Guide to OECD Trade in Gross Output Indicators, ***2023 edition***

OECD, Directorate for Science, Technology and Innovation

Abstract

This guide presents the definitions and intuition behind novel GVC exposure indicators published by the OECD that account for direct and indirect input trade between partner countries. The indicators presented in this guide are based on gross trade concepts. They were generated using the 2023 release of OECD annual Inter-Country Input-Output (ICIO) tables which cover the period 1995 to 2020. The indicators are provided for 76 economies (including all OECD, European Union, ASEAN and G20 countries) and for 45 unique industries and related macro sectors based on the ISIC Rev. 4 classification.

This guide is intended for all users, from experienced Input-Output practitioners familiar with the matrix algebra for generating indicators, to relative novices who wish to use the indicators in their analyses and are seeking guidance on their use and interpretation.

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1 Introduction

This guide presents eight GVC exposure indicators: Foreign Input Reliance and Foreign Market Reliance, developed by Baldwin and Freeman (2022[1]); and Foreign Production Exposure: Import Side (look through, face value, and hidden exposure) and Foreign Production Exposure: Export Side (look through, face value, and hidden exposure) developed in Baldwin, Freeman and Theodorakopoulos. (2023[2]; 2023[3]) When using the indicators, please cite the relevant papers accordingly.

These indicators published by the OECD, provide a key tool to assess vulnerabilities to global value chain (GVC) disruptions by drawing a detailed map of GVC dependencies based on domestic and foreign production.

The indicators were computed using the 2023 release of OECD Inter-Country Input-Output (ICIO) tables which cover the years 1995 to 2020. They are provided for 76 economies (including all OECD, European Union, ASEAN and G20 countries), and for 45 unique industries and related macro sectors.

This guide is intended for all users, from experienced Input-Output practitioners familiar with the matrix algebra for generating indicators, to relative novices who wish to use the indicators in their analyses and are seeking guidance on their use and interpretation.

2 OECD ICIO Tables: basic definitions

This section presents the basic structure of the OECD annual ICIO tables and the elements needed to compute the eight GVC exposure indicators.[1] The OECD ICIO system consists of a set of annual symmetric industry-by-industry global input-output tables. Their structure is presented in Error! Reference source not found. **and Table 2.2. Additional Matrices**

Matrix	Size of the matrix	Description
C	$NK \times NK$	**Allocation coefficients**, calculated as $C_{ij}^{rs} = z_{ij}^{rs} / x_i^r$
G	$NK \times NK$	***Ghosh inverse***, $\mathbf{G} = (\mathbf{I} - \mathbf{C})^{-1}$, where the element g_{ij}^{rs} shows the direct and indirect usage of one unit of inputs from industry i in country r for the production of output by industry j in country s.

Figure 2.1.

1. For readers new to input-output analysis, the book by Miller, R. and P. Blair (2022). Input-Output Analysis: Foundations and Extensions. Cambridge: Cambridge University Press, 3rd Edition is recommended.

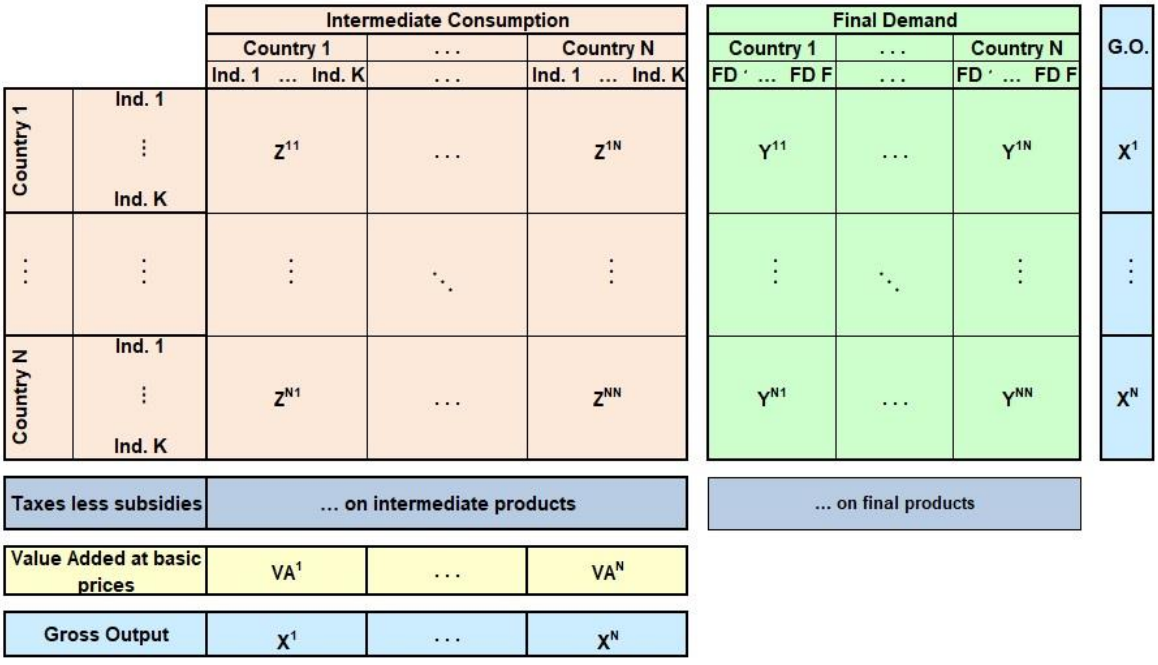
Table 2.1. Basic Matrices in OECD ICIO Tables

Matrix	Size of the matrix	Description
W	$1 \times NK$	**Value added**, where w_i^r is the value added (**at basic prices**) by industry i (1 to K) in country r (1 to N) plus *taxes less subsidies* on intermediate products, so that total value added equals total final demand at basic prices.
X	$1 \times NK$	**Gross output (at basic prices)**, where x_i^r is the gross output from industry i in country r
Z	$NK \times NK$	**Intermediate consumption (at basic prices)**, where z_{ij}^{rs} is the flow of goods from producing industry i in country r to the purchasing industry j in country s.
Y	$NK \times N$	**Final demand,** where the element $\boldsymbol{y_i^{rs}}$ represents final demand of country s for goods and services produced by industry i in country r. Final demand is separated into Household and Government Final Consumption, Gross Fixed Capital Formation (GFCF) and changes in inventories.
A	$NK \times NK$	**Input coefficients**, calculated as $a_{ij}^{rs} = z_{ij}^{rs} / x_j^s$
B	$NK \times NK$	***Leontief inverse***, or "output multipliers", $\mathbf{B} = (\mathbf{I} - \mathbf{A})^{-1}$, where the element b_{ij}^{rs} shows the direct and indirect requirements of inputs from industry i in country r for the production of one unit of output for demand by industry j in country s.

Table 2.2. Additional Matrices

Matrix	Size of the matrix	Description
C	$NK \times NK$	**Allocation coefficients**, calculated as $C_{ij}^{rs} = z_{ij}^{rs} / x_i^r$
G	$NK \times NK$	***Ghosh inverse***, $\mathbf{G} = (\mathbf{I} - \mathbf{C})^{-1}$, where the element g_{ij}^{rs} shows the direct and indirect usage of one unit of inputs from industry i in country r for the production of output by industry j in country s.

Figure 2.1. OECD ICIO Basic Structure



Dimensions for each indicator are provided with the following abbreviations:

Country / Region:

- Prod cou = Production country
- GO src cou = Gross output source country
- FD cou = final demand / destination country

Industry:

- Prod ind = Production source industry
- GO src ind = Gross output source industry

3 Foreign Import Reliance and Foreign Market Reliance

3.1 FIR: Foreign Input Reliance, percentage

Foreign gross output embodied in final demand as a share of final demand.

Indicator dimensions: [GO src cou | Prod ind | Prod cou]

$$\text{FIR}_{r,j,s} = \sum_{i}^{I} b_{ij}^{rs} \text{ for all r} \neq \text{s}$$

where b is a component of the Leontief inverse matrix and subscripts r, i, s, and j denote, respectively, the country and industry of origin of the gross output (r, i) and the destination country and industry (s, j).

FIR accounts for the fact that countries may be exposed to GVC disruptions through both direct suppliers and higher-tier suppliers (the direct suppliers' suppliers etc.). It is a gross trade indicator, meaning that the intermediate inputs sourced from a specific partner country may be counted more than once when goods or services cross borders multiple times. As such, the value of FIR increases with the length of the upstream foreign value chain, possibly making FIR take values greater than 1.

This indicator can loosely be interpreted as the share of total domestic output exposed to foreign upstream disruptions in GVCs. Overall, FIR can be seen as a combination of (1) the size of exposure to a specific partner in the value chain, and (2) the distance to this partner in the value chain. At a given distance in terms of production stages, a larger size implies higher FIR, in line with the intuition that larger trade links with a specific partner increase vulnerability. At a given size of exposure, greater distance implies higher values of FIR, in line with the intuition that a larger number of intermediate production stages between the partner and the destination increases the risk that any given shipment is disrupted at some point of the value chain.

3.2 FMR: Foreign Market Reliance, percentage

Indicator dimensions: [GO src cou | GO src ind | FD cou]

$$\text{FMR}_{r,i,s} = \sum_{j}^{J} g_{ij}^{rs} \text{ for all r} \neq \text{s}$$

where g is a component of the Ghosh inverse matrix and subscripts r, i, s, and j denote, respectively, the country and industry of origin of the gross output (r, i) and the destination country and industry (s, j).

FMR accounts for countries' exposure to GVC disruptions through both direct clients and higher-tier clients (direct clients' clients, etc.). It is a gross trade indicator, meaning that the intermediate inputs purchased by a specific partner country may be counted more than once when goods or services cross borders multiple times. As such, the value of FMR increases with the length of the downstream foreign value chain, possibly making FMR take values greater than 1.

This indicator can loosely be interpreted as the share of total domestic output exposed to foreign downstream disruptions in GVCs. Overall, FMR can be seen as a combination of

(1) the size of exposure to a specific partner in the value chain, and (2) the distance to this partner in the value chain. At a given distance in terms of production stages, a larger size implies higher FMR, in line with the intuition that larger trade links with a specific partner increase vulnerability. For a given share of imported intermediate inputs embodied in gross output, greater distance implies higher values of FMR, in line with the intuition that a larger number of intermediate production stages between the partner and the destination increases the risk that any given shipment is disrupted at some point of the value chain.

3.3 Aggregation of FIR and FMR

FIR and FMR are defined at the domestic country and industry–foreign country level.

In addition, the data set contains aggregations from the domestic industry dimension to the broader macro-sector, as detailed in Table 4.1. These aggregates correspond to the weighted average of FIR, where $GO_{j,s}$, the gross output of the domestic industry is used as weights:

$$\text{FIR}_{r,j,s} = \sum_{j \in J}\left(\text{FIR}_{r,j,s} * W_{j,s}^{GO}\right), \text{ where } W_{j,s}^{GO} = GO_{j,s} / \sum_{j \in J}\left(GO_{j,s}\right)$$

and the weighted average of FMR, where $GO_{i,r}$, the gross output of the domestic industry, is used as weights:

$$\text{FMR}_{r,I,s} = \sum_{i \in I}\left(\text{FIR}_{r,i,s} * W_{i,r}^{GO}\right), \text{ where } W_{i,r}^{GO} = GO_{i,r} / \sum_{i \in I}\left(GO_{i,r}\right)$$

where J and I correspond to the macro sectors at the industry of origin and destination, respectively. r, i, s, and j denote, respectively, the country and industry of origin of the gross output (r, i) and the destination country and industry (s, j).

4 Foreign Production Exposure: Import Side and Foreign Production Exposure: Export Side[2]

4.1 FPEM: Foreign Production Exposure: Import Side, percentage

As shown in Table 2.1, the Leontief inverse matrix (**B**) is equal to $\mathbf{B} = (\mathbf{I} - \mathbf{A})^{-1}$, where **I** denotes the identity matrix and **A** denotes the input coefficients matrix. Expanding terms, $\mathbf{B} = (\mathbf{I} - \mathbf{A})^{-1}$ is equivalent to $\mathbf{B} = \mathbf{I} + \mathbf{A} + \mathbf{A^2} + \mathbf{A^3} + \cdots$. The first term, $\mathbf{I} + \mathbf{A}$, captures the production location of the final good and the location of production of the direct inputs to the final good. These links are directly observable at 'face value' in the data. The subsequent terms, $\mathbf{A^2} + \mathbf{A^3} + \cdots$, capture indirect trade links. Indirect trade links account for higher order trade connections and thus reflect that a country's suppliers also source inputs, and those suppliers source inputs, etc. As such, these links are 'hidden' in the sense that they are not directly observable in the data.

4.1.1 $FPEM^{LT}$: FPEM - Look through exposure, percentage

Indicator dimensions: [GO src cou | FD ind | FD cou]

$$FPEM^{LT}_{r,j,s} = \frac{\sum_i^I b_{ij}^{rs} FD_{j,s}}{\sum_r^R \sum_i^I b_{ij}^{rs} FD_{j,s}} = 100 * \frac{\sum_i^I b_{ij}^{rs}}{\sum_r^R \sum_i^I b_{ij}^{rs}}$$

where b is a component of the Leontief inverse matrix, $FD_{j,s}$ is the final demand of the domestic industry and subscripts r, i, s, and j denote, respectively, the country and industry of origin of the gross output (r, i) and the destination country and industry (s, j).

Like FIR, $FPEM^{LT}$ measures a given country's exposure to inputs sourced from its trade partners both through direct and indirect trade links. The indicator is normalised by total domestic plus foreign linkages (direct and indirect), and thus it ranges between 0% and 100%. Note that at the level of aggregation presented here $FD_{j,s}$ cancels out from the numerator and denominator.

$FPEM^{LT}$ is a gross trade indicator, meaning that the intermediate inputs sourced from a specific partner country may be counted more than once when goods or services cross borders multiple times. See Baldwin, Freeman and Theodorakopoulos (2022) for further description and derivation of this indicator.

[2] Note that conceptually similar indicators which link value added exposure to gross production can be computed using the cost accounting identity and Gosh inverse matrix. See Baldwin, Freeman and Theodorakopoulos (2022) for further description of the indicator, Foreign Value-Added Exposure: Import Side (FVEM) and Foreign Value-Added Exposure: Export Side (FVEX).

4.1.2 FPEM^{FV}: **FPEM - Face value exposure,** percentage

Gross import used in domestic production as share of total gross output embodied in domestic production.

Indicator dimensions: [GO src cou | Prod ind | Prod cou]

$$\text{FPEM}^{\text{FV}}_{r,j,s} = \frac{\sum_i^I (\mathbb{1}[\text{r} = \text{s}] + a_{ij}^{rs}) FD_{j,s}}{\sum_r^R \sum_i^I b_{ij}^{rs} FD_{j,s}} = 100 * \frac{\sum_i^I (\mathbb{1}[\text{r} = \text{s}] + a_{ij}^{rs})}{\sum_r^R \sum_i^I b_{ij}^{rs}}$$

where a_{ij}^{rs} is a component of the input coefficients matrix **A**, $FD_{j,s}$ is the final demand of the domestic industry and subscripts r, i, s, and j denote, respectively, the country and industry of origin of the gross output (r, i) and the destination country and industry (s, j). $\mathbb{1}[\text{r} = \text{s}]$ is the indicator function that equals 1 when r = s.

FPEM^{LT} can be decomposed into direct and indirect trade links. Direct trade links can be observed in the data, and hence represent a country's exposure to supply chain disruption at 'face value'.

FPEM^{FV} is a decomposed part of FPEM^{LT} and its numerator measures a given country's exposure to inputs sourced from its trade partners through direct trade links only. The indicator is normalised by total domestic plus foreign linkages (direct and indirect), and thus it ranges between 0% and 100%. Note that at this level of aggregation $FD_{j,s}$ cancels out from the numerator and denominator.

Loosely speaking, FPEM^{FV} can be interpreted as the share of FPEM^{LT} that is due to direct trade links only. See Baldwin, Freeman and Theodorakopoulos (2023) for further description of this indicator.

4.1.3 FPEM^{HE}: **FPEM - Hidden exposure,** percentage

Indicator dimensions: [GO src cou | Prod ind | Prod cou]

$$\text{FPEM}^{\text{HE}}_{r,j,s} = 100 * \frac{\sum_i^I \left(\sum_{k=2}^{\infty} a_{ij}^{rs\,k}\right) FD_{j,s}}{\sum_r^R \sum_i^I b_{ij}^{rs} FD_{j,s}} = 100 * \frac{\sum_i^I \left(\sum_{k=2}^{\infty} a_{ij}^{rs\,k}\right)}{\sum_r^R \sum_i^I b_{ij}^{rs}} = \text{FPEM}^{\text{LT}}_{r,j,s} \text{-} \text{FPEM}^{\text{FV}}_{r,j,s}$$

where $a_{ij}^{rs\,k}$ is a component of the input coefficients matrix **A** raised to the power of k, $FD_{j,s}$ is the final demand of the domestic industry and subscripts r, i, s, and j denote, respectively, the country and industry of origin of the gross output (r, i) and the destination country and industry (s, j).

FPEM^{LT} can be decomposed into direct and indirect trade links. Indirect trade links are not directly observable in the data, and hence represent a country's exposure to supply chain disruption that is 'hidden'.

FPEM^{HE} is a decomposed part of FPEM^{LT} and its numerator measures a given country's exposure to inputs sourced from its trade partners through indirect trade links only. The indicator is normalised by total domestic plus foreign linkages (direct and indirect), and thus it ranges between 0% and 100%. Because only higher-order (indirect) trade links are considered, FPEM^{HE} captures a country's exposure to global value chains which is 'hidden', or 'unobservable' in the data in that inputs source inputs used to make inputs, etc. Loosely speaking, FPEM^{HE} can be interpreted as the share of FPEM^{LT} that is due to indirect trade links only.

This indicator can be computed as the difference between $FPEM^{LT}$ and $FPEM^{FV}$ which is equivalent to the algebraic expression above. Note that at this level of aggregation $FD_{j,s}$ cancels out from the numerator and denominator. See Baldwin, Freeman and Theodorakopoulos (2023) for further description of this indicator.

4.2 FPEX: Foreign Production Exposure: Export Side, percentage

4.2.1 $FPEX^{LT}$: FPEX - Look through exposure, percentage

Indicator dimensions: [GO src cou | GO src ind | FD cou]

$$FPEX^{LT}_{r,i,s} = 100 * \frac{\sum_j^J b_{ij}^{rs} FD_{i,r}}{\sum_s^S \sum_j^J b_{ij}^{rs} FD_{i,r}} = 100 * \frac{\sum_j^J b_{ij}^{rs}}{\sum_s^S \sum_j^J b_{ij}^{rs}}$$

Where b is a component of the Leontief matrix, $FD_{i,r}$ is the final demand of the domestic industry and subscripts r, i, s, and j denote, respectively, the country and industry of origin of the gross output (r, i) and the destination country and industry (s, j).

Like FMR, $FPEX^{LT}$ measures a given country's exposure to inputs sold to its trade partners both through direct and indirect trade links. The indicator is normalised by domestic plus foreign linkages (direct and indirect), and thus it ranges between 0% and 100%.

Note that at this level of aggregation $FD_{i,r}$ cancels out from the numerator and denominator.

$FPEX^{LT}$ is a gross trade indicator, meaning that the intermediate inputs sold to a specific partner country may be counted several times when goods or services cross borders multiple times. See Baldwin, Freeman and Theodorakopoulos (2022) for further description and derivation of this indicator.

4.2.2 $FPEX^{FV}$: FPEX - Face value exposure, percentage

Indicator dimensions: [GO src cou | GO src ind | FD cou]

$$FPEX^{FV}_{r,i,s} = 100 * \frac{\sum_j^J (\mathbb{1}[\mathrm{r} = \mathrm{s}] + a_{ij}^{rs}) FD_{i,r}}{\sum_s^S \sum_j^J b_{ij}^{rs} FD_{i,r}} = 100 * \frac{\sum_j^J (\mathbb{1}[\mathrm{r} = \mathrm{s}] + a_{ij}^{rs})}{\sum_s^S \sum_j^J b_{ij}^{rs}}$$

where a_{ij}^{rs} is a component of the input coefficients matrix **A**, $FD_{i,r}$ is the final demand of the domestic industry and subscripts r, i, s, and j denote, respectively, the country and industry of origin of the gross output (r, i) and the destination country and industry (s, j). $\mathbb{1}[\mathrm{r} = \mathrm{s}]$ is the indicator function that equals 1 when $\mathrm{r} = \mathrm{s}$.

$FPEX^{LT}$ can be decomposed into direct and indirect trade links. Direct trade links can be observed in the data, and hence represent a country's exposure to supply chain disruption at 'face value'.

$FPEX^{FV}$ is a decomposed part of $FPEX^{LT}$ and its numerator measures a given country's exposure to inputs sold to its trade partners through direct trade linkages only. The indicator is normalised by domestic plus foreign linkages (direct and indirect), and thus it ranges between 0% and 100%. Note that at this level of aggregation $FD_{i,r}$ cancels out from the numerator and denominator.

Loosely speaking, $FPEX^{FV}$ can be interpreted as the share of $FPEX^{LT}$ that is due to direct trade links only. See Baldwin, Freeman and Theodorakopoulos (2023) for further description of this indicator.

4.2.3 $FPEX^{HE}$: FPEX - Hidden exposure, percentage

Indicator dimensions: [GO src cou | GO src ind | FD cou]

$$FPEX^{HE}_{r,i,s} = FPEM^{LT}_{r,i,s} - FPEM^{FV}_{r,i,s} = 100 * \frac{\sum_j^J (\sum_{k=2}^{\infty} a_{ij}^{rsk})\, FD_{i,r}}{\sum_s^S \sum_j^J b_{ij}^{rs}\, FD_{i,r}}$$

$$= 100 * \frac{\sum_j^J (\sum_{k=2}^{\infty} a_{ij}^{rsk})}{\sum_s^S \sum_j^J b_{ij}^{rs}}$$

where a_{ij}^{rsk} is a component of the input coefficients matrix **A** raised to the power of k, $FD_{i,r}$ is the final demand of the domestic industry and subscripts r, i, s, and j denote, respectively, the country and industry of origin of the gross output (r, i) and the destination country and industry (s, j).

$FPEX^{LT}$ can be decomposed into direct and indirect trade links. Indirect trade links are not directly observable in the data, and hence represent a country's exposure to supply chain disruption that is 'hidden'.

$FPEX^{HE}$ is a decomposed part of $FPEX^{LT}$ and its numerator measures a given country's exposure to inputs sold to its trade partners through indirect trade linkages only. The indicator is normalised by domestic plus foreign linkages (direct and indirect), and thus it ranges between 0% and 100%. Because only higher-order (indirect) trade links are considered, $FPEX^{HE}$ captures a country's exposure to global value chains which is 'hidden', or 'unobservable' in the data in that inputs sold feed into inputs which are then sold to make inputs, etc.

This indicator can be computed as the difference between $FPEX^{LT}$ and $FPEX^{FV}$ which is equivalent to the algebraic expression above. Note that at this level of aggregation $FD_{i,r}$ cancels out from the numerator and denominator. See Baldwin, Freeman and Theodorakopoulos (2023) for further description of this indicator.

4.3 Aggregation of FPEM and FPEX

FPEM and FPEX are defined at the domestic country and industry–foreign country level.

In addition, the dataset contains aggregations from the domestic industry dimension to the broader macro-sector, as detailed in Table 4.1. These aggregates correspond for FPEM to:

$$FPEM^{LT}_{r,J,s} = 100 * \frac{\sum_{j \in J} \sum_i^I b_{ij}^{rs}\, FD_{j,s}}{\sum_{j \in J} \sum_r^R \sum_i^I b_{ij}^{rs}\, FD_{j,s}}$$

$$FPEM^{FV}_{r,J,s} = 100 * \frac{\sum_{j \in J} \sum_i^I (\mathbb{1}[\mathrm{r} = \mathrm{s}] + a_{ij}^{rs}) FD_{j,s}}{\sum_{j \in J} \sum_r^R \sum_i^I b_{ij}^{rs}\, FD_{j,s}}$$

$$FPEM^{HE}_{r,J,s} = FPEM^{LT}_{r,J,s} - FPEM^{FV}_{r,J,s} = 100 * \frac{\sum_{j \in J} \sum_i^I (\sum_{k=2}^{\infty} a_{ij}^{rsk})\, FD_{j,s}}{\sum_{j \in J} \sum_r^R \sum_i^I b_{ij}^{rs}\, FD_{j,s}}$$

and for FPEX to:

$$\text{FPEX}^{\text{LT}}_{r,I,s} = 100 * \frac{\sum_{i \in I} \sum_{j}^{J} b_{ij}^{rs} \, FD_{i,r}}{\sum_{i \in I} \sum_{s}^{S} \sum_{j}^{J} b_{ij}^{rs} \, FD_{i,r}}$$

$$\text{FPEX}^{\text{FV}}_{r,I,s} = 100 * \frac{\sum_{i \in I} \sum_{j}^{J} (\mathbb{1}[\text{r} = \text{s}] + a_{ij}^{rs}) FD_{i,r}}{\sum_{i \in I} \sum_{s}^{S} \sum_{j}^{J} b_{ij}^{rs} \, FD_{i,r}}$$

$$\text{FPEX}^{\text{HE}}_{r,I,s} = \text{FPEM}^{\text{LT}}_{r,I,s} - \text{FPEM}^{\text{FV}}_{r,I,s} = 100 * \frac{\sum_{i \in I} \sum_{j}^{J} (\sum_{k=2}^{\infty} a_{ij}^{rsk}) \, FD_{i,r}}{\sum_{i \in I} \sum_{s}^{S} \sum_{j}^{J} b_{ij}^{rs} \, FD_{i,r}}$$

where J and I correspond to the macro sectors at the industry of origin and destination, respectively. r, i, s, and j denote, respectively, the country and industry of origin of the gross output (r, i) and the destination country and industry (s, j).

Table 4.1. Industry aggregates

TiVA 2023 Codes	Old (TiVA 2021) Codes	Economic activity aggregate	ISIC Rev. 4 Divisions
A	D01T03	Agriculture, hunting, forestry and fishing	01, 02, 03
B	D05T09	Mining and quarrying	05 to 09
C	D10T33	Total Manufacturing	10 to 33
D_E	D35T39	Electricity, gas, water supply, sewerage, waste and remediation services	35 to 39
GTT	D45T98	Total Services (excl. construction)	45 to 98
_T	DTOTAL	TOTAL	All Divisions

Note: Since 2022, the TiVA database rely on new codes to conform to new standard codes for all OECD databases that have an economic activity (ISIC Rev.4) dimension.

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