateral imports for the government $VIGMS_{c,s,d}$ and private households $VIPMS_{c,s,d}$.

$$\begin{aligned} VIPMS_{c,s,d} &= VIPM^0_{c,d}\left(\frac{VIUMS^1_{c,"cons",s,d}}{\sum_s VIUMS^1_{c,"cons",s,d}}\right) \\ VIPMS_{c,s,d} &= VIUMS^1_{c,"cons",s,d}\left(\frac{VIPM^0_{c,d}}{VIGM^0_{c,d} + VIPM^0_{c,d}}\right) \end{aligned} \tag{16}$$

## 2.7 Agent values at agent prices

To compute bilateral agent-priced import values across agents, we use sourcing shares from the newly estimated bilateral import values by use, $VIUMS^1_{c,"intm",s,d}$. We apply these market-priced (tariff-inclusive ) shares $\left(\frac{VIUMS^1_{c,"intm",s,d}}{\sum_s VIUMS^1_{c,"intm",s,d}}\right)$ as there is no agent-priced source-specific information. For firms, we apply sourcing shares computed from the value of bilateral intermediate imports ($VIUMS^1_{c,"intm",s,d}$) to the agent-priced industry-specific value of imports ($VIFA^0_{c,"intm"}$).

$$VIFAS_{c,a,s,d} = VIFA^0_{c,a,d}\left(\frac{VIUMS^1_{c,"intm",s,d}}{\sum_s VIUMS^1_{c,"intm",s,d}}\right) \forall\, a \tag{17}$$

For investors, we apply sourcing shares computed from the value of bilateral investment imports ($VIUMS^1_{c,"cgds",s,d}$) to the agent-priced value of imports for investment ($VIFA^0_{c,"cgds",d}$). From these computations for firms and investors, a new coefficient, $VIFAS$ is defined–$VIFAS_{c,a,s,d}$ as the agent-priced value of bilateral imports across activities and $VIFAS_{c,"cgds",s,d}$ for investment.

$$VIFAS_{c,"cgds",s,d} = VIFA^0_{c,"cgds",d}\left(\frac{VIUMS^1_{c,"cgds",s,d}}{\sum_s VIUMS^1_{c,"cgds",s,d}}\right) \tag{18}$$

Similarly, we create new coefficients $VIGAS_{c,s,d}$ and $VIPAS_{c,s,d}$, defined as agent-priced bilateral imports for the government and the private household, respectively. These are calculated using sourcing shares from the value of bilateral consumption imports ($VIUMS^1_{c,"cons",s,d}$) to agent-priced values of imports for the government ($VIGA^0_{c,d}$) and the household ($VIPA^0_{c,d}$).

$$VIGAS_{c,s,d} = VIGA^0_{c,d}\left(\frac{VIUMS^1_{c,"cons",s,d}}{\sum_s VIUMS^1_{i,"cons",s,d}}\right) \tag{19}$$

$$VIPAS_{c,s,d} = VIPA^0_{c,d}\left(\frac{VIUMS^1_{c,"cons",s,d}}{\sum_s VIUMS^1_{c,"cons",s,d}}\right) \tag{20}$$

# 3 GTAP-MRIO Tariff Data

In this section, we analyze the agent-specific tariff structure underlying GTAP-MRIO Data Base. For tractability and ease of analysis, we use a 10-sector and 10-region aggregation which is the so-called default aggregation that comes with GTAPAgg2 or FlexAgg distribution. The list of aggregate sectors classified by broadly defined economic activity and regions classified according to geographical location are shown in Tables 2 and 3, respectively, with detailed concordances shown in Appendix A.

We begin our tariff analysis by looking at bilateral tariff rates across regions shown in Table 4. These information are found in both GTAP-MRIO and standard GTAP Data Base. In general, tariff rates are relatively low with a global average of 2% and bilateral tariff rates less than 10%, except for the 13.8% average tariff rate imposed by South Asia (SAS) on imports from South East Asia (SEA) and 11.6% average tariff rate imposed by Sub-Saharan Africa (SSA) on imports from East Asia (EAS). Both Sub-Saharan Africa (SSA) and South Asia (SAS) impose the highest average import tariff rates of 7% and 6.5%, whereas the European Union (EU28) and North America (NAM) impose the lowest average import tariff rates of 0.6% and 1%, respectively. Across trading partners, the European Union (EU28) imposes the lowest average bilateral tariffs on imports from Sub-Saharan Africa (SSA) at 0.13%.

Figure 3 shows the average tariff rates faced and imposed by regions. This figure shows that, with the exception of East Asia (EAS), South East Asia (SEA), European Union (EU28), and North America (NAM), all other regions impose higher tariff rates on imports relative to the tariff rates their exports face. For instance, the average import tariff imposed by Sub-Saharan Africa (SSA), South Asia (SAS) and Latin America (LAC) are roughly two-times higher than the tariffs their exporters face.

Table 2: **Aggregate Sectors**

| Sector | Description |
|---|---|
| GrainsCrops | Grains and Crops |
| MeatLstk | Livestock and Meat Products |
| Extraction | Mining and Extraction |
| ProcFood | Processed Food |
| TextWapp | Textiles and Clothing |
| LightMnfc | Light Manufacturing |
| HeavyMnfc | Heavy Manufacturing |
| Util_Cons | Utilities and Construction |
| TransComm | Transport and Communication |
| OthServices | Other Services |

*Notes:* Aggregated GTAP sectors

Table 3: **Aggregate Regions**

| Region | Description |
|---|---|
| OCE | Australia, New Zealand, Oceania |
| EAS | East Asia |
| SEA | Southeast Asia |
| SAS | South Asia |
| NAM | North America |
| LAC | Latin America and Caribbean |
| EU28 | European Union 28 |
| MENA | Middle East and North Africa |
| SSA | Sub-Saharan Africa |
| ROW | Rest of World |

*Notes:* Aggregated GTAP regions.

Table 4: **Bilateral Tariff Rates**

| Region | OCE | EAS | SEA | SAS | NAM | LAC | EU28 | MENA | SSA | ROW | World |
|---|---|---|---|---|---|---|---|---|---|---|---|
| OCE | 1.54 | 1.76 | 1.65 | 5.4 | 0.67 | 2.63 | 3.2 | 4.17 | 4.34 | 1.19 | 2.10 |
| EAS | 3.94 | 3.05 | 2.2 | 7.99 | 2.12 | 8.29 | 2.52 | 7.69 | 11.56 | 6.01 | 3.69 |
| SEA | 0.56 | 0.72 | 0.71 | 13.75 | 2.81 | 6.28 | 1.77 | 3.85 | 8.84 | 1.78 | 2.24 |
| SAS | 2.99 | 2.38 | 4.15 | 7.71 | 3.19 | 5.36 | 1.39 | 5.07 | 9.00 | 2.36 | 3.64 |
| NAM | 1.03 | 4.46 | 2.11 | 6.02 | 0.03 | 4.23 | 1.04 | 2.95 | 4.99 | 2.13 | 1.73 |
| LAC | 1.01 | 3.79 | 6.5 | 3.24 | 0.71 | 1.14 | 2.47 | 4.98 | 6.82 | 4.33 | 2.53 |
| EU28 | 3.19 | 4.12 | 2.47 | 6.55 | 0.84 | 5.0 | 0.0 | 2.97 | 5.53 | 2.66 | 1.28 |
| MENA | 0.58 | 1.02 | 1.13 | 3.0 | 0.34 | 2.1 | 0.38 | 2.86 | 5.55 | 3.72 | 1.46 |
| SSA | 2.56 | 0.83 | 1.16 | 2.41 | 0.16 | 1.35 | 0.13 | 1.81 | 3.19 | 0.91 | 1.2 |
| ROW | 1.02 | 2.48 | 1.04 | 7.76 | 0.56 | 3.01 | 0.39 | 3.18 | 5.15 | 0.55 | 1.31 |
| World | 2.49 | 2.73 | 1.96 | 6.46 | 1.03 | 4.63 | 0.57 | 4.13 | 7.05 | 2.86 | 2.07 |

*Notes:* Rows represent exporters; columns represent importers.

Figure 4 decomposes import tariff rates by end-users. Tariff rates imposed on household consumer goods are generally higher than intermediate, government and investment goods. However,

in Oceania (OCE), East Asia (EAS), Latin America and the Caribbean (LAC), and the Middle East and North Africa (MENA), tariffs on investment goods are higher than consumer goods. Tariffs on investment goods are also higher than goods for intermediate and government consumption.

Across regions, Figure 4 shows that South Asia (SAS) and Sub-Saharan Africa (SSA) impose the highest consumer goods tariff at 13.6% and 10.1%, respectively. In contrast, Latin America and the Caribbean (LAC) impose the lowest consumer goods tariffs at 1.3%. Tariffs on intermediate goods are highest in Sub-Saharan Africa (SSA) at 10.1% followed by South Asia (SAS) at 4.9%, whereas the European Union (EU28) and North America (NAM) have the lowest tariffs on intermediate goods at 0.4% and 0.6%, respectively. Tariffs on investment goods are highest in South Asia (SAS) at 9.2% followed by Sub-Saharan Africa (SSA) at 7.4%, Latin America and the Caribbean (LAC) at 7.1%, and the Middle East and North Africa (MENA) at 6.7%. Both the European Union (EU28) and North America (NAM) impose less than 1% tariffs on investment goods.

Figure 3: **Tariff rates, Faced and Imposed**

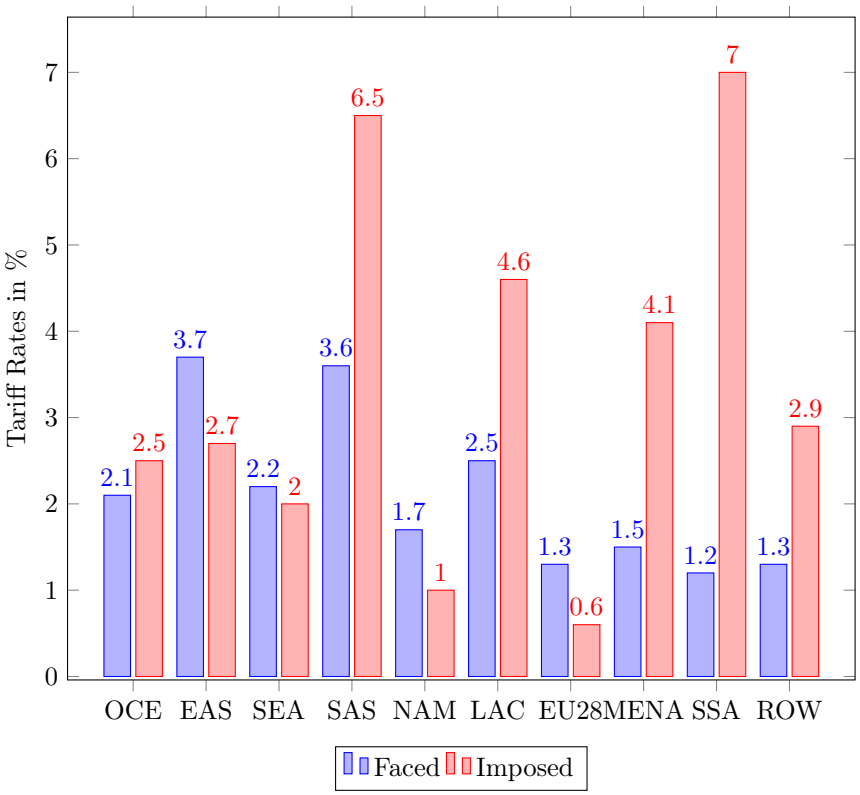


Figure 4: **Tariff Rates, by End-User**

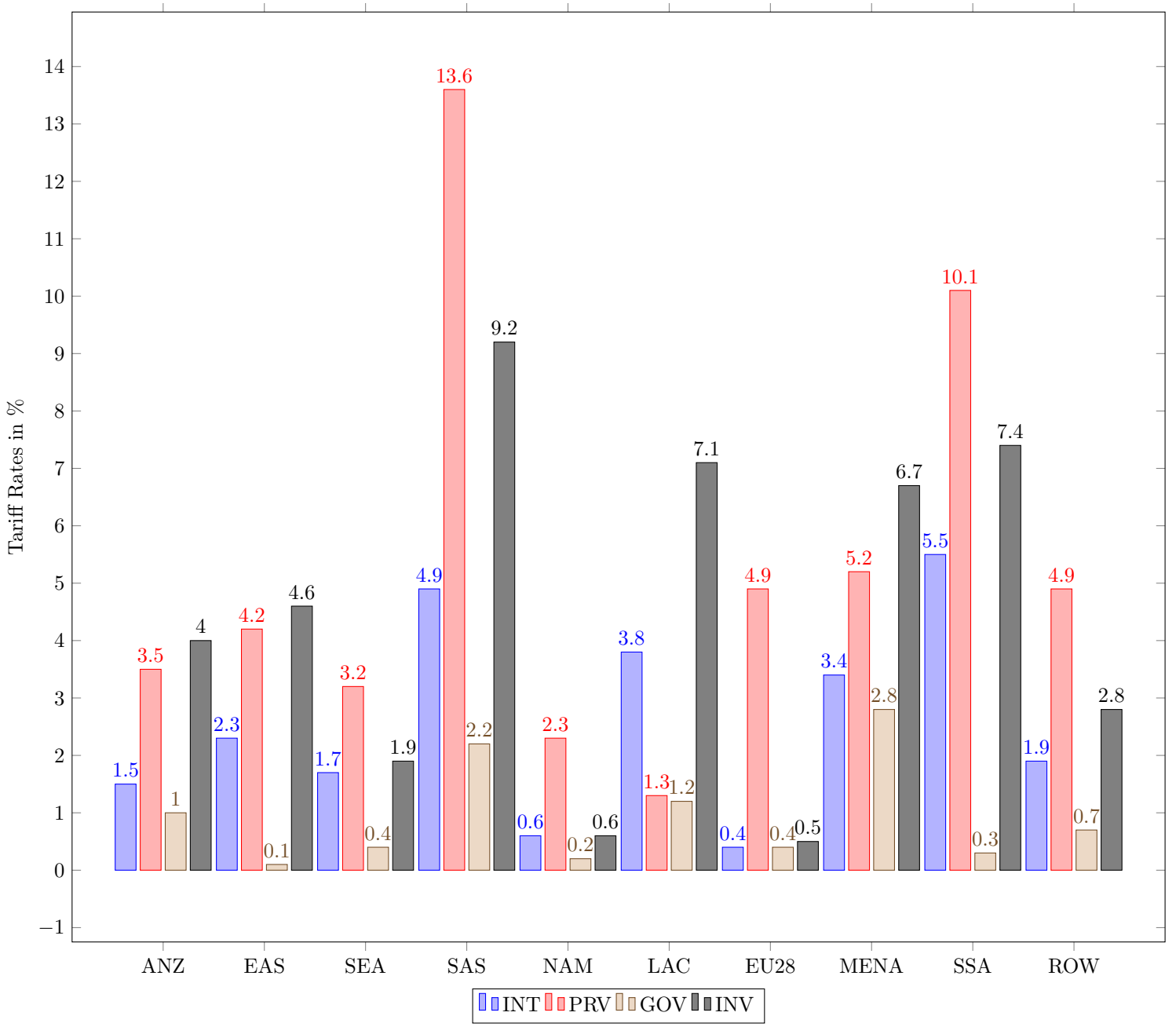
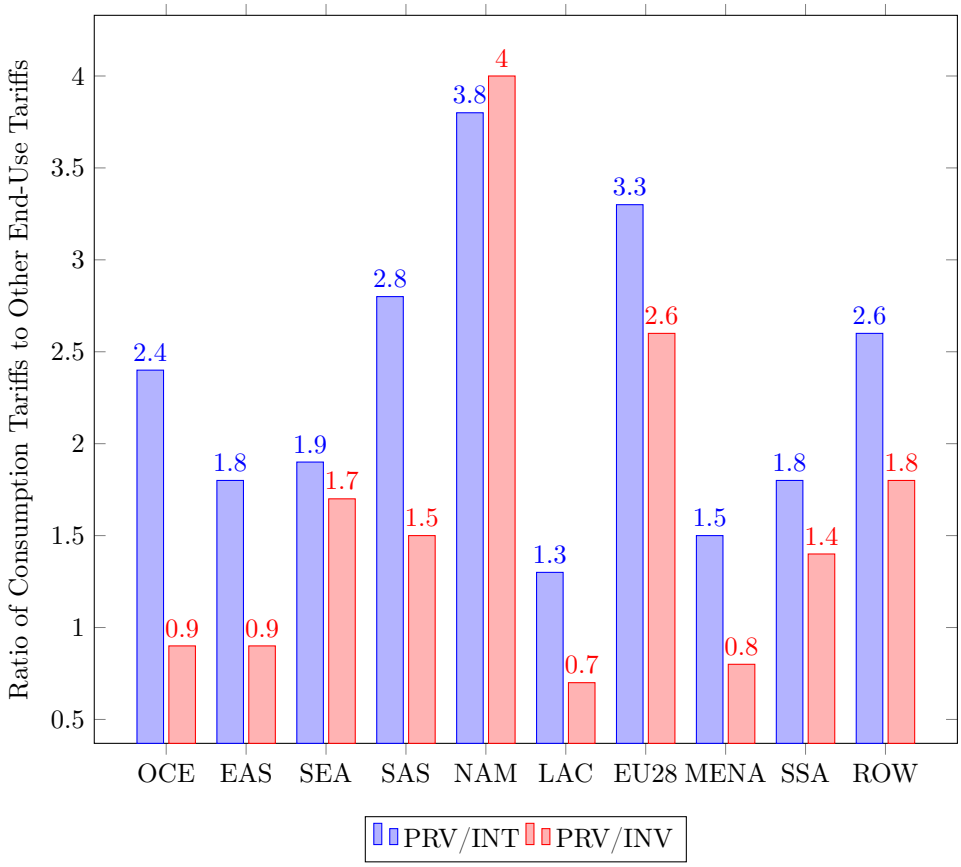


Figure 5 compares tariff differences across end-use categories via the ratio of region-wide household consumption tariffs relative to intermediate and investment goods tariffs. This figure shows that across all regions, average household consumption tariffs are greater than those on intermediate goods but not necessarily for investment goods. In general, household consumption to intermediate goods tariff ratios are between 1.3 (LAC) and 3.3 (EU28), whereas the household to investment tariff ratios are between 0.7 (LAC) and 4 (NAM).[6]

Figure 5: **Ratio of Consumption Tariffs to Intermediate and Investment Tariffs**




To benefit from the depth of information found in GTAP-MRIO, we now compare tariffs on consumer goods relative to investment goods, and intermediate tariffs. We begin by comparing region-wide tariffs on consumer goods relative to investment goods before proceeding to commodity level analysis. In analyzing the tariff rates of consumer goods relative to investment goods (Figures 6 to 15 shown in Appendix A), we divide our aggregate regions into two groups. The first group, composed of Oceania (OCE), East Asia (EAS), Latin America and the Caribbean (LAC), and the Middle East and North Africa (MENA), relates to regions with average consumption tariffs less than investment. The second group is composed of all other regions (South East Asia (SEA), South Asia (SAS), North America (NAM), the European Union (EU28), Sub-Saharan Africa (SSA), and the Rest of the World (ROW)), with average consumption tariffs greater than investment tariffs.

For the first group, we see in Figures 6 7, 11, and 13 that tariffs on investment goods are generally higher than tariffs on consumption goods. However, there are cases where tariffs on specific household commodities are greater than investment counterparts. These are light manufactures and,

[6]Figure 26 in Appendix A shows household to government tariff ratios are between 1.9 (MENA) and 42 (EAS).

to some extent, meat and livestock imports by East Asia (EAS), light manufactures imports by Latin America and the Caribbean (LAC); and meat and livestock imports by the Middle East and North Africa (MENA).

For the second group, Figures 8, 9, 10, 12, 14, and 15 in Appendix A show, as discussed above, that tariffs on consumption goods are generally greater than those on investment goods. There are a few exceptional cases where tariffs on household goods are less than those destined for investments. These are crops imports by South East Asia (SEA); crops, heavy manufactured goods, and meat and livestock imports by South Asia (SAS); crops imports by North America (NAM); crops and meat imports by the European Union (EU28); heavy manufactured goods and meat imports by Sub-Saharan Africa (SSA); and heavy manufactured goods imports by the Rest of the World (ROW).

We also compare tariffs on consumer goods relative intermediate tariffs, as shown in Figures 16 to 25 in Appendix A. Similar to the investment, we first look at the aggregate level before proceeding to commodity level analysis. Across regions, tariffs on consumer and intermediate goods appear similar for processed food, light and heavy manufactured goods as well as textiles and wearing apparels. Exceptions are the relatively higher consumer tariffs on heavy manufactured goods in Oceania (OCE), light manufactured goods in South Asia (SAS), heavy and light manufactured goods in Latin America and the Caribbean (LAC), textiles in the European Union (EU28), and light manufactured goods and textiles in Sub-Saharan Africa (SSA). Another exception is the higher intermediate relative to consumer tariffs are observed on processed food imports into Latin America and the Caribbean (LAC).

Finally, we further observe differences in rates imposed by the importing region across partners (source regions). In Figures 6 to 15, relatively high tariffs are imposed on consumer and investment goods coming from South Asia (SAS), Sub-Saharan Africa (SSA), and, to some extent, the Middle East and North Africa (MENA). In Figures 16 to 25, relatively high consumer and intermediate tariffs are imposed on agro-food commodities coming from South Asia (SAS), Sub-Saharan Africa (SSA) and to some extent the Middle East and North Africa (MENA).

# 4 Conclusion

As global economic integration deepens, new databases are necessary to fully analyze the complexity of cross-border linkages. The main purpose of this memorandum is to describe the GTAP version 10A Multi-Region Input Output (GTAP-MRIO) Data Base. We build upon the prior MRIO work of Carrico (2017) which incorporates source- and agent-specific tariff revenues. Such information allows us to capture not only the nuances of agent-specific trade patterns but also the degree by which bilateral tariffs differ across agents. With illustrations, we described the tariff structure found in a 10-sector and 10-region aggregate of the GTAP-MRIO Data Base.

As we look forward to GTAP version 11 Data Base, we plan to update the GTAP-MRIO by moving to Broad Economic Categories concordances revision 5. We also plan to improve on our proportional allocation method for service commodities and to possibly create a multi-year GTAP-MRIO spanning across GTAP reference years.

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# A Appendix

Table 5: **Sectoral Concordances**

| GTAP Sector | Aggregate Sector | GTAP Sector | Aggregate Sector |
|---|---|---|---|
| pdr | GrainsCrops | bph | HeavyMnfc |
| wht | GrainsCrops | rpp | HeavyMnfc |
| gro | GrainsCrops | nmm | HeavyMnfc |
| v_f | GrainsCrops | i_s | HeavyMnfc |
| osd | GrainsCrops | nfm | HeavyMnfc |
| c_b | GrainsCrops | fmp | LightMnfc |
| pfb | GrainsCrops | ele | HeavyMnfc |
| ocr | GrainsCrops | eeq | HeavyMnfc |
| ctl | MeatLstk | ome | HeavyMnfc |
| oap | MeatLstk | mvh | LightMnfc |
| rmk | MeatLstk | otn | LightMnfc |
| wol | MeatLstk | omf | LightMnfc |
| frs | Extraction | ely | Util_Cons |
| fsh | Extraction | gdt | Util_Cons |
| coa | Extraction | wtr | Util_Cons |
| oil | Extraction | cns | Util_Cons |
| gas | Extraction | trd | TransComm |
| oxt | Extraction | afs | TransComm |
| cmt | MeatLstk | otp | TransComm |
| omt | MeatLstk | wtp | TransComm |
| vol | ProcFood | atp | TransComm |
| mil | ProcFood | whs | TransComm |
| pcr | GrainsCrops | cmn | TransComm |
| sgr | ProcFood | ofi | OthServices |
| ofd | ProcFood | ins | OthServices |
| b_t | ProcFood | rsa | OthServices |
| tex | TextWapp | obs | OthServices |
| wap | TextWapp | ros | OthServices |
| lea | LightMnfc | osg | OthServices |
| lum | LightMnfc | edu | OthServices |
| ppp | LightMnfc | hht | OthServices |
| p_c | HeavyMnfc | dwe | OthServices |
| chm | HeavyMnfc | | |

Table 6: **Regional Concordances**

| GTAP Region | Aggregate Region | GTAP Region | Aggregate Region | GTAP Region | Aggregate Region |
|---|---|---|---|---|---|
| aus | OCE | xca | LAC | arm | ROW |
| nzl | OCE | dom | LAC | aze | ROW |
| xoc | OCE | jam | LAC | geo | ROW |
| chn | EAS | pri | LAC | bhr | MENA |
| hkg | EAS | tto | LAC | irn | MENA |
| jpn | EAS | xcb | LAC | isr | MENA |
| kor | EAS | aut | EU28 | jor | MENA |
| mng | EAS | bel | EU28 | kwt | MENA |
| twn | EAS | bgr | EU28 | omn | MENA |
| xea | EAS | hrv | EU28 | qat | MENA |
| brn | EAS | cyp | EU28 | sau | MENA |
| khm | SEA | cze | EU28 | tur | MENA |
| idn | SEA | dnk | EU28 | are | MENA |
| lao | SEA | est | EU28 | xws | MENA |
| mys | SEA | fin | EU28 | egy | MENA |
| phl | SEA | fra | EU28 | mar | MENA |
| sgp | SEA | deu | EU28 | tun | MENA |
| tha | SEA | grc | EU28 | xnf | MENA |
| vnm | SEA | hun | EU28 | ben | SSA |
| xse | SEA | irl | EU28 | bfa | SSA |
| bgd | SAS | ita | EU28 | cmr | SSA |
| ind | SAS | lva | EU28 | civ | SSA |
| npl | SAS | ltu | EU28 | gha | SSA |
| pak | SAS | lux | EU28 | gin | SSA |
| lka | SAS | mlt | EU28 | nga | SSA |
| xsa | SAS | nld | EU28 | sen | SSA |
| can | NAM | pol | EU28 | tgo | SSA |
| usa | NAM | prt | EU28 | xwf | SSA |
| mex | NAM | rou | EU28 | xcf | SSA |
| xna | NAM | svk | EU28 | xac | SSA |
| arg | LAC | svn | EU28 | eth | SSA |
| bol | LAC | esp | EU28 | ken | SSA |
| bra | LAC | swe | EU28 | mdg | SSA |
| chl | LAC | gbr | EU28 | mwi | SSA |
| col | LAC | che | ROW | mus | SSA |
| ecu | LAC | nor | ROW | moz | SSA |
| pry | LAC | xef | ROW | rwa | SSA |
| per | LAC | alb | ROW | tza | SSA |
| ury | LAC | blr | ROW | uga | SSA |
| ven | LAC | rus | ROW | zmb | SSA |
| xsm | LAC | ukr | ROW | zwe | SSA |
| cri | LAC | xee | ROW | xec | SSA |
| gtm | LAC | xer | ROW | bwa | SSA |
| hnd | LAC | kaz | ROW | nam | SSA |
| nic | LAC | kgz | ROW | zaf | SSA |
| pan | LAC | tjk | ROW | xsc | SSA |
| slv | LAC | xsu | ROW | xtw | ROW |

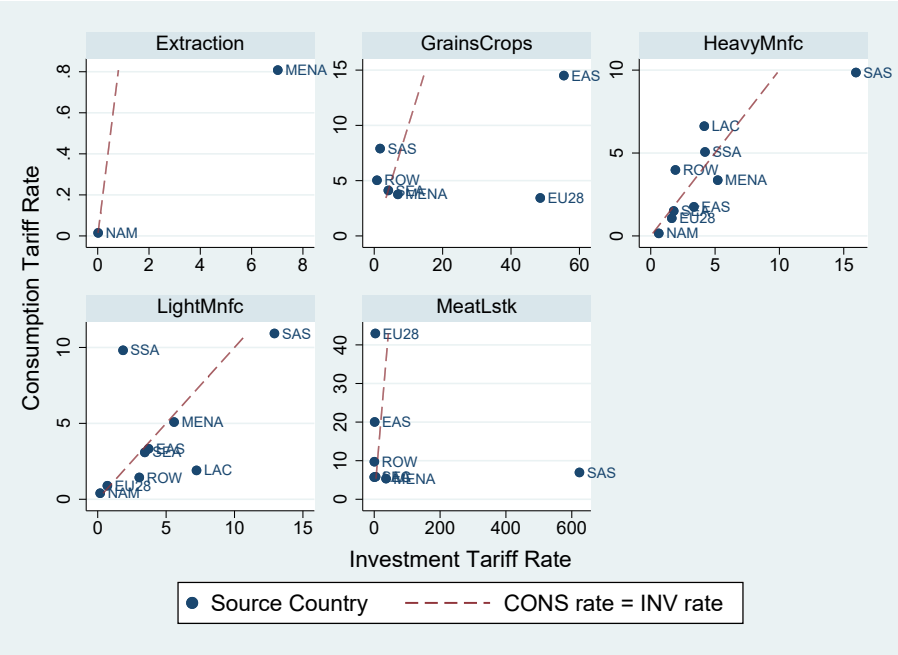


Figure 6: **Import tariffs: Oceania, Cons vs. Inv**

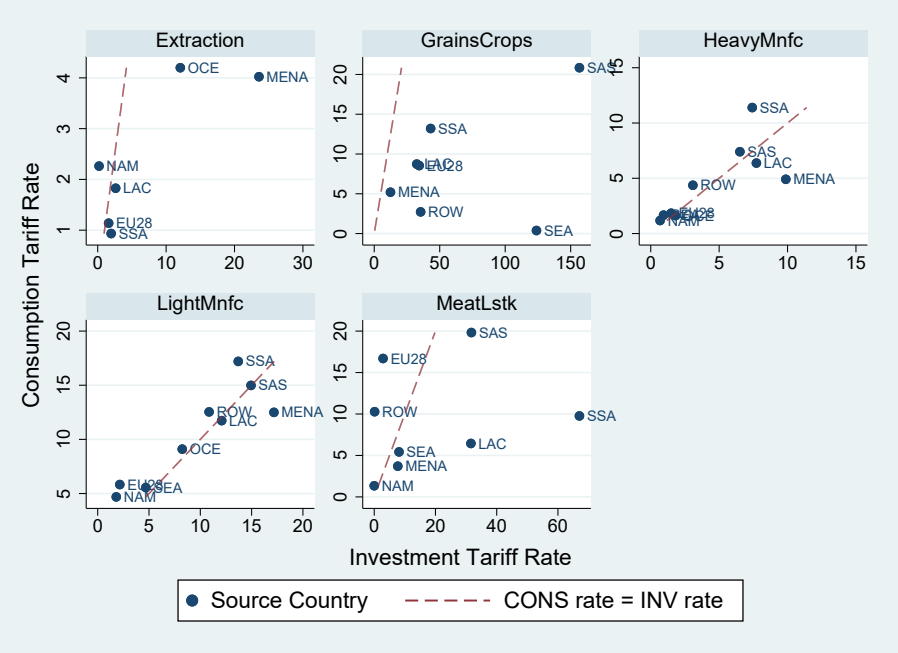


Figure 7: **Import tariffs: East Asia, Cons vs. Inv**

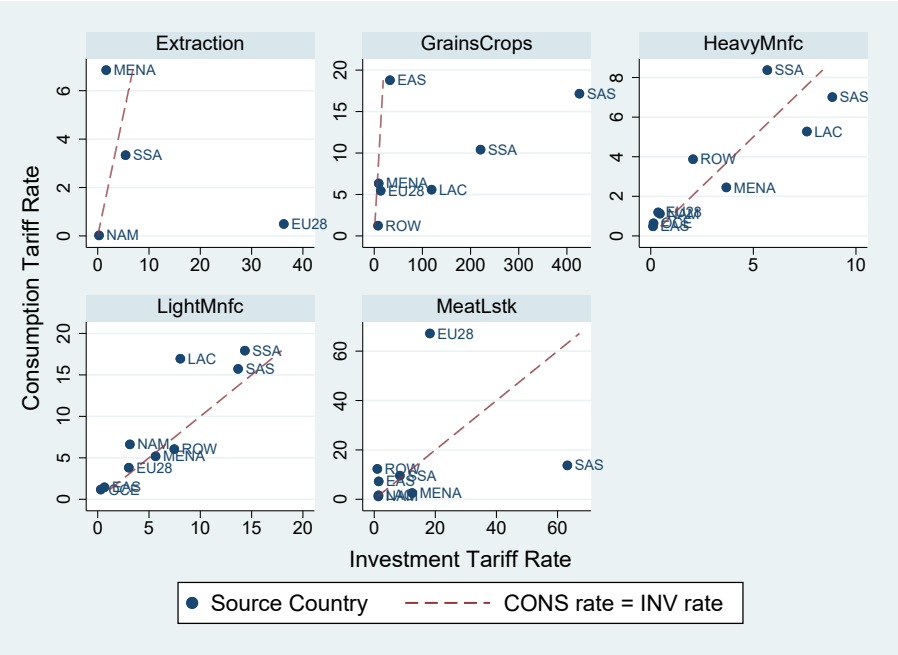


Figure 8: **Import tariffs: South East Asia, Cons vs. Inv**

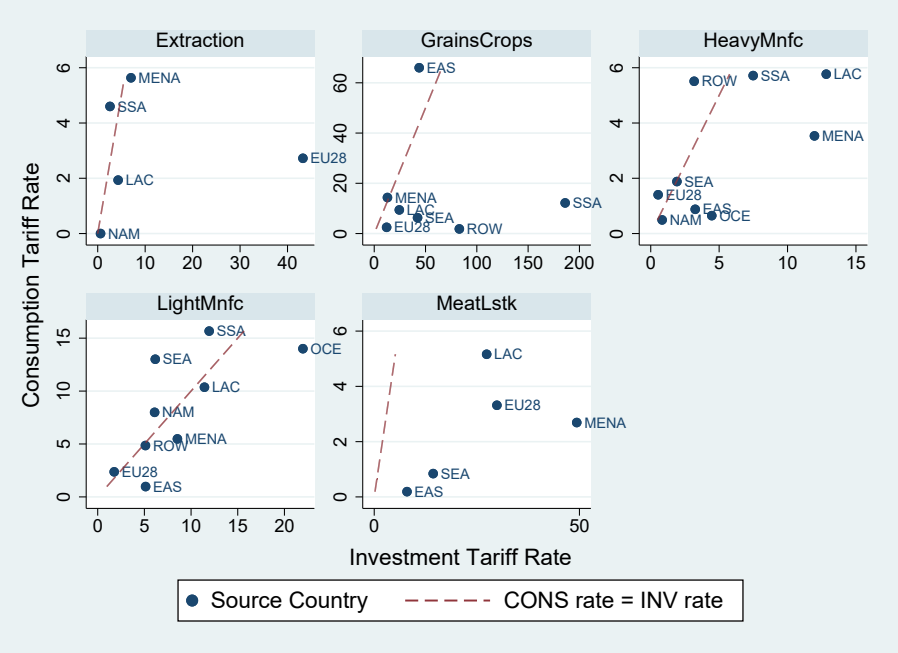


Figure 9: **Import tariffs: South Asia, Cons vs. Inv**

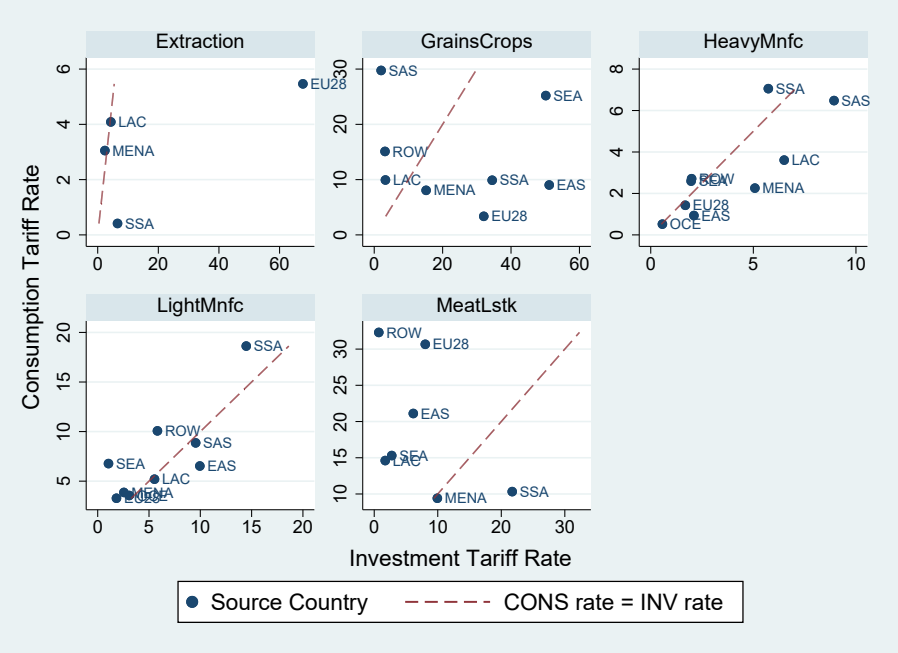


Figure 10: **Import tariffs: North America, Cons vs. Inv**

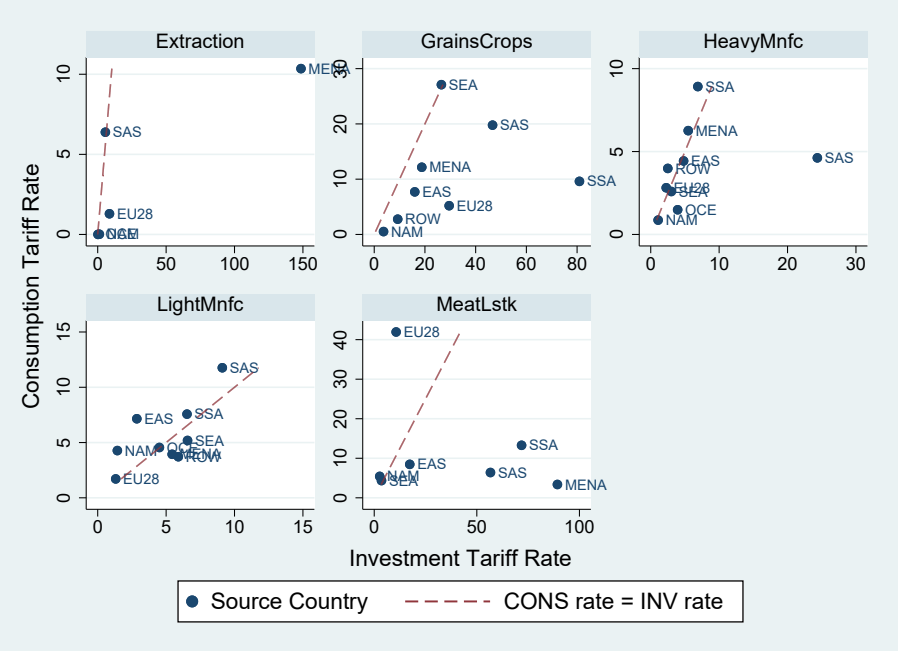


Figure 11: **Import tariffs: Latin America and Caribbean, Cons vs. Inv**

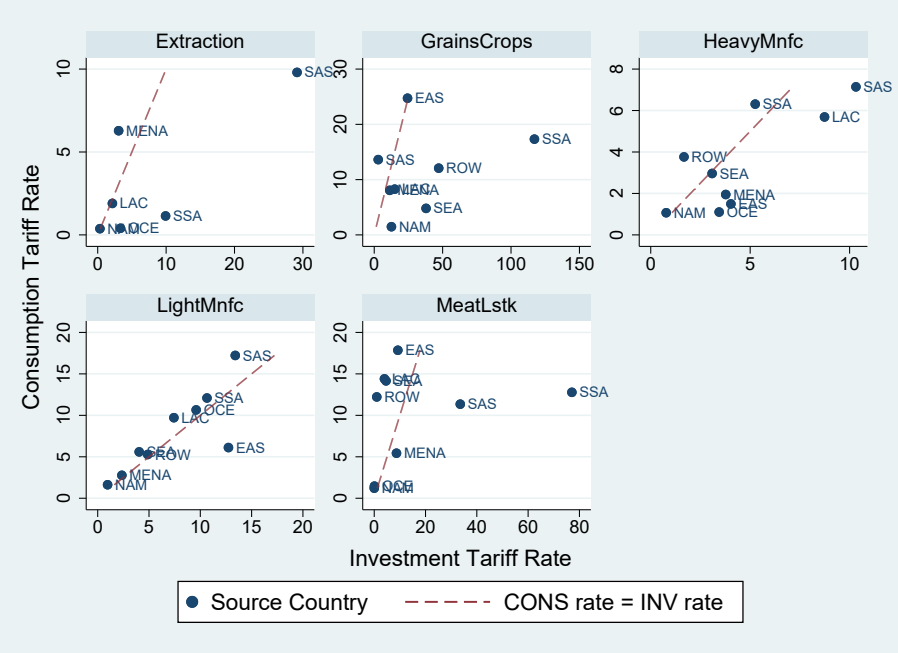


Figure 12: **Import tariffs: EU28, Cons vs. Inv**

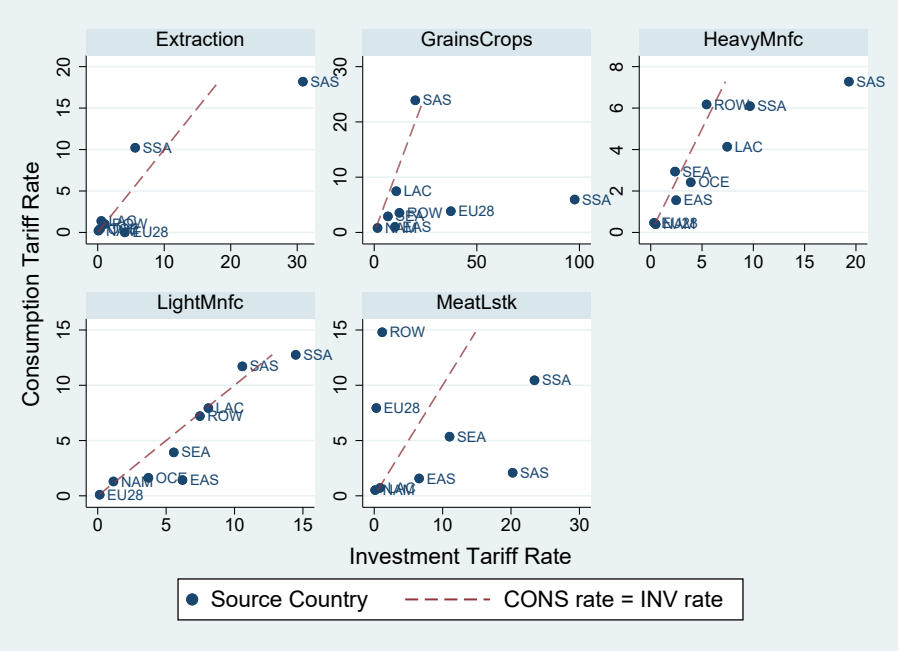


Figure 13: **Import tariffs: Middle East and North Africa, Cons vs. Inv**

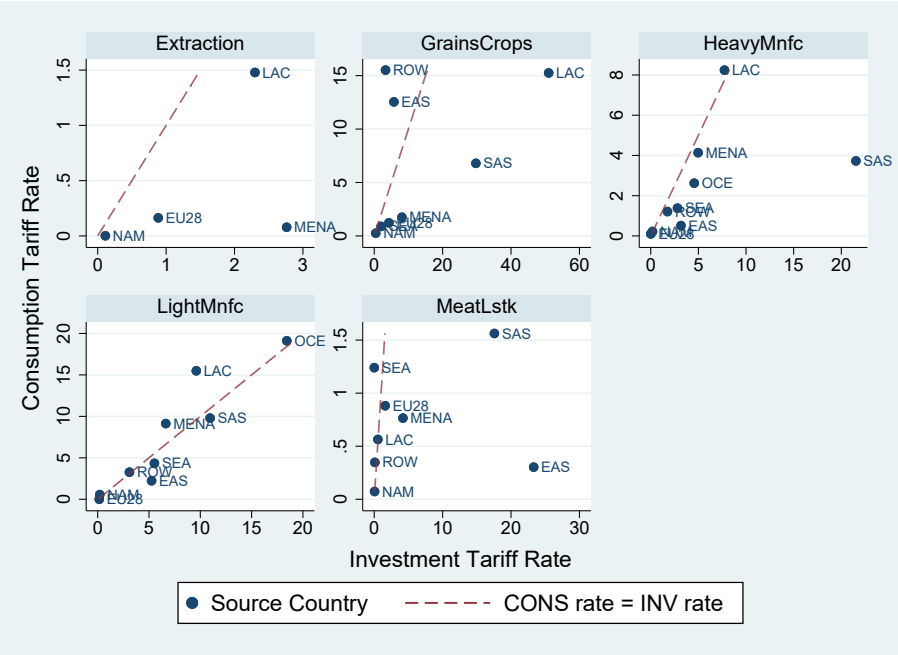


Figure 14: **Import tariffs: Sub-Saharan Africa, Cons vs. Inv**

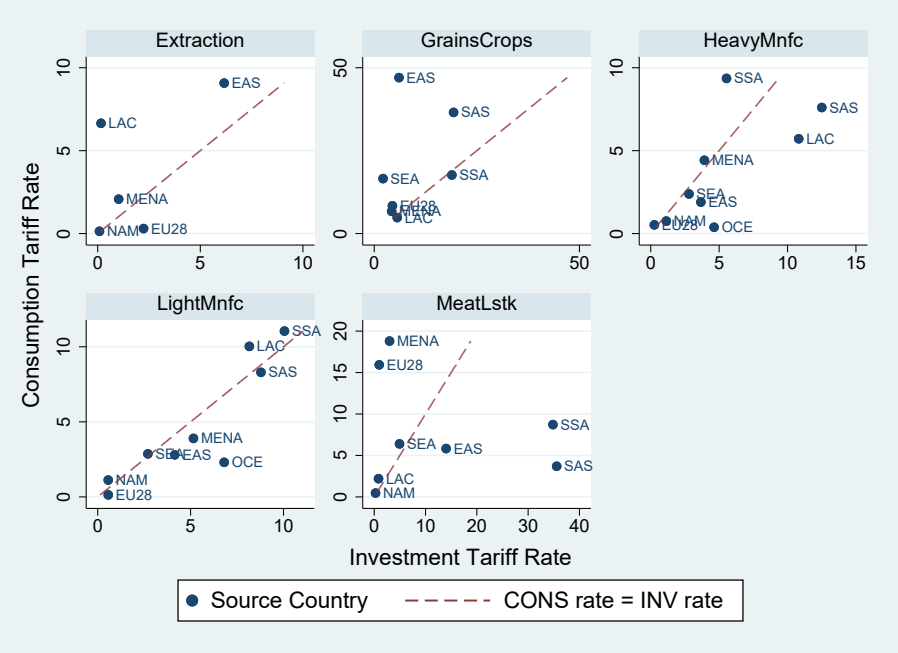


Figure 15: **Import tariffs: Rest of the World, Cons vs. Inv**

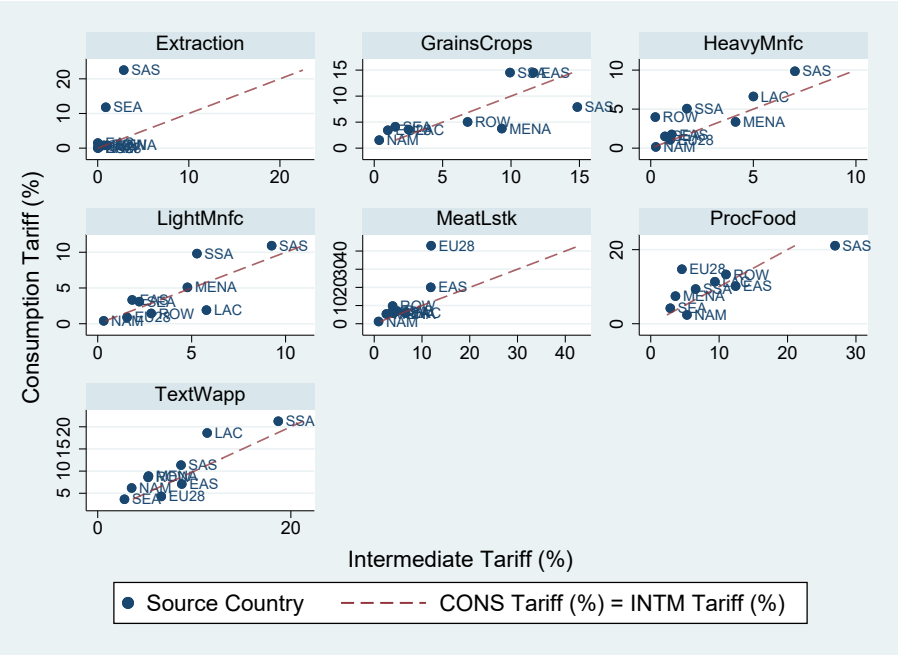


Figure 16: **Import tariffs: Oceania, Cons vs. Intm**

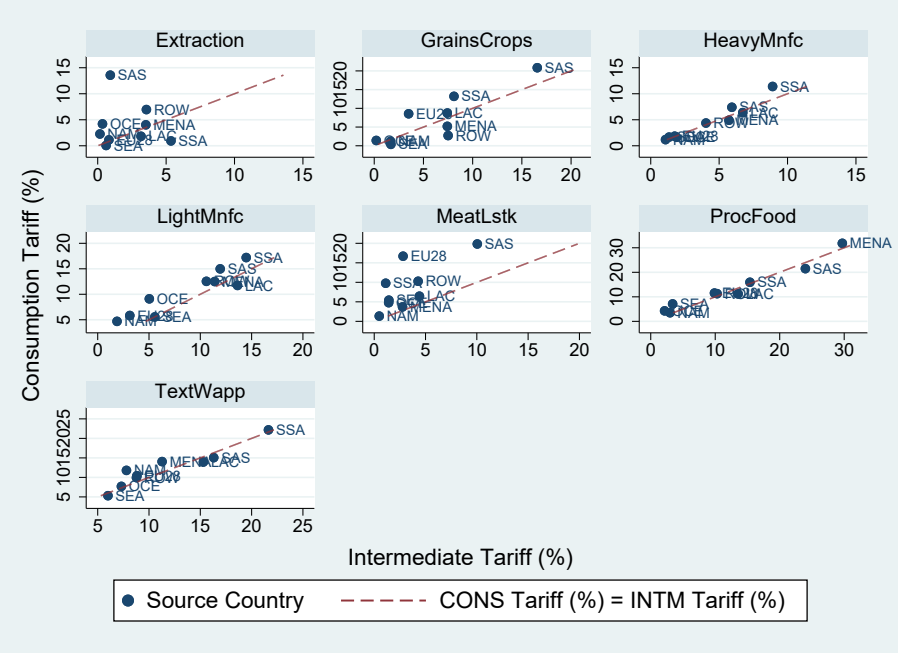


Figure 17: **Import tariffs: East Asia, Cons vs. Intm**

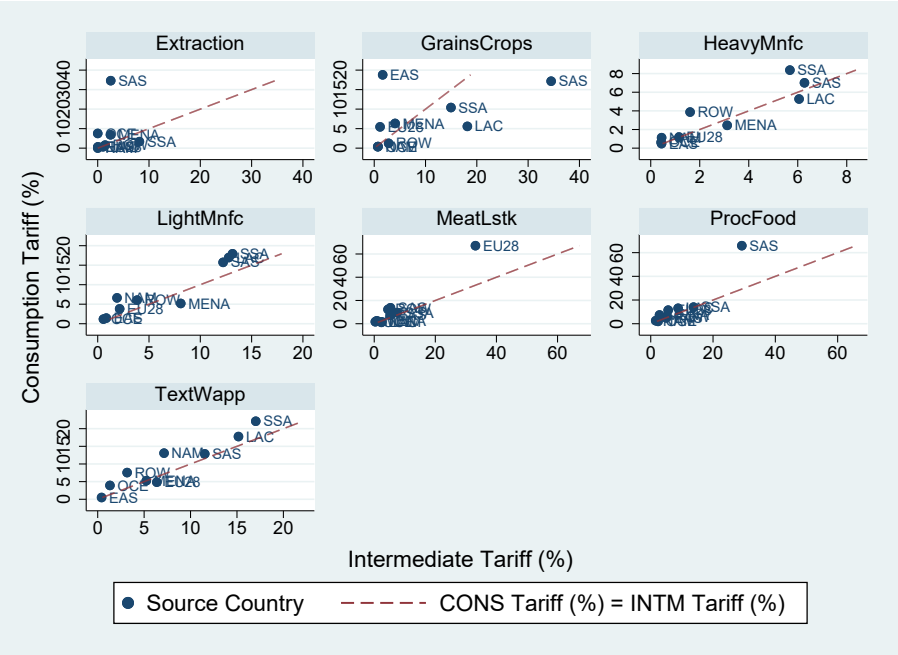


Figure 18: **Import tariffs: South East Asia, Cons vs. Intm**

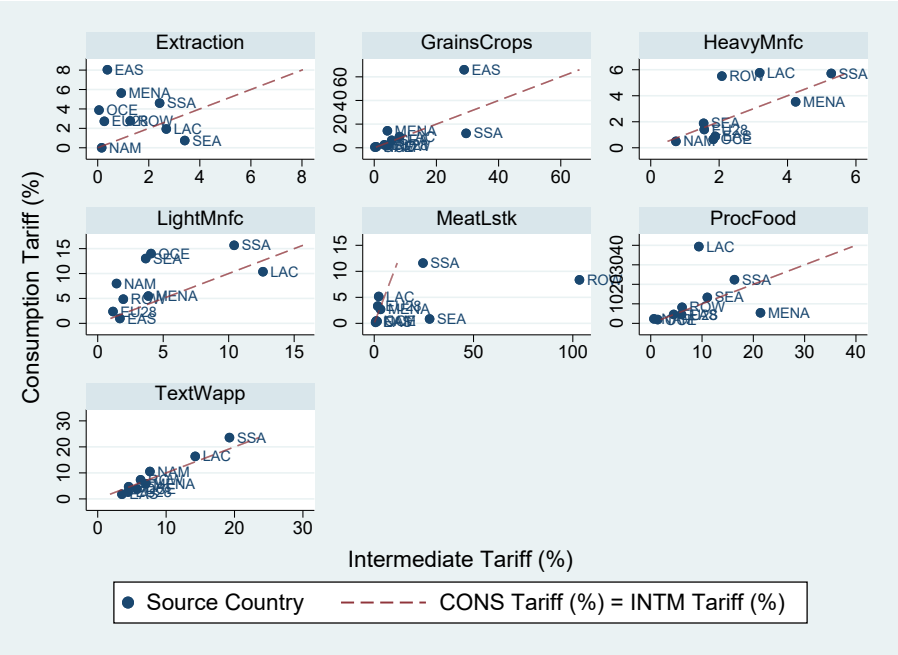


Figure 19: **Import tariffs: South Asia, Cons vs. Intm**

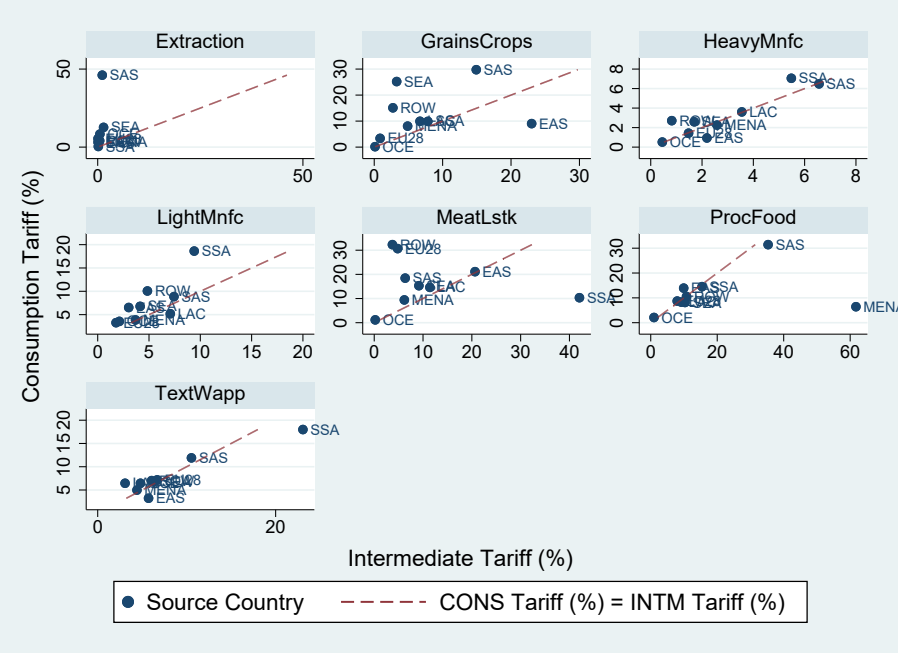


Figure 20: **Import tariffs: North America, Cons vs. Intm**

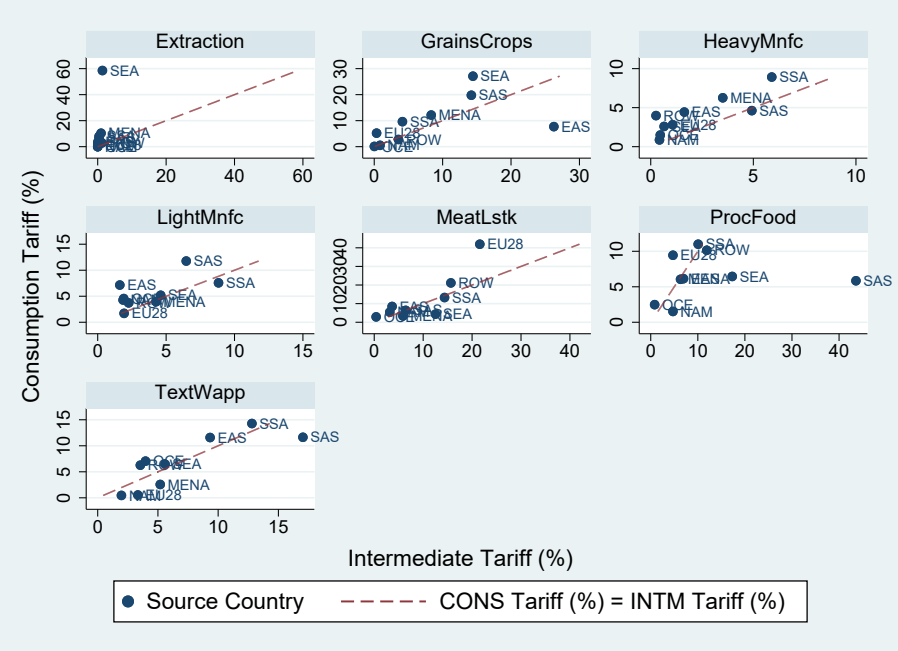


Figure 21: **Import tariffs: Latin America and Caribbean, Cons vs. Intm**

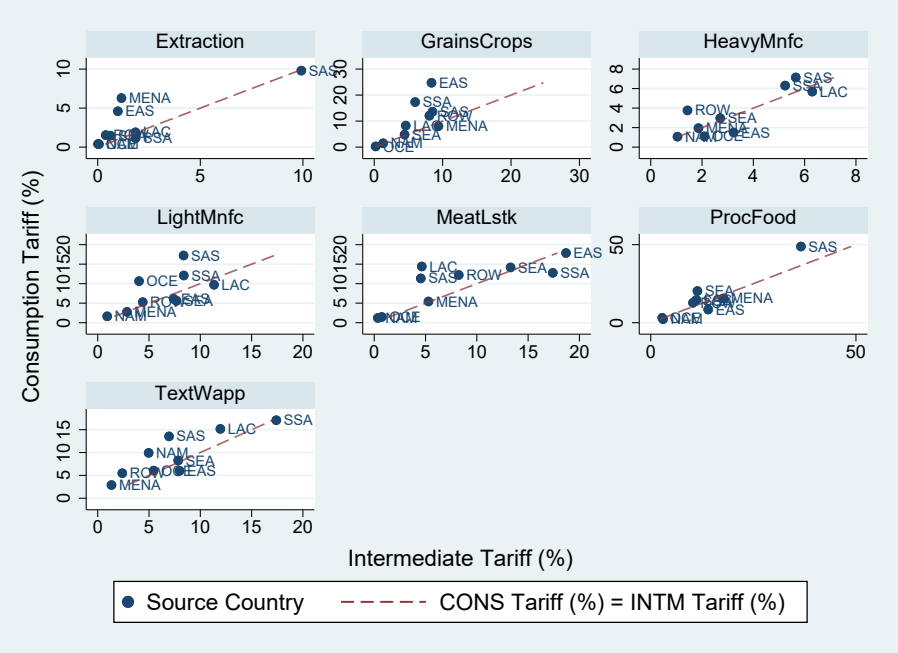


Figure 22: **Import tariffs: EU28, Cons vs. Intm**

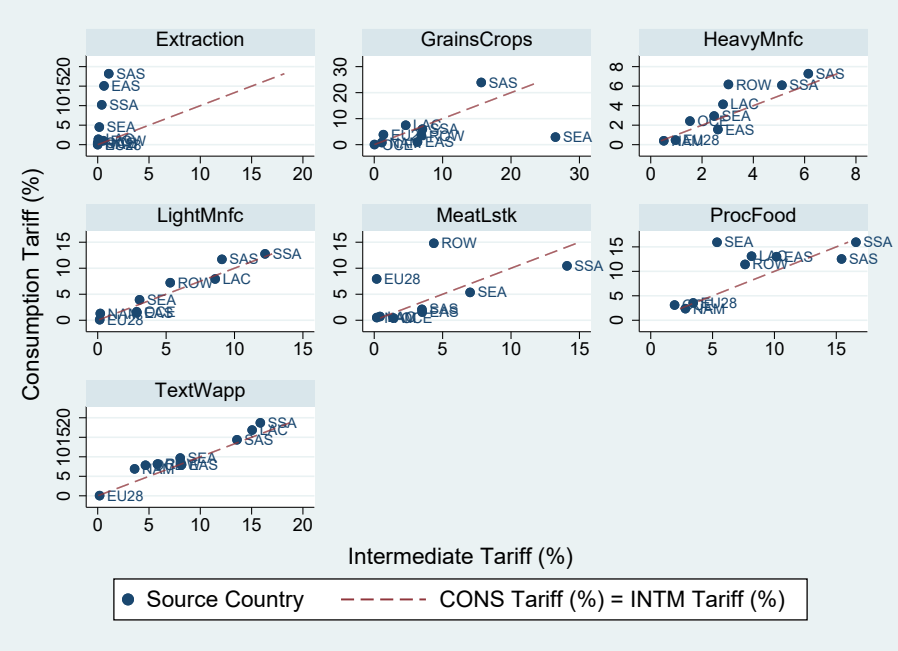


Figure 23: **Import tariffs: Middle East and North Africa, Cons vs. Intm**

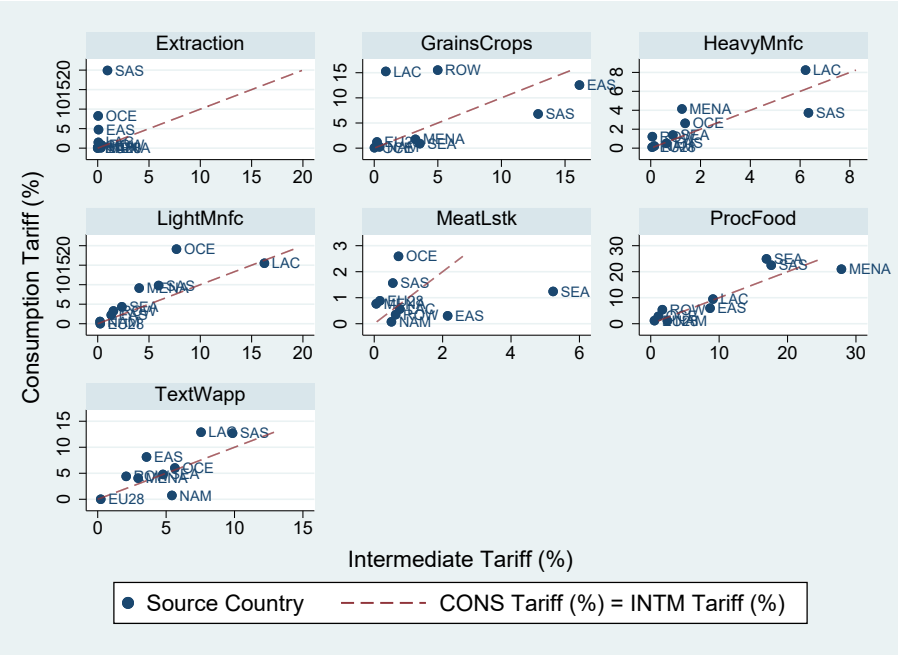


Figure 24: **Import tariffs: Sub-Saharan Africa, Cons vs. Intm**

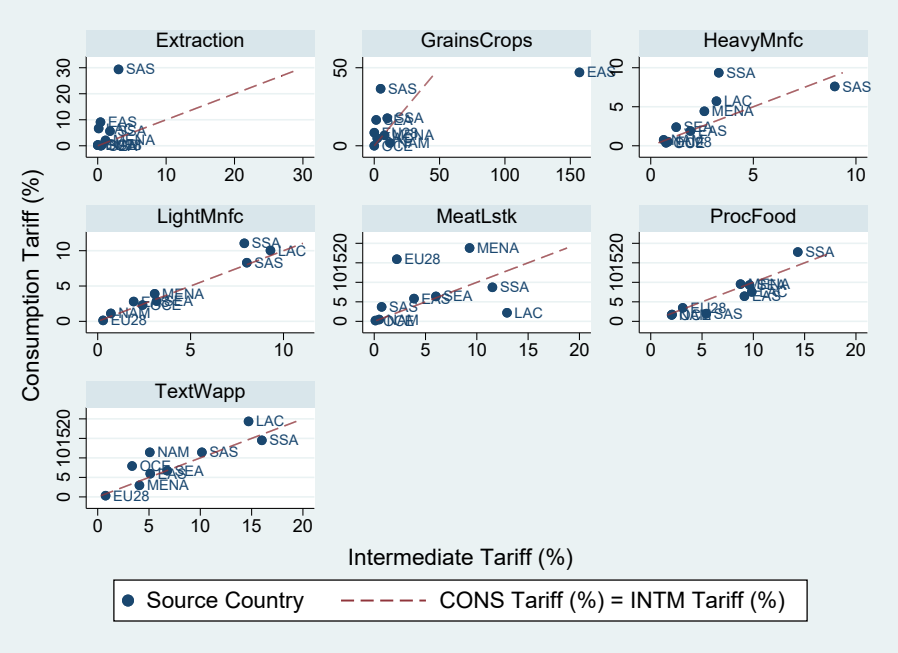


Figure 25: **Import tariffs: Rest of the World, Cons vs. Intm**

Figure 26: **Ratio of Consumption Tariffs to Other End-Use Tariffs**