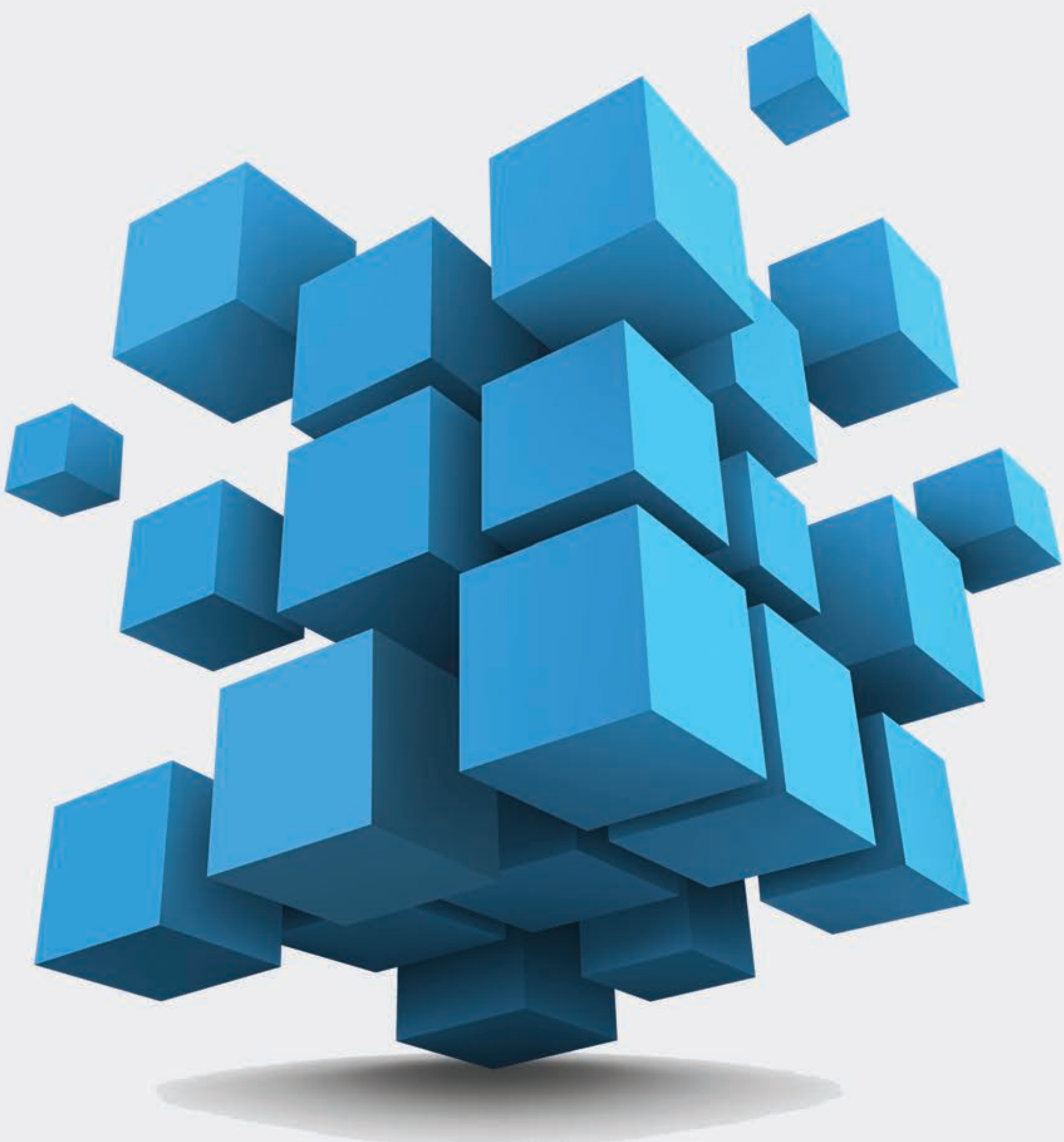
Handbook on Extended Supply and Use Tables and Extended Input-Output Tables



Handbook on Extended Supply and Use Tables and Extended Input-Output Tables

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Preface

Globalisation and the consequent increased interconnectedness between countries has transformed economies and how they function. This has affected the policy options available, particularly in response to economic shocks. Aggregate macroeconomic statistics are not fit for describing the broad variety of experiences across different kind of companies (e.g. small- and medium sized enterprises, multinationals and exporters). More nuanced evidence are needed to inform policies and target specific enterprise types. This has triggered strong demand for high-quality information on how different types of enterprises in the economy are faring, and to what extent they are participating in global value chains. Production, value added, imports, and exports disaggregated by enterprise type, along with important macroeconomic aggregates such as GDP and employment, are now essential tools in the modern policy toolbox.

Traditional supply and use tables (SUTs) and input-output tables (IOTs) do not account for these heterogeneities. In 2014, the OECD launched an Expert Group on Extended Supply and Use Tables (EGESUT) to develop methodologies for the compilation of statistics on different enterprise types consistent with national accounts aggregates. The European Commission’s Joint Research Centre (JRC) has actively participated and supported this initiative since then.

This Handbook is the result of the work of this expert group over the last decade. It sets new international standards and presents guidance on how to compile extended supply and use tables (ESUTs) and extended input-output tables (EIOTs). The Handbook offers a new approach to provide industry breakdowns by enterprise type. The methodologies build on existing data and methods to avoid additional data collection. The numerous country examples in the Handbook demonstrate that these methods are broadly replicable across countries.

The Handbook aims to assist compilers in deriving high-quality information about different enterprises in their economies, their interconnectedness and their role in global value chains, so that policymakers can make informed decisions. The Handbook offers users with more insights into how the results have been derived and how they should be interpreted. Guidance is provided by sharing best practices, catering for situations where enterprise data are available and for when they are not.

We hope that compilers and analysts will find this pedagogical and pragmatic OECD-JRC handbook useful.

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Foreword

An extended supply and use tables (ESUT) framework consistent with the System of National Accounts (SNA) is desirable to disaggregate macroeconomic statistics by type of enterprise. It would better measure the impact of globalisation while providing new insights including, for example, about the role and interconnectedness of small and medium-sized enterprises (SMEs) and multinational enterprises (MNEs) in global value chains (GVCs).

Background

The increasing international fragmentation of production, driven by technological progress, cost reduction and policy reforms, easing access to resources and markets, led to increasing demand for statistics about GVCs and related insights. The OECD-WTO Trade in Value Added (TiVA) initiative was the first initiative at an official level that allowed mapping complete GVCs, not only trade between two countries.

However, although it was an immense step forward, TiVA does not provide all the necessary insights since it only links industries and countries. It does not provide information about SMEs' integration into GVCs, which typically face larger barriers to trade than larger enterprises. Similarly, TiVA does not provide insights on MNEs' role in value chains, and so is also silent on the trade-investment-production nexus. Yet this type of information is essential to better understand the nature of GVCs.

Furthermore, policy makers sometimes focus on specific groups of enterprises such as SMEs, MNEs or exporters. There were no statistics on each enterprise type's contribution to macroeconomic aggregates such as GDP, imports, exports and employment, nor about the interconnectedness of different types of enterprises in GVCs. Assuming that all enterprises in an industry are equal would be incorrect – there is considerable heterogeneity. This heterogeneity can be tackled using microdata (ideal case) or enterprise type aggregates by industry. For example, Ahmad et al. (2013[1]) show that using Turkish trade microdata improved TiVA measures.

In response to the increased interest in linking types of enterprises to macroeconomic aggregates, in 2014 the OECD launched an Expert Group on Extended Supply and Use Tables (EGESUT), comprising participants from national statistical offices and international organisations. The terms of reference (OECD, 2014[2]) called for this group to share experiences and develop a methodology for constructing ESUTs. This Handbook aims to combine the accumulated knowledge on how to compile ESUTs and extended input-output tables (EIOTs), covering presentations and discussions conducted within the expert group, to assist others with compiling the extended tables and help users to properly understand the results. Earlier, Ahmad (2023[3]) provided some general guidance and results.

The extended tables provide new insights and have other advantages as well. In addition to providing more granular data about globalisation by enterprise type (such as by size, ownership and export orientation), the quality of globalisation indicators (such as imports used to export) is better than in the case that one assumes that all enterprises in an industry behave the same. Furthermore, compiling ESUTs and EIOTs will improve the quality of the regular statistical system as well. In the process of balancing supply and use, one works at a more detailed level, which enables identifying the reason for imbalances at the same detailed level as well. This facilitates decision making in the adjustment process and will improve regular supply and use tables (SUTs).

This Handbook adheres to the recommendations of the *Handbook on Supply and Use Tables and Input – Output Tables with Extensions and Applications* (United Nations, 2018[4]), including the recommendation to compile SUTs at the establishment level. However, because of the local data situation, not every country can follow this principle. Therefore, it is recommended to use the same statistical unit for the ESUT as the statistical unit used for the regular SUT. For convenience, throughout this Handbook, a SUT is said to be broken down by enterprise characteristics into an ESUT.

The purpose of the Handbook

This Handbook builds on extensive consultations with a wide range of national statistical compilers, international organisations and other key stakeholders in the domain of statistics and policy analysis. It is at the frontier of statistical measurement and contributes to developing the domain of integrated macroeconomic and microeconomic statistics. The Handbook's key objectives are to:

- Provide policy-related reasons and statistical reasons to compile ESUTs and EIOTs.
- Provide specific compilation guidance, documenting concepts, classifications, methodologies and data sources.
- Share best practices and case studies.
- Indicate possible solutions when data availability is limited.
- Explain how to communicate results to the general public.

The general recommendation is to build on data and methods already in use in the regular statistical production process to avoid extra data collection. Besides SUTs, existing data could include Structural Business Statistics, Trade by Enterprise Characteristics, Services Trade by Enterprise Characteristics Foreign Affiliates Statistics and Activities of Multinational Enterprises.

Target audience and using the Handbook

It follows from these objectives that this Handbook is intended for potential users of ESUTs, EIOTs and the related indicators, and for those involved in compiling the data.

The users of the statistics and indicators will often be policy makers, researchers and institutes that use macroeconomic statistics. For them, the Handbook aims to create a better understanding of the new information that ESUTs, EIOTs and derived indicators can provide; for example, production and value added by industry by type of enterprise, or value added at SMEs due to exports of large enterprises.

For those involved in collecting and compiling data and indicators, the Handbook provides a comprehensive reference, indicating best practices. The chapters build on existing compilation practices and have greatly benefited from inputs received from national compilers. Nevertheless, as the domain is still evolving, and some details of compilation practices are not yet well established, the authors of the Handbook recognise that a co-ordinated international effort is still required to address the remaining practical and conceptual challenges.

Furthermore, countries may face various challenges in putting the Handbook into practice, from applying the core concepts to the specific national context and the available data sources to compiling and disseminating the resulting statistics. Therefore, the Handbook also provides guidance for such cases. The transparency provided by explaining methodologies and highlighting remaining data-quality problems presents an opportunity for debate about what improvements can be made and how they can be achieved.

It is important to stress that this Handbook has been prepared to encourage and assist in compiling ESUTs, EIOTs and related indicators. It does not proclaim to be the final and definitive voice on the subject. Therefore, even though they reflect the current state of the art, some examples in the Handbook are "works in progress". This is particularly relevant for Chapter 8, which discusses indicators that may be used to complement the regular SUTs countries publish. Improvements may be made following lessons learnt during their implementation.

Relation to other work

The work of the EGESUT was closely related to other initiatives in the field of national accounts, business statistics and globalisation. To name a few:

- The *System of National Accounts 2025* (European Commission; IMF; OECD; UN, World Bank, 2025[5]) is the international macroeconomic statistical standard on compiling statistics on national accounts. It "is a statistical framework that provides a comprehensive, consistent and flexible set of macroeconomic accounts for policymaking, analysis and research purposes" (European Commission; IMF; OECD; UN; World Bank, 2009[6]). Among others, it contains chapters on SUTs, IOTs and globalisation. It refers to the current Handbook as a key tool to aid in measuring the impact of globalisation.
- The *Handbook on Supply and Use Tables and Input-Output Tables with Extensions and Applications* (United Nations, 2018[4]) aims "to provide step-by-step guidance for the compilation of supply and use tables and input-output tables and an overview of the possible extensions of SUTs and IOTs which increase their usefulness as analytical tools." The current Handbook builds on this framework and introduces an extension to it.
- *Accounting for Global Value Chains: GVC Satellite Accounts and Integrated Business Statistics* (United Nations, 2021[7]) "provides a framework for the measurement of global value chains, which consists of a multi-country supply and use tables and related institutional sector accounts, and a framework for integrated business, trade, and investment statistics. It outlines how economic statistics can be made more accurate and relevant in measuring the effects of globalisation in national accounts, business, and trade statistics".
- The *Handbook on Integrating Business and Trade Statistics* (United Nations, forthcoming[8]) provides "a conceptual and methodological framework for integrating business and trade statistics, including national best practices, and to provide guidance for building and strengthening capacities on microdata linking (MDL) to compile these statistics in an internationally comparable manner".
- The *Integrated Balance of Payments and International Investment Position Manual, seventh edition (BPM7)* (IMF, 2025[9]) "serves as the standard framework for statistics on the positions, transactions, and other changes in financial assets and liabilities between an economy and the rest of the world".
- The carbon footprint of foreign direct investment (FDI) is part of the Third Phase of the G20 Data Gaps Initiative. The usual method to estimate a carbon footprint is using input-output analysis. However, that type of analysis assumes that enterprises in an industry are homogeneous. Enterprises with FDI are, on average, very different from enterprises without FDI, hence this assumption does not hold. IMF (2024[10]) therefore recommends performing the analysis with an EIOT, where industries are split into a domestically owned part and a foreign-owned part.
- The Eurostat Integrated Global Accounts Expert Group (IGA EG) regularly discusses new methodology, data and indicators related to SUTs and IOTs. Due to globalisation, measurement challenges related to "traditional" macroeconomic aggregates such as GDP, gross national income, etc. appeared. The co-operation of national accountants, the balance of payments statisticians and experts on business and other statistics in this expert group will lead to new methods and data to resolve the challenges.
- The OECD Expert Group on Accounting Frameworks for Measuring Economic Globalisation (EG-MEG) will, among others, tackle the measurement challenges related to both the macro (economy, industry-level) and micro (enterprise-level) perspectives. This is crucial to capture the complexity of economic globalisation in official statistics, for example when considering MNEs.

The structure of the Handbook

Chapter 1 introduces the concept of ESUTs and EIOTs, showing what they could look like. It notes that a statistical reason to compile these tables is that regular tables might not properly capture heterogeneity in industries. For example, in an industry, the exporters may also be the main importers, and the foreign value added in exports is underestimated using regular IOTs. This bias can be (partly) removed by breaking each industry up into exporters and non-exporters, such as metal manufacturing exporters and metal manufacturing non-exporters. The chapter also provides several policy reasons to compile ESUTs and EIOTs. It explains how to decide which breakdown of an SUT is relevant for a particular country. Several country examples show a country's motivation for a particular breakdown, and the results that it obtained. The role of ESUTs and EIOTs as tools for policies is highlighted by the way several stakeholders used the new information.

Chapter 2 is the first of the chapters with compilation guidance. It discusses the three most common extension criteria: 1) trading status (e.g. exporter versus non-exporters); 2) ownership or group affiliation; and 3) enterprise size. It explains how to define the various categories of enterprises and how to classify the enterprises in practise, pointing out the various data sources.

Chapter 3 provides guidance to ESUT compilers that have access to detailed microdata, in particular at the enterprise level. In general, this includes the microdata underlying the construction of the regular SUT, such as the economic census, administrative data or specific surveys. The key idea in the approach described here is to construct an ESUT by disaggregating columns and rows of the regular SUT, using as much microdata as possible to capture the heterogeneity between different types of enterprises. The chapter explains step-by-step how to do this for an individual country, building on earlier experiences of national statistical offices which have compiled ESUTs.

Chapter 4 explains how to proceed in the case that one does not have the resources or access to the data to compile an ESUT and subsequently an EIOT. First, it points out that some of the recommendations in Chapter 3 might be followed up anyway. Subsequently, the chapter describes a step-by-step method to compile an EIOT. This approach requires the share of each enterprise type in output, value added, imports and exports by industry. It explains how to obtain that information in a robust way. Since some countries have an EIOT but do not have an ESUT, the chapter subsequently explains how to compile an ESUT from the EIOT in that specific situation (albeit it is recommended to go from an ESUT to an EIOT). Finally, a comparison is made between the "data-rich" and "data-scarce" approach (in Chapters 3 and 4, respectively) in terms of pros, cons and robustness.

Chapter 5 explains various mathematical methods to balance SUTs in the ESUT when there is lack of data to balance. It discusses various scenarios, providing recommendations on how to deal with each case. It also provides a checklist for designing automated balancing processes. Furthermore, it describes a method to backcast ESUTs, compiling a time series. The methods presented in this chapter are to be considered as second-best choices when there is no other way to improve sources of information and to tackle the main imbalances manually.

Chapter 6 covers the methodology of transforming an ESUT into an EIOT. It starts with a discussion of the underlying theory of IOTs then continues with the choice of dimension for such tables (product-by-product or industry-by-industry) and the construction methods for IOTs and EIOTs. It explains the various ways of doing so, each with its own assumptions, advantages and disadvantages. The chapter provides recommendations on how to adhere to best practices.

Chapter 7 provides compilation guidance on adding country detail to imports and exports in ESUTs and EIOTs. This can take several forms, depending on the information needs and data availability. A country may either wish for better trade in value added (TiVA) and other globalisation indicators, look for better integrating its own data into international data, or be interested in comparing a certain type of enterprises (e.g. MNEs) in the resident economy to that in other countries. The chapter provides methodology, data, concrete examples and references for each of the three common situations.

Chapter 8 provides advice on how to disseminate the new information to a broader public, varying from tables, infographics and video clips. It points out several indicators based on the new data that countries have compiled in the past and what information they convey.

Chapter 9 sets out several country examples of adding information from other domains to ESUTs and EIOTs. These additions vary from value added and income flows to employment, physical ESUTs and emissions. Subsequently, the chapter provides suggestions about the integration of ESUTs and productivity by industry statistics, regional ESUTs and digital SUTs.

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Abbreviations and acronyms

AAMNE	Analytical Activity of Multinational Enterprises (database)
AMNE	Activity of Multinational Enterprises (database)
ARSUT	Administrative region supply and use table
CASIF	Chinese Annual Survey of Industrial Firms
CBCR	Central Bank of Costa Rica
CCS	Cloud computing service
DDVA	Direct domestic value added
DETF	Digital Economy Task Force
DIS	Digital intermediation service
DOE	Domestic-owned enterprise
EGESUT	Expert Group on Extended Supply and Use Tables
EGR	EuroGroups Register
EIOT	Extended input-output table
EMCIOT	Extended multi-country input-output table
ESUT	Extended supply and use table
EU	European Union
EUR	Euro
FATS	Foreign AffiliaTes Statistics
FDI	Foreign direct investment
FIE	Foreign-invested enterprise
FIGARO	Full International and Global Accounts for Research in Input-Output analysis
FOB	Free on board
FPB	Federal Planning Bureau (Belgium)
GDP	Gross domestic product
GNI	Gross national income
GRAS	Generalised RAS
GVA	Gross value added

GVC	Global value chain
ICT	Information and communications technology
IMF	International Monetary Fund
INEGI	National Institute of Statistics and Geography (Mexico) *Instituto Nacional de Estadística y Geografía*
IO	Input-output
IOT	Input-output table
ITG	International trade in goods
MCIOT	Multi-country input-output table
MDL	Microdata linking
MNE	Multinational enterprise
NA	National accounts
NBS	National Bureau of Statistics
NPISH	Non-profit institutions serving households
NSO	National statistical office
NUTS	Nomenclature of Territorial Units for Statistics
R&D	Research and development
RoW	Rest of World
SBS	Structural Business Statistics
SME	Small and medium-sized enterprise
SNA	System of National Accounts
STEC	Service trade by enterprise characteristics
SUBE	Supply and Use Based Econometric approach
SUT	Supply and use table
TEC	Trade-by-enterprise-characteristics
TiVA	Trade in Value Added
TLS	Taxes less subsidies on products
UCI	Ultimate Controlling Institutional Unit
UN	United Nations
UNCTAD	UN Trade and Development
US	United States
VAT	Value-added tax
WIOD	World Input-Output Database
WTO	World Trade Organization

Executive summary

This Handbook is a significant step towards bridging the gap between macroeconomic (national accounts) and microeconomic data (business statistics and trade statistics, at enterprise level or by type of enterprise). It provides methodological guidance to combine the strengths of each. The macroeconomic statistics relate to gross domestic product (GDP) and employment, and they are internally consistent. They are also complete, containing estimates of production that is difficult to survey, such as some activities of microenterprises and illegal activities. The microeconomic statistics provide a wealth of detail on many types of enterprises that interest policy makers, including small and medium-sized enterprises (SMEs), multinationals, and exporters/non-exporters. The Handbook is the result of the work of the OECD Expert Group on Extended Supply and Use Tables (EGESUT), which was launched in 2014.

Combining macroeconomic and microeconomic statistics has many benefits. It relates production, value added, imports and exports by type of enterprise to GDP, total employment and other macroeconomic data in a consistent way. It adds heterogeneity to statistics and indicators such as the domestic value-added content of exports. This is desirable, since the aggregate might mask important information related to the diversity of the components. It also provides new indicators about direct and indirect linkages, of types of enterprises with each other, and of types of enterprises with foreign and domestic supply and use. For example, it is well-known that SMEs generally have a lower propensity to export than large enterprises. The new information shows that due to their sizeable indirect exports, supplying large exporters with goods and services, SMEs still benefit from foreign markets. Furthermore, compiling extended supply and use tables (ESUTs) will improve the current statistical system since it integrates data at a more detailed level, which makes it easier to relate imbalances in supply and use to their source and to resolve them.

The conceptual measurement framework to combine the information consists of compiling ESUTs and extended input-output tables (EIOTs). This is fully consistent with the fundamental measurement framework of the System of National Accounts (SNA). The ESUT approach is mentioned in the 2025 SNA and fully adheres to its principles. Taking as its starting point the regular supply and use tables (SUTs) and input-output tables (IOTs) in the SNA, the ESUT and EIOT introduce an extra dimension for measuring the economy: the type of enterprise. This leads to additional rows and columns within the ESUT and EIOT compared with the regular SUT. Instead of metal manufacturing, one could have metal manufacturing SMEs and metal manufacturing large enterprises. Separating enterprises into different types provides important perspectives on the amount of output, value added, compensation of employees and employment by enterprise type. Enterprises could be classified as a certain type depending on, for example, the size of the enterprise, foreign/domestic ownership or trading status (e.g. exporter and non-exporter).

In 2014, the OECD launched the EGESUT. Country experts and representatives from international organisations have met several times over the past decade to discuss various conceptual and methodological issues and to share best practices. This led to a series of recommendations that have no or minimal impact on data collection and are broadly replicable across countries. The non-prescriptive nature of the ESUT framework (where estimates can be published if the data are available, but compilers can choose not to publish results for which they lack data or have quality concerns) will help countries to make progress and publish results, even if they are “experimental”. The Handbook contains the combined knowledge and experience of the EGESUT members. It has been put into practice in several countries over the last decade (Belgium, Costa Rica, Finland, Italy, Japan, Mexico and the Netherlands, among others).

The Handbook sets out the concepts, methodologies and data sources necessary to compile ESUTs and EIOTs. It provides a thorough step-by step explanation of how the methodologies work. It includes various examples and guidance on how to deal with specific conceptual and practical issues in the compilation process. It also builds on international and national experiences as well as on best practices to expand compilation guidance. The discussion covers examples of data sources used by compilers to produce the estimates and the specific challenges they encountered. The Handbook’s recommendation is, to the extent possible, to build on and combine existing data sources.

Besides providing guidance for the ideal data situation, when all enterprise data are available, the Handbook also indicates what can be done in other situations, when fewer or no enterprise data are available. The latter is typically the case for researchers outside a national statistical office. The Handbook explains how to balance the ESUTs and how to transform them into EIOTs. Since there is much policy interest for the integration of different enterprise types into the global value chain, it explains how to embed an EIOT into a multi-country input-output table (MCIOT, see the United Nations *Handbook on Supply and Use Tables and Input-Output Tables with Extensions and Applications*). An MCIOT allows mapping the whole global value chain, with all industries and countries involved. After the embedding, one can analyse on which countries a particular enterprise type is dependent for direct and indirect imports and exports. The Handbook ends with a chapter on dissemination and a chapter that relates ESUTs and EIOTs to other dimensions, such as productivity, the environment or employment.

Although the main examples illustrate industry breakdowns by enterprise size, ownership or trading status, the methods are applicable in other situations as well. For example, in emerging economies, a breakdown into formal and informal components of the economy might be more relevant. In addition, as the domain is still evolving and some details of compilation practices are not yet well established, the authors of the Handbook recognise that co-ordinated international effort is still required to address the remaining practical and conceptual challenges.

That said, the ESUTs and EIOTs have been compiled assuming the regular SUTs and IOTs exist. Strategically, in developing the regular SUTs and IOTs, the ESUTs and EIOTs could be at the core of the process from the business register through business surveys and then onto national accounts. In this situation, the regular SUTs would be formed by simply aggregating the ESUTs.

1. What are extended supply and use tables and why are they useful?

This chapter starts with a brief description of regular supply and use tables before turning to the analytical issues they face. The chapter then presents the concept of extended supply and use tables and factors for identifying the most relevant dimension to break down in industries in such a table in practice. The chapter further provides various country examples explaining policy relevance and showing results.

Introduction

This chapter starts with a brief description of regular supply and use tables (SUTs) presented in the *Handbook on Supply, Use and Input-Output Tables with Extensions and Applications* (United Nations, 2018[1]). Although they are useful tools, SUTs do not account for enterprise heterogeneity within industries and might result in biased indicators on globalisation. Complementing existing statistics, extended SUTs (ESUTs) do incorporate enterprise heterogeneity into a consistent framework through a breakdown of industries by type of enterprises (e.g. based on size, ownership, trading status or formal/informal). As such, they also help to respond to the increasing demand for statistical information by type of enterprise. In addition to presenting ESUTs from a conceptual point of view, the chapter also discusses how to identify the most relevant dimension to break down in an ESUT in practice. Selected country examples highlight that there is no ideal set-up to produce an ESUT. Rather, the choice of the dimension to focus on in an ESUT will depend on the country-specific policy needs, macroeconomic environment (e.g. trade openness) and data availability.

Usefulness of regular supply and use tables

Regular SUTs provide a balanced framework for describing economic activity by industry and by product in a country, a region or worldwide. This framework links product-level supply and use as well as industry-level inputs, outputs and gross value-added components.

The supply table shows the supply of goods and services by type of product with a distinction by origin: supply from domestic production by type of activity and supply from non-residents through imports. The sum of the two yields total supply.

The use table shows information about the uses of the different products, by either industries (intermediate consumption or gross capital formation), households, government and non-profit institutions serving households (final consumption expenditure), or non-residents (exports). Moreover, the use table provides information about the components of gross value added by industry – namely, compensation of employees, other taxes less subsidies on production, consumption of fixed capital and net operating surplus.

Table 1.1 shows the two basic identities linking the supply table and the use table. To be balanced, total supply by product must be equal to total use by product and total output by industry must be identical in the supply table and the use table.

Gross domestic product (GDP) can be calculated using the three approaches: 1) the production approach; 2) the income approach; and 3) the expenditure approach within the SUT framework. SUTs allow more easily identifying the sources of divergences across the goods and services account, the production account (by industry and by institutional sector) and the generation of income account (by industry and by institutional sector). The detail in products and industries allows one to find the source of a possible imbalance at a detailed level as well. For further details, see Chapter 2 of United Nations (2018[1]).

Table 1.1. Supply and use table framework

<table>
<tr><th></th><th></th><th colspan="4">Products</th><th colspan="4">Industries</th><th colspan="3">Final uses</th><th></th></tr>
<tr><th></th><th></th><th>Agriculture, forestry, etc.</th><th>Mining and quarrying</th><th>…</th><th>Services</th><th>Agriculture, forestry, etc.</th><th>Mining and quarrying</th><th>…</th><th>Services</th><th>Final consumption expenditure</th><th>Gross capital formation</th><th>Exports</th><th>Total</th></tr>
<tr><td rowspan="4">Products</td><td>Agriculture, forestry, etc.</td><td colspan="4" rowspan="4"></td><td colspan="4" rowspan="4">Intermediate consumption by product and by industry</td><td colspan="3" rowspan="4">Final uses by product and by category</td><td rowspan="4">Total use by product</td></tr>
<tr><td>Mining and quarrying</td></tr>
<tr><td>…</td></tr>
<tr><td>Services</td></tr>
<tr><td rowspan="4">Industries</td><td>Agriculture, forestry, etc.</td><td colspan="4" rowspan="4">Output by product by industry</td><td colspan="4" rowspan="4"></td><td colspan="3" rowspan="6"></td><td rowspan="4">Total output by industry</td></tr>
<tr><td>Mining and quarrying</td></tr>
<tr><td>…</td></tr>
<tr><td>Services</td></tr>
<tr><td>Value added</td><td></td><td colspan="4"></td><td colspan="4">Value added by component and by industry</td><td>Value added</td></tr>
<tr><td>Imports</td><td></td><td colspan="4">Total imports by product</td><td colspan="4"></td><td>Total imports</td></tr>
<tr><td>Total</td><td></td><td colspan="4">Total supply by product</td><td colspan="4">Total output by industry</td><td colspan="3">Total final uses by category</td><td></td></tr>
</table>

Note: Empty cells by definition.
Source: United Nations (2018[1]).

Much of the analysis done within an SUT framework pivots around the input-output tables (IOTs), which are analytical tables derived from the SUTs. An industry-by-industry IOT shows how industries supply their output as input for industries (intermediate use) and final use (final consumption expenditure, gross capital formation and exports). The table also shows imports and value added by industry.

Analytical issues of regular supply and use tables

Regular SUTs (and associated IOTs) might not always provide the right answers in analysis. As Michel et al. (2019[2]) point out, such tables assume producers (industries) produce similar goods and services, i.e. relative homogeneity of the production functions (technical coefficients) of units classified under the same activity. This assumption is not always realistic. For instance, economies of scale play a different role in smaller and larger enterprises belonging to the same industrial activity.

Moreover, heterogeneity within industries has increased with globalisation. Enterprises may have specialised in specific tasks of the production process, with both greater (upstream) import and export orientation. For instance, a processing enterprise will have significantly less (recorded) imports than a non-processing enterprise just because it does not own the imports it uses. In addition, factoryless goods producers and enterprises involved in goods for processing arrangements would have even less (recorded) intermediate consumption of goods compared to those enterprises that choose to buy the material goods to be processed.

The increased heterogeneity within the industrial activities has considerably reduced the quality of input-output based indicators such as the Trade in Value Added (TiVA) indicators. These measure, amongst other issues, the extent of integration into global value chains (GVCs). But regular SUTs and IOTs do not always provide an accurate picture (see Box 1.1 for an illustration). The reason is that empirical evidence suggests that enterprises more engaged in global production arrangements have higher import content and, sometimes, higher productivity than others. The first leads to an overestimation of domestic value added in exports, the second to an overestimation of domestic jobs in exports. This is problematic.

Yamano and Webb (2022[3]) compare indicators obtained from a regular multi-country input-output table (MCIOT) with indicators obtained from an MCIOT where industries in the People’s Republic of China (hereafter “China”) and Mexico are split into processing trade and non-processing trade. The authors used different globalisation indicators, e.g. offshoring (Feenstra and Hanson, 1996[4]), import contents of exports (Hummels, Ishii and Yi, 2001[5]) and domestic value added in foreign final use (Johnson and Noguera, 2012[6]; OECD, 2013[7]). China and Mexico were chosen because processing trade is large in these countries and sufficient information is available to incorporate both types of producers.

Yamano and Webb (2022[3]) find that there is substantial bias in domestic value added embodied in international trade in both China and Mexico. For China, the biases were much higher in the mid-2000s (approximately 15%) than in more recent years (approximately 7%). Domestic value added embodied in foreign final use as a share of total domestic value added for China and Mexico was 18% and 20%, respectively, in recent years. But without splitting the export-oriented sectors in the MCIOT, the results are overestimated by 2.1 percentage points for China and 1.0 percentage point for Mexico.

Box 1.1. Fictitious example: Bias in case of strong enterprise heterogeneity

This box provides a simple fictitious example of why it is important to consider heterogeneity in certain circumstances when deriving Trade in Value Added indicators.

If one does not have any information about the import-export pattern of the underlying types of enterprises, one will estimate that for USD 50 in exports, imports embodied in exports amount to 50/200 * 50 = USD 12.5 (Table 1.2). However, if extra information is available, one can see that exports are mainly from large enterprises which also import more. The estimate of imports embodied in exports becomes 10/100 * 10 + 40/100 * 40 = USD 17.

Therefore, the import content of exports is underestimated in an analysis using a regular table, and therefore the domestic value added content of exports is overestimated.

Table 1.2. An example of bias

Values, USD

	Imports	Exports	Domestic sales	Total sales	Imports embodied in exports
Total – assuming all enterprises behave the same	50	50	150	200	12.5
Small and medium-sized enterprises	10	10	90	100	1
Large enterprises	40	40	60	100	16
Total, accounting for heterogeneity in enterprise size	50	50	150	200	17

Increasing the granularity in the data by providing more industry and/or product detail has been one way to tackle the problem of heterogeneity in the past. It is a natural approach, since within a standard SUT framework, efforts to minimise aggregation bias typically centre on choosing industry definitions and industry aggregation levels that maximise homogeneity within the resulting industry groupings. Depending on the specific situation at hand, this approach or the ESUT approach may be the best to reduce heterogeneity within groupings. In the decision process, policy demands, data availability for the specific ESUT and related thematic accounts (e.g. related to employment or environment), and the best option to reduce data-processing burdens can play a part too.

Sometimes, dividing an industry into several subindustries does not solve the heterogeneity problem related to IOTs. The reason is the following: input-output (IO)-multipliers use a matrix of technical coefficients. This matrix can be interpreted as the collection of production functions of different industries in the economy (e.g. the production function of the plastic manufacturing industry). Each production function in the matrix of technical coefficients is the weighted average of the production functions of individual establishments within the corresponding industry grouping. A key assumption that underpins the calculation of a matrix of IO-multipliers is that each industry column captures a set of establishments with similar, or homogeneous, input structures. Aggregation bias results when establishments with dissimilar, or heterogeneous, input structures are grouped together. Much research has been devoted to understanding and minimising the impact of aggregation bias on IO analysis. The heterogeneity within an industry, e.g. between small and medium-sized enterprises (SMEs) and large enterprises, generally does not depend on the different subindustries within an industry. This SME-large enterprise heterogeneity will be present in each subindustry that is not too small.

Extended supply and use tables accounting for enterprise heterogeneity

The ESUT approach has its focus on decomposition of industries by enterprise characteristics. Industries are split into heterogeneous groups, where each group itself is homogeneous. This leads to greater homogeneity of production functions within the resulting industry-by-enterprise-type groupings.

There are many ways to reconfigure the information in SUTs to show new details, but only a reconfiguration that decomposes industries by enterprise characteristics is considered an ESUT. Other common "extensions" of the SUT framework, such as digital SUT and thematic SUTs are not ESUTs and are described in Annex 1.A.

In practical terms, the extension typically consists of splitting columns (industries) further and possibly rows (products) in the SUTs by using (micro)data linked to related different official statistics (see the *Handbook on Integrating Business and Trade Statistics* (United Nations, forthcoming[8]) on micro-data linking). The dimensions used to break down industries and products in the SUTs define the type of ESUTs. For example, in the case of a breakdown by size, each industry could be split into two parts: 1) the SME part; and 2) the large enterprise part (see Table 1.3 for an example).

Similar to ESUTs, an extended input-output table (EIOT) is an IOT where industries are split by enterprise characteristics; see Table 1.3.C for an example. Note that other extensions of IOTs also exist, for example with information on investment, capital and labour. Additional information on energy, emissions, natural resources, waste, sewage and water could be added to the tables as well (United Nations, 2018[1]). However, such extensions are not EIOTs.

Table 1.3. Simplified examples of extended supply, use and input-output tables, by size

A. Extended supply table

Products	Industries				Imports	Total
	Manufacturing		Services			
	SMEs	Large enterprises	SMEs	Large enterprises		
Product 1	Output by product by industry by enterprise type				Imports by product	Total supply by product
Product 2						
…						
Total	Total output by industry by enterprise type				Total imports	Total supply

B. Extended use table

Products	Industries				Final uses			Total
	Manufacturing		Services		Final consumption expenditure	GCF	X	
	SMEs	Large enterprises	SMEs	Large enterprises				
Product 1	Intermediate consumption by product and by industry by enterprise type				Final uses by product and by category			Total use by product
Product 2								
…								
Value added	Value added by component and by industry by enterprise type							
Total	Total output by industry by enterprise type				Total final uses by category			

C. Extended input-output table

		Industries				Final uses			Total
		Manufacturing		Services		Final consumption expenditure	GCF	X	
		SMEs	Large enterprises	SMEs	Large enterprises				
Manufacturing	SMEs	Intermediate consumption of domestic production				Final uses of domestic production			Total use
	Large enterprises								
Services	SMEs								
	Large enterprises								
	Imports	Intermediate consumption of imports				Final uses of imported products			
	Value added	Value added by component							
	Total	Total supply				Total final uses by category			

Note: SMEs: small and medium-sized enterprises; GCF: gross capital formation; X: exports. Empty cells by definition.

It is not necessary, nor generally feasible, to break down each single industry or provide each extension for every industry. As national statistical offices or researchers decide which dimensions to focus on, the opportunity to highlight important aspects of the economy as well as the level of interest by data users in a particular topic are important considerations, as is the availability of the necessary data. Extending SUTs means breaking down product and industry categories (that are fairly aggregated), and several criteria can be applied to this end. Breakdowns by size class would be advisable to analyse the role of SMEs within GVCs, and if the investment agenda is a high-priority policy, a breakdown by ownership will be essential. The decision-making process should consider not only the benefits achieved through mitigation of aggregation bias and practical considerations such as data availability, but also the potential insights that these tables will provide in their own right. Annex 1.B describes an econometric approach that provides guidance on choosing the most technically appropriate breakdown by industry. Another factor is the existence of thematic accounts along the same dimensions, such as factor inputs or environmental stressors. These are crucial for researchers for many types of analysis. This aspect should also play a role in deciding on the disaggregation of the industries.

The enterprise-type extensions that are used might vary from one economy to another. The most common extensions are splits by ownership, size class or exporter status (Table 1.4). These are further elaborated in Chapter 2. Because ESUTs are often used in the calculation of TiVA statistics, enterprise-type categorisations that simultaneously capture differences in production functions and differences in foreign trade patterns are of special interest.

Other types of heterogeneity can be relevant as well. For example, one can consider groups of enterprises related to special trade regimes: processing traders for China (Koopman, Wang and Wei, 2012[9]; Yang et al., 2015[10]; Jiang et al., 2016[11]; Chen et al., 2019[12]), processing traders for regions in China (Duan et al., 2023[13]), enterprises operating under global manufacturing programmes for Mexico (De La Cruz et al., 2011[14]; INEGI, 2018[15]; Yamano et al., 2022[16]) and enterprises operating in free trade zones in Costa Rica (Saborío, 2015[17]). INEGI (2018[15]) describes the methodology of a split of the regular SUT of Mexico by all dimensions at the same time, capitalising on their economic census data.

In many developing countries, completely different EIOTs could be most relevant. In those countries, a large part of GDP and employment is generated by the informal sector. There, policy makers must understand the contributions of the informal sector and its interdependence with the formal sector in developing policies. An informal sector EIOT for India played a critical role in estimating the informal sector's contribution to environmental and social impacts. Mitoma (2023[18]) revealed that the informal sector significantly contributed to the carbon footprint of the top three supply chains with the highest CO_2 emissions in India. Mitoma and Yamano (2024[19]) studied the bias that could arise in IOTs that aggregated the formal and informal sectors. Their analysis of employment in vulnerable groups embodied in Indian exports showed that ordinary IOTs can overestimate or underestimate the impact of exports by 10-40% at the industry level.

More detailed examples are provided throughout this handbook.

Table 1.4. Examples of extended input-output table and extended supply and use tables

Authors	Regional scope		Dimensions
OECD (2015[20])	OECD Member countries	EIOT	Enterprise size
Fortanier et al. (2020[21])	OECD Member countries	EIOT	Ownership
Statistics Denmark and OECD (2017[22])	European Nordic countries (Denmark, Finland, Iceland, Norway and Sweden)	EIOT	Size, ownership, exporter status
Fetzer et al. (2023[23])	United States	ESUT	Size, ownership, exporter status
Chong et al. (2019[24])	Netherlands	ESUT – EIOT	Size
Michel and Hambÿe (2022[25])	Belgium	ESUT and EIOT	Exporter status
Hambÿe et al. (2022[26])	Belgium	ESUT and EIOT	Type of multinational
Sallusti and Cuicchio (2023[27])	Italy	ESUT	Size, ownership, exporter status
INEGI (2018[15]; 2023[28])	Mexico	ESUT	Size, ownership, exporter status

Note: EIOT: extended input-output table; ESUT: extended supply and use table.

Purposes of extended supply and use tables

The creation of an ESUT results in new groupings of enterprises within the economy. It provides an extra layer to existing statistics that is well-integrated into the core accounting framework of National Accounts. In particular, the complete, integrated view of enterprises by size class, ownership or trading status is consistent with macroeconomic indicators such as GDP.

The integrated framework of ESUTs can also improve the quality of the core economic accounts, in particular when the accounts are affected by globalisation. An ESUT takes into account that larger enterprises may have different input structures due to their engagement in international trade as well as different economies of scale than smaller enterprises. The same holds for foreign-owned enterprises or enterprises with affiliates abroad, compared to purely domestically owned enterprises.

ESUTs also provide the basis for a better articulation of globalisation across various domains. Currently, national SUTs are the usual route to systematically and coherently combine national accounts, trade statistics and business surveys into a single integrated economic framework. ESUTs can provide additional information to better understand the various facets of globalisation, by combining information from SUTs with different data sources. Examples of such data sources are foreign affiliates statistics (FATS)/activities of multinational enterprises, commodity trade by enterprise characteristics and services trade by enterprise characteristics.

An ESUT and EIOT also provide valuable new policy-relevant insights on the different roles played by each enterprise category and how they interact with one another. For instance, information on foreign affiliates helps to quantify spillover effects from foreign direct investment and it allows extending analysis beyond value-added concepts such as the international profit (income) distribution of enterprises. Alternatively, the role of SMEs and indirect trade links through large enterprises can be studied.

Selected practical country examples

This section provides concrete country examples in compiling ESUTs and EIOTs. It highlights that there is no ideal enterprise grouping to be used to break down SUTs (Table 1.5). Rather, the choice is likely to depend on the country-specific policy needs, macroeconomic environment (e.g. trade openness) and data availability. The examples show that the methods are broadly replicable across countries.

Table 1.5. Several country experiences in selecting the relevant dimension to compile extended supply and use tables and extended input-output tables

	Criteria	Source of information	Dimension
Belgium	Economic relevance combined with data availability	Feasibility study	Ownership
China (People's Republic of)	Economic relevance	Existing knowledge on enterprise behaviour	Ownership
Costa Rica	Economic relevance	Existing knowledge on enterprise behaviour	Ownership
Finland	Policy relevance	Demand from policy makers	Trading status and a combined enterprise size and group relation
Japan	Characteristics that present the highest level of heterogeneity	Statistical approach	Each industry is split by type of enterprise that is most relevant for this specific industry
Mexico	Economic relevance	Statistical approach	Size, ownership, exporter status
United States	Economic relevance	Academic literature	Size and ownership

Belgium

In Belgium, the Federal Planning Bureau (FPB) started to work on the construction of ESUTs in 2015, pursuing two major aims: 1) incorporating information on enterprise heterogeneity into the macroeconomically consistent framework of the SUT; and 2) producing policy-relevant analytical results.

The initial project focused on a disaggregation by exporter status for manufacturing industries in the 2010 Belgian SUT. It was considered as a test run and therefore limited in scope to keep the workload manageable. The exporter status criterion was chosen because of its relevance for a small and very open economy like Belgium and because it appeared relatively straightforward to implement.

In the wake of this successful initial project, the FPB received funding from Eurostat to pursue its work on ESUTs. This led to a follow-up project that began in 2019 and consisted of two parts: 1) a feasibility study of producing an ESUT for Belgium for each of the three main dimensions of enterprise heterogeneity, i.e. size, ownership and exporter status (Michel and Hambÿe, 2022[25]); and 2) an extended SUT for Belgium for 2015 for one of these heterogeneity dimensions. It was decided to construct an ESUT with a disaggregation by ownership given the strong and growing interest in this dimension. Analytical results based on the ownership-extended tables highlighted the importance of multinational groups in the Belgian economy (Hambÿe et al., 2022[26]).

A new Eurostat-funded project (Hambÿe, Michel and Trachez, 2023[29]) produced ownership-extended tables for 2019. It also investigated a disaggregation of industries by enterprise size class that takes into account whether enterprises belong to a domestic or a multinational group. It was found that, together, Belgian and foreign MNEs accounted for more than half of the total value of output in 2019. Their joint share in GDP stood at almost 45%, with 15% due to enterprises that belong to a Belgian MNE and almost 30% due to affiliates of foreign MNEs. The GDP share of domestic enterprises was 26%, while the non-disaggregated industries accounted for the remaining 30%. For employment, the shares of Belgian MNEs and foreign MNEs were lower, with, respectively, 11% and 18%, whereas the share of domestic enterprises was significantly higher (35%). Finally, Belgian MNEs, and in particular foreign ones, largely dominated Belgian exports of goods and services. Foreign MNEs accounted for 58% of total Belgian exports.

Michel and Hambÿe (2022[25]) combined the export-heterogeneous tables with employment. They found that 585 000 jobs, or 13% of economy-wide employment in Belgium, are sustained by manufacturing exports. This number would be overestimated by 4% if one were to use regular tables. Moreover, they identified who contributes to and who gains from exports for groups of enterprises rather than aggregated industries.

China (People's Republic of)

There is a long tradition of incorporating enterprise heterogeneity into SUTs and IOTs in China (see, for example, Duan et al. (2012[30]); Hong, Wang and Zhu (2015[31]); and Yang, Wei and Zhu (2016[32]).

Yang et al. (2022[33]) compiled an EIOT where each industry is split into foreign-invested enterprises (FIEs) and domestically owned enterprises (DOEs). See Chapter 4 for a description of the methodology. FIEs and DOEs in China are different in many aspects, including production input, export pattern and impacts on the local economy. For example, FIEs are more export-oriented than DOEs. Besides, FIEs and DOEs play different roles in generating local value added, since a large part of value added from GVCs is generated by affiliates of multinational enterprises. FIEs and DOEs also exhibit different performance on technology dissemination and skill building.

The domestic value-added share in gross exports of DOEs was 82% in 2012, which is 17 percentage points higher than that of FIEs (Table 1.6). A possible reason is that DOEs have a higher share of non-processing exports than FIEs (88% and 33%, respectively). Not shown in the table: the share of FIEs' contribution to GDP was 16%, and FIEs' share in total value added in exports was 25%. FIEs' dependence on foreign trade is up to 30%, 13 percentage points higher than for DOEs.

Table 1.6. Domestic and foreign content share of China's exports in 2012

	Total exports (billion CNY)	DOEs' share	FIEs' share	Total exports	DOEs' exports	FIEs' exports
Exports	14 141	53%	47%			
Domestic value added in exports	10 487	58%	42%	74%	82%	65%
Foreign value added in exports (vertical specialisation level)	3 654	36%	64%	26%	18%	35%

Note: CNY: Chinese yuan; DOE: domestically owned enterprise; FIE: foreign-invested enterprise.
Source: Yang et al. (2022[33]).

Looking at the industry breakdown, manufacturing as a whole is characterised by a lower value-added ratio in gross exports both for DOEs and FIEs than the average for these types of enterprises (79% and 62%, respectively; with averages of 82% and 65%, respectively). DOEs export most in "wearing apparel" and "chemical products". FIEs export most in "communication equipment and electronic equipment" followed by "electrical machinery". As for the value-added ratio in gross exports, DOEs and FIEs differ greatly in "electrical machinery", "communication equipment and electronic equipment", and "measuring instruments and meters".

Costa Rica

Costa Rica is a highly open economy. In recent years, exports and imports have each amounted to one third of GDP, while foreign share enterprises (FSEs) have accounted for approximately 64% of exports (Steller et al., 2021[34]). FSEs include multinational corporations that primarily target foreign markets and are connected to different stages within GVCs, resulting in dissimilar levels of interaction with domestic markets. Some of these enterprises have no connection to domestic markets while others have domestic control enterprises (DCEs) as their main suppliers. This dynamic causes heterogeneity within the economy in many areas, such as income payments to the rest of the world, production functions and foreign content ratios. It also creates a need for more granular data about income, employment, supply and demand relationships, and the linkages between export and domestic enterprises.

To meet the needs of policy makers and researchers, the Central Bank of Costa Rica has created an ESUT, an EIOT and institutional sector accounts that present data about FSEs and DCEs. These provide enhanced tools for economic analysis, research and projections.

In 2018, FSEs accounted for 26% of value added, 17% of employment and 66% of the country's exports. They were primarily focused on activities oriented towards external markets, such as medical devices, foods, drinks, and professional and scientific services. Salaries in FSEs were 35% higher than those in the rest of the economy.

FSEs produced a diverse range of products, such as medical appliances, bananas, pineapples, food products, tires and plastic products. Exports of goods carried out by DCEs were more diverse, nonetheless. Almost half of the services exported by FSEs consisted of head offices and management services, followed by computer programming services and administrative and support services. Service exports from DCEs were more diverse than those from FSEs.

The imported component in manufacturing FSEs was double that of DCEs (33% and 16%, respectively) while in services it was quite similar (9% and 8%, respectively). At a more disaggregated level, the economic activities of manufacturing and services exhibited behaviours similar to those of the aggregates. Manufacturing FSEs had a slightly lower value-added/output ratio than the DCEs (37% versus 38%), but the ratio for FSEs in the case of services exceeded that of DCEs by 7 percentage points (62% versus 55%). Differences in these ratios were especially notable in the cases of medical devices and processed fruit and vegetables, where the ratios for DCEs were substantially higher than those of FSEs, and in administrative and support services, where the ratio for FSEs was much higher than that for DCEs.

Finland

Finland is a small open economy with significant exposure to foreign trade, and better knowledge of how trade affects the domestic economy is pivotal to improving policy making and securing economic stability and growth. ESUTs can be a powerful tool to design economic policy and can interest many stakeholders in government offices and research organisations.

The domestic need for better information on trade in value added was initially expressed by the Finnish Ministry for Foreign Affairs in 2017. The ministry stressed the need for information on where Finnish value added is exported, where it is consumed and what kind of imports are important for Finnish enterprises. Other stakeholders expressed specific needs for information as well. Policy makers already had several tools at hand, but the need for detailed and timely data has been ever growing (Box 1.2). Official statistics, and analytical frameworks that build on official statistics, are important to ensure reliable policy making.

In 2020, Statistics Finland and the OECD jointly expanded the scope of TiVA statistics to gain a more detailed and timelier picture of Finland´s role in global production. The project benefited from previous efforts carried out by the Nordic countries in co-operation with the OECD (Statistics Denmark and OECD, 2017[22]). It was financially supported by several domestic stakeholders, including the Finnish Ministry for Foreign Affairs, the Ministry of Economic Affairs and Employment of Finland, the Finnish Prime Minister´s Office, and the Confederation of Finnish Industry and Employers Foundation. Outputs included a report (OECD and Statistics Finland, 2020[35]) and regularly updated indicators (Statistics Finland, 2024[36]).

Box 1.2. Policy demand for extended supply and use tables in Finland

More granular information about globalisation, in the form of Trade in Value Added (TiVA) indicators by type of enterprise – such as the value added by SMEs due to exports from large enterprises – was highly sought after. Stakeholders from government offices, research organisations and academia showed interest in the data during the development phase and actively took part in the development of the project. The Trade in Value Added (TiVA) indicators are freely accessible on Statistics Finland’s website and a comprehensive list of users can, therefore, not be compiled. However, Statistics Finland has been contacted by various organisations since the indicators have been released, including several ministries, business associations and think tanks:

- The Ministry for Foreign Affairs was especially interested in more detailed trade information and information on trading partners. It funded two follow-up reports produced jointly by Statistics Finland and the OECD, which were released in May 2021.
- The Parliament Committee for the Future requested recommendations on how the new indicators can be used for policy making (e.g. trade policy) and was also interested in developing new sustainability indicators and indicators related to the European Green Deal. The Parliament Committee for the Future commissioned Statistics Finland to write a “handbook” on how to interpret and use granular TiVA indicators. The work included mapping of future development possibilities for the framework.

- Business Finland was especially interested in the role of multinational enterprises in domestic and global value chains. Stakeholder interest in the specific heterogeneity breakdown pushed Statistics Finland to accelerate the planned release for additional indicator packages.
- ETLA Economic Research (a private, non-profit economic research institute) was moving towards the use of TiVA in the coming years and indicated it will likely make use of Statistics Finland's granular indicators when building and using its new analytical frameworks.
- The Finnish Prime Minister's Office co-ordinates the government's analysis, assessment and research activities to generate information that supports decision making and evidence-based policies, thus improving working practices. After the first national TiVA publication in November 2020, the Prime Minister's Office launched funding for a research project entitled "Trends in International Trade and Economic Sensitivity" to support the government in policy making. The joint report by the OECD and Statistics Finland (OECD and Statistics Finland, 2020[35]) was mentioned as a possible base for the analysis.

Source: Statistics Finland.

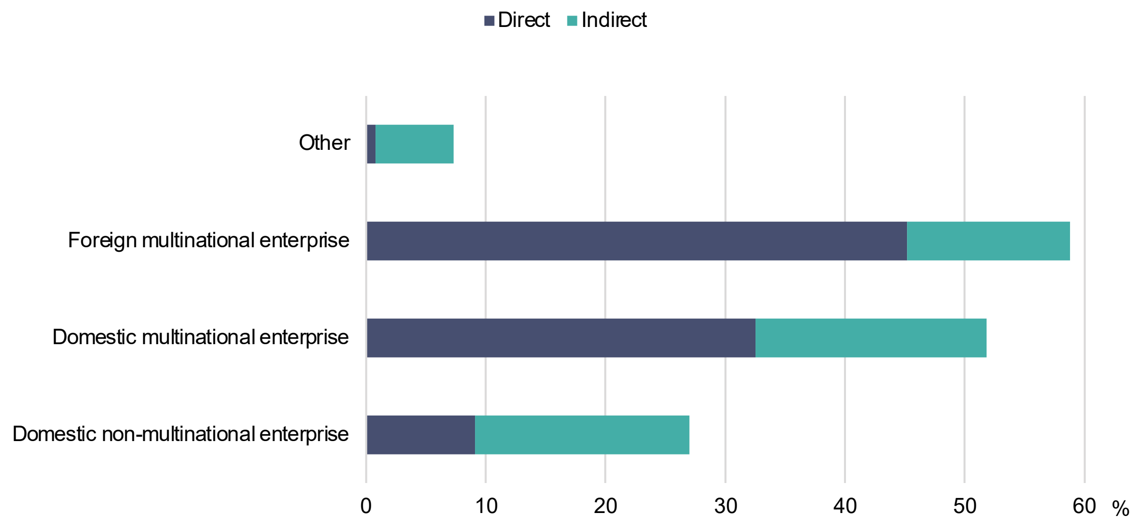
During the project, Statistics Finland and the OECD developed a standardised process for disaggregating domestic SUTs using enterprise-level microdata, generating EIOTs, balancing the extended tables and calculating extended TiVA indicators. Enterprise grouping was chosen to respond to policy demand. Indicators were broken down by enterprise trading status (exporter, importer, two-way trader and non-trader), enterprise size and group relation (independent micro, dependent micro, independent small, dependent small, independent medium, dependent medium, large, and other), and ownership (domestic non-multinational, domestic multinational, foreign multinational and other). In addition to the standard TiVA indicators, the OECD and Statistics Finland also developed employment indicators. These are further broken down by gender and level of education, providing deeper insights into employment structures and GVC dependencies of enterprises and employees.

With the standardised process, Statistics Finland has set up regular publication of granular TiVA indicators at t+17 months after the end of the reference period. Statistics Finland's current publication contains TiVA indicators for 2017-22 and employment indicators for 2017-21. The flexible and standardised production process allows for easy integration of new breakdowns when needed. The extensive register- and survey-based enterprise-level data of the national statistical office can be linked using unique business IDs, which in turn allows for the exploration of various enterprise heterogeneity breakdowns. This led to the publication of indicators by enterprise ownership (domestic non-multinational enterprise, domestic multinational and foreign multinational) in 2024, as there was an increasing need for information on the dynamics of enterprise ownership.

Domestic non-multinational enterprises are found to owe less of their value added due to foreign demand than multinationals do (Figure 1.1). For example, domestic non-multinational enterprises have 9% of their value added due to their own exports, whereas this is 45% for foreign multinationals. Differences in the share of value added due to indirect exports, producing goods and services in the supply chain of an exporter, are much smaller.

Figure 1.1. Finland value added due to direct and indirect exports, 2022

Share of total value added, by enterprise ownership



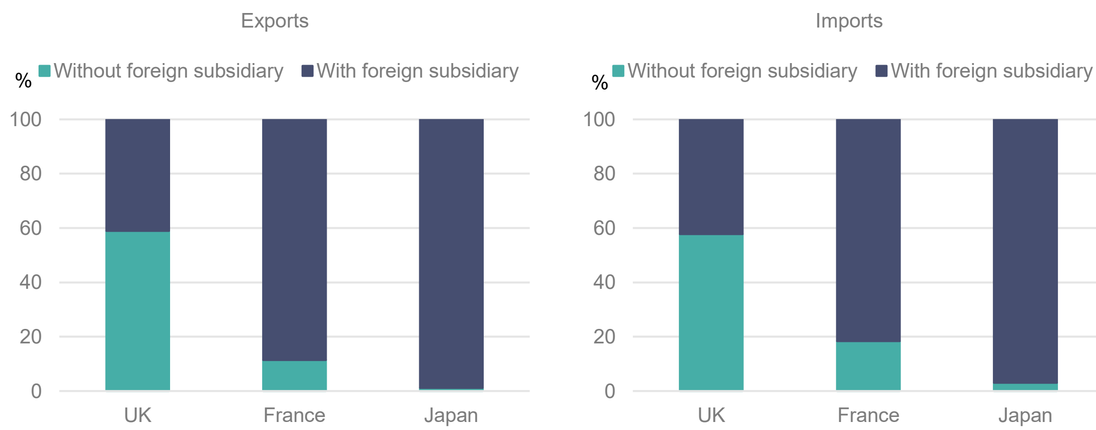
Source: Calculations based on Statistics Finland (2025[37]), Table 131a.

Japan

Hagino and Kim (2021[38]) document how they decided on the type of EIOT the most appropriate for Japan. They started by considering splitting industries into exporters and non-exporters, domestically owned and foreign-owned enterprises, and large and small enterprises as well as enterprises with and without foreign subsidiaries. Subsequently, they examined which type of heterogeneity is the most relevant for Japanese industries, heterogeneity being measured in terms of differences in the ratio of imported intermediate goods to total output, using enterprise-level microdata from the Basic Survey of Japanese Business Structure and Activities.

They found that overall, in Japan, the distinction between enterprises with and without foreign subsidiaries is relevant (Figure 1.2). In Japan, enterprises with foreign subsidiaries account for more than 95% of all exports and imports, which is considerably higher than in France and the United Kingdom. By contrast, foreign-owned enterprises do not play a pivotal role in international trade, therefore, this distinction may be less relevant in Japan than in other countries.

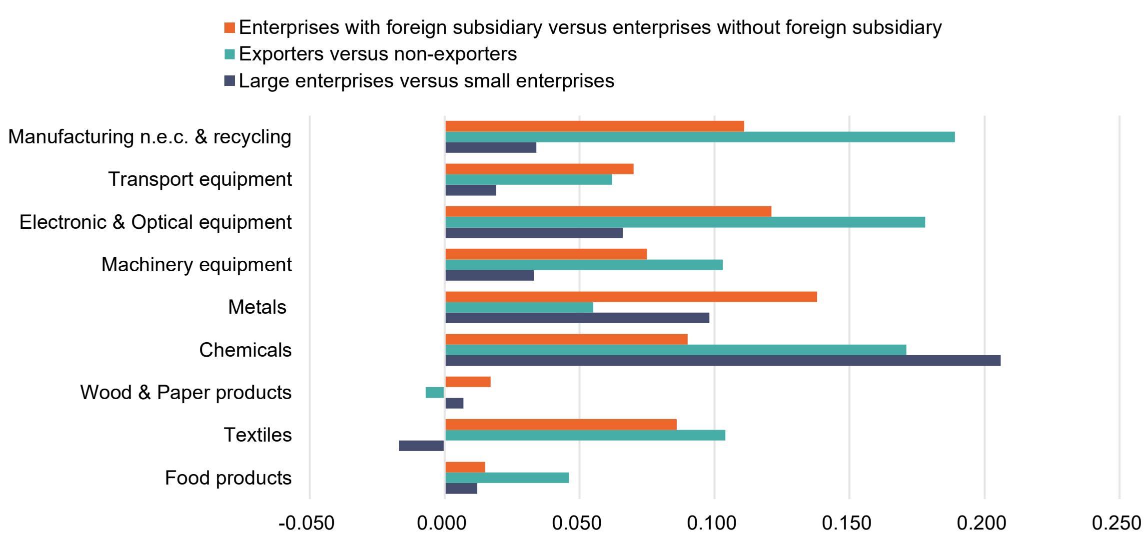
Figure 1.2. Share of enterprises with and without foreign subsidiaries in exports and imports, 2017



Source: For France and the United Kingdom: Trade by Enterprise Characteristics, (OECD, 2024[39]). For Japan: enterprise-level data from the (METI, 2023[40]).

The next step was to identify which breakdown was the most relevant for each industry by calculating the differences in the intermediate import ratio between different types of enterprises (Figure 1.3). In the metal and paper industries, the differences between enterprises with and without foreign subsidiaries are larger than those between exporters and non-exporters, as well as those between small and large enterprises. This reflects that metal and paper corporations, which need to import materials, have established subsidiaries to explore and mine raw materials or grow and harvest wood. In contrast, distinguishing between exporting and non-exporting enterprises is relevant for assembly industries such as the electronic and automobile industries, as widely discussed in the literature. For the chemicals industry, distinguishing between large and small enterprises is the most relevant.

Figure 1.3. Comparisons of intermediate import ratios of enterprises in Japan, 2015



Note: Large enterprises are those with a paid-in capital of at least 1 billion JPY.
Source: Hagino and Kim (2021[38]), based on enterprise-level data of the METI (2023[40]).

Following those results, each industry is split by type of enterprise that is most relevant for this specific industry (Table 1.7). Since differences in industries' intermediate import ratios are mainly due to the import of goods that the industry produces itself, it is assumed that such differences stem from differences in within-industry imports. The differences in intermediate import ratios are reflected in the diagonal cells (the shaded parts in Table 1.7).

Table 1.7. Extended domestic input-output table and import table for Japan, 2015

	3		4		5		6		7-11
	Exporting	Non-exporting	Exporting	Non-exporting	With foreign subsidiaries	Without foreign subsidiaries	Large firms	Small firms	All
Extended domestic input-output table									
Output, billion JPY									
1	1 964	3 864	0	0	69	169	3	1	7
2	0	0	0	0	2	4	210	52	36
3	1 694	3 332	0	0	5	12	92	23	1
4	8	17	159	380	12	30	63	16	220
5	298	587	18	10	1 052	2 563	518	128	876
6	380	748	209	119	309	753	11 666	2 872	7 019
7	173	340	5	3	80	194	541	133	27 942
8	0	0	0	0	4	10	51	12	4 978
9	0	0	0	0	1	2	1	0	9 773
10	0	0	0	0	0	0	0	0	22 796
11	14	27	8	4	32	77	96	24	495
Total output	12 920	25 421	2 281	1 305	4 926	12 001	52 557	12 937	177 001
Extended import table									
Import, billion JPY									
1	559	1 101	18	11	36	88	163	40	56
2	4	7	1	0	14	34	8 129	2 001	1 289
3	1 065	884	5	3	1	2	87	21	10
4	4	9	175	131	12	28	43	11	74
5	12	24	1	1	390	372	33	8	62
6	81	159	84	48	29	71	4 582	1 213	819
7	2	4	1	0	9	22	45	11	4 429
8	0	0	0	0	0	0	0	0	1 535
9	0	0	0	0	1	2	0	0	5 145
10	0	0	0	0	0	0	0	0	2 060
11	2	4	20	11	2	5	5	1	163
Total import	1 730	2 191	305	205	494	624	13 087	3 307	15 644

Note: 1: Agriculture; 2: Mining; 3: Food; 4: Textiles; 5: Paper; 6: Chemicals; 7: Metal; 8: Machinery; 9: Electronics; 10: Transport equipment; 11: Other manufacturing. Imports by an industry from the same foreign industry.
Source: Calculations of Hagino and Kim (2021[38])) based on the Benchmark IOT (MIC, 2024[41])and enterprise-level data of the Basic Survey of Japanese Business Structure and Activities, Ministry of Economy, Trade and Industry (METI, 2023[40]).

The extension of IOTs incorporating differences in intermediate import ratios leads to very different estimates of vertical specialisation than estimates obtained with a non-extended SUT (Table 1.8). Vertical specialisation is defined as the amount of foreign value added embodied in exports and measured as the ratio of imported intermediate goods embodied in exports, following (Hummels, Ishii and Yi, 2001[5]). The vertical specialisation indicator, defined as the amount of VS divided by exports, based on the EIOT (34.3%) is 70% greater than that based on the non-extended IOT (20.5%).

Table 1.8. Vertical specialisation indicators calculated from the extended and non-extended input-output tables for Japan, 2015

		Calculation based on extended IOT			Calculation based on non-extended IOT				
Industry	Extension elements	Industry total of VS coefficient	Exports	Amount of VS	Industry total of VS coefficient	Exports	Amount of VS	Domestic value added included in imported intermediates	Amount of VS after deducting domestic value added
			billion JPY	billion JPY		billion JPY	billion JPY	%	billion JPY
Agriculture		0.17	0	0	0.12	0	0	0.6	0
Mining		0.10	33	3	0.07	33	2	0.5	2
Food	Exporting	0.43	155	66	0.18	155	29	1.2	28
	Non-exporting	0.38	0	0					
Textile	Exporting	0.96	131	126	0.24	131	32	1.6	31
	Non-exporting	0.41	0	0					
Paper	With foreign subsidiaries	0.47	289	135	0.16	375	60	0.9	59
	Without foreign subsidiaries	0.42	86	36					
Chemical	Large	0.54	6 811	3 673	0.36	7 521	2 679	1.8	2 630
	Small	0.55	711	388					
Metal	With foreign subsidiaries	0.35	2 866	1 014	0.16	4 535	739	1.9	725
	Without foreign subsidiaries	0.31	1 669	521					
Machinery	Exporting	0.34	8 685	2 943	0.16	8 685	1 348	7.1	1 253
	Non-exporting	0.36	0	0					
Electronics	Exporting	0.43	14 294	6 200	0.25	14 294	3 536	8.2	3 245
	Non-exporting	0.52	0	0					
Transport equipment	Exporting	0.42	22 919	9 644	0.21	22 919	4 756	4.3	4 552
	Non-exporting	0.48	0	0					
Other manufacturing	Exporting	0.52	526	275	0.16	526	86	7.9	79
	Non-exporting	0.51	0	0					
Electric, gas and water		0.31	23	7	0.30	23	7	0.8	7
Construction		0.08	23	2	0.10	23	2	1.5	2
Wholesale and retail		0.09	18 051	1 602	0.15	18 051	2 650	1.2	2 618
Transportation and warehouse		0.12	158	20	0.08	158	13	2.7	13

		Calculation based on extended IOT			Calculation based on non-extended IOT				
Industry	Extension elements	Industry total of VS coefficient	Exports	Amount of VS	Industry total of VS coefficient	Exports	Amount of VS	Domestic value added included in imported intermediates	Amount of VS after deducting domestic value added
			billion JPY	billion JPY		billion JPY	billion JPY	%	billion JPY
Finance and insurance		0.08	0	0	0.06	0	0	1.1	0
Real estate and leasing		0.05	16	1	0.04	16	1	1.0	1
Community, society and individual services		0.09	278	25	0.04	278	21	2.4	20
Total		9.5	77 725	26 680	2.87	77 725	15 961	2.1	15 632

Note: VS: vertical specialisation.
Source: Calculations of Hagino and Kim (2021[38]) based on the Benchmark IOT (MIC, 2024[41]) enterprise-level data of the Basic Survey of Japanese Business Structure and Activities (METI, 2023[40]) and OECD TiVA indicators (OECD, 2024[42]).

Mexico

In Mexico, the National Institute of Statistics and Geography (INEGI) produced its first ESUT in 2018 (reporting year 2013) and a new ESUT in 2023 (reporting year 2018). The 2023 update was in line with the new base year of National Accounts in Mexico, namely 2018. The reason for compiling an ESUT was to obtain more detailed information about the types of enterprises that are economically relevant.

The main sources of information for the Mexican ESUT are the Economic Census (which takes place every five years), the *Foreign Trade Database* and the regular SUTs. The advantage of using the Census is that it provides a large amount of information at the establishment level. This makes it feasible to characterise them according to the criteria considered appropriate for the extensions to be developed. Thanks to the Census, INEGI obtained maximum detail in its tables. There are different ESUTs, namely with the following focuses:

- Export status, where establishments are classified into exporter, formal non-exporters and informal non-exporters.
- Ownership, where exporting establishments are classified as domestic owner affiliates, foreign owner affiliates, domestic owner and foreign owner.
- Size of the economic unit, grouping the economic units into small, medium and large. This extension covers the total economy, not only the exporting establishments.
- The integrated focus that in a single tabulation distinguishes between export status and ownership and size at the same time. For example, it contains information about the formal non-exporters that are foreign-owned and large establishments.

INEGI's internal ESUTs are very detailed but contain confidential information. Therefore, the published data only contain 20 industries. These industries are according to the North American Industry Classification System (NAICS). The process of compiling the ESUTs involves taking all information from the regular SUT as fixed and a subsequent aggregation towards the specific extension. For this reason, re-aggregating each of the extensions leads to the regular SUT again.

The economic unit that the Mexican ESUTs measure is the establishment, not the company. Chapter 2 emphasises that the compiler decides whether all the establishments that form part of a legal unit (or company) should be classified into the same category. In the case of Mexico, for practical reasons, it was decided that the ideal measurement to extend the SUT is at the establishment level since this is also the way the regular SUT are measured. See Teran-Vargas (2024[43])) for more details about the methodology.

To give an example of the results about the new base year 2018: in manufacturing, 70% of the production is produced by exporting establishments. Of this production by exporters, 44% is at domestically controlled establishments and of this production, 78% is by large establishments (which employ more than 250 persons). The remaining 56% of production in manufacturing by exporters is by foreign-owned establishments and of this production, 88% is by large establishments.

United States

Efforts in the United States to develop ESUTs have focused primarily on adding information on multinational enterprise and ownership status. SUTs have been extended to show breakdowns within each industry for domestically owned multinational enterprises, foreign-owned multinational enterprises and non-multinationals.

Among others, academic literature was a reason for doing so. Melitz (2003[44]) motivated the development of models of international trade that allow for different levels of enterprise-level productivity. Helpman, Melitz and Yeaple (2004[45]) found that only the most productive enterprises engage in foreign activities and the most productive of these enterprises engage in foreign direct investment. Consistent with Melitz's model, there is also evidence that the bulk of trade in both goods (Bernard, Jensen and Schott, 2009[46]) and services (Barefoot and Koncz-Bruner, 2012[47]) has involved MNEs. Therefore, extending SUTs by MNE categorisation is an important way to account for enterprise heterogeneity.

Fetzer et al. (2023[23]) compiled such data and demonstrate how enterprises in different categories play different roles in the production of US exports. They showed that about half the value of US exports in 2005 and 2012 was created by non-multinationals, about 40% by domestically owned and foreign-owned multinationals combined, and the remaining 10% coming from foreign production via imported intermediate inputs. They also underlined the important role that foreign-owned multinationals play more generally in domestic supply chains. Of the value added by foreign-owned multinationals, 30% was embedded as an input into production by other types of enterprises.

Additionally, the imported content of exports as a share of exports varied notably by enterprise type within most industries. The imported content of exports was concentrated in a few industries, the largest being petroleum manufacturing. Most domestic content of exports by enterprises in goods-producing industries was from US MNEs and most domestic content of exports in services industries was from non-MNEs.

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Annex 1.A. Extensions of supply and use tables related to globalisation that are not extended supply and use tables

Ahmad (2023[48]) puts forward four extensions of regular supply and use tables (SUTs), relevant for measuring globalisation, which are not extended supply and use tables (ESUTs):

1. Estimates of goods for processing, merchanting or re-exports. Processing trade involves manufacturing services on physical inputs owned by others and/or the value of the goods imported, and the customs value of the processed goods exported. Merchanting is the purchase of goods by a resident (of the compiling economy) from a non-resident combined with the subsequent resale of the same goods to another non-resident without the goods being physically moved in and out of the compiling economy. Re-exports are goods produced in other economies, and previously imported, that are exported with no substantial transformation from the state in which they were previously imported.
2. Residents' expenditure abroad and non-residents' expenditure in the domestic territories.
3. Conversion of imports of goods from cost, insurance and freight price to free on board (FOB) prices. Multi-country SUTs typically require imports to be valued at FOB prices, just as exports already are in a regular SUT. Furthermore, information on tariffs/duties paid by product is also desirable to help build import matrices (using the proportionality assumption) in basic prices and analysing the impact of tariffs on global value chains.
4. Complementary information on import flow matrices broken down by partner. The geographical breakdown of the import matrix by country of origin within the SUT framework is an essential step to produce global IOTs and may sometimes be useful for the compilation of national SUTs, too.

SUT-based thematic accounts

SUTs provide a powerful foundation for the creation of thematic accounts. These can be focused on a wide range of issues from travel and tourism to arts and cultural production to education, health, and outdoor recreation. Construction of these accounts typically entails identifying specific industries and products within the SUT framework that are wholly or partially in scope for the topic of interest. SUT data are then reconfigured to highlight the portions of those industries and products relevant for the chosen topic.

An SUT that has been reorganised to support a thematic account may include industry decompositions and may be superficially similar to an ESUT in other ways as well. However, the primary goal of these accounts is to highlight activity in specific areas of the economy. Any split of activities by type of enterprise, which distinguishes an ESUT, is only incidental to that purpose.

Thematic accounts involve instead the rearrangement of existing information from National Accounts to enable an area of economic and/or social importance to be analysed in much greater detail, with additional dimensions (United Nations, 2018[1]). The 2008 System of National Accounts (SNA) distinguishes two types of thematic accounts. The first may be seen as an extension of the core National Accounts without changing the underlying concepts of the SNA in any fundamental way. These mostly cover accounts specific to certain fields, such as tourism, education and environmental protection expenditures. The second type is mainly based on concepts that are alternatives to those of the SNA, also possibly with changes in classifications, too. These include, for example, a different production boundary, an enlarged concept of consumption or capital formation, an extension of the scope of assets, etc. (United Nations, 2018[1]). However, none of them can be considered to be an ESUT.

Digital SUTs

The SUT framework has also been discussed extensively as a mechanism for organising information necessary to construct a digital economy thematic account. To this end, the OECD’s framework for Digital SUTs (OECD, 2023[49]) outlines how SUTs may be transformed into a digital SUT by adding and modifying various rows and columns. As with other SUT-based thematic accounts, a digital SUT has many superficial similarities to an ESUT. However, any split of industries by enterprise type is again only incidental to the primary purpose of highlighting digital activity in the economy. Therefore, a digital SUT is not an ESUT. See Chapter 9 for a more detailed discussion of digital SUTs.

Annex 1.B. Testing enterprise heterogeneity for extended supply and use tables

This annex outlines, for the first time in literature, an econometric test to help measure the degree of heterogeneity in an enterprise's surveyed data used for the compilation of extended supply and use tables (ESUTs). The test helps ESUT compilers determine for every product whether a type of enterprise (e.g. multinationals) uses a statistically different technological production structure[1] compared to the average of the industry. This will help countries to identify those industries that would need an additional breakdown by size, ownership, etc. and avoid breaking down all industries and/or products to construct ESUTs.

The first section provides the methodological background and context for an econometric test of enterprises' data heterogeneity. The second section describes the econometric tests applied to supply and use tables (SUTs) in the literature, while the third section develops a new heterogeneity test for ESUTs. It concludes with a few remarks and recommendations for ESUT compilers.

Background and context

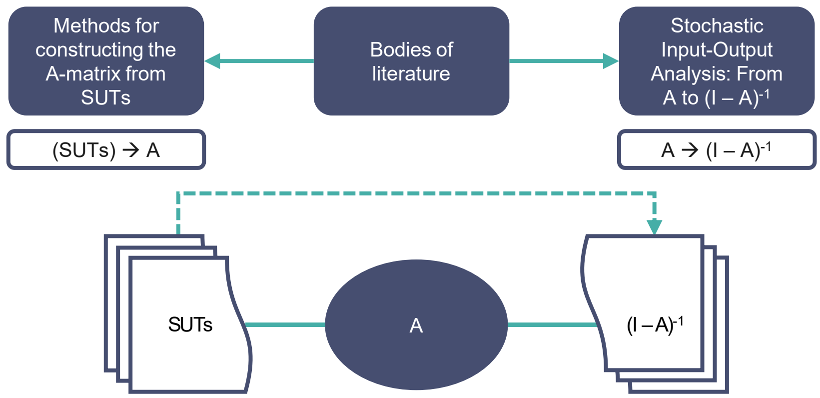
This section describes the methodological background and the context of a new econometric test of enterprises' data heterogeneity. Enterprises' data can be theoretically linked directly to input-output multipliers without the need to compile input-output tables (IOTs), as shown by ten Raa and Rueda-Cantuche (2007[50]). Later, Rueda-Cantuche[2] (2011[51]) named this method the Supply and Use Based (SUBE) econometric approach but using SUTs instead of IOTs. This framework is appropriate for rectangular SUT-type of enterprises' data with more enterprises/industries (broken down by size, ownership, etc.) than products, as may be the case for ESUTs.

By using enterprises' data and appropriate regressions, input-output multipliers can be derived econometrically, thus, testing whether those multipliers are significantly different across enterprises in terms of size, ownership, exporter status, etc. In other words, this tests the product technology assumption that all enterprises produce one product using the same technology for each product.

Econometric input-output multipliers using enterprises' data

This section discusses the theoretical way in which input-output multipliers (or the elements of the Leontief inverse matrix) are directly linked to enterprises' data on their supply and use of products. For each surveyed enterprise, the data tell how much they produce of each product and how much they use of each product as intermediate input.

Annex Figure 1.B.1. From supply and use tables to input-output multipliers



Note: SUT: supply and use table.

As shown in Annex Figure 1.B.1, this approach proposed by ten Raa and Rueda-Cantuche (2007[50]) connected two different bodies of literature. The first body of literature discusses the methods for constructing IOTs from SUTs; the second discusses stochastic input-output analysis, the measurement of uncertainty in the technical coefficients and in the consequent Leontief inverse matrix. The integration permits input-output analysts to estimate directly economic impacts from the enterprises' data[3] underlying the SUTs, without the need to estimate IOTs. We now explain why.

Consider the Leontief quantity model (Miller and Blair, 2022[52]) for estimating demand-driven employment impacts, defining employment multipliers as the number of jobs generated per unit (million EUR, USD, etc.) increase of the final use of products. Mathematically,

$$\lambda = l(\mathbf{I} - \mathbf{A})^{-1} \qquad (1)$$

where *l* and λ are the row vectors of labour coefficients[4] and the employment multipliers, respectively. Bearing in mind that the product technology assumption implies that $\mathbf{A} = \mathbf{U}\mathbf{V}^{-\mathrm{T}}$ and $\mathbf{l} = \mathbf{L}\mathbf{V}^{-\mathrm{T}}$, replacement of A and **l** in (1) yields:

$$\lambda = \mathbf{L}\mathbf{V}^{-\mathrm{T}}(\mathbf{I} - \mathbf{U}\mathbf{V}^{-\mathrm{T}})^{-1} = \mathbf{L}\left(\left(\mathbf{I} - \mathbf{U}\mathbf{V}^{-\mathrm{T}}\right)\mathbf{V}^{\mathrm{T}}\right)^{-\mathbf{1}} = \mathbf{L}\left(\mathbf{V}^{\mathrm{T}} - \mathbf{U}\mathbf{V}^{-\mathrm{T}}\mathbf{V}^{\mathrm{T}}\right)^{-\mathbf{1}} = \mathbf{L}\left(\mathbf{V}^{\mathrm{T}} - \mathbf{U}\right)^{-\mathbf{1}}$$

And therefore,

$$L = \lambda\left(\mathbf{V}^{\mathrm{T}} - \mathbf{U}\right) \qquad (2)$$

By using as independent variables the rows of the so-called net output matrix ($\mathbf{V}^{\mathrm{T}}$- **U**), for each establishment, enterprise or unit, the following multiple linear econometric model[5] is formulated:

$$L_i = \lambda_1 x_{1i} + \lambda_2 x_{2i} + \lambda_3 x_{3i} + \cdots + \lambda_k x_{ki} + \varepsilon_i \qquad \text{for } i = 1, 2 \ldots m \qquad (3)$$

where the respective regression coefficients (λ_i) are input-output multipliers; *k* is the number of products; *m is* the number of surveyed establishments, enterprises or units; and ε_i is an independent random disturbance error, assumed to be normally distributed with zero mean and constant variance. The theoretical model contains no constant term.

Testing heterogeneity in input-output multipliers with enterprises' data

This section builds upon the econometric model presented in the previous section and elaborates on a new test to measure the statistical significance of enterprise heterogeneity in survey data for the compilation of ESUTs.

The econometric model presented in (3) in the previous section can be used for two different purposes:

- The estimation of consistent and unbiased (backward) input-output multipliers (e.g. employment, output, value added and/or emissions), and their confidence intervals. It would also allow testing the statistical significance of each individual input-output multiplier by product.
- Testing econometrically if the estimated input-output multipliers differ significantly between enterprises[6] versus the product technology assumption (by which all enterprises/industries produce the same product with the same technology for each product).

It is precisely the second purpose that can be easily linked to ESUTs and that can be used to test the heterogeneity of the enterprises' data underlying the compilation of ESUTs. The main idea is as follows: from (3), add one dummy variable (z_{ki}) multiplicatively for each product *k*. This yields the following econometric model:

$$L_i = \lambda_1 x_{1i} + \lambda_2 x_{2i} + \lambda_3 x_{3i} + \cdots + \lambda_k x_{ki} +$$
$$+\beta_1 x_{1i}\, z_{1i} + \beta_2 x_{2i}\, z_{2i} + \beta_3 x_{3i}\, z_{3i} \cdots + \beta_k x_{ki}\, z_{ki} + \varepsilon_i \qquad \text{for } i = 1, 2 \dots m$$

Assume now that we are interested in evaluating whether, for a particular product (say product 1), establishments/enterprises/units belonging to multinational enterprises (MNEs) do have a statistically different impact in terms of employment with respect to other non-MNE units producing product 1. In doing so, the interpretation of the regression coefficients is:

- $\lambda_1 x_{1i} = E(L_i|z_{1i} = 0)$; expected employment impact (number of jobs) due to increases in the final use of product 1, being produced by non-MNE enterprises/units/establishments.
- $(\lambda_1 + \beta_1)x_{1i} = E(L_i|z_{1i} = 1)$; expected employment impact (number of jobs) due to increases in the final use of product 1, being produced by enterprises/units/establishments belonging to MNEs.
- $\beta_1 x_{1i} = E(L_i|z_{1i} = 1) - E(L_i|z_{1i} = 0)$; expected difference in the employment impact (number of jobs) due to increases in the final use of product 1, between those produced by enterprises/units/establishments belonging to MNEs and those produced by non-MNE units.

By testing the null hypothesis[7] $H_0\colon \beta_1 = 0$, we will test whether MNEs and non-MNEs have the same employment impact per currency unit (e.g. million USD) in producing one additional unit of product 1, with a pre-fixed confidence level, e.g. 95%. The same applies to all other products, one for each regression coefficient β. Moreover, one can test whether MNEs and non-MNEs can have the same employment impacts for all products by testing the following null hypothesis[8] $H_0\colon \beta_1 = \cdots = \beta_k = 0$.

Concluding remarks

Compilers of ESUTs need to choose the dimension (size, ownership, exporter status, etc.) to break down industries. Enterprises' surveyed data and econometric analysis based on an SUT framework can help in selecting the industries requiring a break down. This choice is related to their statistically significant differences in product technologies and resulting different economic impacts driven by increases in the final use of products. This annex aims to inspire ESUT compilers to test enterprise heterogeneity with surveyed data to help with the decision about which industries/products to break down. Belgium, Mexico and the Netherlands have shown interest in following this approach but have not been able to work on it yet.

Notes

[1] A different technological production structure leads to a different matrix of technical coefficients as well as to a different Leontief inverse matrix and, therefore, to different input-output multipliers and different economic impacts.

[2] Rueda-Cantuche (2011[51]) extended this approach to SUTs, which were considered aggregated versions of the underlying enterprises' data when the enterprises' data were not available. Other relevant literature using SUTs are Rueda-Cantuche and Amores (2010[54]), Rodrigues and Rueda-Cantuche (2013[56]) and more recently, Stehrer et al. (2024[55]) with panel data econometrics. Overall, the use of enterprises' data is more appropriate than the use of SUTs to avoid possible aggregation bias.

[3] The main caveat of this approach is that only statistical offices typically have access to the necessary enterprises' data.

[4] As for technical coefficients, labour coefficients result from dividing employment (**L**) over the total output by industry. **A** is the technical coefficients matrix and **I** the identity matrix. **U** stands for the intermediate use matrix (product by industry) and **V** stands for the transposed of the supply table (product by industry) – also denoted in the literature as the make table. ^{T} denotes transposition and $^{-1}$ the inverse of a matrix, being $^{-T}$ the inverse of a transposed matrix or vice versa.

[5] Further details of this econometric approach with enterprises' data can be found in ten Raa and Rueda-Cantuche (2007[50]). In particular, it is important to note that the data entering such an econometric model should be transformed into basic prices, as described in the appendix of the same article (pp. 332-334). For further details of SUBE, see Rueda-Cantuche (2011[51]).

[6] It can also be industries, following the SUBE approach developed by Rueda-Cantuche (2011[51]). However, aggregation may be an important caveat.

[7] This individual test is well known in the econometric literature and uses a Student's t-distribution (Greene, 2019[53]).

[8] This test is well-known in the econometric literature and uses a F-Fisher distribution (Greene, 2019).

2. Defining the extension criteria and (data) sources of heterogeneity for extended supply and use tables

This chapter discusses the three most common extension criteria for constructing an extended supply and use table: exporter or trading status, ownership or group affiliation, and size. The chapter explains why each criterion is relevant, relating to academic literature. Subsequently, it explains in detail how to define the various categories of enterprises and how to classify the enterprises in practise, pointing out the various data sources. This is illustrated with several country examples. The chapter also discusses the different types of units that can be used in the compilation process.

Introduction

The first step in constructing an extended supply and use table (ESUT) is to choose the source(s) of enterprise heterogeneity for breaking down industries (and product categories) in the supply and use framework. Any such source of heterogeneity is also referred to as an extension criterion. So far, the construction of an ESUT has mainly focused on the following three major enterprise characteristics as extension criteria: 1) exporter or trading status; 2) ownership status or group affiliation; and 3) enterprise size.

The industry breakdown in an ESUT may be based on a single extension criterion or a combination of several extension criteria. Most of the ESUTs that have been produced to date are for a single extension criterion, e.g. exporter status for the People's Republic of China (hereafter "China") (Koopman, Wang and Wei, 2012[1]), ownership status for the United States (Fetzer et al., 2023[2]), size for the Netherlands (Chong et al., 2019[3]). But there are also examples of ESUTs compiled combining these three criteria for all industries (for the Nordic countries; (Statistics Denmark and OECD, 2017[4])) or with the chosen criterion depending on industry characteristics (for Japan; (Hagino and Kim, 2021[5])).

This chapter provides a detailed description of how enterprise categories may be defined for each of these three criteria and which data can be used to classify enterprises in the defined categories. As the definition of categories is closely related to the available data sources, both are discussed together for each extension criterion. Regarding data sources, the focus here is only on those used for the classification of enterprises into the previously defined categories, while Chapter 3 will discuss those used in the construction of an ESUT. Naturally, some data sources will serve for both – enterprise classification and ESUT construction. For example, data on exports of goods are used for determining the exporter status of enterprises and for constructing an ESUT.

In this context, it must be noted that the classification of enterprises into heterogeneous categories generally concerns legal units (some national statistical offices [NSOs] do this for enterprises), while the construction of supply and use tables (SUTs) is based on statistical units as the producers of goods and services. Establishments (local kind-of-activity units) are the preferred statistical units for SUT construction to limit secondary output. When it comes to ESUT compilation, these establishments must be linked to the legal units (or enterprises) classified into heterogeneous categories according to the chosen extension criterion. Normally, such a link is included in the business register. But it is up to the compiler to decide whether all establishments that are part of a legal unit (or enterprise) should be classified in the same category. This is not an issue for countries where the legal unit (or enterprise) is the statistical unit for the construction of SUTs.

Finally, the discussion in this chapter focuses on the situation where compilers have access to the business register and the relevant enterprise-level data sources that allow classifying enterprises. Some compilers, in particular researchers outside NSOs, may not have access to such enterprise-level data sources. This does not rule out the construction of an ESUT, but it implies that these compilers have to rely on more aggregate data. Potential aggregate data sources are mentioned below for each extension criterion, and the consequences of their use – for both the definition of enterprise categories and the ESUT construction process – are briefly discussed.

Exporter or trading status

The exporter status is a source of enterprise heterogeneity that has been investigated extensively in the academic literature. Exporters have been found to be more skill-intensive, more capital-intensive and more productive than other enterprises (see, for example, Melitz (2003[6]); Bernard et al. (2012[7])), and it has been shown that they rely proportionally more on foreign inputs (Bas, 2009[8]). This heterogeneity in production technologies is the motivation for breaking down industries according to the exporter status of enterprises. The resulting ESUTs reveal the specific input structures for the production of exports, which allows, among other things, to improve estimates of domestic and foreign value added in exports (see de Gortari (2019[9]) and Michel, Hambÿe and Hertveldt (2023[10])) .

Defining categories of enterprises

Although the breakdown of industries according to the exporter status of enterprises appears to be conceptually relatively straightforward, several issues need to be addressed in practice. Beyond special trade regimes (see below), the standard approach is to divide enterprises in each industry into exporters and non-exporters. However, the heterogeneity between exporters and non-exporters is not necessarily clear-cut. According to enterprise-level research, it is mostly the major exporters that are different in terms of production technologies (Bernard et al., 2012[7]), while minor exporters tend to be similar to the bulk of non-exporters. Therefore, a threshold may be imposed when defining exporter status to distinguish export-oriented enterprises from domestic-oriented ones – i.e. enterprises that mainly serve the domestic market – to increase the homogeneity of within-industry categories of enterprises in the ESUT. The threshold can either be relative – a minimum percentage share of exports in an enterprise's output – or absolute – a minimum value of total enterprise-level exports. A double threshold in both relative and absolute terms is a powerful way of selecting big enterprises that are major exporters. The absolute threshold will discard small exporting enterprises, and the relative threshold will subsequently discard big enterprises that only export a minor share of their output.

For the optimal choice, compilers may want to test the sensitivity of the categorisation of enterprises (and potentially also the sensitivity of analytical results) with respect to different types of thresholds and different threshold levels (both in relative and in absolute terms). While the application of a threshold is likely to increase within-category homogeneity, it also implies that the category of export-oriented enterprises does not account for all exports, i.e. domestic-oriented enterprises account for at least a small share of exports.

Existing ESUTs for Mexico provide an example of a distinction between exporters and non-exporters (Ostolaza-Berman and Téran Vargas, 2019[11]). Examples of the application of a threshold can be found in work on ESUTs and EIOTs for Belgium (Michel, Hambÿe and Hertveldt, 2023[10]), relative threshold) and Denmark (Nilsson, Rørmose Jensen and Holst Jensen, 2018[12]), absolute threshold). In addition to these thresholds on the value of exports, compilers of ESUTs may also consider alternative export-related sources of heterogeneity, e.g. separating out enterprises that export to multiple destinations or enterprises that export to more distant destinations rather than only neighbouring countries.

With regard to prior investigations of export-related enterprise heterogeneity in the academic literature, it appears as natural to take the exporter status as the source of heterogeneity. Nevertheless, focusing on exporters that also import, so-called two-way traders, may represent a further means of reducing within-industry heterogeneity (Ahmad, 2023[13]). In more general terms, compilers of ESUTs may categorise enterprises according to their trading status, i.e. non-traders, exporters, importers and two-way traders, then determine which categories to separate out and whether to impose thresholds on exports and imports at the level of the enterprise.

Data for classifying enterprises

Ideally, the classification of enterprises by exporter or trading status is based on an individual identification of exporters, importers or two-way traders through enterprise-level export and import data. Depending on data availability and quality, this may be restricted to exports and imports of goods – merchandise trade – or encompass exports and imports of both goods and services. Enterprise-level data on merchandise trade typically come from customs data (see United Nations (2011[14]) or an equivalent source (e.g. Intrastat and Extrastat declarations for European Union [EU] countries). Customs data usually contain monetary values of merchandise trade flows by enterprise, and also by product category and partner country. They may also comprise transaction codes through which enterprises operating under special trade regimes can be identified (see below). Enterprise-level data on exports and imports of services are mostly obtained through surveys for balance of payments statistics. Imposing thresholds requires additional enterprise-level data on total sales or turnover, which may be obtained from enterprises' annual accounts, tax records or structural business surveys.

Such data on exports and imports are generally collected for legal units or enterprises. Unless the construction of SUTs is based on legal units or enterprises, a conversion is needed to attribute these exports and imports to establishments (local kind-of-activity units). In work for the United States, this conversion is based on establishment-level employment data (Fetzer et al., 2023[2]). The compiler must then decide whether all establishments that belong to a legal unit (or enterprise) should be classified in the same category, e.g. whether to consider all establishments of an exporting enterprise as exporters.

Moreover, for exports of goods, the identification of exporters or export-oriented enterprises is generally based on direct exports, i.e. cross-border transactions for which the enterprise is itself responsible. However, enterprises may also export goods indirectly through distributors or intermediaries (wholesalers), which do not transform the goods and only apply a margin on their sales of these goods. Such indirect exports can represent a substantial part of total trade, in particular in small open economies. It is, for example, estimated that approximately 30% of Danish exports of goods go through wholesalers (Nilsson, Rørmose Jensen and Holst Jensen, 2018[12]). In practice, attributing goods that are exported through wholesalers to the original producers is a challenge because it requires additional information on domestic transactions between producers and wholesalers. Value-added tax (VAT) transaction datasets that record all domestic transactions subject to VAT (see, for example, Dhyne, Magerman and Rubínová (2015[15])) appear to be the most promising data source for this purpose. However, even with such data, major methodological challenges remain to be solved, e.g. how to determine whether goods delivered by producers to wholesalers correspond to the goods exported by these wholesalers. This field has not yet been explored in depth and further work is needed.

The issue of trade through wholesalers also arises on the import side. But then the issue of imports distributed by domestic wholesalers is already a challenge when constructing regular SUTs and in particular for the compilation of the import use table. In theory, information on indirect imports through wholesalers used in the construction of regular SUTs should make it possible to estimate indirect import flows to identify all importers and two-way traders.

When ESUT compilers do not have enterprise-level data on exports and imports available to them, they must rely on other data sources. In some countries, structural business statistics contain information on the exporter status of enterprises, and this information can be merged into the business register for the classification of enterprises into the categories of exporters and non-exporters. Of course, this requires access to the business register. Moreover, with such data, it is not possible to apply thresholds.

Finally, for the construction of ESUTs by exporter or trading status, compilers may also use more aggregate data. In particular, the industry-level data on trade by enterprise characteristics (TEC; Box 2.1) published by Eurostat and the OECD provide a second-best alternative, at least for the disaggregation of industry totals. Compilers must be aware that the use of such data does not leave room for choosing a definition of exporter or trading status or for applying thresholds.

Box 2.1. Trade by enterprise characteristics data

Trade by enterprise characteristics (TEC) data go beyond conventional international trade data. Rather than mapping trade flows between countries by types of goods or services, TEC data put the focus on the enterprises that export and import, reporting trade flows broken down by different categories of enterprises. Such data provide additional perspectives for the analysis of international trade, and they may be used in the construction of an extended supply and use table (ESUT).

The OECD publishes TEC data for its member countries and a number of non-member countries (see: www.oecd.org/en/data/datasets/trade-by-enterprise-characteristics-tec.html), and also Eurostat publishes data for EU member countries with a distinction between international trade in goods by enterprise characteristics (TEC) (Eurostat[16]) and service trade by enterprise characteristics (STEC) (Eurostat[17]). These are compilations of TEC data produced by NSOs. For the purposes of producing enterprise-level breakdowns of export and import data, NSOs combine enterprise-level trade data with other enterprise-level data sources that allow categorising enterprises.

In practice, the data on exports and imports of trading enterprises are cross-tabulated by the industry of the enterprises and by several enterprise characteristics including size, ownership/group affiliation and trading status. The data published by the OECD and Eurostat also provide numbers of trading enterprises by industry and enterprise characteristics. When using these TEC data in constructing an ESUT, compilers must be aware of a series of caveats among which the following deserve to be specifically mentioned: they have to take the definition of the enterprise characteristics as given (e.g. the enterprise size classes); the underlying coverage of enterprises may differ between the TEC data and the regular SUT that the compilers want to disaggregate; the TEC data may comprise transactions that are not included in the national accounts and vice versa; and the wholesale industry often accounts for a much larger share of total trade in TEC data than in regular SUTs.

Special trade regimes

The earliest efforts to separate out groups of enterprises according to their trading status in SUTs and input-output tables were related to special trade regimes: processing traders for China (Koopman, Wang and Wei, 2012[1]), enterprises operating under global manufacturing programmes for Mexico (De La Cruz et al., 2011[18]) and enterprises operating in free trade zones in Costa Rica (Saborío, 2015[19]). In all these cases, the aim of the special trade regime is to grant a tariff exemption to provide an incentive for foreign enterprises to locate the assembly stage of their production process in the country, with inputs imported and output sold on foreign markets. This implies that there are differences in production processes and especially input structures between enterprises participating in the special trade regime and other enterprises, due to the design of the special trade regime where participating enterprises purchase (almost) no inputs locally and sell their production abroad. The non-participating enterprises do purchase and sell much locally. The resulting within-industry enterprise heterogeneity provides a strong incentive for the construction of ESUTs. Work on disaggregating industries in SUTs to isolate enterprises participating in these regimes is focused on manufacturing industries and generally based on customs data or specific data collected as part of the operation of the regime. A potential issue is that trade flows under these special trade regimes mostly do not imply a change in ownership and are therefore not recorded in regular SUTs following the rules introduced in the System of National Accounts 2008.

Ownership or group affiliation

Ownership links and group affiliation represent another major source of within-industry enterprise heterogeneity. A vast and long-standing empirical literature based on enterprise-level data has emphasised that production processes of foreign affiliates and enterprises that are part of a multinational enterprise (MNE) group tend to be different from those of other enterprises (Brainard, 1997[20]; Bernard et al., 2012[7]; Yeaple, 2013[21]; Antràs and Yeaple, 2014[22]). In addition, it has been estimated that the export activity of foreign affiliates accounts for two-thirds or more of global trade (UNCTAD, 2013[23]; Miroudot and Rigo, 2022[24]). This illustrates that MNE groups have largely contributed to global integration over the past decades and continue to do so today through exports and local sales of their foreign affiliates.

From the perspective of the national accounts, there is friction between the compilation of accounts for individual countries based on residency rules imposed by the System of National Accounts on the one hand, and global production arrangements of MNE groups, on the other (Moulton and van de Ven, 2023[25]). The most striking evidence for this friction is the Irish 2015 real gross domestic product growth rate of more than 25%, which was driven by the within enterprise group relocation of intellectual property rights (FitzGerald, 2023[26]).

ESUTs with an industry breakdown by group affiliation are an important means of getting a better and more detailed grasp of the nature and scope of MNE groups' activities, within an individual country and in global value chains. Such an extension is based on a categorisation of enterprises within industries according to their affiliation to an enterprise group.

Enterprise groups

The starting point for this categorisation is the definition of an **enterprise group**, which is an association of enterprises bound together by legal and/or financial links and controlled by a group head. An enterprise group may be domestic – when all linked enterprises are residents of the same country – or multinational – with links to enterprises in other countries.

From a theoretical point of view, **control** determines which enterprises belong to a group. Control implies the power to set the general policy of an enterprise and/or to appoint the majority of its directors. It may be exerted by an individual, by an enterprise or by a public authority. For an ESUT, the focus is on enterprises controlling other enterprises, so-called corporate control, while control by individuals or public authorities is generally not considered. Enterprise A is said to control enterprise B if A holds, directly or indirectly, more than half of the shareholders' voting power in B. Furthermore, enterprise A exerts indirect control over enterprise B if A controls one or more enterprises (C, D, etc.) that control B. Finally, in circumstances where voting rights are widely dispersed, enterprise A may control enterprise B through effective minority control, i.e. without holding more than half of the shareholders' voting power.

In practice, delineating an enterprise group based on the concept of control proves challenging because information about the voting power that allows exerting control is mostly difficult to come by or unavailable. Therefore, NSOs generally rely on **ownership** as a proxy for control when it comes to delineating enterprise groups. They determine ownership based on information about **participation rates**, i.e. shares in an enterprise's capital, since this information is easier to come by. This section first describes ownership-based definitions of enterprise groups and group affiliation before turning to a description of potential data sources.

As regards terminology, enterprises that hold a participation in another enterprise are referred to as **parent** enterprises, while enterprises whose capital is held by another enterprise are referred to as **affiliates**. It is common to consider only participation rates of 10% or more as the sign of a lasting interest (foreign direct investment [FDI] threshold). Among affiliates, a distinction is made between **subsidiaries** and **associates**. An enterprise is a subsidiary if another (parent) enterprise owns more than 50% of its capital; it is an associate if another (parent) enterprise holds between 10% and 50% of its capital. Participation rates above 50% are taken to reflect control, and, therefore, an enterprise group is made up of a parent enterprise that is not controlled by another enterprise and all the direct and indirect subsidiaries of that parent enterprise. Associates are not considered to be part of the enterprise group. Finally, a **joint venture** is a special case where two or more parent enterprises have a minority participation of equal size (50% for two parents, 33% for three parents, etc.) in an affiliate.

The **global group head** is the parent enterprise at the top of the enterprise group that is not controlled by another enterprise. This implies that the underlying group structure is assumed to be hierarchical. The notion of global group head is similar to the notion of global decision centre or ultimate controlling institutional unit in the Foreign Affiliates Statistics (FATS; (Eurostat, 2012[27])) or in the Activities of Multinational Enterprises (AMNE; (Cadestin et al., 2018[28])). This is the enterprise that takes global decisions for the enterprise group as a whole. Global group head and global decision centre may, however, differ for large or complex enterprise groups, in particular when a natural person, a family holding, an enterprise located in a tax haven, a holding enterprise or an equity fund is at the top of the enterprise group.

Defining categories of enterprises

Four categories of home country enterprises can be distinguished based on affiliation to an enterprise group:

1. domestic stand-alone enterprises
2. enterprises that are part of a domestic enterprise group
3. enterprises that are part of a domestically controlled MNE group
4. enterprises that are part of a foreign-controlled MNE group.

These four ownership categories are discussed below, with examples for the latter three categories.

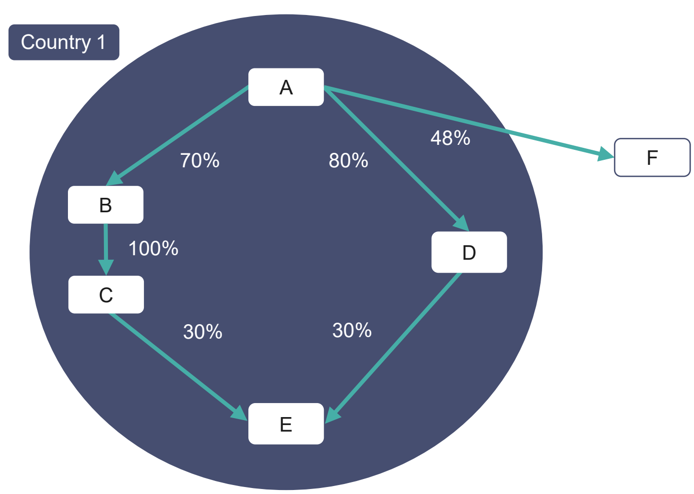
Domestic stand-alone enterprises

Domestic stand-alone enterprises are not part of an enterprise group, i.e. they are neither subsidiaries nor parent enterprises.

Enterprises that are part of a domestic enterprise group

Enterprises that are part of a domestic enterprise group are either the global group head or subsidiaries of an enterprise group which is made up exclusively of enterprises located in the home country (Figure 2.1).

Figure 2.1. Domestic enterprise group



As Figure 2.1 illustrates, enterprise A is the global group head and enterprises B, C, D and E are also part of the group as subsidiaries. They are all located in country 1, which is the home country. The perimeter of the group is indicated by the oval in the figure.

Enterprise E is an indirectly controlled subsidiary of enterprise A. In this example, A exerts its control through two subsidiaries, C and D, with minority participations in E that sum to more than 50%. Enterprise F is an associate since enterprise A and its subsidiaries hold less than 50% of its shares; it therefore does not belong to the enterprise group (it is outside the oval in the figure).

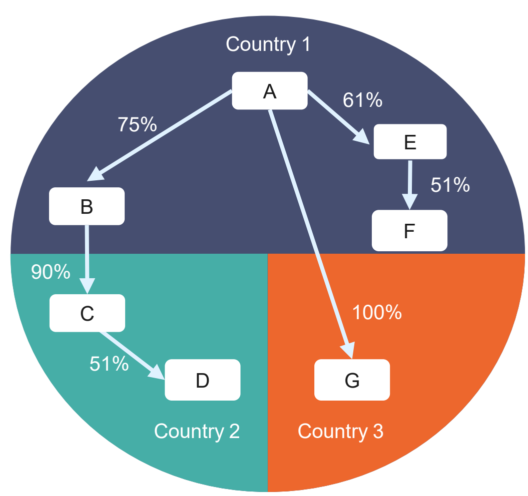
Enterprises that are part of a domestically controlled multinational enterprise group

Enterprises that are part of a domestically controlled MNE group are home country enterprises that belong to an enterprise group with a home country enterprise as global group head and at least one subsidiary in another country.

This is illustrated in Figure 2.2. Here, the perimeter of the group is again given by the oval. It is made up of enterprises located in three countries separated by dashed lines. Enterprises in each country have a different colour. Enterprise A is the global group head located in country 1 and all other enterprises shown in the figure (B to G) are subsidiaries of A. Of these, enterprises B, E and F are located in country 1 (domestic subsidiaries of A), while enterprises C and D are located in country 2 and enterprise G in country 3 (foreign subsidiaries).

From the perspective of country 1, this MNE group is domestically controlled since the global group head (enterprise A) is located in this country. Hence, enterprises A, B, E and F in country 1 are part of the category of enterprises that belong to a domestically controlled MNE group.

Figure 2.2. Multinational enterprise group



Enterprises that are part of a foreign-controlled multinational enterprise group

Enterprises that are part of a foreign-controlled MNE group are home country enterprises that belong to an enterprise group with a global group head located abroad. According to the terminology defined above, they are foreign subsidiaries, but in prior work on ESUTs, they are mostly referred to as foreign affiliates.

This is also illustrated in Figure 2.2. From the perspective of countries 2 and 3, this MNE group is foreign-controlled since its global group head, enterprise A, is located abroad, in country 1. Hence, enterprises C and D in country 2 are part of the category of enterprises that belong to a foreign-controlled MNE group. The same holds for enterprise G in country 3.

Joint ventures require specific attention. While a joint venture should not be considered as a domestic stand-alone enterprise, the compiler must decide whether to classify the enterprise as part of a domestic enterprise group, part of a domestically controlled MNE group or part of a foreign-controlled MNE group. This decision should be based on the location of the parent enterprises and either on extra information on the joint venture collected by the NSO or on a pre-specified rule.

Data for classifying enterprises

Ideally, the classification of enterprises according to group affiliation is based on information on group structures from a groups register. Compilers may either use an existing groups register or build a groups register themselves. Since the construction of a groups register is a work-intensive undertaking, the use of an existing groups register reduces the workload for constructing an ESUT substantially.

In many countries, the NSO produces a groups register on a regular basis. In some cases, group structures are identified directly through specific surveys, but they are mostly derived from data on participations (ownership data). As mentioned earlier, the use of ownership data is generally motivated by the lack of data on control. In practice, group structures are derived from data on participations through an algorithm that identifies all enterprises that belong to a group. The algorithm is based on a 50% plus one share participation threshold so as to proxy for control. It must identify group heads and attribute all subsidiaries to their group head taking into account indirect control.

NSOs use several types of sources for data on participations in the construction of a groups register. They should ideally identify the parent, the affiliate, their respective countries of residence and the participation rate. These data sources include administrative data such as enterprise accounts and tax records, in which enterprises are required to report information about their shareholders and their affiliates, as well as surveys on shareholder structures and affiliates, mostly conducted by central banks or chambers of commerce. In France, for example, the NSO constructs its groups register LiFi, which stands for “Liaisons Financières”, mainly based on shareholder information from tax authorities and the Banque de France. This information is used as input into an algorithm that identifies enterprise groups.

A further example is provided by the groups register for Belgium, which relies heavily on information that enterprises have to report as part of their annual accounts (balance sheet and profit and loss account). In three separate sections of the appendix of these accounts, enterprises list their (domestic and foreign) affiliates with an indication of the rate of participation; provide information on their shareholder structure; and indicate whether they are part of a group that establishes consolidated accounts and reports information on the consolidating enterprise and/or their parent enterprise. This is complemented with information from a group structure survey, which is conducted by the Belgian National Bank and is the basis for selecting samples for FDI and FATS surveys. This group structure survey identifies foreign ownership links for large Belgian enterprises. Reporting enterprises are asked to provide the name and country of residence of all enterprises in the group, resident or non-resident, and the direct participation rate between any two enterprises in the group.

When there is no groups register or when compilers do not have access to the NSO’s groups register, they must determine the group affiliation of enterprises themselves. This is work-intensive, and the quality of the result largely depends on the underlying ownership data. With access to the type of administrative data sources described above, compilers can construct a groups register by applying the appropriate algorithm. Otherwise, they may use survey data from different sources, some of which is also used by NSOs for the construction of groups registers.

Dedicated surveys on enterprise groups and their affiliates are indeed conducted in most OECD member countries. For the United States, the Bureau of Economic Analysis collects data on participations of and in US enterprises through surveys on inward and outward FDI. Likewise, national central banks and NSOs in EU member states gather information on participations through surveys of FDI and through FATS. Data from these surveys are useful not only for identifying group structures and classifying enterprises but also for breaking down industries in ESUT construction.

In addition to dedicated surveys, some NSOs have added specific questions to business surveys in other fields (e.g. structural business statistics, research and development, innovation, exports of services, information and communication technologies) to collect information on group affiliation. Although such information is not necessarily comprehensive, it may complement other data sources and allow classifying large enterprises. Besides, results from profiling carried out by NSOs are another source of information on group affiliation. In manual profiling, the global decision centre and the global group head as well as their location must be identified.

The identification of domestic affiliates or subsidiaries is often a blind spot when it comes to determining group structures and group affiliation, because data on domestic participation links tends to be scarce. This holds true in particular for the determination of group structures based on FDI surveys, and it may even be an issue in the construction of a groups register by the NSO. Therefore, some countries, for example France, have added a specific question on domestic subsidiaries to their FATS surveys to identify the full (domestic and cross-border) scope of enterprise groups.

Another limitation of groups registers and other data on ownership links for individual countries is that, in general, they only cover direct foreign ownership links. Data sources that report indirect foreign ownership links are the exception. In terms of the graphical example of a MNE group, data sources for country 1 are unlikely to cover the ownership link between enterprises C and D in country 2. Hence, the algorithm will not identify the full scope of the group. By the same token, data sources for country 2 will normally fail to identify the link between enterprise A and enterprise B in country 1. In that case, the global group head – enterprise A – is not identified by the algorithm. Such incomplete identification of group structures may lead to errors in the classification of enterprises according to their group affiliation.

The ideal solution for addressing this limitation in data on group structures for individual countries would be to construct a groups register at a multi-country or even global scale. Several international organisations have taken initiatives in this field.

Eurostat compiles the Euro Groups Register (EGR), which is a statistical business register of MNE groups operating in EU and European Free Trade Association countries. It is based on group structure information delivered by the NSOs of these countries, which is sometimes not publicly available. In the process of compiling the EGR, Eurostat validates and consolidates these data on group structures from individual countries; the EGR is then complemented by commercial data sources and other open data sources available online to depict the complete group structure of the MNE groups. Although it is not global but limited to the MNE groups with operations in the EU and European Free Trade Association countries in geographical scope, the EGR can provide valuable input for the classification of enterprises according to their group affiliation. Information from the EGR has been used together with national data for the classification of enterprises in the most recent compilation of ownership-extended SUTs for Belgium (Hambÿe, Michel and Trachez, 2023[29]).

At the global scale, the OECD and the United Nations Statistics Division have developed the Multinational Enterprise Information Platform (see Pilgrim and Ang (2024[30]). It contains a physical and a digital register of the world's largest MNE groups with their affiliates and subsidiaries, aiming for a global coverage. They are built exclusively from publicly available data. The data used include, among others, information from companies' annual reports and from the Global Legal Entity Identifier Foundation. To date, the register covers the 500 largest multinational groups. This limited coverage restricts the use of the register for ESUT compilation. It may, however, prove to be valuable input for confirming, correcting or complementing available national information on group affiliation.

Besides, there are also private initiatives on compiling group structure information at a multi-country or global scale. The most prominent example is ORBIS, a global database of company accounts, put together and published initially by the Bureau van Dijk, and recently taken over by Moody's. The business information compiled by Dun & Bradstreet is another example of such data. These databases have been used in academic work on multinational groups and enterprise heterogeneity and represent a potential source for classifying enterprises in the process of ESUT construction. Data from ORBIS have been used in the construction of the OECD's *Analytical AMNE Database* (Cadestin et al., 2018[28]).

For the construction of an ESUT with an industry breakdown by group affiliation, compilers must not necessarily strive for a full breakdown into the four categories of group affiliation shown above. Even with a less detailed categorisation, an ownership-extended SUT can provide valuable information on within-industry heterogeneity and enhance analytical possibilities. For example, categories 1, 2 and 3 may be merged into a single category of “domestic enterprises”, either due to data constraints or because the aim is limited to distinguishing between “domestic enterprises” and “foreign affiliates”, i.e. enterprises that belong to a foreign-controlled multinational group. Such a breakdown of industries into “domestic enterprises” and “foreign affiliates” can be found in the multi-country tables in the OECD’s Analytical AMNE Database (Cadestin et al., 2018[28]). In a similar vein, industries have been broken down into the three categories of “non-MNEs” or “domestic enterprises”, “domestic MNEs”, and “foreign MNEs” in the ESUT work for the United States (Fetzer et al., 2023[2]) and for Belgium (Hambÿe, Michel and Trachez, 2023[29]). This amounts to merging categories 1 (domestic stand-alone enterprises) and 2 (enterprises that are part of a domestic group) into a single category referred to as “non-MNEs” or “domestic enterprises”.

Furthermore, ESUT compilers often face data restrictions that either directly impose a definition of enterprise categories upon their work or make it necessary to adopt an alternative approach to enterprise classification. For example, the data available to the compiler may only record whether an enterprise has an FDI link, i.e. participation of more than 10% in a foreign enterprise, without mention of the exact participation rate. Such data are limited to direct ownership links and no distinction is made between subsidiaries and associates. Hence, it does not allow for identifying group structures. It may nevertheless be used for classifying enterprises in the process of ESUT construction, and tables with an industry breakdown based on these data will likely yield valuable insights on enterprises with an FDI link. Besides, it would be of interest to explore the impact of different participation rate thresholds. Instead of the 50% participation threshold to proxy for control, compilers may choose a lower participation rate threshold, e.g. the 10% FDI threshold. When applying the usual algorithm, this would lead to the identification of enterprise networks based on FDI links rather than groups where enterprises are bound together by control links. Comparing extended tables based on these two alternative thresholds could provide insights into whether it is investment or control links that account for differences in technology.

Groups registers and alternative data sources on ownership links generally refer to legal units (or enterprises). For countries in which the legal unit (or enterprise) is used as the statistical unit for SUT construction, the classification by group affiliation is straightforward. With establishments (local kind-of-activity units) as the statistical unit, a link between legal units (or enterprises) and establishments is again required. Normally, all establishments that belong to a legal unit (or enterprise) should be classified in the same category of group affiliation.

Finally, when ESUT compilers do not have access to individual enterprise-level data on ownership or group affiliation they may rely on more aggregate industry-level data, e.g. from the TEC or FATS databases. However, in that case, they must take the definition of categories and enterprise classification as given. The prime example of ESUT construction based on industry-level data sources is the OECD’s *Analytical AMNE Database*, which combines the TEC database and several sources of FATS-type data for breaking down industries in the OECD’s Inter-Country Input-Output Tables (Cadestin et al., 2018[28]).

Enterprise size

Enterprise size is the third major source of within-industry enterprise heterogeneity that has been considered as a criterion for the construction of an ESUT. This reflects the classical view that large enterprises are different from small and medium-sized enterprises (SMEs) in terms of production technology. In other words, the scale of operations is assumed to influence cost and input structures. Besides, SMEs are traditionally in the focus of policy makers given that they represent the vast majority of enterprises active in a country and account for a large share of a country’s total employment. Moreover, in many circumstances, enterprise size matters for state aid eligibility. There has been growing interest in recent years in the interaction between SMEs and large enterprises within domestic and global value chains (ADB, 2015[31]; OECD, 2023[32]).

ESUTs with an industry breakdown by enterprise size class can provide valuable insights into the economy-wide importance of SMEs and large enterprises, and these tables can serve as input for analyses of the links between these categories of enterprises. In the first instance, such a breakdown requires a definition of enterprise size classes. In general, these size classes are based on enterprise-level thresholds for one or more variables. Employment stands out as the most widely used variable for setting size class thresholds. However, size classes may also be defined based on other enterprise-level variables such as turnover, total assets or the balance sheet total.

Defining categories of enterprises

The decision on the number of enterprise size classes is up to the compilers. Traditionally, three enterprise size classes are defined: large, medium-sized and small enterprises. Depending on the aims of the exercise and data availability, the number of enterprise size classes may be adapted. In particular, a fourth class of micro enterprises can be split out from small enterprises. Alternatively, small and medium-sized enterprises may be grouped together in a single SME category.

The choice of levels for the thresholds for defining size classes may be very different depending on country size. According to the European Commission's definition (European Commission, 2003[33]), enterprises with 250 employees or more and a turnover of EUR 50 million or more are considered as large, while all others are considered as SMEs (see Box 2.2). However, this EU-wide threshold may imply that the number of large enterprises is very limited in smaller member states. Due to the size of the country's market, thresholds for defining large enterprises and SMEs as identified by the Bureau of Economic Analysis are different for the United States: enterprises with 500 employees or more are labelled as large, enterprises with 100-499 employees are considered as medium-sized, enterprises with 20-99 employees are categorised as small, and all others are taken to be micro enterprises.

Box 2.2. The European Commission's definition of small and medium-sized enterprises

The European Union has adopted a definition of micro, small and medium-sized enterprises in order to harmonise the categorisation of enterprises for all member countries (European Commission, 2003[33]). This responds to the aim of ensuring cross-country consistency in assessing whether an enterprise is entitled to financial support restricted to small and medium-sized enterprises (SMEs). The definition is based on three variables: 1) the number of employees; 2) turnover; and 3) the balance sheet total. In addition, the definition also takes into account whether the enterprise is part of a group.

The category of micro, small and medium-sized enterprises is made up of enterprises that employ fewer than 250 persons and have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million (Figure 2.3).

Within the category of SMEs, small enterprises are defined as those that employ fewer than 50 persons and have an annual turnover and/or annual balance sheet total that does not exceed EUR 10 million. Among small enterprises, micro enterprises are defined as those that employ fewer than 10 persons and have an annual turnover and/or annual balance sheet total that does not exceed EUR 2 million.

It is recommended to apply these thresholds at the level of the enterprise for independent enterprises and at the level of the enterprise group for dependent enterprises. An enterprise is considered as an SME if the group to which it belongs employs fewer than 250 persons and has an annual turnover of less than EUR 50 million or an annual balance sheet total of less than EUR 43 million.

Figure 2.3. The European Commission’s definition of small and medium-sized enterprises

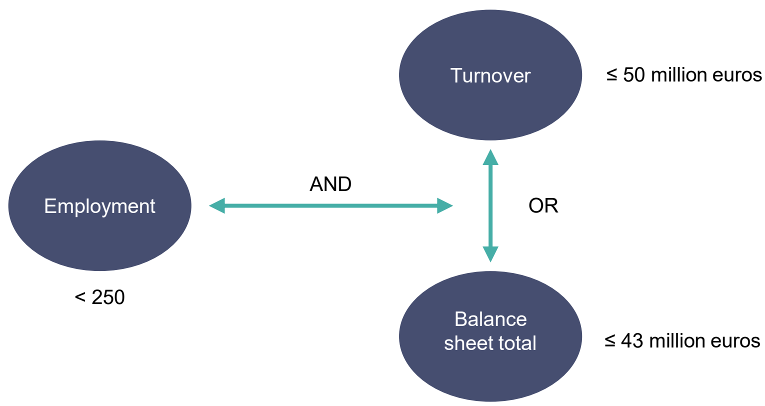


Table 2.1. Enterprise-size classes according to the European Commission’s SME definition: Criteria and thresholds

Size category	Employment	AND	Turnover	OR	Balance sheet total
Large enterprises	≥ 250		> EUR 50 million		> EUR 43 million
Medium-sized enterprises	< 250		≤ EUR 50 million		≤ EUR 43 million
Small enterprises	< 50		≤ EUR 10 million		≤ EUR 10 million
Micro enterprises	< 10		≤ EUR 2 million		≤ EUR 2 million

Data for classifying enterprises

The data on enterprise-level employment required for determining enterprise size typically come from a census or social security records, which are exhaustive administrative data, from an enterprise’s annual accounts or from various surveys such as structural business surveys. Ideally, the number of employees of an enterprise should be calculated in full-time equivalents but if the relevant information is not available, then absolute numbers may be used. Standard data sources on enterprises’ turnover are their annual accounts (balance sheet or profit and loss account), VAT records, and structural business surveys and other surveys.

When it comes to breaking down industries for ESUT construction, the relevant statistical units (local kind-of-activity or legal units) that make up each industry must be categorised by size class, while size is determined at the level of the firm/enterprise. Thus, in practice, the categorisation of statistical units into size classes is dependent on the firm/enterprise definition and information linking these statistical units to firm/enterprise. Statistical units that are part of the same firm/enterprise should be categorised in the same size class, i.e. that of the firm/enterprise as a whole.

To determine the size of a firm/enterprise, compilers can rely either on specific enterprise-level information or on data for the individual statistical units. With thresholds based on employment, the source of information should not make a difference, since a firm’s/enterprise’s total employment normally corresponds to the sum of employment in all the statistical units that belong to the firm/enterprise. The situation is different for turnover because of transactions between the statistical units that make up the firm/enterprise. These transactions are part of the turnover of individual statistical units but are eliminated from consolidated accounts for the firm/enterprise as a whole.

As previously mentioned for the other extension criteria, compilers may rely on more aggregate data in the ESUT construction process when they do not have access to detailed enterprise-level data. For example, TEC data by enterprise size class could be used as a second-best alternative for the disaggregation of industry totals in regular SUTs.

Combining size and group affiliation

In addition, SMEs that are part of an enterprise group are likely to be different from those that are not part of a group. The former are generally referred to as dependent or linked SMEs or even pseudo-SMEs; the latter as independent, autonomous or genuine SMEs. The rationale behind this is that dependent SMEs, even though they meet the usual criteria for belonging to the SME size class, are different in terms of production process and input structure. Indeed, they have access to significant additional resources provided by their group (finance, skills, services, research and development, intellectual property, etc.) due to which they are also likely to face lower barriers to trade.

Therefore, group affiliation should, if possible, be taken into account as an additional source of heterogeneity when breaking down industries by enterprise size, so that SMEs that are part of an enterprise group (domestic or foreign) are separated from SMEs that are not part of a group. This has been done in prior work on ESUTs for the Nordic countries ((Statistics Denmark and OECD, 2017[4]), the Netherlands (Chong et al., 2019[3]) and Belgium ((Hambÿe, Michel and Trachez, 2023[29]).

A combined size-ownership breakdown leads to defining the following main categories of enterprises:

1. independent (autonomous, genuine) SMEs: small and medium-sized enterprises that are not part of an enterprise group (neither domestic nor multinational)
2. dependent (linked, pseudo-) SMEs: small and medium-sized enterprises that are part of an enterprise group (domestic or multinational)
3. large enterprises.

This adapted categorisation of enterprises is in line with the European SME definition (European Commission, 2003[33]) (see Box 2.2. The categories of dependent and independent SMEs can each be further subdivided into micro, small and medium-sized enterprises.

The size class categorisation of enterprises can be further refined by taking into account the size of the group to which an enterprise belongs. SMEs would only be considered as dependent if they are part of a large group, with the threshold for a large group set at the same level as the threshold for a large enterprise. However, in practice, determining the size of an enterprise group can prove difficult, mainly due to a lack of data. Compilers may find aggregated data at the group level for groups that draw up and publish consolidated accounts. Otherwise, compilers will have to deal with several issues. First, they have to delineate enterprise groups to identify all enterprises that belong to a group, which requires detailed information on group affiliation in the home country and abroad. Then, values for the threshold variables (employment, turnover and/or balance sheet total) must be determined for the entire group. In this respect, the non-additivity of the financial variables – turnover and balance sheet total – is again a major issue. For both, the value of the group as a whole does not necessarily correspond to the sum of the values for all enterprises that are part of the group due to within-group transactions. Compilers may therefore decide to rely only on employment, which is additive. However, compilers will mostly have access only to data for enterprises located in their country and therefore not be able to determine the size of multinational groups. A possible solution for this issue is to consider all foreign-controlled subsidiaries of multinational groups as part of a large group, regardless of group size; and all domestically controlled enterprises as SMEs if the group to which they belong has fewer than 250 employees in the home country, regardless of the number of employees in its foreign subsidiaries. This approach has been applied in prior work for the Netherlands (Chong et al., 2019[3]).

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3. Compiling extended supply and use tables using enterprise data

This chapter describes how to compile extended supply and use tables using enterprise data. After a brief overview of the process, it provides an explanation of the six steps of the process: 1) categorising enterprises and choosing industries to be disaggregated; 2) disaggregating total industry-level output and intermediate use; 3) disaggregating the product distribution of output and intermediate use; 4) deriving extended valuation tables and an extended use table at basic prices; 5) disaggregating use into use of imports and of domestic production; and 6) disaggregating the use of domestic input. Sample tables illustrate each step.

Introduction

This chapter provides guidance to extended supply and use table (ESUT) compilers that have access to detailed microdata, in particular at the enterprise level. In general, this includes the microdata underlying the construction of regular (SUTs), such as the economic census, administrative data (annual accounts, tax data, customs data, social security records, etc.) or specific surveys (on business statistics, of industrial production, on households, etc.). Compilers may also have access to additional data on aspects that enterprise data do not cover, e.g. information on the informal or the illegal economy. The key idea in the approach described here is to construct ESUTs by disaggregating columns and rows of the regular SUTs, using as much as possible data to capture the heterogeneity between different types of enterprises. The chapter proceeds by explaining how to do this step by step for an individual country, building on earlier experiences of national statistical organisations (NSOs) which have compiled ESUTs. Since the resulting ESUTs may be unbalanced, it may be necessary to use a balancing procedure, as explained in Chapter 5. The results of this approach are ESUTs that can be used as input for deriving an extended input-output table (EIOT) – the input-output table (IOT) where industries are disaggregated by type of enterprise. Chapter 6 will explain how to do this.

Overview of the process

In theory, ESUTs for an individual country could be compiled entirely bottom-up based on the data sources and methods used to compile the regular SUTs, following the concepts of national accounts, while distinguishing categories of enterprises within industries. Such an approach would also use the same statistical units (establishments are recommended) as the regular SUTs. However, although this is the ideal (and therefore recommended) way to compile ESUTs, it is likely to be very resource-intensive and time-consuming. There are no known examples of ESUTs compiled bottom-up but they could align well with the regular SUTs if planned from the beginning of the process. This chapter describes a top-down method as an alternative approach to compiling ESUTs using microdata. The description builds on experiences of countries that have compiled ESUTs, among them Belgium (Hambÿe, Hertveldt and Michel, 2018[1]), Denmark (Nilsson, Rørmose Jensen and Holst Jensen, 2018[2]), Italy (Sallusti and Cuicchio, 2023[3]), Mexico (INEGI, 2023[4]) and the Netherlands (Chong et al., 2018[5]). This is the recommended approach when microdata are available. Chapter 4 focuses on an approach to compiling ESUTs when microdata are not available.

The method described in this chapter consists of breaking down regular SUTs into ESUTs for an individual country. It takes the country's regular SUTs as a starting point. Compilers leverage whatever microdata they have at their disposal to bring within-industry enterprise heterogeneity into the regular SUTs. Hence, in this process, the disaggregation of industries and product categories is based as much as possible on enterprise-level data. However, when no data are available, disaggregations may be based on assumptions, including straightforward proportionality assumptions. In addition, depending on the aims for constructing ESUTs and the country characteristics, certain disaggregations may not be necessary. It is up to the compiler to determine whether the assumptions made in the ESUTs' construction process are compatible with the pursued statistical and analytical aims. Furthermore, the compiler should also keep in mind the plausibility of the results of each step. Chong et al. (2016[6]) gives the example that an enterprise with less than 50 employees is unlikely to build a complete sea tanker. In such cases, one can substitute the "irregular" product-type of enterprise combinations with other products produced by the industry at hand. If that is not possible, one can shift supply and use to a more likely type of enterprise using expert judgement.

A schematic overview

Table 3.1 provides a schematic overview of the ESUT compilation process covering the steps to be taken, the data to be used in each step and the results of the steps. It is based on the presentation of ESUT compilation work for Belgium in Michel et al. (2019[7]). It follows rather closely the steps of the construction process of the regular SUTs at basic prices according to the recommendations in the United Nations *Handbook on Supply and Use Tables and Input-Output Tables with Extensions and Applications* (United Nations, 2018[8]). Steps 1, 2 and 3 lead to a "column-extended" supply table in basic prices and a "column-extended" use table at purchasers' prices. The derivation of extended valuation tables in Step 4 allows obtaining a "column-extended" use table at basic prices. Steps 5 and 6 cover the disaggregation of the rows or product categories by origin (imports and domestic production of the different types of enterprises) and result in fully extended SUTs at basic prices. Each step is explained in greater detail below.

Table 3.1. Steps in the extended supply and use table compilation process

Steps	1	2	3	4	5	6
Workflow	Categorising enterprises and choosing the industries to be disaggregated	Disaggregating total industry-level output and intermediate use	Disaggregating the product distribution of output and intermediate use	Deriving extended valuation tables and an extended use table at basic prices	Disaggregating use into use of imports and of domestic production	Disaggregating the use of domestic output by producing enterprise category
Data	Enterprise-level data on the extension criteria	Enterprise-level data on total output and purchases	Enterprise-level data on output and purchases by product category	Enterprise-level data on margins, and taxes and subsidies on products	Enterprise-level data on imports by product category	Enterprise-level data on exports by product category and transaction data (value-added tax)
Result	List of enterprises by type	Column totals by type of enterprise in supply and use tables (SUTs)	Columns by type of enterprise → Column-extended SUTs at purchasers' prices	Column-extended valuation tables and use table at basic prices	Extended import flow table	Rows by type of enterprise in use table for domestic output → fully extended SUTs (rows and columns)

Source: Adapted from Michel et al. (2019[7]).

Note that Steps 4, 5, and 6 are, strictly speaking, not necessary when deriving an ESUT. However, they provide the basis for deriving the EIOT. To compile an EIOT, one needs to have an extended use table in basic prices (Step 4). Furthermore, one would like to consider that certain types of enterprises use more (less) imports and have more (less) exports. This is achieved in Steps 5 and 6, respectively.

Step 1: Categorising enterprises and choosing the industries to be disaggregated

First, compilers must decide on the extension criterion (or criteria) for compiling their ESUTs. Chapter 1 provided guidance on this choice. The choice also depends on the characteristics of the economy; for some countries, it can be relevant to disaggregate by formal/informal economy or whether enterprises are "green" or "social". The most frequently used criteria have so far been trading status, group affiliation and size. Chapter 2 reviewed the definitions and data sources for these three criteria.

Whatever the criterion, the available microdata should allow enterprises in the business register to be classified into categories, using a type of category variable. This is the first step according to the overview above. The relevant information for a classification may not be available for part of the enterprises in the business register. These enterprises may then either be assigned to a default category, for example, all enterprises for which there is no information on ownership may be considered as being part of the category of domestic stand-alone enterprises (see Chapter 2), or they may be classified in a separate additional category of their own, i.e. "other" or "non-classified" enterprises.

Which industries to break down?

Second, the question of which industries to disaggregate must be answered early in the construction process of ESUTs because it has implications for the entire process. Ideally, compilers should draw up a list of industries selected for disaggregation and clearly label those that have not been disaggregated when presenting their results. For practical purposes, compilers may define an additional enterprise category that includes all enterprises in industries that are not disaggregated. For example, a disaggregation by size into large enterprises and small and medium-sized enterprises (SMEs) would then be expanded to include a category of "other" enterprises. The values for this category are then: equal to zero in all industries that are disaggregated; and equal to the value for the entire industry in all industries that are not disaggregated.[1] This way of proceeding avoids a "sparse" disaggregation, i.e. not having the same enterprise categories for all industries, and it makes alternative aggregations easier.

In most cases, it is neither feasible nor useful to disaggregate all industries (Ahmad, 2023[9]). In the first instance, the decision on whether to disaggregate an industry will depend on the chosen disaggregation criterion (e.g. the industries to be disaggregated might not be the same for the size criterion as for the ownership criterion). This may have to do with the inherent characteristics of the criterion, legal provisions or institutional arrangements, which imply that it is simply not meaningful to disaggregate certain industries for a criterion. For example, there is no good reason to disaggregate industries that belong to the public administration by ownership/group affiliation, or to isolate exporters in an industry when an export ban affects the main product of the industry. In this context, it is important to distinguish between industries that the compiler decides should not be disaggregated and industries where all enterprises are part of the same category. Enterprises that are part of the same category could include agriculture in countries where farming is exclusively a small-scale family business or for the extraction of crude petroleum in countries where all enterprises in that industry are exporters. Disaggregation of real estate (L in ISIC Rev. 4) deserves special attention. Part of this industry consists of "imputed rents of owner-occupied dwellings" (no enterprises involved) and part consists of "renting and operating of own or leased real estate" (enterprises involved).

The decision not to disaggregate an industry may also be determined by data availability. There may be different underlying reasons for such a lack of data. The data required for classifying enterprises may simply not be collected for an industry. For example, all enterprises in the industry may be below the size threshold for collecting ownership data. Alternatively, even when the data are collected, ESUT compilers may not have access to the required data for classifying enterprises in certain industries.

Furthermore, confidentiality issues regarding the results of the disaggregation may also play a role. This is the case when values for one category of enterprises in an industry are based on observations for very few enterprises or even a single enterprise. Then, to preserve confidentiality, the compiler may not be allowed to publish results by category of enterprises for this industry and may therefore prefer not to disaggregate the industry. Finally, compilers may also decide to restrict the number of industries to be disaggregated to reduce the scope of the exercise and keep the workload manageable, or because the research question at hand does not require the disaggregation of additional industries. For example, Michel, Hambÿe and Hertveldt (2023[10]) restricted their extension of the Belgian SUTs by exporter status to manufacturing industries so as to reduce the workload of the exercise.

The number of industries to be disaggregated also depends on the level of industry breakdown at which the disaggregation into categories of enterprises is implemented. Compilers face a trade-off when choosing the level of breakdown. On the one hand, a more detailed industry classification implies that there are fewer enterprises per category within industries. This may lead to the confidentiality issues discussed above. On the other hand, a more aggregate industry classification reduces within-industry homogeneity in terms of activity, and it is likely that categories of enterprises within more aggregate industries are also less homogenous. Hence, when working with more aggregate industries, compilers must carefully evaluate whether product similarity in more detailed industries or similarity in terms of size, ownership, exporter status or any other alternative criterion matters more for technological homogeneity.

Example for Belgium

A list of industries to be disaggregated was drawn up in the early stages of the construction process of ownership-extended SUTs for Belgium for 2015 (Hambÿe et al., 2022[11]) (Table 3.2). It was decided not to disaggregate industries for which there is no significant activity in Belgium, e.g. certain types of mining; industries for which there is no information about significant ownership links with abroad, e.g. agriculture and certain non-market service activities; industries that belong entirely to the public sector or that have a large public sector share, such as the public administration, defence or education; and financial and insurance industries, for which the relevant enterprise-level data for an industry disaggregation were not available. From the 133 industries in the regular Belgian SUTs, 110 were disaggregated.

Table 3.2. Industries to be disaggregated in Belgium according to ownership status

Section of the ISIC Rev. 4	ISIC 2-digit division	Breakdown by ownership?
Agriculture, forestry and fishing (**A**)	01-03	
Mining and quarrying (**B**)	05-09	✓
Manufacturing (**C**)	10-33	✓
Electricity, gas, steam and air conditioning (**D**)	35	✓
Water supply; sewerage, waste management and remediation services (**E**)	36-39	✓
Construction (**F**)	41-43	✓
Wholesale and retail trade services; repair services of motor vehicles and motorcycles (**G**)	45-47	✓
Transportation and storage (**H**)	49-53	✓
Accommodation and food services (**I**)	55-56	✓
Information and communication services (**J**)	58-63	✓
Financial and insurance activities (**K**)	64-66	
Real estate services (**L**) (except for imputed rents for owner-occupiers)	68	✓
Professional, scientific and technical services (**M**)	69-75	✓
Administrative and support services (**N**)	77-82	✓
Public administration and defence; compulsory social security (**O**)	84	
Education (**P**)	85	
Human health and social work activities (**Q**)	86-88	
Arts, entertainment and recreation (**R**)	90-93	
Other service activities (**S**)	94-96	
Activities of households as employers (**T**)	97	

Source: Hambÿe et al. (2022[11]).

Preparing the data

Before proceeding with the subsequent steps in the top-down method of constructing ESUTs along the lines of Table 3.1, compilers should prepare and perform controls on the data they are planning to use. This involves both the regular SUTs that serve as a starting point and the microdata that they have at their disposal, in particular the business register with the categorisation of enterprises by type and the enterprise-level data. Such controls are elaborated below.

Microdata linking

Once the ESUT compiler has chosen the industries to disaggregate and classified enterprises in the business register according to the extension criterion, the information on the category of the enterprises must be introduced into the enterprise-level databases. This is necessary in preparation for the use of these databases for the disaggregation of columns and rows in the regular SUTs. In practice, this can be achieved for each enterprise-level database by merging in the categorical variable from the business register based on a common identifier of enterprises. However, the ideal situation is one of complete microdata linking, i.e. where, based on a unique enterprise identifier, all the available enterprise-level data are merged into the business register that contains information on the categories of enterprises.

A first check should be performed on the business register extended with a classification of enterprises by category to determine how many enterprises there are for each category in each industry. In a similar vein, compilers should check the distribution over enterprise categories of the relevant variables from the enterprise-level data. This concerns, for example, turnover or sales from business surveys or tax records, exports, and imports of goods from customs data or employment from social security records.

Sample size problems

The controls may reveal sample size problems. For example, in some industries, there may be only very few foreign-owned enterprises, maybe only one or two, with none in the sample of a specific survey. Besides giving rise to confidentiality issues, this is not an ideal basis for extrapolations to estimate industry-level totals by enterprise category, and it may also lead to problems of reliability of the results.

Compilers may consider the following approaches to address such sample size problems:

- Rely on information from other sources with a larger coverage for extrapolation.
- Perform the breakdown by enterprise category at a more aggregate industry level (accepting the caveats on the homogeneity of production processes mentioned earlier).
- Proceed with the disaggregation at the most detailed industry level despite limited sample sizes but publish results only at a more aggregate level.

However, the choice should also be made with the use of the data in mind. When the use of the data is not related to the problem at hand, there will be more solutions. For example, suppose that the main goal is not to have information about foreign-owned multinational enterprises (MNEs), but about domestically owned non-multinationals, and the foreign-owned MNEs are just one of the other remaining groups of enterprises. In that particular case, these remaining groups of enterprises might be grouped together for this particular industry. If the use of the data is related to the problem at hand, for example, when the goal is to have information about foreign-owned MNEs, then one has to estimate anyway, even though the sample size is small.

When sample size is small, an alternative is Statistics Netherlands' approach (Chong et al., 2016[6]). They compiled ESUTs where industries are split by enterprise size, using data at enterprise level from the annual business surveys. In their approach, the industries of the regular SUTs are split into even smaller parts. In total, there were 1 068 clusters/industry x size class combinations. For 77 of those clusters, there were no data in the survey sample whereas there were enterprises in the cluster. Yet it was necessary to estimate several variables for each cluster such as value added. This was accomplished in the following way, which is similar to the method described earlier in this section.

The data situation was as follows: for enterprises in the survey sample, value added was known. For each enterprise in the Netherlands, an estimate of the number of persons employed was known. First, calculate for each industry-size cluster the average of value added by person employed. Information from enterprises where this ratio is very unusual was not taken into account. Second, in a cluster with no or insufficient survey responses, use the information from the previous step of an adjacent cluster and the employment of the enterprises in the cluster itself to estimate value added for each enterprise in the cluster. Third, calculate the totals at industry level and rescale them to the regular industry totals from the annual business surveys.

Differences between microdata and national accounts

As mentioned earlier, the top-down method for constructing ESUTs takes the regular SUTs as a starting point. It relies on microdata/enterprise-level data for the disaggregation of the columns and rows according to the chosen criterion. A major caveat of this approach concerns differences between microdata and the national accounts (NA).

In general, NSOs construct NA and SUTs from available microdata (and other more aggregate data sources). This includes enterprise-level data such as the business surveys underlying (structural) business statistics or customs data underlying international trade in goods statistics. There are, however, differences between aggregates derived directly from these raw microdata/enterprise-level data and NA aggregates (or values in the SUTs). These differences are primarily due to the accounting principles of the System of National Accounts (SNA). They can be substantial. For example, Cai, Miroudot and Zürcher (2023[12]) report that, in the OECD's AMNE data that are directly derived from enterprise-level data, output of the manufacture of chemicals and pharmaceutical products in the United Kingdom amounted to USD 46 billion in 2016, against output of USD 76 billion for that industry in the country's IOT. Such differences are an issue for the top-down method of compiling ESUTs where columns and rows in the regular SUTs are disaggregated based on microdata. Larger differences between NA and source data should be investigated and, where possible, assigned to the correct enterprise category. Remaining minor corrections can be distributed proportionally.

There are many aspects where the rules of the SNA for the compilation of the NA and SUTs lead to changes compared to the underlying microdata. A few of the major ones are listed below (see also the relevant discussion of this point in Cadestin et al. (2018[13])):

- Universe of enterprises/activities: For the compilation of the NA, all enterprises and all activities must be considered, even illegal activities, e.g. smuggling, that are not reported in administrative data and standard surveys.
- Statistical unit: The SNA recommends compiling the NA and SUTs using information on kind-of-activity units/establishments as statistical units, while survey and administrative data are often collected at the level of legal units/enterprises. Now consider an enterprise in the automotive industry which encompasses a wide array of establishments in different industries. In the NA, production is recommended to be assigned to the various industries of the establishments. But in business statistics, it would be assigned to the automotive industry only. Whether the data are at establishment or enterprise level therefore influences the results at the industry level.
- Supply table in NA data in basic prices while business statistics data are in producers' prices: The total output of an enterprise in business statistics contains the value of its production but may also include taxes minus subsidies on the product, trade and transport margins. However, in the supply table in the NA data, these taxes and margins are removed to arrive at a basic price. The margins are reallocated, namely to wholesale and retail trade and transport sectors and taxes minus subsidies on production included.
- Definition of output vs. turnover/sales: Turnover or sales reported by enterprises in administrative data and surveys underlying business statistics reflects the revenue of these enterprises and differs from output as defined in the NA. For example, when goods are purchased for resale without transformation (retail and wholesale activities), only the margin related to this resale activity may be considered as output in the NA. On the other hand, output in the NA should include the production of goods even when these are not sold.

- Secondary production: Secondary production can be reassigned to another industry by the NA in the SUTs.
- International trade in goods (ITG): There are significant differences between ITG and NA when it concerns trade in goods. First, according to the SNA (which is the same as the Balance of Payments Manual in this respect), the NA should only record imports and exports of goods when there is transfer of economic ownership from a non-resident to a resident, and vice versa, whereas in the customs data underlying merchandise trade statistics, goods are considered to be imported or exported when they enter or leave the economic territory (United Nations, 2011[14]), i.e. "when they cross the border".[2] The transfer of ownership does not always coincide with the crossing of a border, e.g. in the case of transit trade or when goods are sent abroad for processing or repair. Second, in the NA, exports and imports of goods are assigned to the industries that respectively produce or consume these goods, whereas merchandise trade statistics assign imports and exports to the industry of the enterprise that reports the trade. This can lead to large differences, in particular for wholesale trade. When a country has already compiled a reconciliation table between trade and SNA/Balance of Payments, this table would provide valuable input for dealing with the differences. Third, NA matches all trade to an industry, but not all trade in ITG can be matched to enterprises and subsequently to industries. This might be due to general mismatching or to the fact that the trader is unknown, e.g. because of a reporting threshold. Another explanation is that not all traders can be linked to the general business register, because they are only fiscally, but not physically, present in the country. Generally, it is advised to use as much of the microdata as possible to take the differences into account. Particularly for parts that are expected to be distributed differently among different types of enterprises, such as production abroad, processing, merchanting and re-exports. Annex 3.A provides guidance on dealing with re-exports at the micro-level.
- Balancing of SUTs: The compilation of SUTs brings together data from many sources in a single framework. Ensuring consistency between data from various sources within this framework requires balancing, which leads to changes compared to the original data.

In certain cases, a National Statistical Office (NSO) introduces some of the changes required to conform to SNA rules directly into the microdata/enterprise-level data. For example, some of the corrections for imports and exports required by the SNA may be applied at the level of individual enterprises, e.g. the identification of transit and processing trade. The resulting adapted microdata are then more closely in line with NA aggregates/SUTs totals. If they can get access, ESUT compilers should use those adapted microdata as input for the disaggregation of industries and product categories. However, most of the corrections for conforming to SNA rules are introduced at a more aggregated level and are, therefore, not reflected in the microdata/enterprise-level data used by ESUT compilers. In particular, extrapolations are typically performed at the industry level. Naturally, the same holds for the balancing of supply and use of products as part of SUTs compilation.

ESUT compilers may try to replicate some of these corrections, e.g. extrapolations, at the level of enterprise categories within industries. For this purpose, they may rely on certain assumptions and additional data that are used in the construction of the NA and regular SUTs. Chong et al. (2018[5]) and Sallusti and Cuiccho (2023[3]) provide some examples of such assumptions and use of additional data:

- Incomplete coverage within an industry: If sources cover only part of an industry's population of enterprises, then the missing part of activity must be estimated. This may require specific assumptions in ESUT compilation depending on the data situation. For example, if smaller size classes in holdings or group services are not covered by structural business surveys, compilers may allocate this estimated part of the industry-level activity to SMEs. Similarly, own account production activities like homebuilding or growing vegetables in allotments can be allocated to SMEs, non-multinationals and non-traders.

- Undeclared work and illegal economy: Production and costs for undeclared work and illegal activities are estimated and included in the NA. If they have access to these estimates, ESUT compilers may decide to allocate these to SMEs if they think it is appropriate. Adjusting can also be achieved during the balancing by product and with information from the labour surveys.
- Research and development (R&D) and intangible assets: Expenditure on R&D and intangible assets like software or intellectual property rights, whether purchased or internally produced, is considered as gross capital formation (investment) in the NA but is often recorded as operating costs in enterprise surveys. Therefore, NSOs apply a correction for these items when compiling the NA. If ESUT compilers have access to the survey data underlying this correction, they can allocate such expenditure to enterprise categories within industries. Otherwise, such expenditure may be allocated based on total use of the different enterprise categories within each industry.
- Financial intermediation services indirectly measured: Banks often do not charge directly for loans or deposits, instead earning through interest margins. NA make this implicit financial service on loans and deposits explicit based on interest rates. Industry and final use allocations are distributed based on production as per international agreements.
- In-kind compensation: In-kind compensation concerns goods and services provided by employers, like company cars or meals. These are recorded as operating costs but must be registered as wages in NA. Adjustments for private use of business assets by self-employed individuals are distributed proportionally.
- Expense fraud: Private expenses wrongly recorded as business expenses, like personal fuel or hotel stays, should be classified as consumption in NA. If the category of enterprises in which this type of fraud is mainly found is known, this information can be used to distribute corrections.

Nonetheless, the microdata that are used for disaggregation will generally not be fully in line with the totals in the regular SUTs. Therefore, the underlying idea of the top-down method is to derive shares from the microdata and then use proportional methods, e.g. a GRAS[3] method, to match the constraints imposed by the regular SUTs. Compilers can choose to take only industry- and product-level aggregates or individual cells from regular SUTs as constraints. However, taking individual cells as constraints is much more restrictive and may be too restrictive in some cases.

In one country's experience, there were some sources about production or compensation of employees for very small enterprises and the underground economy but no sources about costs, imports and exports. Some components were estimated by industry and type of enterprise. However, the proportionality assumption for costs, imports and exports sometimes leads to inconsistencies with production (and compensation of employees), thus generating negative entries for value added and gross operating surplus. The NSO's solution was to assume that for problematic cells, the distribution of compensation of employees and total costs was like the distribution of production.

Step 2: Disaggregating total industry-level output and intermediate use

In this second step, total output and intermediate inputs by industry are disaggregated by type of enterprise. Industry-level gross value added by type of enterprise is derived by difference. The rows for "total output" and "total intermediate use" in the SUTs in Table 3.3 and Table 3.4 illustrate the starting point and the result of this step. It should be noted that this is an intermediate step in the disaggregation of the columns of the regular SUTs that can be implemented but need not necessarily be implemented. Compilers may decide to skip this step and proceed directly to Step 3 in Table 3.1 if they consider their data for implementing Step 3 are sufficient. They can then simply derive total output and total intermediate use for all industry-enterprise category combinations as the sum of the columns in the column-extended SUTs (Table 3.3 and Table 3.4).

In the NA and regular SUTs, output is estimated for most industries from turnover or sales, and total intermediate use is estimated from purchases. Enterprises report these variables in business surveys or administrative data such as annual accounts or tax data and this information naturally constitutes the ideal enterprise-level data for disaggregating these industry totals by enterprise category.

However, the information on turnover, sales and purchases in the enterprise-level data might not be available for all enterprises in an industry. Hence, the enterprise-level data will not cover all the industry's total output and intermediate use in the regular SUTs. In that case, the disaggregation of total output and intermediate use by enterprise category can be achieved either by using the shares of the enterprise categories in turnover or sales and in purchases derived from the enterprise-level data or by using employment data for extrapolation if employment is available for the entire population of enterprises in the industry. This latter approach may also be applied for the disaggregation of total output and intermediate use of industries for which compilers have no microdata. For example, see the approach of Chong et al. (2018[5]) that was mentioned earlier in the chapter.

Step 3: Disaggregating the product distribution of output and intermediate use

In this third step of the top-down approach to ESUT compilation, the product structure of output and use of industries is disaggregated by type of enterprise. This comes down to disaggregating the columns of the SUTs (intermediate part). Table 3.3 and Table 3.4 illustrate, in reduced form, the starting point (regular SUTs) and the result (column-extended tables) for the supply table and the use table, respectively. They show a disaggregation into SMEs and large enterprises (large) as an example.

Table 3.3. Column-wise disaggregation of the supply table

Starting point: Regular supply table

	Industry 1	Industry 2	Total output	Total imports
Product 1	$p_{1,1}$	$p_{1,2}$	PP_1	PM_1
Product 2	$p_{2,1}$	$p_{2,2}$	PP_2	PM_2
Total output	IP_1	IP_2		

Result: Extended supply table

	Industry 1		Industry 2		Total output	Total imports
	SME	Large	SME	Large		
Product 1	$p_{1,1,s}$	$p_{1,1,l}$	$p_{1,2,s}$	$p_{1,2,l}$	PP_1	PM_1
Product 2	$p_{2,1,s}$	$p_{2,1,l}$	$p_{2,2,s}$	$p_{2,2,l}$	PP_2	PM_2
Total output	$IP_{1,s}$	$IP_{1,l}$	$IP_{2,s}$	$IP_{2,l}$		

Note: SME: small and medium-sized enterprise.

Table 3.4. Column-wise disaggregation of the use table

Starting point: Regular use table at purchasers' prices

	Industry 1	Industry 2	Total intermediate use	Final use
Product 1	$u_{1,1}$	$u_{1,2}$	PU_1	
Product 2	$u_{2,1}$	$u_{2,2}$	PU_2	
Total intermediate use	IU_1	IU_2		

Result: Extended use table at purchasers' prices

	Industry 1		Industry 2		Total intermediate use	Final use
	SME	Large	SME	Large		
Product 1	$u_{1,1,s}$	$u_{1,1,l}$	$u_{1,2,s}$	$u_{1,2,l}$	PU_1	
Product 2	$u_{2,1,s}$	$u_{2,1,l}$	$u_{2,2,s}$	$u_{2,2,l}$	PU_2	
Total intermediate use	$IU_{1,s}$	$IU_{1,l}$	$IU_{2,s}$	$IU_{2,l}$		

Note: SME: small and medium-sized enterprise.

In the construction of the regular SUTs, NSOs tend to use several enterprise-level data sources to estimate the product detail of industry-level output and intermediate use. Among these sources, there may be:

- surveys of turnover or sales by product type and of purchases for intermediate use by product type (for an example of questionnaires of such surveys, see the annexes to Chapters 5 and 6 in United Nations (2018[8]))
- a survey of industrial production with detail by product type
- customs data on exports and imports of goods (data from Intrastat and Extrastat for EU member countries)
- surveys of exports and imports of services
- administrative records of transactions under value added tax (VAT transaction data)
- other enterprise-level data sources for specific activities/industries (e.g. surveys of agricultural production) or for certain types of activities/products (e.g. surveys of R&D expenditure).

To avoid proportionality assumptions, ESUT compilers should use as many of these sources as possible. This allows them to determine, for each enterprise category in each industry that they disaggregate, a different distribution of turnover/sales by product category and a different distribution of purchases for intermediate consumption by product category, as appropriate. Combining such enterprise-level data from various sources requires correcting for inconsistencies between these sources. For example, the value of an enterprise's exports of a good obtained from customs data may exceed the value of its production of that good reported in a survey of industrial production. Additional adjustments become necessary, for example, when the samples covered by these sources differ. These issues may already have been dealt with in the compilation process of regular SUTs. Hence, it is a definite advantage if ESUT compilers can rely on the adapted enterprise-level data that have been used for regular SUT construction.

The resulting product distribution of turnover/sales and that of purchases of intermediates – both based on the enterprise-level data sources that are available to the ESUT compiler – can serve as first estimates for the vectors of output and intermediate use of the industry-enterprise category combinations in the ESUT. For each industry, these first estimates must be adjusted to the column and row constraints which are, respectively, the totals of output and intermediate use of the enterprise categories in that industry derived in Step 2 (see above), and the industry-level product distribution (column vector) of output and intermediate use from the regular SUTs (see columns for industries in the regular supply table in Table 3.3 and in the regular use table in Table 3.4). These adjustments can be made based on proportional methods such as GRAS.

The results of this step are column-wise extended SUTs at purchasers' prices, i.e. SUTs in which the columns for all or a selection of industries have been disaggregated by enterprise category (see the result tables of Table 3.3 and Table 3.4).

The next steps are not strictly needed to compile the ESUT framework. However, they are very useful for the EIOT, as was explained after Table 3.1.

Step 4: Deriving extended valuation tables and an extended use table at basic prices

Step 4 consists of deriving a column-extended use table at basic prices. Following the recommendation on the compilation of regular SUTs at basic prices in the *Handbook on Supply and Use Tables and Input-Output Tables with Extensions and Applications* (United Nations, 2018[8]), a use table at basic prices is obtained by subtracting use-side valuation tables from the use table at purchasers' prices. These use-side valuation tables comprise information by industry and product category on trade margins, transport margins, taxes on products including non-deductible VAT, and subsidies on products. This information allows bridging between different valuation concepts in the supply and use tables framework. To derive ESUTs at basic prices, it is necessary to extend the valuation tables by enterprise category for the industries that have been selected for disaggregation.

For trade and transport margins, the usual approach to estimating use-side valuation tables for regular SUTs consists of three steps:

1. Estimate the production of margins by industry – these margins originate from the enterprises' resale of goods that they purchase but do not transform (trade margin) and from the enterprises' separately invoiced shipping to customers of goods they sell (transport margin).
2. Distribute these supply-side margins over product categories and then sum by product category to obtain a vector of product-level margins.
3. Allocate the total product-level margins to users of the products in the use table.

This approach is illustrated in the *Handbook on Supply and Use Tables and Input-Output Tables with Extensions and Applications* (see Box 7.1 in United Nations (2018[8]). The estimation of the production of margins by industry is generally based on enterprise-level data from business surveys and surveys of industrial production on purchases for resale and transportation invoiced separately. These data sources may also contain information that is relevant for the distribution of margins over product categories. Since data for the allocation to users are rarely available, this allocation is mostly based on assumptions.

For taxes and subsidies on products, the approach to estimating valuation tables is similar to the approach for margins but shorter as it comprises only two steps: 1) estimate the value of these taxes and subsidies by product category; and 2) allocate these product-level totals to users of the products in the use table. The estimation of the amounts of the taxes and subsidies on products and their allocation to specific product categories in the SUTs are usually based on government revenue accounts and assumptions. For the allocation of these product-level totals to users, information from specific tax legislation is combined with assumptions. The approach for non-deductible VAT is specific and so are the data used for this purpose. The overwhelming part of non-deductible VAT is recorded as being levied on household final consumption expenditure.

In the top-down method for ESUT compilation, the valuation tables of the regular SUTs are the starting point for deriving extended valuation tables. The columns of the industries selected for disaggregation must then be disaggregated in these regular valuation tables. As can be easily understood from the description above of the construction of regular use-side valuation tables, there is limited enterprise-level data involved in the allocation of supply-side margins and taxes and subsidies on products to users, i.e. to the entries in the use table. Hence, there is little information that ESUT compilers could use for disaggregating the industry columns in the regular valuation tables. In these circumstances, the best they can do is reproduce and extend the assumptions made in the allocation of margins and taxes and subsidies on products to users in the regular valuation tables. For taxes and subsidies on products, they may also re-examine the relevant legislation for a specific allocation, for example, the use of VAT rates. However, for most industries, it is unlikely that the results will be substantially different from a disaggregation of the industry column in proportion to the use of the enterprise categories. Therefore, ESUT compilers may choose such a use-based proportional disaggregation by default. This is what has been done in work on ESUTs by exporter status for Belgium (Michel, Hambÿe and Hertveldt, 2023[10]).

However, sometimes information is available to do more than proportional distributions. For margins, this could be knowledge about the distribution channels relevant for each cell in the use table or even survey data from wholesalers and retailers covering the product sales and purchases of goods for resale with further processing. With information about the share of a product flowing through each relevant distribution channel, an effective margin rate can be estimated for each cell. In the case of the extended table, this process can be carried out independently for each enterprise type within each industry, which allows information about inter-industry relationships specific to a given enterprise type to be leveraged during the estimation process. For example, if it is known that most foreign MNEs operating within a certain wholesale category primarily serve manufacturing units also within the foreign MNE enterprise type, then this information should be used to direct the allocation of these margins to industries within the specified enterprise type. This information must be constrained to the control totals from the regular SUTs. For taxes and subsidies, the ability to distinguish them by underlying legislation may be helpful to the extent that different taxes or subsidies are applicable in different ways to different enterprise types. In that case, taxes and subsidies may be allocated to specific enterprise types as appropriate.

Once the use-side valuation tables have been extended column-wise, they can be subtracted from the column-extended use table at purchasers' prices (Table 3.4) to obtain a column-extended use table at basic prices.

Step 5: Disaggregating use into use of imports and of domestic production

The next step is to split the column-extended use table at basic prices into a column-extended use table of domestic production (domestic use table) and a column-extended use table of imports (import use table), both also at basic prices. The way of proceeding is to first compile the extended use table of imports from the use table of imports in the regular SUT by disaggregating the columns of the industries selected for disaggregation, then derive the extended domestic use table by subtracting the extended import use table from the extended use table at basic prices obtained in the previous step (Step 4) of this top-down method of ESUT compilation. Table 3.5 and Table 3.6 illustrate the starting points and results of these operations.

Table 3.5. Disaggregation of the import use table

Starting point: Regular import use table

	Industry 1	Industry 2	Total imports
Product 1	$m_{1,1}$	$m_{1,2}$	PM_1
Product 2	$m_{2,1}$	$m_{2,2}$	PM_2
Total imports	IM_1	IM_2	

Result: Extended import use table

	Industry 1		Industry 2		Total imports
	SME	Large	SME	Large	
Product 1	$m_{1,1,s}$	$m_{1,1,l}$	$m_{1,2,s}$	$m_{1,2,l}$	PM_1
Product 2	$m_{2,1,s}$	$m_{2,1,l}$	$m_{2,2,s}$	$m_{2,2,l}$	PM_2
Total imports	$IM_{1,s}$	$IM_{1,l}$	$IM_{2,s}$	$IM_{2,l}$	

Note: SME: small and medium-sized enterprise.

Table 3.6. Derivation of the domestic use table

Starting point: Extended use table at basic prices

	Industry 1		Industry 2		Total Intermediate use	Final use
	SME	Large	SME	Large		
Product 1	$p_{1,1,s}$	$p_{1,1,l}$	$p_{1,2,s}$	$p_{1,2,l}$	PU_1	
Product 2	$p_{2,1,s}$	$p_{2,1,l}$	$p_{2,2,s}$	$p_{2,2,l}$	PU_2	
Total intermediate use	$IU_{1,s}$	$IU_{1,l}$	$IU_{2,s}$	$IU_{2,l}$		

Result: Extended domestic use table

		Industry 1		Industry 2		Total Intermediate use	Final use
		SME	Large	SME	Large		
Domestically produced	Product 1	$d_{1,1,s}$	$d_{1,1,l}$	$d_{1,2,s}$	$d_{1,2,l}$	PD_1	
	Product 2	$d_{2,1,s}$	$d_{2,1,l}$	$d_{2,2,s}$	$d_{2,2,l}$	PD_2	
	Total intermediate use of domestic output	$ID_{1,s}$	$ID_{1,l}$	$ID_{2,s}$	$ID_{2,l}$		
	Total imports for intermediate use	$IM_{1,s}$	$IM_{1,l}$	$IM_{2,s}$	$IM_{2,l}$		
	Total intermediate use	$IU_{1,s}$	$IU_{1,l}$	$IU_{2,s}$	$IU_{2,l}$		

Note: SME: small and medium-sized enterprise.

In the compilation of import use tables for regular SUTs, NSOs distribute the imports of each product category (from the supply table) over intermediate and final use, i.e. they determine how much of the consumption of a product category by industries and final users is imported. Ideally, they do so based on import data by enterprise and product category – for both goods and services – that are corrected to conform to SNA rules (corrections for transit trade, merchanting, processing trade, etc.; see the discussion on the preparation of enterprise-level data above). These data allow for an estimation of industry-level imports for each product category. Nonetheless, the compilation of the import use table generally also involves some form of proportional allocation, for example, for allocating imports to categories of final use and ensuring that the row totals in the import use table match imports by product category from the supply table. A central issue in the compilation method based on enterprise-level import data is that any entry in the import use table may not exceed the corresponding entry in the use table at basic prices.

For the construction of the extended import use table according to the top-down method, the ideal situation is that compilers have access to the corrected enterprise-level import data that have been used in the construction of the regular import use tables. This enables them to disaggregate the industry's use of imported products by enterprise category and to restrict proportional disaggregations to entries in the import use table for which no underlying data are available. Ideally, there is also information available about re-exports (see also Annex 3.A) and production abroad[4] if they are relevant trade flows for the country under concern. It is recommended to place such imports and exports that are not related to production in the domestic economy apart. This procedure has two types of constraints: 1) the imports of a product by an industry-enterprise-category combination may not exceed total intermediate use of that product by that industry-enterprise-category combination, i.e. the value of an entry in the extended import use table may not exceed the value of the corresponding entry in the extended use table at basic prices; and 2) the sum of the imports of a product by all enterprise categories in an industry may not exceed the industry's value of imports of that product in the regular import use table. These constraints may turn out to be conflicting, which requires compilers to check the plausibility of their disaggregation of the use table and/or to release one of the constraints. Hambÿe, Michel and Trachez (2023[15]) provide an example of the construction of an extended import use table along these lines in their work on an ESUTs by group affiliation for Belgium for the year 2019.

There are sometimes large differences between NA and ITG when it concerns imports and exports by industry. As explained earlier in this chapter, ITG might see more imports and exports by wholesalers and transporters whereas NA might see more imports and exports by other industries. Clearly, this is the case when these industries trade significantly according to ITG but the allocations need to be reviewed for coherence and plausibility.

Chong et al. (2016[6]) describe one way for dealing with this. They assume that exports of goods from industries other than wholesale, transport and storage are produced by the industries themselves. Exports of domestically produced goods by the wholesale, transport and storage industries are mostly produced by other industries and tend to be very small. These exports have, just as the exports that cannot be matched to enterprises, to be assigned to the producing industries, by enterprise type. Similarly, many imports of goods by wholesale, transport and storage must be assigned to other industries and to final use. A way to do this for imports is described below; the method for exports is similar.

1. Comparison of imports (in ITG) and use (in SUTs) in each industry by enterprise type:
    a. If use exceeds imports, the assumption is that all imports by this industry by enterprise type are being used by themselves.
    b. If imports exceed use, the assumption is that all imports by the industry by enterprise type are being used by that industry and that the additional imports are used by other industry by enterprise types. This yields a remainder of imports that needs to be redistributed over industry by enterprise types where use exceeds imports.
2. Remaining use by industry by enterprise type is calculated, i.e. the part of use that is not imported.
3. The remaining imports from Step 2 and unassigned trade are proportionally redistributed over industry by enterprise types with use exceeding imports based on their remaining use as calculated in Step 2.
4. Total imports by industry by enterprise type are calculated by adding imports from Steps 1 and 3.

This is illustrated in Table 3.7. For simplicity, the enterprise category is not taken into account.

Table 3.7. Example of the distribution of imports of a product by destination industry

	Imports in ITG	Use in SUT	Step 1	Step 2	Step 3	Step 4
Furniture industry	20	40	20	20	5	25
Wholesale	40	10	10	0	0	10
Household consumption	0	20	0	20	5	5
Subtotal (excluding re-exports)	60	70		40		
Re-exports	0	20	20	0		20
Total	60	90	50	40	0	60
Redistributed	-	-	10	-	-	-

Note: ITG: international trade in goods; SUT: supply and use table.
Source: Chong et al. (2016[6]).

One alternative was to distribute the excess imports proportionally by total use of the product by industry by enterprise type or to distribute proportionally by imports that are already distributed. However, it is thought that the method of Chong et al. is superior. For example, it assigns imports to enterprise types that have relatively few imports in the linked business-trade data. Since larger traders usually link well to enterprises, due to the efforts of the NSOs, the larger traders are overrepresented. Another alternative is to use a mix of the method of Chong et al. and a proportionality method.

If they do not have access to relevant enterprise-level import data, compilers may rely on a proportional attribution of import use to enterprise categories, although this fails to reflect the fact that certain categories of enterprises, e.g. large ones or affiliates of MNEs, tend to import a larger share of the intermediates they use.

The resulting extended import use table must then be subtracted from the extended use table at basic prices to obtain the extended domestic use table. All these tables are extended column-wise (see Tables 3.5 and 3.6). In line with the recommendations in the *Handbook on Supply and Use Tables and Input-Output Tables with Extensions and Applications* (United Nations, 2018[8]), the extended domestic use table comprises a row reporting total imports by enterprise categories within industries and by final users.

Step 6: Disaggregating the use of domestic output

In this final step, one can use two approaches. The first is to disaggregate domestic output by producing enterprise category. This entails compiling fully extended SUTs, where fully extended means a column-wise and row-wise disaggregation by enterprise category. After Step 5, there is only a column-wise disaggregation by enterprise category. The second approach is to disaggregate domestic output by producing enterprise category and industry. This entails compiling an extended supply table for domestic use table by removing supply for exports. Both approaches will provide the necessary data to compile an EIOT. The second approach is theoretically more appealing, since it uses the additional information which type of enterprise in which industry is exporting which product. The first approach does not use the industry detail. However, the second approach needs more data and it might put some constraints on the data in practice. It could be a worthwhile avenue when the export data in the NA and ITG do not differ too much by product and industry. When each product is almost completely produced by one industry (in other words, there is not much secondary production), both approaches will lead to similar results.

Disaggregating by producing enterprise category: Fully extended SUTs

In this approach, the rows of the tables – relating to the product categories of domestic production – are disaggregated. For the supply table, this requires no further data or calculations and comes down to a simple expansion of the column-extended supply table derived in Step 3. For the use table, this consists of the disaggregation of the rows for product categories in the column-extended domestic use table at basic prices derived in Step 5.

Fully extended supply table

The fully extended supply table can be directly derived from the column-extended supply table as illustrated in Table 3.8. The underlying disaggregation of the rows concerns only domestic production, not imports. Hence, the table is restricted to domestic production. The starting point is the column-extended supply table that was the result of Step 3 (see Table 3.3), in which the industry columns are disaggregated by enterprise category. Without any further calculations, this table can be rewritten as a fully extended supply table in which the product categories are also disaggregated by enterprise category. For any product (or row) in the column-extended supply table, entries indicate by which type of enterprise the product has been produced. So, the rows can simply be expanded to show the producing enterprise category, e.g. SME and large enterprises as in Table 3.8 (result table). In the rows for an enterprise category (e.g. SME), the entries in the columns corresponding to other enterprise categories (large enterprises) must be filled with zeros. Summing along the rows yields total (domestic) output for product categories by enterprise type.

Table 3.8. Disaggregating the rows in the supply table

Starting point: Column-extended supply table (make table)

	Industry 1		Industry 2		Total output
	SME	Large	SME	Large	
Product 1	$p_{1,1,s}$	$p_{1,1,l}$	$p_{1,2,s}$	$p_{1,2,l}$	PP_1
Product 2	$p_{2,1,s}$	$p_{2,1,l}$	$p_{2,2,s}$	$p_{2,2,l}$	PP_2
Total output	$IP_{1,s}$	$IP_{1,l}$	$IP_{2,s}$	$IP_{2,l}$	

Result: Fully extended supply table (make table)

		Industry 1		Industry 2		Total output
		SME	Large	SME	Large	
Product 1	SME	$p_{1,1,s}$	0	$p_{1,2,s}$	0	$PP_{1,s}$
	Large	0	$p_{1,1,l}$	0	$p_{1,2,l}$	$PP_{1,l}$
Product 2	SME	$p_{2,1,s}$	0	$p_{2,2,s}$	0	$PP_{2,s}$
	Large	0	$p_{2,1,l}$	0	$p_{2,2,}l$	$PP_{2,l}$
Total output		$IP_{1,s}$	$IP_{1,l}$	$IP_{2,s}$	$IP_{2,l}$	

Note: SME: small and medium-sized enterprise.

Fully extended use table

The domestic use table resulting from Step 5 of the top-down method of ESUT compilation is extended column-wise (see Table 3.6). In other words, the information in the rows of this table on the use of products, which comes from domestic production, has not yet been disaggregated in terms of the producing enterprise category. This needs to be done to obtain a fully extended use table (see result table in Table 3.9). Determining which type of enterprise has produced the goods and services purchased for intermediate and final use is a complex task. ESUT compilers may rely on various sources of information to accomplish this.

First, the proportions of enterprise categories in total domestic output of each product category are known from the fully extended supply table “total output” column in the result table of Table 3.8). Any proportional disaggregation of the rows for product categories in the column-extended domestic use table should be based on these proportions. With such a proportional disaggregation, the row totals in the fully extended domestic use table automatically respect the values of total domestic output of each product by enterprise category (“total output” column in the fully extended use table of Table 3.9 matching the “total output” column in the fully extended supply table of Table 3.8). When compilers use additional enterprise-level data for a non-proportional disaggregation of the rows in the column-extended use table, the values of total domestic output of products by enterprise category from the fully extended supply table become a constraint in terms of the row totals for the resulting fully extended use table (last column with “total output” in the fully extended domestic use table in Table 3.9).

Second, for disaggregating exports of products by producing enterprise category, compilers should ideally rely on enterprise-level export data that are corrected to conform to SNA rules and that contain information on exported products (goods and services). This is of relevance since it has been shown that certain enterprise categories are more export-oriented than others, e.g. affiliates of MNEs compared to domestic enterprises. The way of proceeding is to cross-tabulate these enterprise-level export data by product and enterprise category to calculate shares that can be used to distribute total product-level exports in the domestic use table over enterprise categories. The result is a disaggregation of the rows in the export column of the domestic use table (see the column “exports” in Table 3.9) by enterprise category.

Third, enterprise-level data for disaggregating the remaining parts of the rows in the column-extended domestic use table are harder to come by. Such disaggregations require data that record domestic transactions between enterprises and between enterprises and final consumers. This is the case in data on transactions under the VAT regime, so-called VAT transaction data. If available, such data may indeed be used for disaggregating the rows of the column-extended domestic use table, except for the entries for exports. However, such data are not collected in many countries, and it may prove difficult for ESUT compilers to get access to these data. So far, there is no example of ESUT compilation in which VAT transaction data have been used for the purpose of disaggregating the rows of the use table by enterprise category. Clearly, this is a possibility that should be further explored. Potential issues in the use of VAT transaction data for row disaggregation includes limited coverage, particularly for transactions with final consumers, and the identification of the products that are delivered as the data record transactions between enterprises or enterprises and final consumers. In the absence of such enterprise-level data, compilers must rely on a proportional disaggregation of the rows as described above.

Table 3.9. Disaggregating the rows in the domestic use table

Starting point: Column-extended domestic use table

		Industry 1		Industry 2		Total intermediate use	Domestic final use	Exports
		SME	Large	SME	Large			
Domestically produced	Product 1	$d_{1,1,s}$	$d_{1,1,l}$	$d_{1,2,s}$	$d_{1,2,l}$	PD_1	PF_1	PX_1
	Product 2	$d_{2,1,s}$	$d_{2,1,l}$	$d_{2,2,s}$	$d_{2,2,l}$	PD_2	PF_2	PX_2
	Total intermediate use of domestic output	$ID_{1,s}$	$ID_{1,l}$	$ID_{2,s}$	$ID_{2,l}$			
	Total imports for intermediate use	$IM_{1,s}$	$IM_{1,l}$	$IM_{2,s}$	$IM_{2,l}$			
	Total intermediate use	$IU_{1,s}$	$IU_{1,l}$	$IU_{2,s}$	$IU_{2,l}$			

Result: Fully extended domestic use table

		Industry 1		Industry 2		Total intermediate use	Domestic final use	Exports	Total output
		SME	Large	SME	Large				
Product 1	SME	$d_{1,1,s,s}$	$d_{1,1,s,l}$	$d_{1,2,s,s}$	$d_{1,2,s,l}$	$PD_{1,s}$	$PF_{1,s}$	$PX_{1,s}$	$PP_{1,s}$
	Large	$d_{1,1,l,s}$	$d_{1,1,l,l}$	$d_{1,2,l,s}$	$d_{1,2,l,l}$	$PD_{1,l}$	$PF_{1,l}$	$PX_{1,l}$	$PP_{1,l}$
Product 2	SME	$d_{2,1,s,s}$	$d_{2,1,s,l}$	$d_{2,2,s,s}$	$d_{2,2,s,l}$	$PD_{2,s}$	$PF_{2,s}$	$PX_{2,s}$	$PP_{2,s}$
	Large	$d_{2,1,s}$	$d_{2,1,l,l}$	$d_{2,2,l,s}$	$d_{2,2,l,l}$	$PD_{2,l}$	$PF_{2,l}$	$PX_{2,l}$	$PP_{2,l}$
Total intermediate use of domestic output		$ID_{1,s}$	$ID_{1,l}$	$ID_{2,s}$	$ID_{2,l}$				
Total imports		$IM_{1,s}$	$IM_{1,l}$	$IM_{2,s}$	$IM_{2,l}$				
Total intermediate use		$IU_{1,s}$	$IU_{1,l}$	$IU_{2,s}$	$IU_{2,l}$				

Note: SME: small and medium-sized enterprise.

The result of this approach is fully extended SUTs at basic prices. These tables show industry-enterprise-category combinations in the columns and product-enterprise-category combinations in the rows (see result tables in Table 3.8 and Table 3.9). They may be used to derive an EIOT according to one of the methods described in the *Handbook on Supply and Use Tables and Input-Output Tables with Extensions and Applications* (United Nations, 2018[8]). These methods are further elaborated in Chapter 6.

Disaggregating the use of domestic output by producing enterprise category and industry

In this approach, the goal is to obtain an extended table with supply of domestically produced goods and services to be used in the domestic economy. Table 3.10 illustrates the data at start and finish.

Table 3.10. Disaggregating supply of domestic production

Starting situation

Extended supply table (Table 3.3)

	Industry 1		Industry 2		Total output	Total imports
	SME	Large	SME	Large		
Product 1	$p_{1,1,s}$	$p_{1,1,l}$	$p_{1,2,s}$	$p_{1,2,l}$	PP_1	PM_1
Product 2	$p_{2,1,s}$	$p_{2,1,l}$	$p_{2,2,s}$	$p_{2,2,l}$	PP_2	PM_2
Total output	$IP_{1,s}$	$IP_{1,l}$	$IP_{2,s}$	$IP_{2,l}$		

Regular export table

	Industry 1	Industry 2	Total exports
Product 1	$X_{1,1}$	$X_{1,2}$	XP_1
Product 2	$X_{2,1}$	$X_{2,2}$	XP_2
Total exports	XI_1	XI_2	

Extended export table based on enterprise-level data

	Industry 1		Industry 2		Total exports
	SME	Large	SME	Large	
Product 1	$XF_{1,1,s}$	$XF_{1,1,l}$	$XF_{1,2,s}$	$XF_{1,2,l}$	XP_1
Product 2	$XF_{2,1,s}$	$XF_{2,1,l}$	$XF_{2,2,s}$	$XF_{2,2,l}$	XP_2
Total exports	$XF_{1,s}$	$XF_{1,l}$	$XF_{2,s}$	$XF_{2,l}$	

Result

Extended export table based on enterprise-level data, matching the regular export table

	Industry 1		Industry 2		Total exports
	SME	Large	SME	Large	
Product 1	$X_{1,1,s}$	$X_{1,1,l}$	$X_{1,2,s}$	$X_{1,2,l}$	XP_1
Product 2	$X_{2,1,s}$	$X_{2,1,l}$	$X_{2,2,s}$	$X_{2,2,l}$	XP_2
Total exports	$XI_{1,s}$	$XI_{1,l}$	$XI_{2,s}$	$XI_{2,l}$	

Extended supply table for domestic use

	Industry 1		Industry 2		Total domestic production for domestic use
	SME	Large	SME	Large	
Product 1	$DU_{1,1,s}$	$DU_{1,1,l}$	$DU_{1,2,s}$	$DU_{1,2,l}$	DU_1
Product 2	$DU_{2,1,s}$	$DU_{2,1,l}$	$DU_{2,2,s}$	$DU_{2,2,l}$	DU_2
Total supply for domestic use	$DU_{1,s}$	$DU_{1,l}$	$DU_{2,s}$	$DU_{2,l}$	

Note: SME: small and medium-sized enterprise.

For example, the element $DU_{1,1,s}$ is equal to $p_{1,1,2}$ minus $X_{1,1,s}$.

In this process, it is assumed that one has a regular export table, which shows how much each industry exports each product. This table is combined with enterprise-level export data by product category. These export data are corrected for re-exports (see Annex 3.A) and ideally also for production abroad. The reason is that only domestically produced goods and services are needed. Subsequently, the enterprise-level data are aggregated by product and by industry and enterprise type. Just as in the imports case before, aggregating the results will yield something that is different from the regular export table. Therefore, the data have to be rearranged. The method that was used to rearrange the import data can be applied again.

After rearranging the data, aggregating the extended export table to an export table will still lead to a different table than the regular export table. One can choose to ignore this or force the extended flow table to add up to the regular export table by applying a GRAS procedure again. The data would have to suffice two constraints. The first is that at product level, total exports would be the same as that in the regular export table. The second is that at industry level, total exports are the same as that as in the regular export table. One can choose to put additional constraints, namely that aggregating the extended export table yields the regular export table, but that condition might be too strong. Now subtract the extended export table from the total extended supply table to obtain the extended supply table with supply of domestic goods and services to the domestic market.

The result of this step is an extended domestic supply for domestic use table. This, together with the extended supply table from Step 3, may be used to derive an EIOT according to one of the methods described in the *Handbook on Supply and Use Tables and Input-Output Tables with Extensions and Applications* (United Nations, 2018[8]). These methods are further elaborated in Chapter 6.

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Annex 3.A. Dealing with re-exports

Re-exports are "transactions of goods which were previously imported with a change in economic ownership and then exported without any substantial transformation" (United Nations, 2018[8]). For example, imports of laptops from the People's Republic of China via the port of Rotterdam by a Dutch merchant who subsequently exports the laptops to the European hinterland. Since re-exports are often conducted by foreign multinationals, who use a country as a conduit to reach other markets, the subject is relevant in the ESUT and EIOT framework as well. One cannot assume that each type of enterprise has the same share of re-exports in total exports for a given product. Bias in re-exports leads to bias in exports of domestic production, which leads to biased estimates of domestic dependencies from foreign markets for each type of enterprise. Since information on determining re-exports is generally scattered in the literature, this annex provides guidance.

Data sources

Generally, the data sources are the following:

- National accounts data, with imports, exports, domestic supply and domestic use at product level.
- An import use table with estimates of how much imports are used to export directly, at product level.
- Trade in goods statistics, with imports and exports at product level for each trader.
- A bridge table that links traders to enterprises in the general business register. The general business register contains information about industry, size and possibly other relevant information about enterprises.

Methods

There are various ways to delineate the **export side** of re-exports; see Roos (2006[16]) for an overview. Examples are:

- In a SUT framework, identifying when exports of a given product exceed the domestic production of this product.
- Using trade in goods surveys that explicitly ask whether exports are re-exports. However, it is known that the concept of re-exports is difficult for traders. This may lead to underreporting of re-exports.
- Using information from large case units, who are in close contact with major enterprises, or information obtained via another contact with the relevant enterprises.
- Analysing product information, e.g. fruits that are typically not domestically produced in large quantities.
- Assuming that when imports are at least half of exports at product by trader level, the exports of this product by this trader are re-exports.

Note that information is available at the trader level for all the above methods, except for the first one (SUT framework). Matching traders to the general business register, adding industry and type of enterprise (e.g. small and medium-sized enterprises) yields information at the desired level. It may also allow one to match the information of the re-exporter to information from other surveys, ideally at the level of the enterprise, and if not, at the level of the industry.

Information on the **import side** might be useful to obtain information about the country of origin; see Lemmers and Wong (2019[17]). One needs various data to arrive at an estimate of the value of imports for re-exports, for example, transport margins and taxes less subsidies on products such as import tariffs, ideally at product level. One also needs more specific information, such as distribution margins, ideally at product level, of the enterprise involved. The latter information can be obtained from surveys. In the European Union, it would be the Structural Business Statistics.

In the ideal case, one has complete information at enterprise level. Then one can obtain the value of imports for re-exports at product level by peeling off the re-export value. Removing the transport margins, taxes less subsidies on products and the distribution margins yields an estimate of the import value. Ideally, this process takes into account that tariffs will be different across countries of origin. The OECD regularly estimates and publishes such information (OECD, 2024[18]); see Fiallos et al. (2024[19]) for the methodology.

Notes

[1] This category of "other" enterprises may also include enterprises which cannot be classified for the chosen criterion but belong to industries that the compiler wants to disaggregate. In that case, there will also be values for this category of "other" enterprises in industries that are disaggregated.

[2] Note that this is not an issue for international trade in services, since in this statistic there is always transfer of ownership.

[3] See Chapter 5 for a more detailed discussion of the GRAS scaling method.

[4] Production abroad refers to the economic activities related to the production of goods and services owned by a country's residents that take place outside of the country's economic territory. Following the economic ownership principle, when the residents buy something from non-residents these are imports; when they sell something to non-residents these are exports.

4. Compiling extended supply and use tables and extended input-output tables in a data-scarce environment

This chapter describes how to compile extended supply and use tables (ESUTs) and extended input-output tables (EIOTs) in a data-scarce environment. After a short introduction, it begins by explaining the method used to compile an EIOT. It then examines how to obtain shares for value added and trade to disaggregate the input-output table. The next section gives a step-by-step guide to disaggregating the input-output table into an EIOT. The chapter also considers how to compile extended supply and use tables when extended input-output and supply and use tables are available. The chapter concludes with a comparison of the compilation of an EIOT in a data-rich and in a data-scare environment.

Introduction

One might not have the time nor (access to) the data to compile an extended supply and use table (ESUT) and subsequently an extended input-output table (EIOT) using all possible microdata. This chapter explains how to proceed in such cases: how to compile an EIOT with less data or how to compile an ESUT from an EIOT. First, it points out that some of the recommendations made in Chapter 3 might be followed up anyway. Subsequently, the chapter describes a method to compile an EIOT step by step. This approach requires the share of each enterprise type in output, value added, imports and exports by industry. The chapter thus explains how to obtain that information in a robust way. Since some countries have an EIOT but not an ESUT, the chapter then details how to compile an ESUT in that specific situation. Finally, it compares the pros, cons and robustness of the data-rich and data-scarce approaches.

General considerations

Even without all the data described in Chapter 3, an EIOT can be compiled. It is still advisable to use as much information as possible, following the guidelines provided in Chapter 3. For example, it is recommended to compare the industry totals derived from enterprise data and national accounts and investigate possible large differences. Furthermore, some information might still be available about undeclared work and/or illegal activities and implicit financial services. In addition, in real estate, it is either necessary to distinguish between “imputed rents of owner-occupied dwellings” (no enterprises involved) and “renting and operating of own or leased real estate” (enterprises involved) or making no disaggregation at all.

It is always necessary to shift some imports from wholesalers (and possibly other industries such as transport) to the intermediate and final users. Similarly, some exports need to be shifted from wholesalers (and possibly other industries) to goods-producing industries. Chapter 3 explained the reason why much trade goes via wholesalers but trade statistics assign it to the wholesalers and national accounts assign it to the users and producers. Chapter 3 recommended shifting imports and exports using the method of Chong et al. (2016[1]). Since this method uses information at the product level, which in this chapter is assumed to be unavailable, the method of Cadestin et al. (2018[2]) is proposed. This method is explained later in the chapter.

A method to compile an extended input-output table

This section describes the method in OECD (2015[3]), which was later elaborated and extended in OECD (2018[4]). Assuming the desired breakdown of an industry is into small and medium-sized enterprises (SMEs) and large enterprises, the following data are needed:

- share in gross output by industry by type of enterprise
- share in value added by industry by type of enterprise
- share in imports by industry by type of enterprise
- share in exports by industry by type of enterprise
- the input-output table (IOT) that is to be broken down by type of enterprise.

Chapter 2 described possible data sources for this type of breakdown and for the other main breakdowns (by ownership or by trading status). The share of SMEs and the share of large enterprises in each industry that will be broken down must add up to 100%. The main hurdle is expected to be imports and exports of services. Compared to trade in goods, it is not so common for these to be broken down by enterprise type.

In these cases, researchers have used the share of a type of enterprise in the imports (exports) of goods in the industry as a proxy for their share in total imports (exports).

The method consists of the following steps:

1. disaggregating the columns in the IOT: value added, gross output and imports by industry
2. disaggregating the columns in the IOT: domestic intermediate use
3. disaggregating the rows in the IOT: exports
4. disaggregating the rows in the IOT: domestic intermediate and final use.

The steps are explained in detail with basic numerical examples below, using the fictitious data in Table 4.1 and Table 4.2 as a starting point.

Table 4.1. Shares of small and medium-sized enterprises and large enterprises in key macroeconomic variables, by industry

	SMEs		Large enterprises	
	Industry 1	Industry 2	Industry 1	Industry 2
Gross output	30%	60%	70%	40%
Value added	25%	55%	75%	45%
Imports	20%	50%	80%	50%
Exports	25%	45%	75%	55%

Note: SME: small and medium-sized enterprise.

Table 4.2. Input-output table

	Industry 1	Industry 2	Domestic final use	Exports	Gross output
Industry 1	40	10	50	100	200
Industry 2	30	20	100	30	180
Value added	50	100			
Taxes less subsidies on production	20	10			
Imports	60	40			
Gross output	200	180			

Obtaining the shares for value added and trade to disaggregate the input-output table

Although the shares of SMEs and large enterprises that are observed in the data directly can be used, it is advised to use the method of Cadestin et al. (2018[2]) instead. The advantage of this method is that it can easily deal with missing values while easily enabling sanity checks of the parameters. Furthermore, it can be used to obtain a higher quality when compiling time series of EIOTs.

The method deals with differences between microdata and national accounts. As explained in Chapter 3, under “Differences between microdata and National Accounts”, these two sources yield different industry totals for output, value added, imports and exports. Therefore, the data have to be reconciled. The following paragraphs explain how to do this for value added; the methodology for trade is the same.

Define v as the value added at the industry level, v_s as value added at SMEs in this industry and v_l as value added at large enterprises in this industry. Then $v = v_s + v_l$. For output at industry level, similar variables x, x_s and x_l are defined. Since value added is equal to the value added per unit of output times output, the following equation holds:

$$v = \frac{v_s}{x_s}.x_s + \frac{v_l}{x_l}.x_l$$

Define parameter p as the ratio between large enterprise value-added intensity and SME value-added intensity:

$$p = \frac{\frac{v_l}{x_l}}{\frac{v_s}{x_s}}$$

Integrating p into the earlier equation leads to:

$$x_s + p.x_l = v.\left(\frac{x_s}{v_s}\right)$$

Value added at SMEs is then equal to:

$$v_s = \frac{v}{1 + p.\left(\frac{x_l}{x_s}\right)}$$

Value added at large enterprises is defined as $v_l = v - v_s$.

This reconciled the value added by industry from national accounts with that in the enterprise data: value added of SMEs plus value added of large enterprises is now equal to total value added from national accounts, for every industry. The methodology facilitates the estimation of missing values, since the only information that is required from the enterprise data is the ratio p, which represents the difference in the value added to output ratio between large enterprises and SMEs. When p is missing, one can use information about the "upstreamness" in value chains of the different types of enterprises if this information is available. If it is, for example, known that SMEs mainly focus on turning 'almost-finished' products into products ready for final use, while large enterprises take care of more upstream activities as well, the value added to gross output ratios for SMEs tend to be smaller than those of large enterprises. Alternatively, one can use the value of the ratio p from a more aggregate level, similar industries, comparable countries or a different year.

This approach might lead to value added that is higher than output. First, when $p < \frac{v - x_s}{x_l}$, value added of SMEs will be larger than their output. Second, when $p > \frac{x_s}{v - x_l}$, the value added of large enterprises will be higher than their output. When this happens, it is recommended to have a close look at the data. Preferably, speak to experts. Otherwise, use estimates from a different year, a similar industry or a similar country. Only for cases that cover a very small part of the economy, is it recommended to take the closest value of p, such that value added is lower than output. The advantage is that this is easy to program.

The same methodology is employed for trade, based on differences in export intensity and import intensity among SMEs and large enterprises.

When compiling time series of EIOTs, it is recommended to monitor the value-added intensities and trade intensities by type of enterprise by industry over time. Furthermore, it is recommended to keep an eye on the ratio p that represents the intensity of large enterprises divided by the intensity of SMEs.

Disaggregating the input-output table to an extended input-output table

This section provides a step-by-step explanation on how to disaggregate an IOT into an EIOT.

Step 1. Disaggregating the columns in the IOT: Value added, gross output and imports by industry

If no product detail information is available on the imports by SMEs or by large enterprises, one has to assume that in an industry, the SMEs import the same products in the same proportions as large enterprises. Combining the shares of SMEs and large enterprises in value added, gross output and imports with these variables in the IOT allows disaggregating these data. Table 4.3 shows the result of this step.

Table 4.3. Result of step 1

	SMEs		Large enterprises	
	Industry 1	Industry 2	Industry 1	Industry 2
Industry 1				
Industry 2				
Value added	12.5	55	37.5	45
Taxes less subsidies on production	5	5.5	15	4.5
Imports	12	20	48	20
Gross output	60	108	140	72

Note: SME: small and medium-sized enterprise.

Step 2. Disaggregating the columns in the IOT: Domestic intermediate use

Total domestic intermediate use is equal to gross output – value added – taxes less subsidies on production – imports. Applying this to Table 4.3 yields, for example, that the total intermediate use of SMEs and large enterprises in industry 1 is equal to 30.5 and 39.5, respectively. This implies that the share of SMEs in total intermediate use of industry 1 is equal to 100*30.5/(30.5+39.5) = 43.6%. Combining this share with the intermediate use of industry 1 obtained from industry 1 (40, see Table 4.2) yields that the intermediate inputs of SMEs in industry 1 obtained from industry 1 are equal to 43.6% * 40 = 17.4. Performing similar calculations for the other cells related to intermediate use.

In this process, a proportionality assumption similar to that for imports is used: SMEs and large enterprises obtain their intermediate goods and services from the same industries, proportional to their total intermediate use.

Table 4.4. Result of step 2

	SMEs		Large enterprises	
	Industry 1	Industry 2	Industry 1	Industry 2
Industry 1	17.4	9.2	22.6	0.8
Industry 2	13.1	18.3	16.9	1.7
Value added	12.5	55	37.5	45
Taxes less subsidies on production	5	5.5	15	4.5
Imports	12	20	48	20
Gross output	60	108	140	72

Note: SME: small and medium-sized enterprise.

Step 3. Disaggregating the rows in the IOT: Exports

Combining the shares of SMEs and large enterprises in total exports by industry with the total exports in the IOT yields exports by SMEs and large enterprises by industry. For example, the share of SMEs in exports of industry 1 is 25% while these exports are equal to 100. Therefore, exports by SMEs in industry 1 equal 25.

Table 4.5. Result of step 3

		SMEs		Large enterprises		Domestic final use	Exports	Gross output
		Industry 1	Industry 2	Industry 1	Industry 2			
SMEs	Industry 1						25	60
	Industry 2						13.5	108
Large enterprises	Industry 1						75	140
	Industry 2						16.5	72
Value added		12.5	55	37.5	45			
Taxes less subsidies on production		5	5.5	15	4.5			
Imports		12	20	48	20			
Gross output		60	108	140	72			

Note: SME: small and medium-sized enterprise.

Step 4. Disaggregating the rows in the IOT: Domestic intermediate and final use

Again, if no extra information is available (such as value-added tax or payments information), one has to rely on proportionality assumptions. In this step, it would be assumed that SMEs and large enterprises supply the same intermediate and final users proportionally to their total domestic sales. This is implemented as follows: total domestic sales are equal to gross output – exports. Hence, the total domestic sales by SMEs and large enterprises in industry 1 are 35 and 65, respectively. The share of SMEs in domestic sales by industry 1 is 100*35/(35 + 65) = 35%. Then it is assumed that the share of sales by SMEs in industry 1 to SMEs in industry 1, the share of sales by SMEs in industry 1 to domestic final use and so on is equal to 35% as well. For example, SMEs' sales in industry 1 to domestic final use are equal to 35% * 50 = 17.5. The result of Step 4, Table 4.6, is an EIOT.

Table 4.6. Result of step 4

		SMEs		Large enterprises		Domestic final use	Exports	Gross output
		Industry 1	Industry 2	Industry 1	Industry 2			
SMEs	Industry 1	6.1	3.2	7.9	0.3	17.5	25	60
	Industry 2	8.2	11.6	10.7	1.1	63.0	13.5	108
Large enterprises	Industry 1	11.3	6.0	14.7	0.5	32.5	75	140
	Industry 2	4.8	6.8	6.3	0.6	37.0	16.5	72
Value added		12.5	55	37.5	45			
Taxes less subsidies on production		5	5.5	15	4.5			
Imports		12	20	48	20			
Gross output		60	108	140	72			

Note: SME: small and medium-sized enterprise.

Compiling an extended supply and use table when an extended input-output table and a supply and use table are available

It is possible that an EIOT is available but an ESUT is not. For example, if an EIOT has been compiled using the previously described method or using value-added tax and/or payments data. Or a country produces the IOT first and only then compiles the supply and use table (SUT). An example is the People's Republic of China (hereafter "China"). Due to constraints in basic statistical units and data availability, the National Bureau of Statistics' (NBS) routine practice in China in compiling SUTs is different from the System of National Accounts recommendation (Yang, Wei and Zhu, 2016[5]). The NBS first compiles the IOTs and supply tables based on special input-output surveys every five years, then estimates the use tables based on IOTs, supply tables, annual national accounts data and technology assumptions.

The following country example by Yang et al. (2022[6]) applies the same practice to compile an ESUT. Among others, it uses the regular SUTs and EIOTs capturing enterprise ownership that were compiled by Duan et al. (2012[7]) and Ma, Wang and Zhu (2015[8]). First, it constructs an extended supply table, then an extended use table capturing enterprise ownership. The reason for using this extension of an SUT is that foreign-invested enterprises (FIEs) and domestically owned enterprises (DOEs) are different in many aspects, such as production input, export pattern and impacts on the local economy. Furthermore, FIEs and DOEs play different roles in generating local value-added, and they might have different effects on technology dissemination and skill building as well.

Data sources

The ESUT compilation process uses the regular SUTs compiled by the NBS for 2012, with 62 industries and 96 products. In addition, other data included product-by-product IOTs with 139 products from the NBS, output-related data by ownership for various sectors from the *China Industry Statistical Yearbook 2013*, *China Statistical Yearbook 2013*, *China Economic Census Yearbook 2013*, other statistical yearbooks about related service sectors and the *CEInet Statistics Database* (China Economic Information network).

Estimation of the extended supply table

The extended supply table can be estimated by splitting the make matrix in the supply table into two parts with FIEs and DOEs (F and D in Table 4.7).

Table 4.7. Framework of the extended supply table

		Industry		Valuation			Total supply at purchasers' prices
		DOEs	FIEs	Import	Margin	Taxes on product	
Product	Domestically owned enterprises (DOEs)	D					
	Foreign-invested enterprises (FIEs)		F				
Total output							

Specifically, set s_{ij} as the element of the make matrix of the regular supply table, denoting the supply of product *i* by industry *j*. Let x_j, x_j^F and x_j^D denote the output of industry *j*, at total level, of FIEs and DOEs, respectively. Now set

$s_{ij}^F = s_{ij} * (x_j^F / x_j)$, where s_{ij}^F denotes the supply of product i by FIEs in industry *j*

$s_{ij}^D = s_{ij} * (x_j^D / x_j)$, where s_{ij}^D denotes the supply of product i by DOEs in industry *j*

This method has the implicit assumption that in each industry, the product structure of FIEs and DOEs is identical.

The key question is how to estimate x_j^F / x_j or x_j^D / x_j. First, due to data availability, the NBS' regular SUT was aggregated to 84 commodities by 52 industries. The subsequent approach to obtain the shares of FIEs and DOEs in output differs by industry. It is a nice example of "use what you have":

- Farming, forestry, animal production, fishery and related support services: take the ratio of "foreign direct investment" (cumulative amount for 2003-12) and "gross fixed capital formation" (cumulative amount for 2003-12) as the share of FIEs in output of the industry.
- Thirty-four mining/manufacturing industries: use "sales of enterprises above designated size"[1] of FIEs and DOEs, by industry.
- Construction: use "gross output" by FIEs and DOEs.
- Wholesale and retail trade: use "output" of FIEs and DOEs; alternatively, for larger FIEs and DOEs (with a revenue higher than the threshold of designated size for the industry), "revenue from principal business" minus "cost of principal business" can be used, or "total sales value" minus "total purchases value".
- Accommodation: use "revenue from principal business above designated size" by FIEs and DOEs.
- Food and beverage services: use "revenue from principal business above designated size" by FIEs and DOEs.
- Finance (exclude insurance): use the "paid-in capital" share of foreign-funded banks and domestic-funded banks.
- Insurance: take the ratio of "premium of primary insurance between FIEs and the total industry" as the share of FIEs in output of the total industry.
- Real estate: use the "completed investment of real estate development companies" by FIEs and DOEs.
- Other ten service sectors: take the ratio of "foreign direct investment" (cumulative amount for 2003-12) and "gross fixed capital formation" (cumulative amount for 2003-12) as the share of FIEs in output of the industry. Alternatively, use the share of FIEs in "business revenue".

Estimation of the extended use table

This table is constructed in two steps. First, as an unbalanced table, then as a balanced table.

In the previous step, the extended supply table was constructed. Using this table and the extended product-by-product IOT, one can now derive the extended use table under the product technology assumption.[2]

Table 4.8. The framework of the extended use table

		Industries		Final use	Total use at basic prices
		DOEs	FIEs		
Product	Domestically owned enterprises (DOEs)				
	Foreign-invested enterprises (FIEs)				
	Import				
Taxes less subsidies on products					
Value added					
Total output					

The extended product-by-product IOT and the extended supply table contain the following information: the output coefficients matrix by industry (T), the output vector by industry X_I, the total use of domestic product X, the total use of import product X_m, the domestic intermediate input coefficients matrix by product A, the import intermediate input coefficients matrix by product A_m, the value-added matrix by product A_v, the final use matrix for domestic product F and the final use matrix for import product F_m.

Table 4.9. Calculation of the unbalanced extended use table by enterprise heterogeneity

		Industries		Final use	Total use at basic prices
		DOEs	FIEs		
Product	Domestically owned enterprises (DOEs)	$U = AT\hat{X}_I$		F	X
	Foreign-invested enterprises (FIEs)				
	Import	$M = A_m T\hat{X}_I$		F_m	X_m
Value added		$V_I = A_v T\hat{X}_I$			
Total output		X_I			

Using the product technology assumption, the domestic intermediate input matrix U in the extended use table can be calculated as $U = AT\hat{X}_I$. Similarly, the import intermediate input matrix M ($M = A_m T\hat{X}_I$) and the value-added matrix V_I ($V_I = A_v T\hat{X}_I$) can be derived. Other data can be obtained directly from the EIOT and the extended supply table, such as the total input by industry X_I, the final use matrix for domestic product F and import product F_m.

This extended use table is still unbalanced. Yang et al. (2022[6]) used a Quadratic Programming Model to balance the table. The table had to suffice several constraints. Namely, when the DOEs and the FIEs in the extended use table were added up, the value of each cell needed to match the value of the corresponding cell in the NBS' regular use table. Furthermore, the table also needed to satisfy the row and column constraints. In more detail, minimise S where S is:

$$
\begin{aligned}
S = {} & \sum_{j=1}^{84}\sum_{i=1}^{52}\sum_{l}\sum_{k}\left[\left(u_{ij}^{lk} - u0_{ij}^{lk}\right)^2 / u0_{ij}^{lk}\right] + \sum_{j=1}^{84}\sum_{i=1}^{52}\sum_{k}\left[\left(m_{ij}^{k} - m0_{ij}^{k}\right)^2 / m0_{ij}^{k}\right] \\
& + \sum_{s2=1}^{4}\sum_{i=1}^{52}\sum_{k}\left[\left(v_{s2,j}^{k} - v0_{s2,j}^{k}\right)^2 / v0_{s2,j}^{k}\right] + \sum_{j=1}^{84}\sum_{s1=1}^{3}\sum_{l}\left[\left(f_{i,s1}^{l} - f0_{i,s1}^{l}\right)^2 / f0_{i,s1}^{l}\right] \\
& + \sum_{j=1}^{84}\sum_{s1=1}^{3}\left[\left(fm_{i,s1}^{l} - fm0_{i,s1}^{l}\right)^2 / fm0_{i,s1}^{l}\right]
\end{aligned}
$$

such that the following identities and constraints hold:

- Row sum identities required by the use table

$$\sum_{j=1}^{52}\sum_{k} u_{ij}^{lk} + \sum_{s1=1}^{3} f_{i,s1}^{l} = x_i^l, i = 1,2,\cdots,84; l = DOEs, FIEs$$

$$\sum_{j=1}^{52}\sum_{k} m_{ij}^{k} + \sum_{s1=1}^{3} fm_{i,s1} = xm_i, i = 1,2,\cdots,84$$

- Column sum identities required by the use table

$$\sum_{i=1}^{84}\sum_{l} u_{ij}^{lk} + \sum_{i=1}^{84} m_{i,j}^{k} + \sum_{s2=1}^{4} v_{s2,j}^{k} = xI_j^k, j = 1,2,\cdots,52; k = DOEs, FIEs$$

- Adding up conditions for intermediate inputs

$$\sum_{l}\sum_{k} u_{ij}^{lk} + \sum_{k} m_{i,j}^{k} = u_{ij}, i = 1,2,\cdots,84;\ j = 1,2,\cdots,52; l,k = DOEs, FIEs$$

- Adding up conditions for product outputs

$$\sum_{k} v_{s2,j}^{k} = v_{s2,j}, \qquad s2 = 1,2,3,4;\ j = 1,2,\cdots,52;\ k = DOEs, FIEs$$

- Non-negative constraints

$$u_{ij}^{lk}, m_{i,j}^{k}, fm_{i,s1} \geq 0$$

where:

- The initial values $u0_{ij}^{lk}, m0_{ij}^{k}, v0_{s2,j}^{k}, f0_{i,s1}^{l}, fm0_{i,s1}^{l}$ are from the unbalanced extended use table, corresponding to U, M, V, F, F_m in Table 4.9.
- The constraints x_i^l, xm_i, xI_j^k are from the unbalanced extended use table, corresponding to X, X_m, X_I in Table 4.9.
- $k = DOEs, FIEs$ means the industry is DOEs or FIEs while $l = DOEs, FIEs$ means the product is from DOEs or FIEs; $s1 = 1,2,3$ represents consumption, capital formation and export in final use; $s2 = 1,2,3,4$ represents the compensation of employees, net taxes on production, depreciation of fixed assets and operating surplus in value added, respectively.
- u_{ij} is the intermediate input matrix and $v_{s2,j}$ is the value-added matrix in the use table provided by the NBS.

This process yields the balanced extended use table.

Comparing the compilation of an extended input-output table in data-rich and data-scarce environments

This chapter and Chapter 3 showed that, generally, there are two ways to compile ESUTs and EIOTs. Namely, in a data-rich environment, using as much data as possible, and in a data-scarce environment, using less data and more assumptions. Both methods are discussed below and Table 4.10 summarises both methods, indicating their stronger and weaker points. Work by the OECD and Statistics Netherlands shows that the results in their specific cases are robust under different approaches. However, note that these findings were obtained in specific contexts, concerning the countries, years, and dimensions of enterprise heterogeneity studied. Therefore, one should not draw general conclusions from the two cases discussed.

Data-rich environment

Ideally, one reuses as much as possible the existing data and software infrastructure that is used for the compilation of regular SUTs. For example, if the infrastructure is flexible with respect to industries, one might feed the system with value added and production by industry by enterprise type. The "industry by enterprise type" is then a quasi-industry. This was the approach used by Chong et al. (2016[1]; 2019[9]). They used as much as possible the existing microdata, infrastructure and methods then compiled an ESUT and subsequently an EIOT.

This approach requires a lot of data and a lot of time to compile and adjust the data. It is not feasible for external researchers unless they have access to microdata, which is often not the case. The advantage of this approach is that it maximally capitalises on what is used in the regular process, staying as close as possible to that process. It allows integrating supply and use at a detailed level as well as for different input structures for different types of enterprises in the same industry, both for foreign/domestic inputs and for production technology. Furthermore, the approach allows for flexibility, since one can enter detailed information when desired.

Data-scarce environment

Since the necessary detailed data are generally not accessible for external researchers, other methods have been devised, as was described earlier in this chapter. In this approach, data consumption and time consumption are limited, which makes it accessible for external researchers. Obviously, this comes at a cost. There is no integration of supply and use at a detailed level. The method does not allow for differences in production technology for different types of enterprises in the same industry. The method has limited flexibility; one cannot adapt detailed items since one works at an aggregated level. However, some adaptions will still be possible, for example, assigning illegal production in an industry non-proportional over the different types of enterprises. Or using information about production, imports and exports at product level. Since there is no integration at supply and use of products, this method must make more assumptions. For example, a proportionality assumption is used to assign the intermediate supply of a type of enterprise in an industry to the users (enterprise types by industry). Still, the method yields extra information compared to a completely proportional disaggregation. First, since it allows for differences in foreign/domestic inputs. Second, because imports and value added form a sizeable part of inputs of an industry, and these numbers are set correctly by construction, only the intermediate part of the IOT can be partly wrong.

Table 4.10. Comparison of the data-rich and data-scarce methods

	Data-rich	Data-scarce
Data consumption	Very high	Limited
Time consumption	Very high	Limited
Quality	High	Average
Possible for external researchers	Not often	Yes
Assumptions	Some	More
Trade in services*	Problematic	Problematic
Flexible	Yes	Average

Note: * This is a general data gap. Many countries do not have trade by services by industry split by type of enterprise as well.

Robustness of the data-scarce method

In practice, most researchers will have to use the data-scarce approach since they do not have access to the data needed for the data-rich approach. Therefore, it is necessary to assess its quality by checking the robustness of the results. Both OECD (2018[4]) and Lemmers (2020[10]) do exactly that. OECD (2018[4]) point out that the data-scarce method has three important assumptions:

- There is no substitution between imports and domestically purchased products among small and large enterprises. The share of imports in purchases will differ by enterprise type, but the product baskets for imports and domestic purchases are the same within each enterprise type.
- There are no differences in the use of the production of small and large enterprises. Their production is proportionally distributed to domestic intermediate and final use.
- Enterprises have no preference for purchasing from either small or large enterprises.

They find that indicators such as imports embedded in exports hardly differ under different scenarios, but that the domestic intermediate relations between different types of enterprises can be different.

Lemmers uses the EIOT by Chong et al. (2016[1]) that was compiled using a data-rich approach. He then aggregates to a usual IOT without types of enterprises and calculates the shares of each type of enterprise in an industry. This information is subsequently used to compile a top-down EIOT. That table is compared by calculating several indicators to the table of Chong et al. These indicators are domestic value added embodied in exports, value added embodied in exports as share of total value added and export spillovers (value added at suppliers/value added at exporting industry). They are calculated at the level of industry by enterprise type. Generally, the differences between indicators based on the two EIOTs are small. There are, however, some exceptions, i.e. the beverages and tobacco industry. However, there are usually clear causes for the differences; for example, in the aforementioned industry, a sizeable part of the SME production is the illegal production of cannabis. Large enterprises do not produce this. Hence the input-output structure of the different types of enterprises in the same industry will be very different.

As mentioned earlier, these two findings were obtained in specific contexts. Therefore, one should not draw general conclusions from these cases.

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Notes

[1] The term "industrial enterprises above designated size" refers to enterprises with an annual main business revenue that exceeds a certain threshold set by the government. This threshold can differ by industry and by year.

[2] This assumes that a product has the same input structure regardless of the industry in which it is produced.

5. Balancing methods applied to extended supply and use tables

This chapter outlines strategies and practical implications in balancing extended supply and use tables in the absence of sufficient information. It begins with a discussion of automatic balancing procedures before turning to an examination of proportional scaling methods. Next, the chapter considers conditions for unique solutions. It also reviews other problematic scenarios. It concludes with a checklist for designing automatic balancing processes and a set of recommendations.

Introduction

This chapter outlines strategies and practical implications in balancing extended supply and use tables (ESUTs) in the absence of sufficient information. The main imbalances should be tackled manually, as this ensures robustness across varying data quality. For example, trade data are typically more reliable than intermediate use data. Other balancing methods should be used only when improving data sources is not feasible. The handling of conflicting data in ESUTs presents a significant challenge when balancing. This chapter, written by Juan M. Valderas-Jaramillo and José M. Rueda Cantuche (European Commission's Joint Research Centre), describes various strategies in detail, including proportional and optimisation methods, to address the challenges and ensure meaningful outcomes. The chapter also discusses conditions for achieving unique solutions in non-negative matrices and identifies potential pitfalls. Note that theoretical and methodological aspects of extending supply and use table (SUT) frameworks need careful consideration, ensuring that all available information is synthesised efficiently.

Automatic balancing procedures

This section briefly describes automatic balancing techniques to focus the attention on proportional adjustment methods in the following section. United Nations (2018[1]) provides a good overview[1] of the existing projection methods for SUTs that can, in principle, be used in the reconciliation of information from different data sources and in the balancing process of SUTs. There are three different ways to address the problem where data gaps for the interior elements of the matrices outnumber the external constraints in the form of, for example, row and column totals. These are:

1. constrained optimisation methods based on probability and information theory or on distance measures
2. proportional scaling methods, which can be one-sided or biproportional
3. model-based methods.

The first group of methods, in general, has in common the fact that they minimise some measure of distance between all elements of the two matrices, the prior and the resulting estimated matrix. There are many types of distance measures, such as absolute differences and square differences, among others. Alternatively, this group of methods also comprises objective functions that are based on the statistical concept of information loss, taken from the probability and information theory laid out by Kullback and Leibler (1951[2]). The measure typically represents a solution to the problem that provides minimum information loss. This group of methods can also incorporate constraints or weights in the objective function to account for different robustness in the data (United Nations, 2018[1]).

This concept is also associated with the second group, that of proportional scaling methods. Indeed, this balancing problem could also be expressed in terms of a simple biproportional[2] iterative scaling method, which was the so-called RAS method used by Stone (1961[3]). This method prompted a lot of discussion because the elements of the matrices can be positive and negative (generalised RAS method), key examples include Günlük-Senesen and Bates (1988[4]); Junius and Oosterhaven (2003[5]); Huang, Kobayashi and Tanji (2008[6]); Lenzen, Wood and Gallego (2007[7]); and Lemelin (2009[8]). The literature also provides several refinements, such as those dealing with row and column totals with positive and negative elements, and non-preserving sign (Temurshoev, Miller and Bouwmeester, 2013[9]; Lenzen et al., 2014[10]) or allowing more flexibility to find a compromise with exogenous conflicting constraints (Lenzen, Gallego and Wood, 2009[11]). More recently, there have been further developments in multidimensional proportional balancing methods (Temursho, Oosterhaven and Cardenete, 2021[12]; Valderas-Jaramillo and Rueda Cantuche, 2021[13]), where the constraints are also sums of various parts of the interior matrices, on top of the row and column totals.

The third group of methods, model-based methods, uses input-output models to balance SUTs and input-output tables, for example, Leontief price and quantity models used by Snower (1990[14]); Beutel (2002[15]; Beutel, 2008[16]); Valderas-Jaramillo et al. (2019[17]); time series analysis covered by Wang et al. (2015[18]); and econometric methods used by Kratena and Zakarias (2004[19]).

This chapter focuses on the second group of methods because of their prevalent use in balancing SUTs and input-output tables at national statistical offices.

This chapter specifically focuses on the generalised RAS (GRAS) method, which seeks to find a unique solution to the balancing problem. Moreover, the SUT-RAS method is a particular case of the GRAS method for balancing SUTs all at once (Temursho, Oosterhaven and Cardenete, 2021[12]). However, the process is not entirely automatic, and the solution algorithm of RAS-type proportional methods (e.g. GRAS) is only equivalent to that of constrained optimisation problems if the problem is well-defined and a unique solution[3] exists. Therefore, a crucial concern is to ascertain in advance the conditions that guarantee a unique solution and to establish some guidelines for this purpose. Elucidating these conditions and offering guidance are the main objectives of this chapter.[4]

Proportional scaling methods

Throughout this chapter, a stylised example will be used to guide the reader (Table 5.1). For a particular industry, integrating regular SUT data (e.g. industry and product output) with information from other sources (as described in Chapter 2) to delineate activities among, for instance, domestic multinational enterprises (MNEs), foreign MNEs and domestic non-MNEs, may lead to inconsistencies in the total output figures. From the regular SUTs, total intermediate use by industry 1 of product 1 is 8; for product 2, it is 12; and for value added, it is 10. Similarly, one only ascertains that the total output of industry 1 is 28 by examining the regular SUTs. Nevertheless, alternative data sources indicate that the distribution of industry output is 10 (for domestic MNEs), 12 (for foreign MNEs) and 6 (for domestic non-MNEs). Assuming a predetermined input structure for each type of enterprise (derived from ad hoc surveys, enterprises' annual accounts, etc.), the challenge lies in determining a matrix of intermediate uses that satisfies the constraints imposed by the regular SUTs and other relevant data sources that disaggregate industries (the shaded cells).

Table 5.1. Illustrative example of an unbalanced extended supply and use table

	Industry 1			
	Domestic MNE	Foreign MNE	Domestic non-MNE	Intermediate use
Product 1	1	2	5	8
Product 2	4	2	3	12
TLS	-1	2	-2	-2
Value added	6	1	2	10
Output	10	12	6	

Note: MNE: multinational enterprise; TLS: taxes less subsidies on products. Predetermined constraints.

The GRAS method

United Nations (2018, pp. 491-494[1]) describes in detail the iterative process of the GRAS method with real numerical examples. This chapter presents succinctly how the GRAS solution algorithm applies to obtain a balanced matrix. This is applied to one specific industry (i.e. industry 1) but can easily be extended to others. It can even be used to automate the whole process. Therefore, each row or column total of Table 5.1 (the shaded cells) is treated independently, as a one-dimensional vector with positive and negative values. Following the GRAS method, for each total vector, a quadratic equation[5] for *k* like the following needs to be solved:

$$kP - \frac{1}{k}N = S$$

where *P* is the sum of the positive elements of the vector, *N* the sum of the negative elements (in absolute value) and *S* the desired target value (i.e. shaded cells in Table 5.1). The solution for *k* would be given by:

$$k = \frac{S + \sqrt[2]{S^2 + 4PN}}{2P}$$

In the first iteration, the column of domestic MNEs is already balanced, so there is no need to make any change to the column values. Hence, k = 1. For foreign MNEs, there are no negative elements in the column, so the solution would be reached by multiplying all column elements by the ratio 12/7 = 1.71. For instance, 2*12/7 = 3.43. However, there is a negative element in the column of domestic non-MNEs, where the solution for *k* would therefore be given by:

$$k = \frac{6 + \sqrt[2]{6^2 + 4 * 10 * 2}}{2 * 10} = 0.84$$

Table 5.2 and Table 5.3 show the results for the first iteration by columns.

Table 5.2. Unbalanced extended supply and use table with P, N and k

	Industry 1			
	Domestic MNE	Foreign MNE	Domestic non-MNE	Intermediate use
Product 1	1	2	5	8
Product 2	4	2	3	12
TLS	-1	2	-2	-2
Value added	6	1	2	10
Output	10	12	6	
Sum	10	7	8	
P	11	7	10	
-N	-1	0	-2	
k	1.00	1.71	0.84	
1/k	1.00	0.58	1.19	

Note: MNE: multinational enterprise; TLS: taxes less subsidies on products. Predetermined constraints.

Table 5.3. Results after the first iteration (by columns)

	Industry 1								
	Domestic MNE	Foreign MNE	Domestic non-MNE	Intermediate use	Sum	P	-N	k	1/k
Product 1	1	3.43	4.19	8	8.62	8.62	0.00	0.93	1.08
Product 2	4	3.43	2.52	12	9.94	9.94	0.00	1.21	0.83
TLS	-1	3.43	-2.39	-2	0.04	3.43	-3.39	0.74	1.34
Value added	6	1.71	1.68	10	9.39	9.39	0.00	1.06	0.94
Output	10	12	6						
Sum	10.00	12.00	6.00						
P	11.00	12.00	8.39						
-N	-1.00	0.00	-2.39						
k	1.00	1.00	1.00						
1/k	1.00	1.00	1.00						

Note: MNE: multinational enterprise; TLS: taxes less subsidies on products. Predetermined constraints.

As shown in Table 5.3, the sum of the column values matches the desired output totals exactly. However, the product totals (by each row) have not yet been balanced. Following the same strategy as outlined for the columns, Table 5.3 shows the values of *k* that would yield the same product totals that were defined as target. By applying these new *k* values row-wise, Table 5.4 shows the results obtained. At this point, the first iteration ends with a perfect match at the product level but with a mismatch at the industry level, as it was in the beginning.

Table 5.4. Results after the first iteration (by rows)

	Industry 1								
	Domestic MNE	Foreign MNE	Domestic non-MNE	Intermediate use	Sum	P	-N	k	1/k
Product 1	0.93	3.18	3.89	8	8.00	8.00	0.00	1.00	1.00
Product 2	4.83	4.14	3.04	12	12.00	12.00	0.00	1.00	1.00
TLS	-1.34	2.55	-3.21	-2	-2.00	2.55	-4.55	1.00	1.00
Value added	6.39	1.83	1.79	10	10.00	10.00	0.00	1.00	1.00
Output	10	12	6						
Sum	10.80	11.69	5.51						
P	12.14	11.69	8.71						
-N	-1.34	0.00	-3.21						
k	0.94	1.03	1.04						
1/k	1.06	0.97	0.96						

Note: MNE: multinational enterprise; TLS: taxes less subsidies on products. Predetermined constraints.

Subsequent iterations can be run column-wise and row-wise until both industry output and product output totals match with the desired target. In our illustrative example, as shown in Table 5.5, after the fifth iteration, the maximum divergence is $9.07*10^{-11}$.

Table 5.5. Results after the fifth iteration

	Industry 1								
	Domestic MNE	Foreign MNE	Domestic non-MNE	Intermediate use	Sum	P	-N	k	1/k
Product 1	0.83	3.20	3.97	8	8.00	8.00	0.00	1.00	1.00
Product 2	4.50	4.30	3.20	12	12.00	12.00	0.00	1.00	1.00
TLS	-1.46	2.56	-3.10	-2	-2.00	2.56	-4.56	1.00	1.00
Value added	6.13	1.94	1.93	10	10.00	10.00	0.00	1.00	1.00
Output	10	12	6						
Sum	10	12	6						
P	11.46	12.00	9.10						
-N	-1.46	0.00	-3.10						
k	1.00	1.00	1.00						
1/k	1.00	1.00	1.00						

Note: MNE: multinational enterprise; TLS: taxes less subsidies on products. Predetermined constraints.

This proportional scaling algorithm can be replicated in as many directions of a hyper-matrix (with n dimensions) as needed, in a sequential way. Temursho, Oosterhaven and Cardenete (2021[12]) set out a particular case for an additional constraint (dimension) added to a matrix balancing problem with non-overlapping elements and unity[6] coefficients. Valderas-Jaramillo and Rueda-Cantuche (2021[13]) defined the general methodological framework for 3, 4 and n dimensions. KRAS (Lenzen, Gallego and Wood, 2009[11]) provides a framework allowing deviations from the target vectors to achieve balance, with unity coefficients.

However, balancing actual data is not straightforward and can introduce potential inconsistencies in the data, which may hinder the balancing method from reaching a solution. Such a scenario occurs when the method fails to converge to the intended target within a specified maximum deviation (threshold). The following section examines the conditions required for convergence in a matrix balancing problem. Understanding these conditions can assist ESUT compilers in pre-emptively resolving issues, thereby enhancing the likelihood of achieving convergence.

Conditions for unique solutions

This section elaborates on the conditions for unique solutions. It starts by considering non-negative matrices and then considers matrices with positive and negative elements.

Non-negative matrices

In the context of the RAS-type methods for matrix balancing, a pivotal reference is the necessary and sufficient conditions for convergence established by Bacharach (1965[20]), specifically for non-negative matrices. Bacharach (1965[20]) introduces the concept of “connectedness” to describe the structure of a matrix. A matrix is called disconnected if rows and columns can be ordered, in at least one way, so it can be expressed as a block-diagonal matrix, as in the following example. A matrix is called connected if it is not disconnected. Connectedness relates to the concept of sparsity, which refers to the number or proportion of zero entries in a matrix. While there is no universally accepted threshold to classify a matrix as sparse, generally a matrix with a higher proportion of zero[7] entries is considered sparser.

Three different situations can be distinguished to illustrate Bacharach's necessary and sufficient conditions:

1. disconnected matrix
2. connected matrix without zeros
3. connected matrix with zeros.

For the disconnected matrix one can use a simple 3x3 matrix as an example, such as:

$$
\boldsymbol{A} = \begin{bmatrix} 1 & 2 & 0 \\ 4 & 2 & 0 \\ 0 & 0 & 2 \end{bmatrix}
\begin{array}{c} \mathbf{u} \\ \begin{bmatrix} 8 \\ 12 \\ 10 \end{bmatrix} \end{array}
$$

$$
\mathbf{v} \quad \begin{bmatrix} 10 & 13 & 7 \end{bmatrix}
$$

In this example, the element at the intersection of the third row and third column is disconnected from the rest of the matrix. Consequently, matrix A can be divided into two independent submatrices, forming a block-diagonal structure. This configuration results in an infeasible problem that will not converge because the solitary element in the third row and column cannot simultaneously meet both the row and column targets. The same issue applies to the first diagonal block. Attempting to resolve this problem is futile because it is impossible to force an independent submatrix to have the same sum when adding the elements by rows (which totals 20) as when adding them by columns (which totals 23).

In conclusion, if a matrix is disconnected, a solution may not exist. However, the connected sub-blocks within the matrix can be examined. Then, convergence needs to be checked for all the connected sub-blocks, as described hereafter.

Second, the connected matrix without zeros needs to be addressed. Table 5.1 shows an example of a connected matrix without zeros. This matrix does not contain any null elements (i.e. it is a full matrix) and is considered "connected" according to Bacharach's terminology. Bacharach (1965[20]) proves[8] that if a matrix is connected, then a solution of the RAS-type problem is unique if the sum of the row targets matches the sum of the column targets of the matrix. Therefore, the example in Table 5.1 is a well-posed problem, and a unique solution will exist in accordance with Bacharach's conditions. Although it seems logical to think so, it is essential to verify that the sum of the row targets matches the sum of the column targets of the initial matrix. It may be the case that this condition would not naturally be met. Careful attention must be given to ensure that the newly added or modified rows and columns in the ESUT uphold this critical requirement. In the illustrative example, the sum of the row targets equals 28, as the sum of the column targets (i.e. the shaded cells).

Third, for a connected matrix with some zeros, a solution will exist if and only if for any sub-matrix of null values $\mathbf{A}_{I'J} = \mathbf{0}$ that can be built reordering rows and columns, the following two conditions[9] hold:

$$\boldsymbol{\iota}'\boldsymbol{u}_{I'} \leq \boldsymbol{v}_{J'}\boldsymbol{\iota} \tag{1}$$

$$\boldsymbol{\iota}'\boldsymbol{u}_{I} \geq \boldsymbol{v}_{J}\boldsymbol{\iota} \tag{2}$$

for a matrix **A** such that:

$$
\begin{bmatrix} \boldsymbol{A}_{IJ} & \boldsymbol{A}_{IJ'} \\ \mathbf{0} & \boldsymbol{A}_{I'J'} \end{bmatrix} \begin{bmatrix} \boldsymbol{u}_I \\ \boldsymbol{u}_{I'} \end{bmatrix}.
$$

$$
\begin{bmatrix} \boldsymbol{v}_J & \boldsymbol{v}_{J'} \end{bmatrix}
$$

Otherwise, the RAS-type problem is not feasible, and no solution exists. For the sake of simplicity, consider the following example of a connected matrix with zeros where there is no other way to reorder rows and columns to obtain a different null sub-matrix.

$$\mathbf{A} = \left[\begin{array}{cc|c} 1 & 2 & 5 \\ 4 & 2 & 1 \\ \hline 0 & 0 & 2 \end{array}\right] \quad \begin{array}{c} \mathbf{u} \\ \left[\begin{array}{c} 8 \\ 12 \\ \hline 10 \end{array}\right] \end{array}$$

$$\mathbf{v} \quad \left[\begin{array}{cc|c} 10 & 13 & 7 \end{array}\right]$$

As shown in the example, equation (1) does not hold since $\boldsymbol{\iota}'\boldsymbol{u}_{\boldsymbol{I}'} = 10 > \boldsymbol{v}_{\boldsymbol{J}'}\boldsymbol{\iota} = 7$ and equation (2) does not hold either, since $\boldsymbol{\iota}'\boldsymbol{u}_{\boldsymbol{I}} = 20 < \boldsymbol{v}_{\boldsymbol{J}}\boldsymbol{\iota} = 23$. Therefore, no solution to this problem exists. Intuitively, considering that the third row of the matrix contains only one non-zero element, and the sum of that row must equal 10, one might think to change the value of a_{33} from 2 to 10 to achieve the row's target sum. However, this adjustment renders it impossible to attain the target sum for the third column, which already exceeded the desired total. A similar reasoning can be applied for the other set of rows and columns.

It is crucial to scrutinise the target values when dealing with a matrix that has a high level of sparsity to verify whether conditions (1) and (2) are met. If conditions (1) and (2) are not satisfied, the assumptions or the target values themselves must be re-evaluated to determine appropriate adjustments for the balancing problem.

Matrices with positive and negative elements

On certain occasions, the presence of negative elements can significantly alter the necessary conditions outlined by Bacharach (1965[20]), thereby introducing a degree of additional flexibility to the problem. Conversely, in other cases, the impact is the opposite. In other words, problems that were originally insolvable with non-negative matrices can become solvable when negative values are introduced. However, the reverse is also true: negative values can hinder the convergence of a solution. Furthermore, the inclusion of negative numbers is often associated with sign changes – whether in the aggregate totals or in the individual elements when comparing the initial and target matrices.

Apparently, there are no theorems that guarantee the convergence of general matrices that include both positive and negative elements (see Valderas-Jaramillo and Rueda-Cantuche (2021[13]) for a broader discussion on this issue). Experience suggests that for matrices with positive and negative elements, the greater the sparsity, the higher the likelihood of encountering convergence issues. Nonetheless, the conditions for the existence and uniqueness of a solution to a GRAS (generalised RAS) problem remain an open area of research.

Let us assume the following matrix as an illustrative example:

$$\boldsymbol{A} = \begin{bmatrix} 3 & 1 \\ 0 & 2 \end{bmatrix} \quad \begin{array}{c} \mathbf{u} \\ \begin{bmatrix} 5 \\ 5 \end{bmatrix} \end{array}$$

$$\mathbf{v} \quad \begin{bmatrix} 6 & 4 \end{bmatrix}$$

This matrix does not have a solution as can be easily proved. The first condition does not hold since $\boldsymbol{\iota}'\boldsymbol{u}_{\boldsymbol{I}'} = 5 > \boldsymbol{v}_{\boldsymbol{J}'}\boldsymbol{\iota} = 4$; neither does the second condition, i.e. $\boldsymbol{\iota}'\boldsymbol{u}_{\boldsymbol{I}} = 5 < \boldsymbol{v}_{\boldsymbol{J}}\boldsymbol{\iota} = 6$. In other words, the element a_{22} should be 5 (instead of 2) in order to match the target value (= 5). However, this would make it impossible to match the second column target, which is already lower (= 4). Assuming that a_{12} is negative (= -1), then there would exist a solution such that:

$$\begin{array}{ccc} & & \mathbf{u} \\ \boldsymbol{A} = & \begin{bmatrix} 6 & -1 \\ 0 & 5 \end{bmatrix} & \begin{bmatrix} 5 \\ 5 \end{bmatrix} \\ \mathbf{v} & \begin{bmatrix} 6 & 4 \end{bmatrix} & \end{array}$$

The opposite case is when a matrix with a solution becomes infeasible due to a negative value. Assuming the following example:

$$\begin{array}{ccc} & & \mathbf{u} \\ \boldsymbol{A} = & \begin{bmatrix} 3 & 1 \\ 0 & 2 \end{bmatrix} & \begin{bmatrix} 5 \\ 5 \end{bmatrix} \\ \mathbf{v} & \begin{bmatrix} 4 & 6 \end{bmatrix} & \end{array}$$

This matrix fulfils the two conditions of Bacharach (1965[20]), i.e. $\boldsymbol{\iota}'\boldsymbol{u}_{\boldsymbol{I}'} = 5 < \boldsymbol{v}_{\boldsymbol{J}'}\boldsymbol{\iota} = 6$ and $\boldsymbol{\iota}'\boldsymbol{u}_{\boldsymbol{I}} = 5 > \boldsymbol{v}_{\boldsymbol{J}}\boldsymbol{\iota} = 4$. The solution would be given by:

$$\begin{array}{ccc} & & \mathbf{u} \\ \boldsymbol{A} = & \begin{bmatrix} 4 & 1 \\ 0 & 5 \end{bmatrix} & \begin{bmatrix} 5 \\ 5 \end{bmatrix} \\ \mathbf{v} & \begin{bmatrix} 4 & 6 \end{bmatrix} & \end{array}$$

However, assuming now that a_{12} is negative (= -1), then there would not be any solution to the new problem, even when Bacharach's two conditions still hold. That is:

$$\begin{array}{ccc} & & \mathbf{u} \\ \boldsymbol{A} = & \begin{bmatrix} 3 & -1 \\ 0 & 2 \end{bmatrix} & \begin{bmatrix} 5 \\ 5 \end{bmatrix} \\ \mathbf{v} & \begin{bmatrix} 4 & 6 \end{bmatrix} & \end{array}$$

Analogously, a_{22} should be 5 (instead of 2) in order to match the second row target value (= 5). However, this would make it impossible to match the second column target, which would be lower (= 4) due to the negative value.

Other possible problematic scenarios

Other potential scenarios can be proactively examined to detect issues of infeasibility and undesirable behaviours in matrices containing both positive and negative elements. These situations are generally straightforward to spot and may expose inconsistencies in the initial assumptions of the matrix and the dataset. It is both feasible and beneficial to develop algorithms capable of identifying these issues and implementing automatic solutions. This section discusses various scenarios, including zero (non-zero) targets with non-negative or non-positive (zero) elements.

Non-zero target with all elements null

The first problematic scenario is such that a null vector must match a non-zero target value, as shown in the example below.

$$\begin{array}{lcc} & & \textbf{target} \\ \mathbf{v} \quad \begin{bmatrix} 0 & 0 & \dots & 0 & 0 \end{bmatrix} & \longrightarrow & 10 \end{array}$$

Identifying a multiplying factor *k* using the GRAS algorithm is unfeasible because zeros will consistently remain as such. This situation is readily identifiable, and multiple potential solutions can be considered. The choice to have a full row or a full column of null values should be substantiated or otherwise abandoned, and a different row/column structure should be estimated. Alternatively, in the absence of information, a binary vector of zeros and ones can be created. By doing so, it must be established those elements for which one believes zeros must remain and ones otherwise. It is also possible that the target value should be null, which would imply setting the target to zero as a solution. In this respect, expert knowledge is key to defining either one or the other solutions to the infeasibility problem.

Zero target with all elements non-positive or non-negative

The second scenario entails a situation where a vector consisting solely of non-positive or non-negative values is required to align with a target value of zero:

$$\begin{array}{lcc} & & \textbf{target} \\ \mathbf{v} \quad \begin{bmatrix} 1 & 2 & 3 & 4 & 5 \end{bmatrix} & \longrightarrow & 0 \\ & & \textbf{target} \\ \mathbf{v'} \quad \begin{bmatrix} -1 & -2 & -3 & -4 & -5 \end{bmatrix} & \longrightarrow & 0 \end{array}$$

This particular circumstance results in the nullification of the vector following the initial iteration. While it is conceivable that this may not affect the problem substantially, as previously observed, it enhances the sparsity of the prior matrix, potentially complicating the algorithm's convergence. It is possible that the problem was initially well formulated; however, subsequent rounds after the first iteration may turn the problem into an ill-posed and infeasible one. This can be shown in the following example:

$$\begin{array}{cccc} & \begin{array}{cc|c} \multicolumn{2}{c}{J} & J' \end{array} & \mathbf{u} & \\ \boldsymbol{A} = & \left[\begin{array}{cc|c} 1 & 1 & 0 \\ \hline 3 & 2 & 4 \\ 4 & 3 & -1 \end{array}\right] & \left[\begin{array}{c} 5 \\ \hline 5 \\ 5 \end{array}\right] & \begin{array}{c} I \\ I' \\ \end{array} \end{array}$$

$$\mathbf{v} \quad \left[\begin{array}{cc|c} 4 & 0 & 11 \end{array}\right]$$

Although the Bacharach's conditions (1) and (2) hold[10] there may not be a solution since $v_2 = 0$ and the elements of the second column are all positive. After the first iteration (matching v), the initial matrix yields:

$$\boldsymbol{A} = \begin{bmatrix} 0.5 & 0.0 & 0.0 \\ 1.5 & 0.0 & 11.4 \\ 2.0 & 0.0 & -0.4 \end{bmatrix} \begin{array}{c} \mathbf{u} \\ \begin{bmatrix} 5 \\ 5 \\ 5 \end{bmatrix} \end{array}$$

$$\mathbf{v} \quad \begin{bmatrix} 4 & 0 & 11 \end{bmatrix}$$

For the next iteration, the second column has been set to zero. Hence, the problem has turned infeasible because the first element a_{11} cannot be 5 (to meet $u_1 = 5$) and at the same time meet $v_1 = 4$ if a_{21} and a_{31} are positive elements.

The solutions to this type of infeasibilities will depend on the context and assumptions inside the initial matrix and the target vectors that should be considered carefully by the ESUT compilers.

Zero target with positive, negative and null elements

The third scenario entails a situation where a vector consisting of positive and negative values is required to align with a target value of zero. In principle, nothing should be wrong in this particular situation (as long as negative values make sense).[11] Otherwise, experts will have to evaluate what the zero target means (e.g. absence of activity) and whether that would entail setting all the elements to zero as a solution to the infeasibility problem.

$$\mathbf{v} \quad \begin{bmatrix} -4 & -3 & \ldots & -5 & 4 & 2 & \ldots & 7 \end{bmatrix} \longrightarrow \begin{array}{c} \textbf{target} \\ 0 \end{array}$$

This scenario, while not initially leading to infeasibilities, merits preventive examination to allow for informed decision making rather than deferring to the algorithm's discretion. Furthermore, such situations may give rise to secondary complications. At times, all positive values may escalate due to the other targets, obligating the negative values to increase correspondingly to balance the positives. It is therefore advisable to set up alert controls in every iteration to detect large positive and large negative values compensating each other. Moreover, this situation can result in an unnecessary proliferation of iterations required for convergence or may even render the problem infeasible.

Negative (positive) target with non-negative (non-positive) elements

The preceding paragraphs addressed scenarios involving zeros, such as null vectors or those with zero targets. This section considers a different situation in which zeros are not relevant but there is a change in sign among the vector elements in the prior vector compared to the desired target. For instance, there may be a situation like the one described in the following example:

$$\mathbf{v} \quad \begin{bmatrix} 5 & 3 & 0 & 2 & 6 & 4 \end{bmatrix} \longrightarrow \begin{array}{c} \textbf{target} \\ -12 \end{array}$$

As the GRAS method is sign-preserving, this is a clear example of an infeasible situation since there is a non-negative vector as prior and a desired negative target. However, the GRAS algorithm may still produce a solution, although not necessarily the solution to the initial optimisation problem. Indeed, the GRAS algorithm is equivalent to solving an optimisation problem when the problem is well-defined – that is, when a solution exists and is unique. However, if the optimisation problem is ill-defined and lacks a feasible solution, the GRAS algorithm might still operate and potentially yield a plausible outcome. In such cases, the solution is not really a solution to the initial optimisation problem but to a different one. Consequently, any solution derived is not a result of the original optimisation problem,[12] as discussed by Lenzen et al. (2014, p. 203[10]) and Valderas-Jaramillo and Rueda-Cantuche (2021, p. 1611[13]). Analogous conclusions come from situations where the vector has non-positive elements, and the target is positive.

There are three outstanding issues to consider in this scenario. First, the initial optimisation problem is infeasible. Second, the economic meaning of the negative target (or the negative values of the vector) has to be substantiated, as does the subsequent results of the GRAS algorithm, if necessary. Third, the GRAS algorithm is providing a solution to a different optimisation problem.

As a result, it is important to evaluate the economic soundness of the prior data, the targets and the sign change derived from the GRAS algorithm. Furthermore, as shown earlier, the introduction of new negatives in the initial matrix may also cause convergence problems.[13]

Fixing elements and reducing degrees of freedom

Balancing methods in compiling ESUTs can also profit from additional information on specific elements. Paelinck and Waelbroeck's (1963[21]) modification of the RAS method, which they termed M-RAS, incorporated additional information into a pre-existing matrix by specifying certain known cells. This process leverages the characteristic of sign preservation inherent in RAS/GRAS problems, allowing any predetermined (known) elements to be initially set to zero in the matrix. Subsequently, target adjustments are made to reflect the presence of these known elements. Following these modifications, the M-RAS algorithm is executed to find a solution, after which the zero placeholders are replaced with the pre-known values.

There are two significant considerations when dealing with predetermined elements. First, fixed elements inherently limit the degrees of freedom within the matrix. This limitation can increase the sparsity of the matrix, potentially transforming the optimisation problem into an infeasible one or contributing to increased difficulties in achieving convergence.

Second, the use of known elements also necessitates modifications to the target values, which can also lead to infeasibility or the loss of economic meaning. This is particularly evident when dealing with a vector of non-negative numbers, and the predetermined cells exceed the desired target values. In such cases, the additional information renders the problem economically meaningless or unfeasible, as it forces the remaining coefficients in the vector to change signs. Under these circumstances, it becomes apparent that either the target values or the additional information must be reconciled, potentially requiring a compromise, especially when both sets of information are less reliable.

Checklist for designing automatic balancing processes and recommendations

This section presents a checklist for compilers to consult prior to executing the GRAS method during the compilation of ESUTs. It also contains recommendations for using expert knowledge to address the complexities of balancing ESUTs, emphasising the importance of understanding the economic implications of the sourced data.

If the checklist items are incorporated into automatic software scripts (such as those written in R, Python or similar programming languages), the pre-balancing verification can be conducted systematically. Ensuring that this protocol is followed increases the probability of successfully converging the balancing algorithm. This checklist is also valid for matrices with predetermined information.

Checklist for ESUT compilers:

1. Check that the overall row sum matches the overall column sum.
2. For non-negative matrices, check Bacharach's conditions.
3. Check for zero targets with:
    a. all elements non-negative
    b. all elements non-positive
    c. elements positive, negative and zero.
4. Check for negative targets.
5. Check for non-zero targets with null columns and/or rows.

This checklist does not prevent convergence problems from occurring, but it will at least increase the probability of successful convergence.

This chapter aimed to emphasise the importance of careful preparation and verification before employing the GRAS method for balancing ESUTs. Its main conclusions and recommendations are:

- Refer to a checklist to ensure that the overall row sum matches the overall column sum and that the necessary conditions for convergence, such as Bacharach's conditions for non-negative matrices, are met after each iteration.
- Be cautious of potential infeasibilities in each iteration, such as zero targets with all elements null or non-negative or non-positive, and negative targets with non-negative elements, which can lead to convergence issues or economically meaningless results.
- Consider the impact of fixed elements known in advance, as they reduce the degrees of freedom and can increase the sparsity of the matrix, potentially making a feasible problem infeasible.
- Reconcile any discrepancies between the known elements and the target values, especially when both pieces of information are unreliable, to avoid rendering the problem economically meaningless or unfeasible.
- Implement automatic scripts to conduct pre-balancing verification systematically, which can enhance the likelihood of achieving a successful convergence in the balancing process.

These recommendations highlight the importance of understanding the economic implications of the data sources and the complexities involved in the balancing processes.

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Annex 5.A. Costa Rica's experience with ESUTs

This annex describes Costa Rica's experiences with extended supply and use tables (ESUTs), in particular the way they are balanced during a backcasting process.

Costa Rica is a highly open economy. In recent years, exports and imports accounted for 34% and 33% of gross domestic product (GDP), respectively, while foreign share enterprises (FSEs) accounted for approximately 64% of exports and foreign direct investment for around 4% of GDP.

FSEs include multinational corporations that primarily target foreign markets and are connected to different stages within the global value chains, resulting in dissimilar levels of interaction with domestic markets; some of these enterprises have no connection with domestic markets, while others have domestic control enterprises (DCEs) as their main suppliers. FSEs complement domestic savings, transfer technology and knowledge, and generate employment and spillover effects that contribute to economic growth.

This dynamic causes heterogeneity within the economy in many areas, such as income payments to the rest of the world, production functions and foreign content ratios. To deal with these particularities, with the new reference year of national accounts (2017) and under the auspices of the OECD Expert Group on ESUTs, the Central Bank of Costa Rica (CBCR) compiles ESUTs with a bottom-up approach to provide enhanced tools for economic analysis, research and projections. Costa Rica's ESUTs provide a breakdown between DCEs and FSEs for each economic activity.

Long time series are very important for analytical purposes and maintaining the economic history of a country. Given this, as of 2017, the ESUT had a radical change due to the increased granularity by economic activity according to DCEs and FSEs, so it was necessary to revise previously published ESUTs to adapt them to the classification of products/activities and facilitate comparability. This involved the use of balancing methods to extend the main macroeconomic aggregates to 1991 to warrant the coherence of the new economic series with the historical series.

A series of main macroeconomic aggregates, namely gross value added by each industry, final use by component (final consumption expenditure, gross capital formation, exports), imports, taxes less subsidies on products and others, were obtained through bottom-up and interpolation methods. Once the individual consistency of the main macroeconomic aggregates was achieved, the CBCR assessed the integrated coherence for the period 2012-16 using the GRAS method within a SUT framework (i.e. SUT-RAS method). The GRAS worked out adequately despite the large number of columns (more than 140) given the additional ESUT breakdowns in each economic activity. The method seeks to generate ESUTs that are consistent with backwards revised official macroeconomic estimations, ensuring consistency between supply and demand.

GRAS/SUT-RAS to integrate backwards revised data into ESUTs

Concerning the theory and methodology, the CBCR used the SUT-RAS method with an explicit treatment of taxes less subsidies on products and output by industry exogenously available, as described in Section 3.3 in Valderas-Jaramillo et al. (2019[17]). As they show, the SUT-RAS method provides better estimates than other methods such as the SUT-EURO, under the same assumptions and exogenous information. Besides, the SUT-RAS method is a particular case of the GRAS method for balancing supply and use tables all at once (Temursho, Oosterhaven and Cardenete, 2021[12]).

The SUT-RAS method implemented by the CBCR belongs to the RAS family of methods, which are based on biproportional adjustments in the rows and columns of a reference matrix to obtain a new projected matrix. This is done through iterative steps and by solving a restricted optimisation problem, as described in Valderas-Jaramillo et al. (2019[17]).

Following the same notation as in Valderas-Jaramillo et al. (2019[17]), let us assume that supply and use tables of the base year consist of the following components (already including FSEs and DCEs):

- Let $\mathbf{U}^d_{b,0}$ and $\mathbf{U}^m_{b,0}$ be the domestic and imported intermediate uses at basic prices, with dimension product (*p*) by industry (*r*).
- Let $\mathbf{Y}^d_{b,0}$ and $\mathbf{Y}^m_{b,0}$ be the domestic and imported final use matrices, with dimension product (*p*) by final use category (*f*).
- Let $\mathbf{V}_{b,0}$be the transposed supply matrix (*r* x *p*).
- Let $\mathbf{v}_0$ be the vector of gross value added by industry, with dimension (*r* x 1).
- Let $\mathbf{tls}_0$ be the vector of taxes less subsidies on products, with dimension (*r* + *f*) x 1. In turn, this vector is split into two sub-vectors, one for intermediate uses and another for final uses.

$$\mathbf{tls}_0 = \begin{pmatrix} \mathbf{tls}_0^{ID} \\ \mathbf{tls}_0^{FD} \end{pmatrix}$$

Annex Table 5.A.1 depicts the integrated supply and use framework of the base year.

Annex Table 5.A.1. Integrated supply and use framework for the base year*

	Domestic products (p^d)	Imported products (p^m)	Industries (r)	Final use (f)	Total
Domestic products (p^d)			$\mathbf{U}^d_{b,0}$	$\mathbf{Y}^d_{b,0}$	$\mathbf{U}^d_{b,0}\mathbf{i} + \mathbf{Y}^d_{b,0}\mathbf{i} = \mathbf{q}^d_{b,0}$
Imported products (p^m)			$\mathbf{U}^m_{b,0}$	$\mathbf{Y}^m_{b,0}$	$\mathbf{U}^m_{b,0}\mathbf{i} + \mathbf{Y}^m_{b,0}\mathbf{i} = \mathbf{m}_0$
TLS			$\mathbf{tls}_0^{ID\prime}$	$\mathbf{tls}_0^{FD\prime}$	$\mathbf{tls}_0^{ID\prime}\mathbf{i} + \mathbf{tls}_0^{FD\prime}\mathbf{i} = tls_0$
Industries (r)	$\mathbf{V}_{b,0}$				$\mathbf{V}_{b,0}\mathbf{i} = \mathbf{x}_{b,0}$
Imports		$\mathbf{m}_0'$			$\mathbf{m}_0'\mathbf{i} = m_0$
Total	$\mathbf{i}'\mathbf{V}_{b,0} = \mathbf{q}^{d\prime}_{b,0}$	$\mathbf{m}_0'$	$\mathbf{x}_{b,0}' - \mathbf{v}_{b,0}'$	$\mathbf{y}_{p,0}'$	

* All the elements in this table are known.
Note: TLS: taxes less subsidies on products.

Similarly to the original SUT–RAS method (Temurshoev and Timmer, 2011[22]), let **A** be the integrated supply and use framework of the base year, with all elements known:[14]

$$\mathbf{A} = \begin{pmatrix} \mathbf{O}_{(p^d+p^m+1)x(p^d+p^m)} & \overline{\mathbf{U}}_0 \\ \overline{\mathbf{V}}_0 & \mathbf{O}_{(r+m)x(r+f)} \end{pmatrix} \in \mathcal{M}_{(p^d+p^m+r+2)x(p^d+p^m+r+f)} \qquad \text{(A1)}$$

where:

$$\overline{\mathbf{V}}_0 \in \mathcal{M}_{(r+1)x(p^d+p^m)} = \begin{pmatrix} \mathbf{V}_{b,0} & \mathbf{O}_{r\,x\,p^m} \\ 0'_{p^d} & \mathbf{m}_0' \end{pmatrix},$$

are the elements of the supply side for the base year, and

$$\overline{\mathbf{U}}_0 \in \mathcal{M}_{(p^d+p^m+1)x(r+f)} = \begin{pmatrix} \mathbf{U}^d_{b,0} & \mathbf{Y}^d_{b,0} \\ \mathbf{U}^m_{b,0} & \mathbf{Y}^m_{b,0} \\ \mathbf{tls}_0^{ID\prime} & \mathbf{tls}_0^{FD\prime} \end{pmatrix},$$

the extended use matrix for the base year.

Similarly, Table 5.A.2 shows the integrated supply and use framework of the target year.

Annex Table 5.A.2. Integrated supply and use framework of the target year*

	Domestic products (p^d)	Imported products (p^m)	Industries (r)	Final use (f)	Total
Domestic products (p^d)			$\mathbf{U}_{b,t}^{d}$	$\mathbf{Y}_{b,t}^{d}$	$\mathbf{U}_{b,t}^{d}\mathbf{i}+\mathbf{Y}_{b,t}^{d}\mathbf{i}$
Imported products (p^m)			$\mathbf{U}_{b,t}^{m}$	$\mathbf{Y}_{b,t}^{m}$	$\mathbf{U}_{b,t}^{m}\mathbf{i}+\mathbf{Y}_{b,t}^{m}\mathbf{i}$
TLS			$\mathbf{tls}_{t}^{ID\prime}$	$\mathbf{tls}_{t}^{FD\prime}$	tls_t (**)
Industries (r)	$\mathbf{V}_{b,t}$				$\mathbf{x}_{b,t}$ (**)
Imports		$\mathbf{m}_t'$			m_t (**)
Total	$\mathbf{i}'\mathbf{V}_{b,t}$	$\mathbf{m}_t'$	$\mathbf{x}_{b,t}'-\mathbf{v}_{b,t}'$ (**)	$\mathbf{y}_{p,t}'$ (**)	

**Only these elements are known. The others need to be estimated, and unknown totals calculated by summation.
Note: TLS: taxes less subsidies on products.

Analogously, let **X** stand for the supply and use integrated framework for the target year t,

$$\mathbf{X}=\begin{pmatrix}\mathbf{O}_{(p^d+p^m+1)x(p^d+p^m)} & \overline{\mathbf{U}}_t \\ \overline{\mathbf{V}}_t & \mathbf{O}_{(r+m)x(r+f)}\end{pmatrix}\in\mathcal{M}_{(p^d+p^m+r+2)x(p^d+p^m+r+f)} \qquad \text{(A2)}$$

The main objective is to estimate **X,** starting from **A**, in a consistent way using the exogenous information of the target year. The exogenous information and certain accounting identities (restrictions) coming from the integrated supply and use framework are formulated as follows:

Domestic production supply and use balance: $\mathbf{U}_{b,t}^{d}\mathbf{i}+\mathbf{Y}_{b,t}^{d}\mathbf{i}-\mathbf{V}_{b,t}'\mathbf{i}\ =\mathbf{0}$ (A3)

Imports supply and use balance: $\mathbf{U}_{b,t}^{m}\mathbf{i}+\mathbf{Y}_{b,t}^{m}\mathbf{i}=\mathbf{m}_t$ (A4)

Industry output preservation: $\mathbf{V}_{b,t}\mathbf{i}=\mathbf{x}_{b,t}$ (A5)

Imports preservation: $\mathbf{m}_t'\mathbf{i}=m_t$ (A6)

Intermediate consumption preservation: $\mathbf{U}_{b,t}^{d}{}'\mathbf{i}+\mathbf{U}_{b,t}^{m}{}'\mathbf{i}+\mathbf{tls}_t^{ID}=\mathbf{x}_{b,t}-\mathbf{v}_t=\mathbf{IC}_{p,t}$ (A7)

Final use preservation: $\mathbf{Y}_{b,t}^{d}{}'\mathbf{i}+\mathbf{Y}_{b,t}^{m}{}'\mathbf{i}+\mathbf{tls}_t^{FD}=\mathbf{y}_{p,t}$ (A8)

Taxes less subsidies on products preservation: $\mathbf{tls}_t^{ID\prime}\mathbf{i}+\mathbf{tls}_t^{FD\prime}\mathbf{i}=tls_t$ (A9)

It is important to note that since industry output ($\mathbf{x}_{b,t}$) and gross value added ($\mathbf{v}_t$) are exogenous, they are used to set up the restriction (A7) on intermediate consumption at purchasers' prices.

Thus, let a_{ij} be the entries of matrix **A**, x_{ij} the entries of matrix **X**. In addition, z_{ij} is defined as:

$$z_{ij}\ =\begin{cases}\dfrac{x_{ij}}{a_{ij}} & if\ a_{ij}\neq 0\\ 1 & if\ a_{ij}=0\end{cases}$$

Now, the elements of **X** are to be found from the values of z_{ij} that minimise the following objective function ((Huang, Kobayashi and Tanji, 2008, p. 114[6]), equation 6) subject to the restrictions (A3) to (A9).

$$\min_{z_{ij}} \sum_{i} \sum_{j} |a_{ij}| \left(z_{ij} \cdot \ln\left(\frac{z_{ij}}{e}\right) + 1 \right)$$

To address the optimisation problem, the CBCR used a Lagrangian function based on the system of equations (restrictions). The process is carried out iteratively until convergence is achieved, i.e. when the difference between the estimated multipliers of one iteration and the next is smaller than a given tolerance level.

The CBCR implemented this methodology using the R programming language and successfully achieved convergence for the period 2012-16, using 2017 as the reference year. Beyond attaining algorithmic convergence, the CBCR conducted several tests to validate the estimated data. These tests included calculating GDP from the three different approaches (namely from output, income and demand approaches) as well as using professional judgment to assess the results.

The CBCR is currently in the process of updating their national accounts with the new base year of 2022. This update necessitates a similar procedure to adjust the previous ESUTs from 2017-21 to align with the classifications and products of 2022. With additional exogenous data, such as product-specific imports and exports, becoming available, the CBCR plans to make further refinements to the GRAS/SUT-RAS model to enhance the accuracy of their estimates.

Notes

[1] See a complete review of the relevant literature in Chapter 18 of United Nations (2018[1]).

[2] However, this solution does not always turn out to be simply a scaling method. For example, Stone, Champernowne and Meade (1942[27]); Robinson, Cattaneo and El-Said (2001[25]); Golan, Judge and Robinson (1994[24]); Rodrigues (2014[26]); Lugovoy, Vladimirovich Polbin and Potashnikov (2015[28]); and Fernández, Hewings and Ramos Carvajal (2015[23]) also proved the Bayesian approach with success.

[3] RAS-type proportional methods can still provide a solution to the problem although sometimes they are not meaningful in terms of a well-defined constrained optimisation problem with a unique solution.

[4] Other alternative objective functions and different distance measures have been evaluated by the literature (see United Nations (2018[1]), Chapter 18) but are not reported here. It is recommended though to provide information on the adjustments made by the balancing processes under several of those options if time allows, Moreover, sometimes the column and row targets may have lower reliability than some of the inner parts of the matrices, which will require a different approach (e.g. KRAS). This is beyond the scope of this chapter.

[5] If N = 0, then the solution would be *k* = S/P and if P = 0, the solution would be *k* = - N/S (i.e. RAS method).

[6] Sums or subtractions of the elements of submatrices.

[7] These zeros, from a mathematical perspective, limit the degrees of freedom in the optimisation problem. Both the RAS and GRAS algorithms are designed to preserve signs, which means that any zero in the initial matrix will remain zero in the balanced matrix. Therefore, these zero entries can be excluded from the optimisation problem.

[8] Theorem 2 and Corollary 1 (Bacharach, 1965, pp. 301-302[20]).

[9] Theorem 3 and Corollary 2 (Bacharach, 1965, pp. 301-302[20]). If there were several ways to create different null sub-matrices $\mathbf{A}_{I'J}$ (i.e. sub-matrices with different subsets of rows and columns), these two conditions should be checked for all of them. The ı (iota) symbol is a vector of ones and is being used as a summation operator.

[10] $\boldsymbol{\iota}'\boldsymbol{u}_{\boldsymbol{I}'} = 10 \leq \boldsymbol{v}_{\boldsymbol{J}'}\boldsymbol{\iota} = 11$ and $\boldsymbol{\iota}'\boldsymbol{u}_{\boldsymbol{I}} = 5 \geq \boldsymbol{v}_{\boldsymbol{j}}\boldsymbol{\iota} = 4$.

[11] An example is a vector of trade and transport margins that should sum up to zero.

[12] As shown in footnote 4, the GRAS solution (*k*) to the example is *k* = S/P, for N = 0. This implies that all the elements of the vector will change their sign since k < 0 because S < 0. In the next iterations, the solution would be *k* = -N/S > 0, for P = 0 and S < 0. As a result, the algorithm's solution solves a modified optimisation problem with negative elements (after a sign change) and a negative target.

[13] For instance, some elements of a non-negative vector with a zero target can become negative because of a sign shift, thus altering the potential convergence of the GRAS algorithm.

[14] $\mathbf{O}$ and $\mathbf{0}$ are null matrices and vectors, respectively, with appropriate dimensions. $\mathbf{i}$ stands for a unitary column vector of ones.

6. Extended input-output tables

This chapter outlines the strategies and practical guidelines to construct extended input-output tables from extended supply and use tables. It begins with a discussion of the underlying theory of input-output tables. It then considers the choice of dimension for such tables: product-by-product or industry-by-industry. The following section examines construction methods for input-output tables and extended input-output tables. The final section provides concluding remarks and recommendations.

Introduction

This chapter outlines the strategies and practical guidelines to construct extended input-output tables (EIOTs) from extended supply and use tables (ESUTs) based on the literature on the construction of input-output tables (IOTs) from supply and use tables (SUTs). SUTs describe the supply and demand of products by industries, households and government. However, input-output analysis uses IOTs, which are mathematical constructs that describe the supply and demand of products by product-adjusted[1] industries (in product-by-product IOTs) and the supply and demand of industry-adjusted[2] products by industries (in industry-by-industry IOTs). As a result, the problem to derive IOTs is twofold. It consists of adjusting industries in SUTs (by columns)[3] to construct product-by-product IOTs or adjusting products in SUTs (by rows)[4] to construct industry-by-industry IOTs.

The first section of this chapter describes the underlying theory to construct IOTs from SUTs according to the literature. Choices must be made with respect to the dimension of a table, product-by-product or industry-by-industry, and with respect to the method of construction. The next two sections discuss the alternative dimensions of an IOT and an EIOT, respectively. The chapter then discusses the alternative methods of construction of IOTs and EIOTs. The final section provides concluding remarks and practical recommendations for compilers of EIOTs from ESUTs, who must make the two choices.

Underlying theory of input-output tables

This section briefly describes the underlying theory of the methods to construct IOTs from SUTs under a generalised framework based on Rueda-Cantuche (2017[1]) and reported in the United Nations (UN) *Handbook on Supply, Use and Input-Output Tables* (United Nations, 2018[2]). The UN generalised framework considers the amount of product *i* used by industry *j* to produce product *k*:

product $i \rightarrow$ industry $j \rightarrow$ product k

This suggests input-output coefficients a_{ijk}, i.e. with three indices. The industry technology assumption states that an industry uses the same amount of product *i* irrespective of the products it produces (i.e. for all *k*), reduces the number of indices to two[5] and yields a product-by-product[6] IOT. Alternatively, the product technology assumption states that all products have unique input structures, irrespective of the industry of fabrication (for all *j*).

The industry technology assumption yields non-negative IOTs and accommodates rectangular SUTs (different numbers of products and industries). The product technology assumption yields square IOTs (equal numbers of products and industries), with some cells possibly negative. The final use components of the use tables remain unchanged in product-by-product IOTs.

A similar framework can be set up in terms of the contribution of product *i* to the delivery from industry *j* to industry *k*:

industry $j \rightarrow$ product $i \rightarrow$ industry k

This suggests input-output coefficients a_{jik}, i.e. with three indices. The fixed industry sales structures assumption states that all industries have unique sales structures to other industries, irrespective of the products they produce (for all *i*), reduces the number of indices to two and yields an industry-by-industry IOT. Alternatively, the fixed product sales structures assumption states that all products have unique output structures, irrespective of the supplier industry (for all *j*).

The fixed product sales structures assumption yields non-negative IOTs and accommodates rectangular SUTs. Conversely, the SUTs need to be square if fixed industry sales structures are assumed and this assumption may yield new negatives in the resulting IOT. The fixed industry sales structures assumption yields square IOTs with some cells possibly negative. The gross value added components of the use tables remain unchanged in industry-by-industry IOTs.

For details about the different methods of construction of IOTs from SUTs, see Chapter 12 and annexes in United Nations (2018[2]), Beutel (2017[3]), and Eurostat (2008[4]), including the breakdown of domestic and import use matrices.

Product-by-product versus industry-by-industry input-output tables

This section discusses the choice of dimension of an IOT, either product-by-product or industry-by-industry. Rueda-Cantuche (2017[1]) reviewed the literature on the choice of dimension of an IOT, specifically comparing product-by-product and industry-by-industry IOTs. Prior to the 2008 System of National Accounts (European Commission; IMF; OECD; UN; World Bank, 2009[5]), industry-by-industry IOTs were not considered as useful as product-by-product IOTs. This was mainly because final use components are rarely expressed in terms of industries and that an industry group might be less realistic due to the estimation methods used to obtain an overall total industry output of the domestic economy.

The 2008 System of National Accounts was the first to acknowledge that IOTs of different dimensions serve different analytical purposes and recognised a change of emphasis from product-by-product IOTs to industry-by-industry IOTs (para. A4.21). On the European side, neither the 1995 European System of Accounts (Eurostat, 1995[6]) nor the 2010 European System of Accounts (Eurostat, 2013[7]) explicitly mentioned the issue of the choice of the dimension of an IOT. However, *Eurostat Manual of Supply, Use and Input-output Tables* (Eurostat, 2008, p. 301[4]) recognised the pros and cons of the use of product-by-product IOTs and industry-by-industry IOTs. In this sense:

- Product-by-product IOTs are theoretically more homogenous than industry-by-industry ones since a single element of the industry-by-industry IOTs can refer to products that are primary for other industries as well.
- Product-by-product IOTs have clearer input structures in terms of products and factor inputs used. Industry-by-industry IOTs report mixed bundles of goods and services produced within each industry.
- Industry-by-industry IOTs are more transparent in the sense that their construction is relatively simple and often easily traceable back to the original (rectangular) SUTs when using the fixed product[7] sales assumption. This is not the case for the product[8] technology assumption for product-by-product IOTs, as it requires a procedure after removing the negative coefficients that may arise.
- Industry-by-industry IOTs are close to national accounts data and their statistical sources while product-by-product IOTs have been compiled using analytical methods (e.g. to remove negatives) that result in less comparability with original data sources and, sometimes, across countries.
- Product-by-product IOTs are well suited for specific analytical purposes involving homogenous products (e.g. environmental and energy policies, productivity-related analysis, or the analysis of new product technologies in the economy). However, industry-by-industry IOTs are well suited for other types of analyses such as tax reforms or employment impacts of industrial, fiscal and monetary policies. While this distinction and list of potential applications might be useful, there is currently no clear guidance on the choice of IOT dimension in the literature.

Another important aspect highlighted by Eurostat (2008[4]) is the relevance of secondary production in the choice of the dimension of an IOT. Relatively low levels of secondary production reported in the supply tables would imply that the distinction between products and industries would become superfluous, thus making the dimension of the IOT a minor issue. However, the level of secondary activities can vary considerably across industries and most times the choice of type of IOT is relevant.

Rueda-Cantuche (2011[8]) and Lenzen and Rueda-Cantuche (2012[9]) advocate the use of SUTs instead of product-by-product IOTs and industry-by-industry IOTs for impact analysis. This alternative approach has the potential to circumvent product-by-product and industry-by-industry IOT issues, which are due to the symmetry of their dimensions, unlike the SUTs, which have a product-by-industry dimension. For instance, environmental policies can alter households' consumption patterns of products, which may affect the employment of industries (not products). Another example is the price effects on products (not industries) due to increased costs in the labour inputs used by industries.

As also noted by United Nations (2018[2]), users of IOTs will often be required to choose the dimension of an IOT – product-by-product or industry-by-industry – rather than the type of technology or sales assumption that has been applied (as explained in the next section). This is because users often need to combine the IOTs with other types of data to conduct their analysis. For many types of analysis, the IOTs must be combined with structural or time series data, which are based on industry-based classifications, such as energy and productivity analysis. For other types of analysis, such as those related to prices, the matching data are usually available and based on products.

However, as shown by Rueda-Cantuche (2011[8]) and Lenzen and Rueda-Cantuche (2012[9]), the chosen dimension of an IOT should not exclude *a priori* any type of analysis. This is because the information contained in the supply table can be used to transform product-classified data into the industry classification, and vice versa[9] (United Nations, 2018[2]).

Product-by-product versus industry-by-industry extended input-output tables

This section elaborates on the choice of the dimension of an EIOT, taking into account the product and industry dimensions of the ESUTs. EIOTs are preferably derived from ESUTs. The additional information by size, ownership and/or export orientation, by either products or industries, provides a better statistical ground to compile EIOTs and even subsequent regular IOTs, by aggregation. The use of enterprise heterogeneity data provides new insights into the input structures of industries and product deliveries that could not be captured otherwise. Alternatively, although EIOTs could also be constructed based on regular IOTs, the information required to break down product-adjusted industries into product-by-product IOTs (i.e. columns) is not readily available or directly observable in enterprise surveys. The same applies to the required information to split industry-adjusted products (i.e. rows) into industry-by-industry IOTs.

United Nations (2018, p. 397[2]) provides a compelling illustration of how industry-by-industry IOTs generated from rectangular SUTs (which have more products than industries) can produce different outcomes compared to those derived from aggregated SUTs (where the number of products and industries are equal), even when both are built on the premise of fixed product sales structures.

When building EIOTs from ESUTs, similar to standard IOTs, the initial step is to choose the dimension of the IOT – product-by-product or industry-by-industry. Next an assumption for its construction must be selected, which involves deciding how to handle secondary products or industries.

Breakdown only by industries

Assuming square[10] or rectangular ESUTs with more industries than products, due to the breakdown of certain industries by size, ownership and/or export status, the construction of product-by-product EIOTs would imply the same input structures[11] across various sizes of enterprises (multinational enterprises [MNEs], small and medium-sized enterprises [SMEs], etc.) and/or different types of enterprises (by ownership or export status). Indeed, this is precisely the limitation that ESUTs seek to address, thus making little sense in this case[12] to construct product-by-product EIOTs (i.e. product-by-industry adjusted products). Therefore, when breaking down industries only, industry-by-industry EIOTs have the recommended dimension, irrespective of the dimensions of the regular SUTs.

Breakdown only by products

Analogously, assuming square[13] or rectangular ESUTs with more products than industries, due to the breakdown of certain products by the size, ownership and/or export status of the industries that produce them, the construction of industry-by-industry EIOTs would imply the same output structures[14] across various extended types of products within industries. Similarly, this is particularly the caveat that ESUTs seek to address, thus making little sense to compile industry-by-industry EIOTs (i.e. product-adjusted industries by industry). Therefore, when breaking down products only, product-by-product EIOTs have the recommended dimension, irrespective of the dimensions of the regular SUTs.

However, due to the lack of observable data on product breakdowns and the existing experience of national statistical offices, real examples of breakdowns by product only are seldom found.

Breakdown by industries and products

When both industries and products are broken down simultaneously, there is no specific criterion to determine the most suitable dimension of the EIOT, unless either industries (or products) are split into more types of categories than products (or industries) are. If industries are categorised by size (small, medium and large) and ownership (foreign and domestically owned) into six categories, it would be best to create industry-by-industry EIOTs to maintain the detailed information captured by the extended ESUTs. This is especially important because products may only be categorised by size due to limited survey-based data.[15]

The most common breakdown of regular SUTs leads to the same numbers of extension categories by industries and by products and hence yields square EIOTs. In this case, the choice of the dimension of the EIOT can be driven by the purpose of the analysis, as described for regular IOTs.

Construction methods for input-output tables

This section addresses the choice of assumption in the construction of product-by-product and of industry-by-industry IOTs.

From national statistical offices' current experiences, the fixed product sales structures assumption is the preferred option to compile industry-by-industry IOTs. It seems logical to assume that the market sales structure of products remains unchanged independent of who the supplier industries are. In other words, secondary outputs typically have different destinations than the primary outputs (Thage and Ten Raa, 2006[10]; Yamano and Ahmad, 2006[11]).

Likewise, the product technology assumption is generally the preferred option to compile product-by-product IOTs, although limited by its requirement to have the same number of industries as products and the potential negatives that may arise. It seems logical to assume that one product can be produced with a unique input structure irrespective of the industry that actually produces it. Indeed, at a microdata level, the product technology assumption seemed to work best in the tests provided by Mattey and Ten Raa (1997[12]) and Ten Raa and Rueda-Cantuche (2013[13]). Moreover, Steenge (1990[14]) and Konijn (1994[15]) showed that it is theoretically possible to find a non-negative IOT using the product technology assumption.

However, the theoretical properties of input-output coefficients determine the superior model/assumption based on the fulfilment of the so-called material balance, financial balance, price invariance and scale invariance axioms[16] (Rueda-Cantuche, 2017[1]; Kop Jansen and Ten Raa, 1990[16]; Ten Raa and Rueda-Cantuche, 2003[17]; Rueda-Cantuche and Ten Raa, 2009[18]). In the case of product-by-product IOTs, the product technology assumption satisfies all four axioms, whereas for industry-by-industry IOTs, it is the fixed industry sales structures assumption that satisfies all of them.

Hybrid technology assumptions have gained importance in national statistical offices' compilation practice. For product-by-product IOTs, the common practice is to use the product technology assumption and then treat the biggest negatives[17] as potential errors of measurement and/or aggregation. The industry technology assumption is used as a last resort to remove negative coefficients or when the bundle of products under one single industry is highly heterogeneous. This practice has been confirmed by a survey conducted by Eurostat among the EU member states (Eurostat, 2015[19]). For industry-by-industry IOTs, the practice is more straightforward since the fixed product sales structures assumption does not yield negatives by definition.

Rueda-Cantuche and Ten Raa (2013[20]) proposed an econometric framework using surveyed enterprises' data to help IOT compilers to construct product-by-product IOTs, identifying the assumption that fits best with the empirical evidence, either the product technology assumption or the industry technology assumption. These tests lead to statistically significant conclusions that complement experts' judgement in the compilation process. The Statistical Institute of Catalonia (IDESCAT, 2015[21]) successfully used this approach for the compilation of the 2011 IOTs of Catalonia. The power of these tests can be affected by the heterogeneity in the product classification, the lack of granularity in the surveyed data and/or potential errors of measurement at the establishment level. Conversely, industry-by-industry IOTs do not admit similar econometric tests.

Construction methods for extended input-output tables

This section provides further insights into the choice of assumption for EIOTs, for both product-by-product and industry-by-industry tables, based on the actual dimensions of the ESUTs.

The choice of assumption for the construction of EIOTs highly relies on their own definitions. For product-by-product EIOTs, the product technology assumption is the only one that allows one differentiated product technology for each category of enterprises (e.g. SMEs, MNEs, etc.) independent of the industry that actually produces them. Otherwise, differentiated products are assumed to be produced with the same industry technology.

For industry-by-industry EIOTs, the fixed product sales structures assumption is the only one that allows differentiated sales structures for each of the different products produced by SMEs, MNEs, etc., independent of the industry that actually produces them. Otherwise, the fixed industry sales structures assumption would imply that, for instance, differentiated products produced typically by SMEs and MNEs would have the same sales structure as other industries that can actually produce them, as secondary output.

Table 6.1 summarises the guidance and recommendations for the choice of assumption in the construction of EIOTs and provides information about the assumptions that might yield negative values. In essence, the recommended assumptions are those allowing capturing the heterogeneity in categories by size, ownership, etc. of ESUTs, i.e. the product technology assumption for product-by-product EIOTs and the fixed product sales structures assumption[18] for industry-by-industry EIOTs. This also reflects the standard practice of national statistical offices.

Table 6.1. The choice of assumption for extended input-output tables: Extensions by size, as example

	Product technology assumption	Industry technology assumption	Fixed industry sales structures	Fixed product sales structures
Assumption	**MNEs and SMEs** have **DIFFERENT technology** for the production of their respective differentiated products	**MNEs and SMEs** have the **SAME technology** for the production of their respective differentiated products	**MNEs and SMEs** have the **SAME fixed sales structures** as the industry that actually produces their respective differentiated products	**MNEs and SMEs** have **DIFFERENT fixed sales structures** for their respective differentiated products
Dimension	Product	Product	Industry	Industry
Negatives	Yes	No	Yes	No

Note: MNE: multinational enterprise; SME: small and medium-sized enterprise.

Concluding remarks and recommendations

This section provides concluding remarks and practical recommendations for compilers of EIOTs from ESUTs regarding the choice of type of EIOT and the choice of assumption to construct product-by-product and industry-by-industry EIOTs.

When constructing EIOTs from ESUTs, as for regular IOTs, one must first decide on the type of IOT[19] – product-by-product vs. industry-by-industry – then choose an assumption for its construction – a way to treat secondary products or industries (Rueda-Cantuche, 2017[1]).

Regarding the choice of the dimension of an EIOT, industry-by-industry EIOTs are preferable when the regular SUTs are broken down by industries only; analogously, product-by-product EIOTs are the preferred option when breaking down products only, although this is much less observable from national statistical offices' current experience.

If products and industries are broken down simultaneously into a different number of categories/dimensions,[20] it would be best to create industry-by-industry EIOTs to maintain the detailed information captured by the ESUTs, particularly when the number of industry categories is greater than the number of product categories. Otherwise, product-by-product EIOTs would be advisable but less likely given the lack of available survey-based data to break down products into much more detail than industries.

The typical scenario involves breaking down square regular SUTs into the same number of industry and product categories, resulting in the construction of square EIOTs. In this situation, the selection of the dimension of an EIOT would be solely determined by the specific purpose of the analysis, similar to the approach used for regular IOTs.

Regarding the choice of assumption for the construction of product-by-product EIOTs, the preferred option is the product technology assumption, for which, for instance, MNEs and SMEs have different technologies for the production of their respective differentiated products, independent of the industry that actually produces them. As usual, this assumption requires square ESUTs and a special treatment of the resulting negatives. This is in line with the theoretical approach of the existing literature and national statistical offices' current practice for regular IOTs.

For industry-by-industry EIOTs, the preferred option is the fixed product sales structures assumption, for which, for instance, MNEs and SMEs have different sales structures for their respective differentiated products, independent of the industry that actually produces them. Opposite to product-by-product EIOTs, this assumption requires neither square ESUTs nor any special treatment of negatives.

Another important finding for EIOT compilers is that ESUTs, when broken down by industries only (rectangular), can be used to generate fully fledged industry-by-industry EIOTs, assuming a fixed product sales structures across different industry categories. This becomes especially important when resources are limited and only industry breakdowns are feasible. Similar reasoning applies to ESUTs broken down by products only, although it is less common due to the lack of observable data for product breakdowns. Additionally, the fact that the preferred option (i.e. product technology assumption) requires square ESUTs makes it more challenging, unless the less preferred industry technology assumption is used.

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Notes

[1] As described in United Nations (2018, pp. 373-374[2]).

[2] As described in United Nations (2018, pp. 373-374[2]).

[3] This also includes adjustments to the components of the gross value added and taxes less subsidies on products by industries. However, the final use components remain unchanged.

[4] This also includes adjustments to the final use components by product. However, gross value added and taxes less subsidies on products remain unchanged.

[5] Other reductions are not considered here, e.g. using base year prices or different units of measurement.

[6] Strictly speaking, the two dimensions are "product-by-product adjusted industries" but for simplicity, they are denoted as product-by-product IOTs. The same applies for industry-by-industry IOTs, i.e. "industry-adjusted product by industry", as stated in United Nations (2018, pp. 373-374[2]).

[7] This assumption is the preferred option for most of the national statistical institutes (Eurostat, 2008[4]) to compile industry-by-industry IOTs.

[8] This assumption is the preferred option for most of the national statistical institutes (Eurostat, 2008[4]) to compile product-by-product IOTs.

[9] A recent example is Ten Raa and Stahlie's (2024[23]) footprint analysis.

[10] Square ESUTs here refer to rectangular SUTs with more products than industries, which become square ESUTs because of the new extensions by industries.

[11] This is independent of how the EIOT is constructed, with either the product technology assumption for square ESUTs or the industry technology assumption for rectangular ESUTs.

[12] This might seem contradictory since many observations to estimate the proportions between inputs and outputs should better inform the aggregated estimated technical coefficients. However, if the primary objective is to develop an extended industry-by-industry IOT that explicitly includes new industry extensions (for example, by size), it stands to reason that generating a product-by-product extended IOT would hide the industry heterogeneity (such as size distinctions), thereby rendering the extension of the SUTs ineffective.

[13] This applies to rectangular SUTs with more industries than products that become square ESUTs because of the new extensions by products.

[14] This is independent of how the EIOT is constructed, with either the fixed industry sales structures assumption for square ESUTs or the fixed product sales structures assumption for rectangular ones.

[15] The reasoning is similar when the number of product categories is greater than the number of industry categories, but less frequent, if not inexistent.

[16] For the material balance axiom, the theoretical intermediate input requirements by product must be equal to the observed values in the use table. For the financial balance axiom, the theoretical intermediate costs of each industry must be equal to the observed costs in the use table. For the price invariance axiom, input-output coefficients must remain unchanged with respect to units of measurement. For the scale invariance axiom, input-output coefficients must not change when industry inputs and outputs vary proportionally. See Rueda-Cantuche (2017[1]) for a summary of the theoretical framework, theorems and properties.

[17] See United Nations (2018[2]) and Rueda-Cantuche (2017[1]) for a comprehensive list of the methods and solutions used for the treatment of negatives.

[18] Sallusti, Pallott and Cuicchio (2024[22]) already follow this approach for the compilation of the Italian ESUTs.

[19] There could be a previous step that is to decide whether to use ESUTs directly for impact analysis instead of EIOTs (see, for example, Rueda-Cantuche (2011[8]); Lenzen and Rueda-Cantuche (2012[9]); Ten Raa and Stahlie (2024[23])). Following this argument, the choice of dimensions (product-by-product, industry-by-industry or product-by-industry) should better be problem-driven, e.g. footprints are emissions (by industry) related to consumptions (by product) that are better suited for SUTs than for IOTs. Notwithstanding the importance of this issue, this chapter only focuses on providing guidelines for the use of EIOTs in impact analysis.

[20] Typically, more industry categories than product categories due to the lack of observable data.

7. Adding partner country information to extended input-output tables and compiling an extended multi-country input-output table

This chapter provides guidance to compilers of extended supply and use tables and extended input-output tables for adding country detail to exports and imports and explains how to integrate an extended input-output table into a multi-country input-output table (MCIOT). It briefly describes three different approaches. Finally, it discusses how to split an MCIOT by ownership, foreign or domestic.

Introduction

This chapter provides guidance to compilers of extended supply and use tables (ESUTs) and extended input-output tables (EIOTs) for adding country detail to exports and imports and explains how to integrate an EIOT into a multi-country input-output table. There are three different approaches that compilers can take, depending on their analytical aims and the available dataset. This chapter briefly describes them, sorted by increasing difficulty and data requirements. First, countries can add partner country detail to exports and imports in their EIOT, or even integrate their EIOT into an MCIOT. This allows seeing how different types of enterprises are connected to the world economy, e.g. whether small and medium-sized enterprises (SMEs) are well-connected to emerging markets with high growth or whether they are missing out. Second, international organisations (e.g. the OECD) may want to improve the quality of globalisation indicators (such as national trade in value added or employment and emissions related to trade) by taking into account that processing exporters[1] account for a large part of production in some countries. They are very different from regular exporters. This information is policy-relevant. Therefore, the OECD MCIOT distinguishes between processing trade and regular trade for industries in the People's Republic of China (hereafter "China") and Mexico. Preferably, national ESUTs are created first, transformed into national EIOTs then integrated into MCIOTs. A third approach is to split each industry in each country into an MCIOT by enterprise characteristics (e.g. foreign/domestic ownership). In other words, this approach compiles an extended MCIOT. Cai, Miroudot and Zürcher (2023[1]) describe the *OECD Analytical AMNE Database*, which is an example of this approach that allows to analyse the role of multinational enterprises (MNEs) in global value chains.

General background

Over the past years, several institutions have developed MCIOTs. Examples are the OECD and WTO's Trade in Value Added (TiVA) (see, for example, OECD and WTO (2013[2]); Yamano et al. (2022[3])), Eurostat and the JRC's FIGARO (Remond-Tiedrez and Rueda-Cantuche, 2019[4]), and the Asian Development Bank's MCIOT.[2] Table 7.1 provides an example.

Table 7.1. Multi-country input-output table in basic prices, a two-country, two-industry example

		Intermediate demand				Final use		
		Country A		Country B		Country A	Country B	Output
		Industry 1	Industry 2	Industry 1	Industry 2			
Country A	Industry 1							
	Industry 2							
Country B	Industry 1							
	Industry 2							
Value added								
Output								

These new data have brought new insights. For example, they provide alternative views on bilateral trade balances, quantification of the indirect involvement of non-trading industries (e.g. supporting services for exporting industries) and information about high international fragmentation of manufacturing processes. National EIOTs have several advantages. It is, therefore, not surprising that an extended MCIOT, where industries are split by another dimension, has benefits as well. For example, the literature shows that the direct trade of SMEs, compared to large enterprises, is relatively more focused on countries close by. But how does this work out for indirect trade? Can SMEs benefit from economic growth in emerging markets without exporting there themselves? Extended MCIOTs will also yield new insights related to specific types of enterprises regarding environmental pressure, social-economic responsibilities in the value chain (due diligence), dependence on specific countries, inflationary shocks, etc. Answering such questions is possible with an MCIOT, where each industry in each country is split by the desired dimension, but it is not always feasible nor necessary. It may not be feasible, since a national statistical office might have trouble finding the necessary data outside its own country. It may not be necessary, since splitting only the industries in the domestic economy might already be sufficient to answer the questions at hand.

Adding partner country detail to exports and imports in national extended input-output tables

There have been several projects where partner country detail has been added to the exports and imports in national ESUTs and EIOTs. Chong et al. (2019[5]) use their EIOT for the Netherlands and add the country dimension for trade in goods only. They find that SMEs have a much larger share in value added embodied in exports to China and the United States than their share in the gross exports to these countries. OECD and Statistics Denmark (2017[6]) created three types of MCIOTs where the domestic economies of Denmark, Finland, Iceland, Norway and Sweden were split by a given dimension. These three types were size, ownership and trader status. They found a similar pattern as in the Netherlands. Namely, that larger enterprises export relatively more to distant markets than SMEs in gross exports terms but that the differences are far smaller in trade in value-added terms. Michel and Hambÿe (2022[7])[3] compile an EIOT for Belgium where manufacturing is split into foreign-oriented and domestic-oriented enterprises. They add the country dimension by integrating their EIOT into an MCIOT. Among others, they use it to estimate employment sustained in direct exports to a country and exports to a country via the value chain.

Data sources

Generally, the data sources are the same as described in Chapter 2, 3 and 4. The only additional information is the country dimension of imports and exports that can be found in trade statistics. Note that Chong et al. (2019[5]) and Michel and Hambÿe (2022[7]) consider trade in goods only. OECD and Statistics Denmark (2017[6]) consider trade in services as well, but since data are lacking, they use proxies from trade in goods. For example, they assume that in each industry the share of the SMEs' exports of services to the United States is equal to the share of the corresponding exports of goods to the United States.

Methods

Chong et al. (2019[5]) do not embed their EIOT in an MCIOT; hence it is sufficient to add the country information in a similar way as they assign imports and exports in an industry to each type of enterprise.

OECD and Statistics Denmark (2017[6]) used software that was run at the national statistical offices of the five countries involved. The national statistical offices compiled datasets about trade, split by industry, type of enterprise, good and country, from the microdata. First, the data were used to create a national EIOT with total imports and exports, as described in Chapter 4. The basis for the national input-output table (IOT) was the OECD's MCIOT. Then the geographical detail was added to imports and exports, embedding the extended table in the OECD MCIOT. This involved two major steps. First, the data from trade statistics might have zero imports from a country or zero exports to a country for a given type of enterprise in a given industry, whereas this is not the case in the EIOT. For example, enterprises that have no imports in the microdata might import via wholesalers. Then there is no country breakdown in the microdata, hence the country breakdown will follow that of the MCIOT. Second, total trade of an industry with a country will be different in the microdata and the MCIOT. Therefore, trade flows were distributed stepwise (increments of 1%) to countries, using the information in the microdata. As soon as assigned trade to a specific partner country was equal to the value in the MCIOT data, this country was no longer used for further distribution of trade.

Michel et al. (2023[8]) integrated their EIOT into an MCIOT created by the *World Input-Output Database* (WIOD) project (Timmer et al., 2015[9]). They note that the intermediate structure of their IOT is, with good reason, different from that in WIOD. This problem does not exist in OECD and Statistics Denmark (2017[6]) since they use the OECD MCIOT as a basis for the national IOT. The Belgian approach consists of five steps. They start by converting the Belgian data from euros into dollars. In the second step, they use the Belgian microdata to determine the country distribution of exports and imports of export-oriented manufacturers. Next, they assign the use of Belgian exports among the various categories in the destination countries by using proportions from WIOD. In the fourth step, all data about Belgium in the WIOD data are replaced by the Belgian data. Namely, the data about domestic transactions and about the foreign transactions from the previous step. This leads to an imbalanced MCIOT; hence, they use a RAS procedure (Junius and Oosterhaven, 2003[10]) to adapt the data for all countries except Belgium in the fifth and final step. The result is an MCIOT consistent with the Belgian EIOT.

Embedding the national extended input-output tables for one country into a multi-country input-output table

This section explains how to take the national EIOT of a given country and embed it into an MCIOT. In other words, the imports (exports) of industries split by the chosen extension criterion are disaggregated by the producing (receiving) industries and countries abroad. Table 7.2 shows an example. Here the EIOT of country A, where industries in the national IOT were extended by size class, is embedded in the MCIOT shown in Table 7.1.

Table 7.2. Multi-country input-output table in basic prices, a two-country, two-industry example, industry extended for one country

			Intermediate demand						Final use		
			Country A				Country B		Country A	Country B	Output
			Ind 1	Ind 1	Ind 2	Ind 2	Ind 1	Ind 2			
			SME	Large	SME	Large					
Country A	SME	Ind 1									
	Large	Ind 1									
	SME	Ind 2									
	Large	Ind 2									
Country B		Ind 1									
		Ind 2									
Value added											
Output											

Note: ind: industry; SME: small and medium-sized enterprise; Large: large enterprise.

The approach is based on the description by Yamano et al. (2022[3]) of the methods used to compile the OECD MCIOT. Part of that text explains how the OECD splits several industries in China and Mexico for TiVA purposes. For China, industries are split into domestic suppliers, processing exporters and non-processing exporters. For Mexico, industries are split into domestic suppliers and global manufacturers. This addresses the substantial heterogeneity within these industries by taking into account that enterprises who produce for the domestic market are very different from those who produce for the global market. By definition, the production of enterprises who produce for the domestic market hardly goes abroad, and it is known that they import less as well. With the extension of the MCIOT, indicators about, for example, imports in exports, value added in exports and employment in exports will be less biased than with a standard MCIOT. See Table 7.2 for a fictitious example. Besides higher quality indicators, the new data also provide additional policy-relevant information. For example, in the case of China, it was relevant to know how exports of domestic produced goods fare on the world market and how they are used subsequently. Using a standard MCIOT, this is not possible, since the exports of a domestic industry are combined with the exports of the corresponding processing industry into one number.

Note that the method is similar to that of embedding a subnational IOT of a given country into an MCIOT, as in Meng, Zhang and Inomata (2013[11]) and Meng and Yamano (2017[12]).

Data sources

There are three different data sources:

- The annual MCIOTs used to estimate the extended MCIOT in Yamano et al. (2022[3]) come from the 2021 edition of the OECD MCIOT Database (http://oe.cd/icio). These industry-by-industry MCIOTs at basic prices cover 67 economies and 45 industries.
- Ideally, extended national IOTs are available. The extended input-output structures of reference years are provided by Mexico's National Institute of Statistics and Geography (INEGI) and the Chinese Academy of Sciences, respectively.
- If national EIOTs are not available, customs trade statistics and balance of payments statistics can complement the missing industrial activity information.

In the case of China, since the customs data (General Administration of Customs, China) are available for different enterprise groups (domestic, processing exporters and non-processing exporters), the different column constraints (products imported by different enterprise groups) are available to improve the quality of the import matrices.

Methods

The process consists of several steps. In brief:

1. Adapt the national EIOT to the classifications, concepts, etc. of the MCIOT.
2. Obtain constraints for several variables in the EIOT, by industry and by type of enterprise, based on the corresponding numbers in the MCIOT by industry.
3. Adapt the numbers in the resulting EIOT such that aggregating to a national IOT corresponds with the numbers of the country in the MCIOT.
4. Balance the international trade flows by enterprise characteristics.

In the first step, the national EIOT is adapted to the MCIOT. This procedure includes the conversion to basic prices, harmonisation of industry classifications, reconciliation of the expenditure items of the final use, the estimation of an import matrix, the removal of re-exports and the transfer of re-imports to domestic transactions. If the national IOT is only available in a product-by-product format, the inter-industry intermediate transactions are converted to an industry-by-industry format using the product supply ratios from the supply table.[4] After this process, aggregating the national EIOT to a national IOT yields something similar to the national part of the MCIOT, but the numbers will be different.

In the second step, the constraints for the data in the EIOT, by industry and by type of enterprise, are derived to match those in the MCIOT. To be more specific, output, value added, trade flows and domestic expenditure items have to be the same as the country's total figures in the aggregated MCIOT, by industry and type of final use. Output and value added in each industry *i* are constrained by the country aggregate MCIOT as:

$$\text{Output:} X_{ip}^{A} + X_{in}^{A} = \tilde{X}_{i}^{A}$$

and

$$\text{Value added:} V_{ip}^{A} + V_{in}^{A} = \tilde{V}_{i}^{A}$$

where X_{ip}^{A} and V_{ip}^{A} represent the output and value added of processing manufacturers and X_{in}^{A} and V_{in}^{A} are those for other manufacturers, respectively, while $\tilde{X}_{i}^{A}$ and $\tilde{V}_{i}^{A}$ are, respectively, the output and value added of industry *i* in country *A* from an MCIOT. The notation $\tilde{}$ indicates the country constraint variables from the cells aggregated in the reference MCIOT.

Set *A* as the country under concern. Set EX_{ip}^{AC} and EX_{in}^{AC} as the cross-border exports from processing exporters and non-processing exports from industry *i* of country *A* to importing partner country *C*, respectively. Set $\widetilde{EX}_{i}^{AC}$ as the exports of products in a reference MCIOT. Similarly, $\widetilde{IM}_{i}^{CA}$ is the variable for intermediate imports by industry *j* of country *A* from exporting partner country *C* in the MCIOT. Then set the following cross-border constraints:

$$\text{Exports: } EX_{ip}^{AC} + EX_{in}^{AC} = \widetilde{EX}_{i}^{AC}$$

$$\text{Imports: } IM_{ip}^{CA} + IM_{in}^{CA} = \widetilde{IM}_{i}^{CA}$$

The next part of this second step is only specific to the case under concern: processing trade. This production is for foreign markets only, but indirectly, domestic consumption might take place anyway. Therefore, the trade data have to be adapted slightly. In other cases, e.g. a national EIOT by ownership, this part is not necessary, and in trade only the constraints for exports and imports should be set into place.

By definition, products manufactured by processing exporters are not immediately consumed within the domestic territory in the single country (extended) input-output framework. This leads to the equation:

$$X_{ip}^{A} = EX_{ip}^{A}$$

where EX_{ip}^{A} is exports of products produced in country *A*'s processing trade industry. However, the exported products manufactured in the export processing zones can still be consumed by the domestic residents in the multi-country framework via direct purchases abroad. On the other hand, foreign resident households cannot consume the products from the export-processing zones in country *A* since these products are only sold abroad.

To tackle this issue, the inter-country exports and imports flows must be explicitly separated into direct purchases and cross-border trade flows in the MCIOT framework. Direct purchases of non-residents in country *A*'s territory are constrained as:

$$DP_{in}^{A} = \sum_{C} \widetilde{DP}_{i}^{AC}$$

where DP_{in}^{A} is direct purchases of product *i* by all non-residents in country *A* and $\widetilde{DP}_{i}^{AC}$ is direct purchases by country *C*'s residents for product *i* of country *A*. By definition, DP_{ip}^{A}=0, since products manufactured by processing exporters cannot be obtained in country *A*.

Since the products from processing manufacturers are all exported, domestically produced goods used for domestic final use are all produced in the non-processing manufacturing industries. This leads to two additional constraints, namely:

$$FA_{\boldsymbol{in}}^{\boldsymbol{A}} = \widetilde{FA}_{\boldsymbol{i}}^{\boldsymbol{A}} \text{ and } FA_{ip}^{A} = 0$$

where $FA_{\boldsymbol{in}}^{\boldsymbol{A}}$ is the final use expenditure in country *A* of products produced by the domestic non-processing trade industry *i*, $\widetilde{FA}_{\boldsymbol{i}}^{\boldsymbol{A}}$ is the final use expenditure in country *A* of products produced by the domestic industry *i* in the MCIOT and $FA_{\boldsymbol{ip}}^{\boldsymbol{A}}$ is the final use expenditure in country *A* of products produced by the domestic processing trade industry *i*.

These steps lead to constraints on output, value added, imports, exports and domestic final use expenditure, by industry and by type of enterprise.

The third step rebalances the national EIOT to the constraints given by the MCIOT. This can be achieved using a variant of bi-proportional adjustment methods such as the conventional RAS and GRAS methodologies (Junius and Oosterhaven, 2003[10]; Temurshoev, Miller and Bouwmeester, 2013[13]).

The fourth step balances the international trade flows by enterprise characteristics. In the previous step, the trade flows in the national EIOT were fully reconciled with the trade flows derived from an MCIOT. There was not yet a country extension of imports and exports in the national EIOT. This final step is for this remaining adjustment.

The intermediate exports from country *A* (with the EIOT) to trade partner country *C* are the sum of exports from the processing exporters and non-processing exporters:

$$Z_{ip,j}^{AC} + Z_{in,j}^{AC} = \tilde{Z}_{ij}^{AC}$$

where $Z_{ip,j}^{AC}$ is intermediate exports by industry *i* from country *A* to country *C*'s industry *j* from processing exporters and $Z_{in,j}^{AC}$ is intermediate exports from non-processing exporters, and $\tilde{Z}_{ij}^{AC}$ is intermediate exports in the MCIOT.

Now assume that the trade partner shares are equal for processing exporters and non-processing exporters, hence equal to the trade partner shares calculated from an MCIOT. This leads to initial values for the bilateral trade flows for intermediate and final products.

The trade for final use is also the sum of exports from processing and non-processing exports:

$$F_{ip}^{AC} + F_{in}^{AC} = \tilde{F}_{i}^{AC}$$

where F_{ip}^{AC} denotes exports by industry *i* in country *A* for final use in country *C* by processing exporters, F_{in}^{AC} is the same for exports by non-processing exporters and $\tilde{F}_{i}^{AC}$ is the corresponding entry in the MCIOT.

The exports from country *A* to all partners are constrained to the exports in the national EIOT as:

$$EX_{ip}^{A} = \sum_{j}\sum_{c} Z_{ip,j}^{Ac} + \sum_{c} F_{ip}^{Ac}$$

and

$$EX_{in}^{A} = \sum_{j}\sum_{c} Z_{in,j}^{AC} + \sum_{c} F_{in}^{AC}$$

where EX_{ip}^{A} is exports from processing exporters and EX_{in}^{A} is exports from non-processing exporters in the national EIOT.

The sum of intermediate imports by processing and non-processing industries are constrained to the MCIOT import flows of target country *A* for each trade partner *C* as:

$$Z_{i,jn}^{CA} + Z_{i,jp}^{CA} = \tilde{Z}_{i,j}^{CA}$$

where $Z_{i,jn}^{CA}$ are intermediate imports by non-processing industry *j* in country *A* from industry *j* in country *C*, $Z_{i,jp}^{CA}$ are the same but for processing industry *j*, $\tilde{Z}_{i,j}^{CA}$ are total intermediate imports by industry *i* in country *A* from industry *j* in country *C* in the MCIOT.

The imports from all partners are constrained to the import part of the national EIOT as:

$$IMZ_{i,jp}^{A} = \sum_{C} Z_{i,jp}^{CA}$$

and

$$IMZ_{i,jn}^{A} = \sum_{C} Z_{i,jn}^{CA}$$

where $IMZ_{i,jp}^{A}$ and $IMZ_{i,jn}^{A}$ are intermediate imports by processing industries and non-processing industries, respectively, in the national EIOT. The imports of products for final use remain the same because the split is only considered in the types of enterprises; there are no differentiations in household types.

The components of exports and imports are separately balanced using a framework of linear programming optimisation. However, the optimisation constraints can be relaxed for the bilateral trade constraints from an MCIOT, since most countries' bilateral trade flows and import matrix are derived by numerical non-survey calculations.

Splitting a multi-country input-output table by ownership: The example of the *AAMNE Database*

This section explains how each industry in an MCIOT can be disaggregated by the chosen extension criterion while keeping a balanced table. The result is an extended MCIOT (EMCIOT) showing, for example, intermediate sales from SMEs in industry 1 in country *A* to large enterprises in industry 2 in country *B*. Table 7.3 depicts an example of an MCIOT.

Table 7.3. Multi-country input-output table in basic prices, a two-country, two-industry example, industry extended for two country

			Intermediate demand								Final use		
			Country A				Country B				Country A	Country B	Output
			Ind 1	Ind 1	Ind 2	Ind 2	Ind 1	Ind 1	Ind 2	Ind 2			
			SME	Large	SME	Large	SME	Large	SME	Large			
Country A	SME	Ind 1											
	Large	Ind 1											
	SME	Ind 2											
	Large	Ind 2											
Country B	SME	Ind 1											
	Large	Ind1											
	SME	Ind 2											
	Large	Ind 2											
Taxes less subsidies													
Value added													
Output													

Note: ind: industry; SME: small and medium-sized enterprise.

The approach builds on Cadestin et al. (2018[14]) and Cai, Miroudot and Zürcher (2023[1]) who describe the methods behind splitting an MCIOT by ownership. These two OECD projects led to the *Analytical AMNE (AAMNE) Database*. This comprehensive database, which is publicly available, covers 76 economies and 41 industries over the period 2000-20 in its 2024 edition. The *AAMNE Database* includes a set of EMCIOTs derived from OECD MCIOTs that are split according to ownership. Each row in these MCIOTs (referring to output in a specific country and industry) is split between the output of domestically owned enterprises and foreign-owned enterprises. Similarly, each column in the intermediate consumption matrix distinguishes inputs used by domestically owned and foreign-owned enterprises in each country and industry. In an additional set of MCIOTs, not publicly available, rows and columns include a further split for domestic MNEs' activities, as opposed to enterprises that do not have foreign affiliates. Another example in this direction, similar to an EMCIOT but with provinces instead of countries, is the inter-provincial input-output database distinguishing ownership in China (Chen et al., 2023[15]).

The *AAMNE Database* provides valuable insights into the activities of MNEs from a global value chain perspective. It supports governments, academia and industry in evidence-based policy making and research in a wide range of topics: from MNE taxation policy and informing trade agreement negotiations to tracking MNE environmental footprints and technology transfers, among many others.

Data sources

The *AAMNE Database* is built on two main sources: 1) data on MNE activity from official statistics for countries and industries in the MCIOT; and 2) the OECD MCIOTs, which provide the whole economic structure. The data are transformed as described in Chapter 4 to transform aggregated national statistics into a basis for compiling a national EIOT. The result is three matrices:

1. A balanced bilateral output matrix by country, industry and country of ownership. The country of ownership dimension is subsequently consolidated into domestic and foreign ownership.
2. A matrix with value added, by country, industry and ownership (domestic or foreign).
3. A matrix with exports and imports, by country, industry and ownership (domestic or foreign).

The data about output, value added, exports and imports aggregated by ownership perfectly match the corresponding MCIOT data for all years in the dataset. It is needless to say that all data are according to the 2008 System of National Accounts (SNA). Therefore, international transactions are only recorded as imports or exports when there is a change of ownership. If a foreign subsidiary of an MNE produces goods as input for the parent, the export value will be the full value of the goods minus the value of used intermediates that were owned by the parents. When the foreign subsidiary owned all used intermediates, the export value is the full value of the produced goods. When the parent owned all used intermediates, for example in some cases of processing trade, the export value is only the value of the services provided by the foreign subsidiary to process the intermediates.

Methods

Given an MCIOT and output, value added, and trade matrices as described before, the EMCIOT is compiled as follows:

1. Use the industry-ownership level output to determine the relative proportion of domestic and foreign value within each industry in each country.
2. Obtain the initial values for the intermediate trade table.
3. Obtain the initial values for the tables with final use and value added.
4. Derive constraints for intermediate trade, final use, value added, exports and imports, by country, industry and ownership. These determine additional balancing conditions.
5. Transform these starting values, which form an unbalanced EMCIOT, into a balanced table using a quadratic optimisation method,[5] while respecting the constraints from the previous step.

Steps 1-3 lead to the construction of the initial unbalanced split MCIOT. Steps 4-5 yield consistent tables which reconcile AMNE data as much as possible with the original MCIOT. The resulting EMCIOT fits the MCIOT data with values as closely as possible to the AMNE matrices of output, value added, exports and imports while preserving as much of the original structure of the MCIOT as possible.

Step 1 starts by defining an MCIOT composed of G countries, n industries and m types of final use. Z_{ij} is an $n \times n$ matrix and its elements indicate the delivery of intermediate inputs from country i to country j. The special case $i = j$ therefore corresponds to domestic deliveries. Let V_i define a vector of dimension $1 \times n$ whose elements indicate the value added in country i and Y_{ij} a matrix of dimension $n \times m$ that denotes final goods and services produced in industries in country i and consumed by final use categories country j.

$X_i^{D^*}$ and $X_i^{F^*}$ are defined as country i's output of domestically owned and foreign-owned enterprises, respectively, in the output matrix. By construction, $X_i^{D^*} + X_i^{F^*} = X_i$ where X_i is the vector of output for country i. Define the vector of output ratios by domestically owned enterprises as $\sigma_i^D = X_i^{D^*}/X_i$ and define the vector of output ratios by foreign-owned enterprises as $\sigma_i^F = X_i^{F^*}/X_i$.

In Step 2, Z_{ij} is split into four matrices using proportionality assumptions: Z_{ij}^{DD}, Z_{ij}^{DF}, Z_{ij}^{FD} and Z_{ij}^{FF}. Z_{ij}^{DD} is the matrix of intermediate inputs supplied by domestically owned enterprises to domestically owned enterprises. Z_{ij}^{DF} is a matrix of intermediate inputs supplied by domestically owned enterprises to foreign-owned enterprises; and so forth for Z_{ij}^{FD} and Z_{ij}^{FF}. This is shown in Table 7.4.

Table 7.4. The initial value for the intermediate trade block, by industry, country and ownership

			D				F			
			Country i		Country j		Country i		Country j	
			Ind 1	Ind 2	Ind 1	Ind 2	Ind 1	Ind 2	Ind 1	Ind 2
D	Country i	Ind 1	Z_{ij}^{DD}				Z_{ij}^{DF}			
		Ind 2								
	Country j	Ind 1								
		Ind 2								
F	Country i	Ind 1	Z_{ij}^{FD}				Z_{ij}^{FF}			
		Ind 2								
	Country j	Ind 1								
		Ind 2								

Note: D: domestically owned enterprise; F: foreign-owned enterprise; ind: industry.

The starting values Z0 of the four Z matrices are calculated using the previously defined σ_i^D and σ_i^F (with the hat notation used for the diagonal matrix of the vector):

$$Z0_{ij}^{DD} = \hat{\sigma}_i^D Z_{ij} \hat{\sigma}_j^D,\ Z0_{ij}^{DF} = \hat{\sigma}_i^D Z_{ij} \hat{\sigma}_j^F,\ Z0_{ij}^{FD} = \hat{\sigma}_i^F Z_{ij} \hat{\sigma}_j^D \text{ and } Z0_{ij}^{FF} = \hat{\sigma}_i^F Z_{ij} \hat{\sigma}_j^F$$

This split produces the initial values in the balancing procedure. The coefficients will then change in the optimisation to reflect the constraints. At the end of the balancing process, there will be different production functions and a different mix of inputs for domestically owned and foreign-owned enterprises, both as suppliers of inputs and as purchasers of inputs.

Step 3 derives starting values for final use and value added. The final use of country *j* supplied by country *i*, the Y_{ij} matrix, also needs to be split into the two matrices: Y_{ij}^D and Y_{ij}^F where Y_{ij}^D is the final use of the output of domestically owned enterprises and Y_{ij}^F is the final use of the output of foreign-owned enterprises. The starting values of these two matrices are calculated as follows:

$$Y0_{ij}^D = \hat{\sigma}_i^D Y_{ij} \text{ and } Y0_{ij}^F = \hat{\sigma}_i^F Y_{ij}$$

The value added in country *i*, V_i, is split into two vectors: V_i^D and V_i^F. V_i^D is the value-added vector for country i's domestically owned enterprises and V_i^F is the value-added vector for country i's foreign-owned enterprises. The starting values of these two vectors are extracted from the value-added matrix.

$$V0_i^D = V_i^{D^*} \text{ and } V0_i^F = V_i^{F^*}$$

Step 4 derives constraints for the optimisation process. To obtain the unobservable input-output coefficients, the new intermediate input blocks in the MCIOT: Z_{ij}^{DD}, Z_{ij}^{DF}, Z_{ij}^{FD} and Z_{ij}^{FF}, the new final use blocks, $\mathrm{Y}_{\mathrm{ij}}^{\mathrm{D}}$ and $\mathrm{Y}_{\mathrm{ij}}^{\mathrm{F}}$, as well as the new value-added vectors, V_i^D and V_i^F, need to be estimated. Each block should satisfy these constraints: 1) the sum of the split new blocks should be equal to the original matrices/vectors in the MCIOT; 2) the new MCIOT should be balanced, i.e. the sum of each row and sum of each column should be equal to output.

These constraints can be written as follows:

$$Z_{ij}^{DD} + Z_{ij}^{DF} + Z_{ij}^{FD} + Z_{ij}^{FF} = Z_{ij}$$

$$\mathrm{Y_{ij}^{D}} + \mathrm{Y_{ij}^{F}} = \mathrm{Y_{ij}}$$

$$V_i^D + V_i^F = V_i$$

$$\sum_j Z_{ij}^{D\circ} + \sum_j Y_{ij}^D = \sum_j Z_{ji}^{\circ \mathrm{D}} + V_i^D = X_i^{D^*}$$

$$\sum_j Z_{ij}^{F\circ} + \sum_j Y_{ij}^F = \sum_j Z_{ji}^{\circ \mathrm{F}} + V_i^F = X_i^{F^*}$$

where the notation ○ corresponds to the set {D, F} that identifies the domestic and foreign blocks in the split MCIOT.

Additional constraints are needed to split the exports E and imports M data in a way that is consistent with the matrices created with AMNE data. These constraints are:

$$E_i^D = \sum\nolimits_j Z_{ij}^{D\circ} + \sum\nolimits_j Y_{ij}^D \,, j \neq i, E_i^F = \sum\nolimits_j Z_{ij}^{F\circ} + \sum\nolimits_j Y_{ij}^F \,, j \neq i$$

$$M_i^D = \sum\nolimits_j Z_{ij}^{\circ \mathrm{D}} + \sum\nolimits_j Y_{ij}^D \,, j \neq i, M_i^F = \sum\nolimits_j Z_{ij}^{\circ \mathrm{F}} + \sum\nolimits_j Y_{ij}^F \,, j \neq i$$

Step 5 concerns the actual balancing process. The outcome of this process is as close as possible to the starting values created above, while respecting the constraints. Using the previous notations, the objective function in the optimisation (minimisation of distance to the starting values) is specified as:

$$\begin{aligned} Min\ S = {} & \sum_{i,j} \frac{(Z_{ij}^{DD} - Z0_{ij}^{DD})^2}{Z0_{ij}^{DD}} + \sum_{i,j} \frac{(Z_{ij}^{DF} - Z0_{ij}^{DF})^2}{Z0_{ij}^{DF}} + \sum_{i,j} \frac{(Z_{ij}^{FD} - Z0_{ij}^{FD})^2}{Z0_{ij}^{FD}} + \sum_{i,j} \frac{(Z_{ij}^{FF} - Z0_{ij}^{FF})^2}{Z0_{ij}^{FF}} \\ & + \sum_{i,j} \frac{(Y_{ij}^D - Y0_{ij}^D)^2}{Y0_{ij}^D} + \sum_{i,j} \frac{(Y_{ij}^F - Y0_{ij}^F)^2}{Y0_{ij}^F} + 100 * \left(\sum_i \frac{(V_i^D - V0_i^D)^2}{V0_i^D} + \sum_i \frac{(V_i^F - V0_i^F)^2}{V0_i^F} \right) \\ & + 100 * \left(\sum_i \frac{(E_i^D - E_i^{D\bullet})^2}{E_i^{D\bullet}} + \sum_i \frac{(E_i^F - E_i^{F\bullet})^2}{E_i^{F\bullet}} + \sum_i \frac{(M_i^D - M_i^{D\bullet})^2}{M_i^{D\bullet}} + \sum_i \frac{(M_i^F - M_i^{F\bullet})^2}{M_i^{F\bullet}} \right) \end{aligned}$$

where $E_i^{D^*}$, $E_i^{F^*}$, $M_i^{D^*}$ and $M_i^{D^*}$ are the exports and imports values from the AMNE matrices created in the previous steps.

This process leads to a full split of the MCIOT by domestic and foreign ownership, producing balanced tables which are fully consistent with the initial tables that do not distinguish between foreign-owned and domestically owned enterprises.

At the national level, it is expected that extra enterprise-level data can be used to derive more accurate estimates of the intermediate consumption of domestically owned and foreign-owned enterprises as well as their respective imports and exports. Even if data are not fully available, the optimisation and balancing processes described in Chapter 5 can also be used to fill the gaps and derive a consistent EIOT split according to ownership.

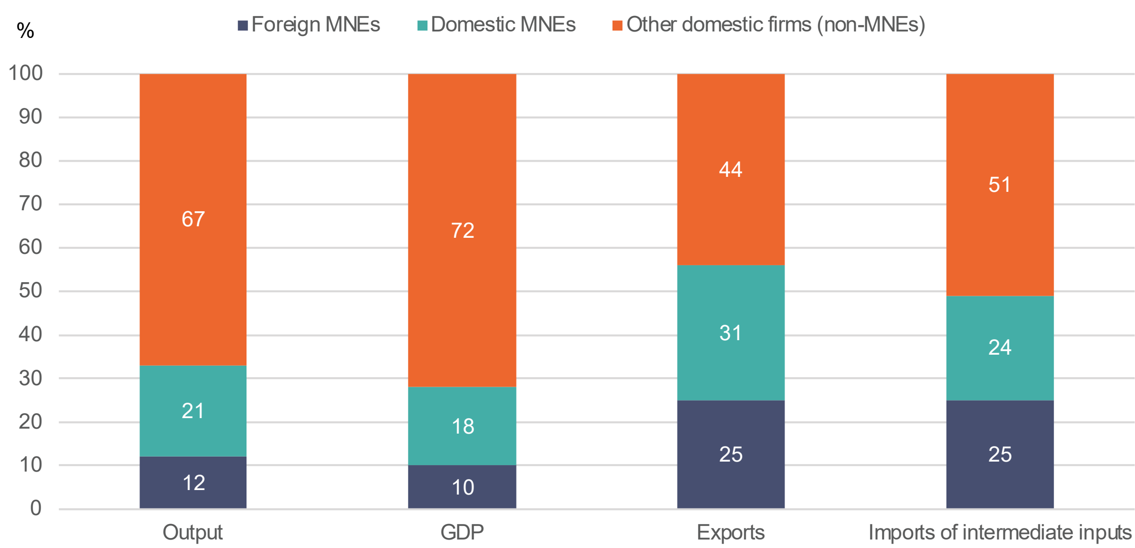
Examples of the results

Just as an EIOT yields new information about the domestic economy, the extended MCIOT yields new information about the world economy: 1) in indicators describing the direct effect of MNEs, when the EMCIOT and subsequent input-output analysis is not needed; 2) in indicators describing the worldwide links of MNEs, where input-output analysis is necessary. Examples of both types of indicators follow.

Indicators about MNEs in the global economy without input-output analysis

MNEs and their foreign affiliates account for one-third of world output and gross domestic product (GDP) and half of international trade (Figure 7.1). MNEs' contribution to world GDP was estimated at 28% in 2019, of which roughly one-third was from foreign affiliates abroad and two-thirds from MNE headquarters and domestic affiliates in the home country. Taken together, this means that MNEs produce about one-third of global output, illustrating the importance of MNEs and their networks in today's global economy.

Figure 7.1. Direct effects of multinational enterprises in host countries, 2019



Note: GDP: gross domestic product; MNE: multinational enterprise.
Source: Calculations based on the OECD Analytical AMNE Database.

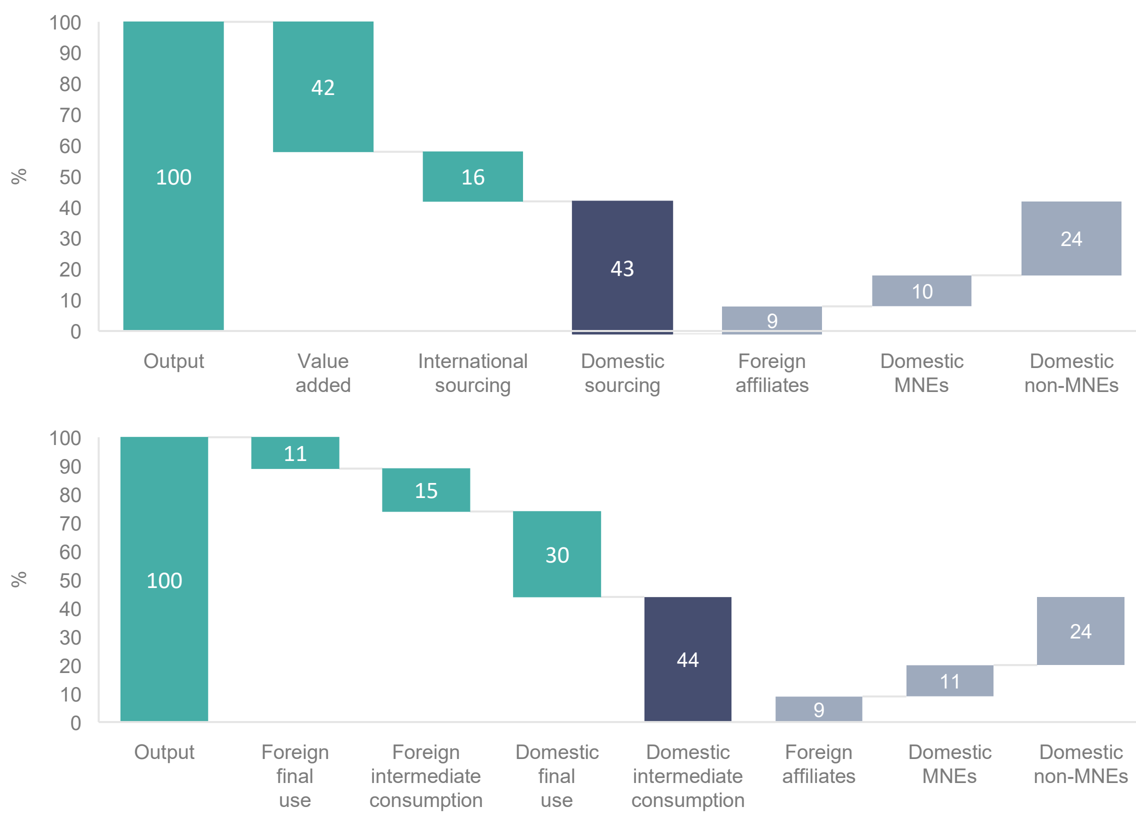
Foreign affiliates accounted for about 10% of world GDP in 2019. They relatively often sourced intermediate goods/services internationally (see below), which explains why their share in GDP is smaller than their share of output. Indeed, the value of imported intermediates is counted only once as a contribution to the original country's GDP, while it is included in the output statistics multiple times in different countries. For instance, when a foreign affiliate sources inputs from its headquarters to be incorporated into a final product, the value of the inputs is counted twice – in the output of the home country and that of the host country of the affiliate – while it is only counted once in the GDP of the home country.

MNEs and their affiliates are found to be relatively more important in exports and imports, demonstrating the large trading activities of this group of enterprises. Foreign affiliates were responsible for 25% of global exports and 25% of global imports in 2019. These shares are similar to those of MNE headquarters (31% and 24%, respectively), but important differences exist across countries, as available data for individual countries demonstrate. For example, MNEs accounted for more than 70% of exports from both France and Hungary, but mainly because of foreign affiliates in the case of Hungary, while domestic MNEs play a much more important role in France.

Indicators using the added value of the multi-country input-output perspective

Building on an MCIOT allows for analyses beyond what is possible from foreign affiliate statistics data or ownership-split national SUTs alone, providing policy makers and researchers with a better understanding of MNE activities across borders and in global value chains.

Figure 7.2. Sourcing structure (top) and output use (bottom) of foreign affiliates globally, 2019



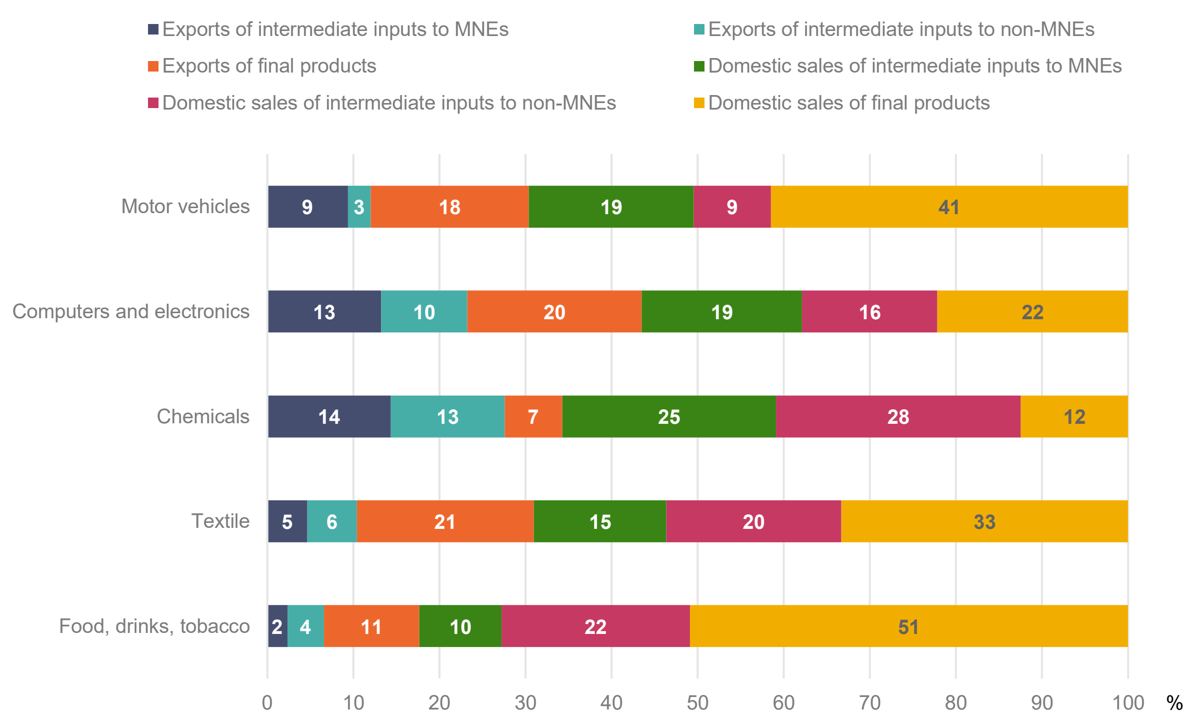
Note: MNE: multinational enterprise.
Source: Calculations based on the OECD Analytical AMNE Database.

The *AAMNE Database* shows, for example, that contrary to traditional wisdom, foreign affiliates have strong backward and forward linkages with domestic companies, including SMEs. Foreign affiliates source more than two-thirds of intermediates from their host economy (Figure 7.2, top panel) and more than 50% of domestic intermediate consumption is supplied by non-MNEs (of which the majority are SMEs). Further on, foreign affiliates operate not only as customers in host countries, but also as suppliers of intermediates and final products. More than two-thirds of the production of foreign affiliates feeds into domestic value chains: 30% of affiliates' production in 2019 was for the final domestic market, while 44% was used locally as an input to other enterprises in the domestic economy (Figure 7.2, bottom panel). Once again, the most important domestic clients of foreign affiliates are domestic non-MNEs, buying 55% of foreign affiliate domestic intermediate production.

Leveraging the granularity of the database and its global value chain perspective to take the analysis a step further shows that MNEs use trade and investment for different purposes in the value chain and have complex strategies. Figure 7.3 shows that foreign affiliates can be involved in horizontal strategies when producing final products for the domestic market or for exports (export-platform foreign direct investment), as well as intermediate inputs used by domestic enterprises. The exports of inputs by foreign affiliates rather reflect MNEs' vertical strategies. Figure 7.3 also suggests that these vertical strategies are not as prevalent as sometimes argued. This finding is consistent with recent evidence suggesting that the use of third-party suppliers is more prevalent within MNEs than originally thought. The literature has shown that while MNEs often prefer to source inputs from independent enterprises through non-equity partnerships like franchising, contractual relationships, strategic partnerships, etc., they mainly use their foreign affiliates to either transfer capabilities (Atalay, Hortaçsu and Syverson, 2014[16]; Ramondo, Rappoport and Ruhl, 2016[17]) or to produce technologically important inputs (Berlingieri, Pisch and Steinwender, 2019[18]).

The detail in the extended MCIOT also allows one to find differences across industries in the role played by foreign affiliates. For example, foreign affiliates in the computer and electronics industry are more involved in vertical strategies than foreign affiliates in the food industry. Moreover, foreign affiliates in the chemicals industry provide a significant share of inputs to domestic enterprises that are not part of MNEs, something not observed in the computer and electronics industry, which is another industry where the international fragmentation of production is prevalent.

Figure 7.3. Decomposition of output of foreign affiliates by type of transaction, selected industries, 2019



Note: MNE: multinational enterprise.
Source: Calculations based on the *OECD Analytical AMNE Database*.

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Notes

[1] Domestic enterprises import raw materials or other intermediate inputs from abroad before processing them in local manufacturing facilities. The finished goods are then exported.

[2] Accessible at: https://kidb.adb.org/globalization.

[3] See also Michel, Hambÿe and Hertveldt (2023[8]).

[4] See Chapter IV, “Converting supply and use tables into a symmetric I/O table: Treatment of secondary products” in United Nations (1999[19]).

[5] Chapter 5 explained another method to obtain a balanced table, namely a biproportional method. The reason to describe that method, and not a quadratic programming model, was explained in Chapter 5: national statistical offices often use biproportional methods to balance supply and use tables and IOTs.

8. Dissemination of extended supply and use tables, extended input-output tables, and related indicators

This chapter provides advice on the dissemination of extended supply and use tables, extended input-output tables, and related indicators. It starts with general advice on the dissemination process, emphasising the importance of identifying the users and their specific needs. It then outlines different ways to reach users, ranging from the tables themselves and related analysis to graphs and videos. Special attention is given to confidential data, with guidance on how to handle this while still publishing as much relevant information as possible. The chapter concludes by proposing several indicators, both basic and more complex, that can be derived from extended supply and use tables and extended input-output tables.

Introduction

Data dissemination involves the release of information obtained through a statistical activity. It consists of transmitting statistical data to the users through various media (paper publications, files available to specific users or for public use, official websites, social networks, public speeches, and press releases). Data dissemination is a crucial part of statistical activity as most official statistics, including extended supply and use tables (ESUTs) and extended input-output tables (EIOTs), are produced for public use. Dissemination provides visibility to the results and contributes to spreading statistical information and economic analysis to the public. Effective data dissemination requires good communication to make the information both accessible and clear to users. This process involves identifying user needs, determining what information will be released, communicating the dissemination schedule, ensuring timeliness and coherence among the disseminated data sets, maintaining statistical confidentiality, disseminating metadata and information on data quality, selecting formats (which are regularly reviewed for alignment with demand and standard practices), and means of dissemination.

General dissemination advice

Dissemination rules and good practices are largely similar to those described in the *Handbook on Supply and Use Tables and Input-output Tables with Extensions and Applications* (United Nations, 2018[1]). The purpose of this section is therefore not to provide detailed general principles of dissemination of statistics but to reiterate the main principles and to propose good practices of disseminating ESUTs to countries.

Identify users and their needs

Identifying the users and their needs is crucial when determining the appropriate level of information, explanations and messages and developing a good dissemination strategy. Promotion on professional social media can help to identify and reach more users and to understand their needs. Generally, there are two main types of users. First, expert users with analytical needs and regular data requirements for detailed variables, breakdowns and time series. Second, general users who need fewer details but more guidance on the interpretation and value added of statistics related to ESUTs and EIOTs. Good knowledge of users' needs allows better prioritising the appropriate breakdowns in the supply and use tables (SUTs), providing more details on the behaviour of specific categories of enterprises that are of interest (e.g. by size, trading status and ownership).

The availability of a release calendar is an important element of the dissemination strategy that allows users, especially institutional users, to plan their activities. An advance release calendar with the first dissemination and revisions should be available at the beginning of each year, or at least well before the release date, on the websites of the national offices in charge of the dissemination. Punctuality (i.e. adherence to the schedule) is important too. It is one of the dimensions of quality in the *Quality Framework and Guidelines for OECD Statistical Activities* (OECD, 2011[2]).

Presentation of the ESUTs, EIOTs and related analysis

While ESUTs and EIOTs can address policy questions regarding the role of certain types of enterprises, they remain complex. Thus, it is crucial to present and explain the ESUTs, EIOTs and related indicators in the most user-friendly manner possible. It is recommended to make ESUTs, EIOTs, the analysis and all related publications available together, as they complement each other. This enables users to find all relevant information about this topic quickly. For the first release, it may be appropriate to organise specific media briefings or a conference for specific users to present insightful information derived from the findings.

This may also be appropriate when there are substantial changes in the methodology or interesting key results.

The following elements can support the dissemination process as well.

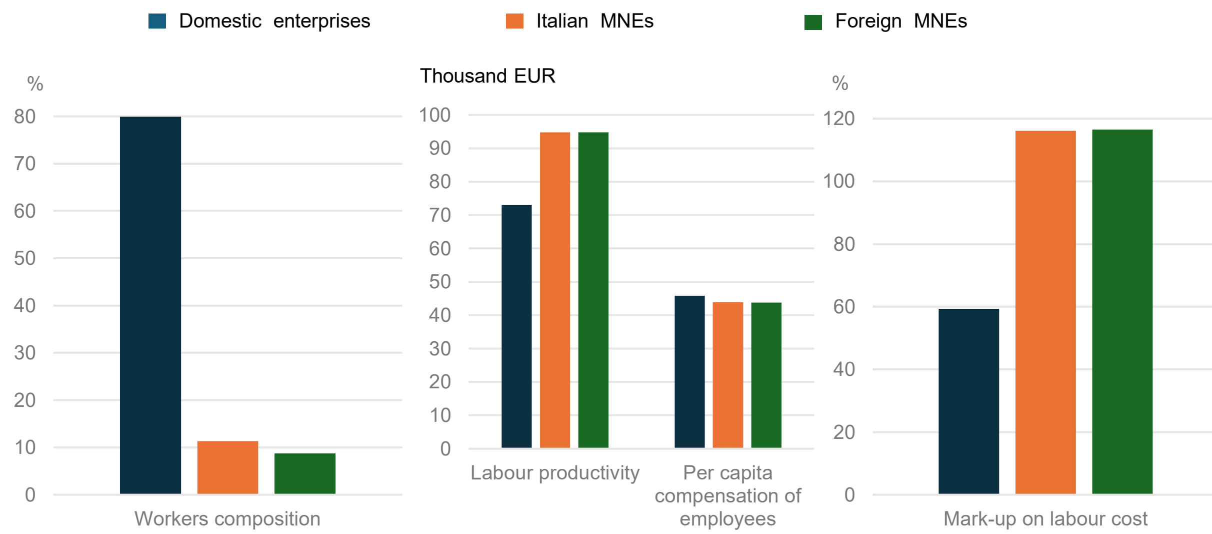
Provide clear and detailed metadata. Metadata may be defined as "everything one needs to know to understand the results". They describe the complete statistical production process. They ease sharing, querying, understanding and using statistical data at their various levels of aggregation. Metadata encompasses the data or data collection, concepts, definitions, classifications, thresholds, and main statistical processing before the compilation, dissemination and storage of the results in a database. Metadata are a very important tool for understanding the statistical process, how the data should or should not be used, together with the nature of the information they contain. For ESUTs, it is important to detail all the microdata linking and the sources used for the extension of the SUTs, as well as the methods and sources that were used to delineate the different enterprise characteristics.

Use different ways to disseminate the tables and related analyses. The ESUTs' data can be disseminated in various forms and formats, for example in Excel, with several worksheets covering different parts of the ESUT framework for a specific year to enhance clarity. Many statistical offices have developed a large and detailed open database as well as an API (application programming interface) allowing users to select the specific data they need, view the data as graphs or download the data for use.

It remains a challenge to digest the main points from the data because of the possible large size of the tables. Although this is desirable for a specific audience that is interested in detailed information, this makes it difficult to analyse and visualise for the general public. Therefore, it is recommended to present aggregated information as well, for example, the main indicators for each type of enterprise in the table or the main indicators for manufacturing, services, possibly another industry grouping depending on data availability, by type of enterprise. Alternatively, focus on the larger industries, or the larger industries that are policy relevant, and provide the indicators by enterprise type.

Graphs can make the information more accessible and effectively highlight some specific points related to the specific ESUT/EIOT. Several countries use graphic presentations to complement their ESUTs with basic explanations of the main results. Such initiatives can be helpful to complement the ESUTs, illustrating the main global messages. For example, Sallusti and Cuicchio (2023[3]) compiled three types of ESUTs for Italy. These tables detail industries for three types of groupings: size, trading status and ownership. Examples of their work are described below.

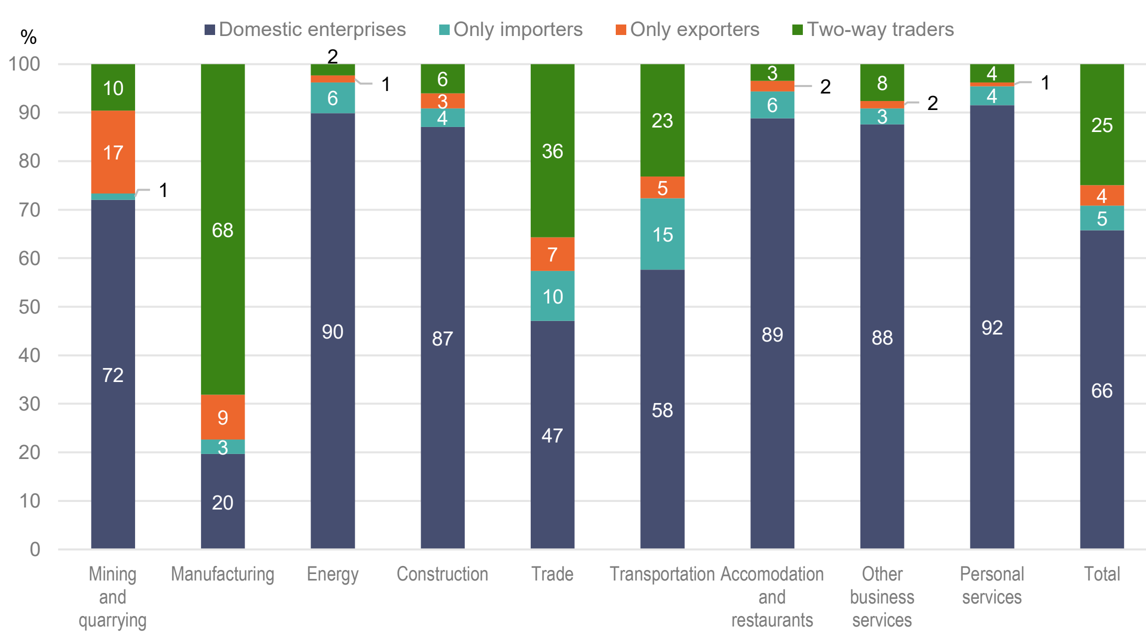
Figure 8.1. Labour productivity and labour market indicators by governance status, Italy, 2019



Note: MNE: multinational enterprise.
Source: Sallusti and Cuicchio (2023[3]).

From Figure 8.1, the authors derived four key messages: MNEs employ 20% of total workers, there is a productivity gap between MNEs and domestic enterprises (over EUR 94 000 vs. less than EUR 73 000 per worker respectively), per capita compensation is slightly higher for domestic enterprises, and MNEs show a higher mark-up on labour costs (measured as value added divided by labour costs).

Figure 8.2. Value added by industry by type of trader, Italy, 2019



Source: Sallusti and Cuicchio (2023[3]).

Three key messages from Figure 8.2 are that 66% of overall value added is generated by enterprises that neither import nor export; two-way traders account for 25% of value added; and two-way traders are relatively large in manufacturing, trade and transportation.

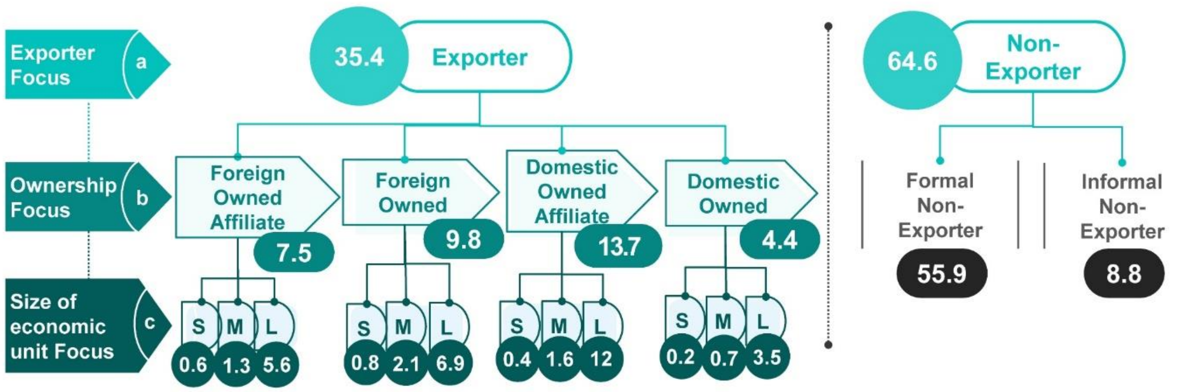
Figure 8.3. Value added by industry by size class, Italy, 2019

Source: Sallusti and Cuicchio (2023[3]).

Three key messages from Figure 8.3 are that 51% of value added is generated by microenterprises (1 to 9 persons employed); 21% of value added is generated by large enterprises (250 persons employed or more); and large enterprises are relatively more prominent in mining and quarrying, energy, and transportation.

INEGI (2023[4]) has implemented a similar framework for Mexico. It presented the main results using visuals that are easy to understand, while emphasising the main points of interest. For example, Figure 8.4 clearly shows that exporters in Mexico account for 35.4% of domestic production. Exporting foreign-owned large enterprises account for 6.9% of domestic production.

Figure 8.4. Production by type of enterprise, Mexico, 2018



Note: S: small enterprises, M: medium-sized enterprises, L: large enterprises.
Source: INEGI (2023[4])

A short pedagogic video can present ESUTs and EIOTs, their uses, and meaning through appropriate examples. For example, Israel (CBS Israel, 2022[5]) and Singapore (Singapore Department of Statistics, 2020[6]) have each designed a short clip that illustrates the function of an SUT through concrete examples (olive oil production for Israel and oil refining industry for Singapore). The European Commission (2021[7]) provided a short pedagogic video to explain FIGARO (Full International and Global Accounts for Research in Input-Output analysis) and its possible uses. Such user-friendly videos can be an attractive way to make ESUTs, EIOTs and related indicators accessible to a larger audience. They can help explain why it is so important to introduce additional dimensions such as the size of the enterprise or its involvement in the globalisation process (trading status, ownership) and highlight insights offered by the new data.

Indicators based on extended supply and use tables and extended input-output tables

Compiling ESUTs or EIOTs allow new indicators to be derived. These may relate to the type of enterprise in the domestic economy, links in the domestic economy or links with foreign economies. The links with foreign economies provide new insights into the participation of different types of enterprises in global value chains. It is worth noting that some indicators are very similar to existing indicators from regular SUTs and input-output tables, or to Trade in Value Added analysis (TiVA) (Martins Guilhoto, Webb and Yamano, 2022[8]), while others are new.

As an illustration, this section presents indicators for the case where industries are broken down by size class. Of course, all indicators can be calculated in a similar way when the industries are broken down by another category. Furthermore, note that one can calculate the indicators for the total economy or by industry as well, not using a breakdown by enterprise type. As indicated in Chapter 1, this will lead to higher quality estimates when heterogeneity within industries is high and disaggregated information is of high quality.

Basic indicators about the domestic economy by size class

Using ESUTs

- production
- value added
- gross operating surplus
- compensation of employees
- value added as a share of production
- compensation of employees as a share of value added.

The first four indicators show the share of each size class in well-known macroeconomic totals. These can be obtained using business statistics as well. However, such estimates can be inconsistent, do not entail illegal activities and are not comparable to macroeconomic aggregates such as gross domestic product. Value added as a share of production indicates whether production is relatively in-house or that inputs of goods and services are sourced mainly outside the enterprise, from domestic or foreign suppliers. It tells something about the cost structure. Compensation of employees as a share of value added shows how much value added goes to the providers of labour and how much to the providers of capital. This indicator is similar to the labour share. Its inverse, value added divided by compensation of employees, can be used to calculate the mark-up on labour costs, which is 100%*(this inverse minus 1).

Using EIOTs

Just as in regular SUTs, ESUTs show which products are imported and exported, but not who is importing or exporting. This information can be obtained from an input-output table or an EIOT. Combining information about imports and exports with production and value added yields several indicators describing globalisation. These can be by size class or by size class and industry:

- Imports.
- Exports.
- Import intensity, defined as imports divided by production. This shows the importance of own/direct imports for a size class, how much it directly depends on foreign countries for its inputs.
- Export intensity, defined as exports divided by production. This shows the importance of own/direct exports for a size class, how much it directly depends on foreign countries for its sales.
- Value added due to direct exports, also known as direct domestic value-added content of exports, defined as export intensity times value added. This shows how much of its value added is directly related to foreign sales. This value added can be further split into compensation of employees and gross operating surplus.

The three latter indicators are examples of OECD's Trade in Value Added (TiVA) indicators (Martins Guilhoto, Webb and Yamano, 2022[8]) and the Eurostat's Macroeconomic Globalisation Indicators (Eurostat, 2024[9]).

Indicators using extended input-output tables by size class

Using an EIOT can yield estimates for indirect trade and the corresponding value added, for example, how much small and medium-sized enterprises (SMEs) depend on large enterprises to provide them access to emerging markets, or to what extent large manufacturing enterprises depend on SMEs in the services industries. Combining information about indirect trade with that of direct trade shows foreign dependence of a size class at total level.

To facilitate computations with the EIOT, it may be advisable to group the different size classes together instead of grouping the different industries together. This is depicted in Table 8.1.

Table 8.1. An extended input-output table to facilitate computations

		SMEs		Large enterprises		Other	C	GCF	X
		Manufacturing	Services	Manufacturing	Services				
SMEs	Manufacturing								
	Services								
Large enterprises	Manufacturing								
	Services								
Other									
Imports									
Gross value added									
Total output									

Note: SME: small and medium-sized enterprise. C: final consumption expenditure; GCF gross capital formation; X: exports

Standard input-output analysis yields a table that shows how much value added one type of enterprise has due to production that is ultimately used by a type of enterprise to produce for domestic final use (such as household consumption) or exports. For example, the value added of SMEs due to production for the exports by large enterprises. This input-output analysis can be carried out as follows:

- Set f_1 and f_2 as the vectors of domestic final use and exports, respectively.
- Set x as the vector of production and Int as the matrix of intermediate supplies.
- The technical coefficient matrix A is defined as usual; each of the columns of Int is divided by the column's total (an element of x).
- The Leontief matrix L is also defined as usual, namely $L = (I-A)^{-1}$, where I is the identity matrix of the appropriate dimension. Then $x = L \cdot (f_1 + f_2)$.
- Set v as the vector of value added per unit of production.
- For a vector c, diag(c) is the matrix with vector c on the diagonal and 0 elsewhere.
- Set $B = \text{diag}(v) \cdot L \cdot \text{diag}(f_2)$.

The matrix B is a who-to-whom matrix; a matrix element b_{ij} represents the value added at (industry by size class) i due to exports of (industry by size class) j. Or, interpreting the data the other way around, given exports of (industry by size class) j, how much value added is at (industry by size class) i. Direct exports are defined as the production of a size class that is ultimately used in its own exports. These are the diagonal elements of $L \cdot \text{diag}(f_2)$. Define indirect exports as production of one size class that is ultimately used in exports of another size class. These are the off-diagonal elements of $L \cdot \text{diag}(f_2)$.

Table 8.2 depicts a who-to-whom table. The numbers in the table refer to parts of the who-to-whom table that will be used in later calculations.

Table 8.2. A who-to-whom table: Value added of one type of enterprise due to exports of another

		SMEs		Large enterprises		Other
		Manufacturing	Services	Manufacturing	Services	
SMEs	Manufacturing	1	2	3	4	5
	Services	6	7	8	9	10
Large enterprises	Manufacturing	11	12	13	14	15
	Services	16	17	18	19	20
Other		21	22	23	24	25

Note: SME: small and medium-sized enterprise.

Indicators

- Value added due to indirect exports, when one produces goods and services that are ultimately embodied in exports by others in other size classes. For SMEs, this is equal to 3+4+5+8+9+10.
- Value added due to exports is calculated by summing value added due to direct and indirect exports.
- Value added due to exports relative to total value added. This indicator shows how important foreign sales are for this particular size class.
- Value added due to indirect exports by size class and exporting industry (e.g. manufacturing, services and other). This is a further breakdown of the total value added due to indirect exports. It shows how size class A is dependent on the exports of which industries in size class B. For example, SMEs have value added due to direct exports of large manufacturers equal to 3+8.
- Value added of others supplying for one's exports, by size class and supplying industry (e.g. manufacturing, services and other). It shows how the exports of size class A enable its suppliers in size class B, and in which industries, to reach foreign markets indirectly. For example, exports of SMEs embody 11+12 value added by large manufacturers.
- Domestic value added embodied in exports, by size class, is calculated as value added due to direct exports plus value added at other size classes supplying for the exports of this size class. For example, the exports of large enterprises in services embody 4+9+14+19+24 domestic value added.
- Domestic value added embodied in exports by size class as a share of exports by this size class. This shows how much of the exports are locally produced. One minus this share is the foreign content of exports, showing the dependency of the size class on foreign inputs.
- Value added generated by domestic suppliers for one unit of domestic value added due to direct exports, by size class, shows a multiplier effect. For example, the multiplier effect of SMEs in services is (2+12+17+22)/7.

Similar indicators can be calculated for value added embodied in production for final domestic use and for value added embodied in production for total final use. While these indicators are not that common, they may be useful for large economies such as the People's Republic of China or the United States which rely relatively more on domestic consumption than smaller open economies such as Belgium and the Netherlands, which rely more on foreign demand.

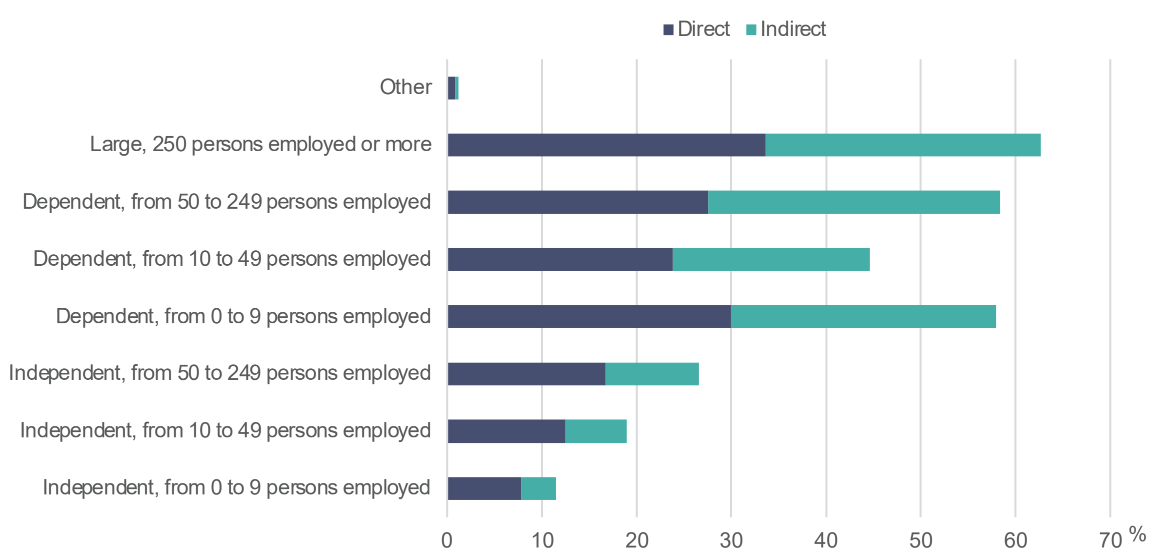
The previous indicators are related to exports, providing information about the supply to foreign markets, by size class. Note that many indicators related to imports can be calculated in a similar way. That would provide information about the use of foreign inputs, by size class. Combining them with indicators about domestic inputs from other size classes and the own value added would provide insights into the input structure of industries by size class.

Country experiences

Statistics Finland regularly produces and publishes numbers based on linked trade and business statistics in combination with national accounts. Currently, seven tables are publicly available (Statistics Finland, 2024[10]). They contain TiVA indicators where industries are split by size class and group relation, ownership, or trading status, for example, the direct value added of gross exports, or the total domestic value added in gross exports of SMEs. To put this in a broader perspective, gross imports, gross exports and value added are provided too. This allows gauging the importance of exports for a specific type of enterprise in a specific industry. Similar information is available for employment related to exports. The data are available yearly for the period 2017-22. OECD and Statistics Finland (2020[11]) used a previous version to present granular insights on Finland's integration into global value chains.

Figure 8.5 presents information for 2022, differentiating enterprises by size and group relation. An enterprise is said to be dependent when it has intra-enterprise relations with larger entities and independent when it does not. Dependent enterprises attribute more of their value added to foreign demand than independent enterprises do. For example, dependent enterprises with 50-249 persons employed have 28% of their value added due to their own (direct) exports, compared to 17% for independent enterprises of the same size. That is because a larger share of the turnover of dependent enterprises consists of exports. Differences between dependent and independent enterprises in the share of value added attributed to indirect exports (producing goods and services in the supply chain of an exporter) are substantial as well.

Figure 8.5. Finland: Value added due to direct and indirect exports as a share of total value added, by size class and group relation, 2022



Source: Calculations based on Statistics Finland (2025[12]).

Statistics Netherlands had several projects examining the role and interplay of SMEs, large enterprises and multinationals. One such example is Onat et al. (2018[13]). For 48 industries, a Dutch input-output table was split into five categories: 1) foreign multinational; 2) Dutch multinationals large enterprises; 3) Dutch multinational SMEs; 4) non-multinational large enterprises; and 5) non-multinational SMEs. Enterprises in 17 industries, such as agriculture, financial services and government services, were not split into the five categories but were classified under another category "other". Subsequently, different indicators of the mutual interdependencies were calculated (Exel et al., 2018[14]). Table 8.3 shows value added in a type of enterprise due to exports of a type of enterprise.

Table 8.3. The Netherlands: Which types of enterprise generate value added as a result of exports from whom, 2016

Million EUR

	Total	Direct exports	Indirect exports via					
			Non-multinational SMEs	Non-multinational large enterprises	Dutch multinational SMEs	Dutch multinational large enterprises	Foreign multinationals	Other
Non-multinational SMEs	64 559	28 884	7 795	1 386	2 727	6 531	15 292	1 943
Non-multinational large enterprises	15 148	6 799	1 719	315	597	1 543	3 717	458
Dutch multinational SMEs	12 825	9 683	619	118	239	606	1 389	170
Dutch multinational large enterprises	30 447	21 017	1 926	369	692	1 852	4 006	584
Foreign multinationals	71 595	53 778	3 182	649	1 223	3 395	8 409	958
Other	26 721	12 904	2 406	569	825	2 678	4 787	2 553
Total	221 295	133 067	17 646	3 406	6 304	16 605	37 601	6 666

Source: (Onat et al., 2018[13])[1].

Non-multinational SMEs have more value added due to indirect exports than due to direct exports. The other types of enterprises serve as a channel through which non-multinational SMEs reach foreign markets. In contrast, the value added due to exports for multinationals is mostly due to their own (direct) exports.

Confidentiality

Confidentiality should remain a core principle in dissemination, with specific attention paid to the confidentiality rules to avoid any possible direct or indirect identification. In ESUTs, attention should be paid to the adequate degree of granularity for dissemination. Chapter 3 discussed this problem. General guidance on preserving confidentiality is provided in Chapter 6 in the *Handbook on Integrating Business and Trade Statistics* (United Nations, forthcoming[15]).

Disaggregating data leads to greater granularity, which is bound to lead to confidentiality issues and the necessity to safeguard that confidentiality. Confidentiality problems arise when the sample of remaining enterprises producing or using a given product is too small, or when data about an individual enterprise might be deduced, for example when there is a dominating enterprise. In general, national statistical offices are not allowed to publish such data by law. Furthermore, Principle 6 of the Fundamental Principles of Official Statistics stipulates that data collected by statistical agencies for statistical compilation about individual entities are to be kept strictly confidential. Use is allowed only for statistical purposes, regardless of whether the entity is a natural or legal person. Preserving confidentiality is necessary to gain and maintain the trust of survey respondents.

There are several ways to address this issue in an ESUT setting. Two of the methods, namely aggregating industries and aggregating the extension, are described in the country experiences below. The *Handbook on Supply, Use and Input-output Tables with Extensions and Applications* (United Nations, 2018[1]) mentions a third option. In the case with one or two dominant producers in an industry, it recommends, "when necessary, that specific permission is sought from the business when their data are publicly available from other public sources, for example published company annual reports and accounts".

Country experiences

This section present case studies from Mexico and the Netherlands. Note that generally it is advisable to work at a level as detailed as possible to allow for flexibility in aggregation later. If the aggregation step occurs at the beginning, this is no longer possible.

Mexico's ESUTs (INEGI, 2023[4]) were developed at the 822 industries level. Each industry in the regular SUT was expanded according to the different focuses. However, it was clear that publishing the data at this level of disaggregation would not be possible due to the likely breaches of confidentiality.

The Mexican solution was to aggregate the 822 industries into the 20 main sectors of the North American Industry Classification System (NAICS). In that way, the ESUTs were able to provide sufficient granularity – as each industry was disaggregated – without risking the identification of particular entities. A more resource-intensive solution would have been to analyse each cell under the 822 industries in the ESUTs and compare it with the individual records from the Economic Censuses. For example, if, in a particular industry (say 325130 – Synthetic Dye and Pigment Manufacturing), the Economic Censuses (source) data show that there are only three exporters, then such an industry could be aggregated with another one (close to it) under the export-oriented focus. However, if the same industry shows ten small enterprises, then it can be disaggregated under the size of enterprise focus. The advantage of this approach is that it provides a maximum amount of detail. The disadvantage is that it might lead to discrepancies when comparing between extensions. However, those discrepancies could be addressed by comparing the focuses according to the least disaggregated one.

The Dutch ESUTs (Chong et al., 2019[16]) were developed at 128 industries. Of these, 115 industries were split by size and 13 (e.g. agriculture, financial intermediation, government services) were not. The published tables contained 56 industries split by size and 12 industries that were not. Even after this aggregation step, some confidentiality issues appeared. The guiding principle to solve them was to leave as much as possible relevant information for the user. One can choose to aggregate industries or to aggregate size classes.

An example of the industry aggregation is information services and IT services. In these industries, there is a lot of heterogeneity when it concerns size. For instance, IT services can range from a one-person enterprise to a large conglomerate. It seems better to keep the detailed information about size and aggregate the two industries instead. The *Handbook on Supply, Use and Input-output Tables with Extensions and Applications* (United Nations, 2018[1]) also recommends that "The aggregation of industries and products with non-disclosive industries and products should, however, be avoided, as this results in the loss of useful details for non-disclosive industries and products."

An example of aggregation by size class is mining of oil and gas. In economic reality, this industry is not operated by small enterprises. Therefore, it was not split by size. Similarly, veterinary services, predominantly comprising small enterprises, were also not split by size.

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9. Extensions of extended supply and use tables and extended input-output tables in theory and practice

Several countries added information from other domains to ESUTs and EIOTs. These additions vary from value added and income flows to employment, physical ESUTs and emissions. The chapter also provides suggestions about the integration of ESUTs and productivity by industry statistics, regional ESUTs and digital SUTs.

Introduction

Extended supply and use tables' (ESUTs) and extended input-output tables' (EIOTs) contribution to economic analysis can be further extended by adding information from other domains. This chapter provides several examples from theory and practice, from different countries, providing an international perspective on (possible) implementation of these extensions. These topics can be seen as inspiration; the relevance of each topic for policy makers and other users will vary from country to country. The chapter starts with a link to income flows since value added in the domestic economy, in particular that generated by multinational enterprises (MNEs) or their affiliates, can flow abroad as property income. The chapter then considers ESUTs' and EIOTs' links to employment data, providing a means to illustrate how employment is related to the activities of different types of enterprises, including, in particular, their exports, which remain an area of high policy interest. This is followed by two examples from the environmental realm, namely, looking at ESUTs through prisms of material efficiency and emissions intensity. For these examples, experiences from practice are shared: why these topics were deemed relevant, which data and methods were used, and the results obtained. The chapter concludes with three examples that are either more theoretical (since they have not yet been carried out in practice) or strongly related to ESUTs. The first considers the integration of ESUTs with KLEMS-type productivity frameworks. The second looks at regional extended supply and use tables (ESUTs) (i.e. national ESUTs disaggregated into regional components). The third example considers digital SUTs, which, although technically not ESUTs, are closely related in many aspects.

Value added and primary income flows

Value added is often considered when thinking about economic impact. It is well-known how domestic production of a given industry, a type of enterprise or type of final expenditure translates into value added. However, part of that value added may flow abroad through increased foreign direct investment (FDI) and internationalisation of ownership. This can happen directly, for example because foreign-owned MNEs transfer profits to the parent enterprise abroad. It can also happen indirectly, for example because a small and medium-sized enterprise (SME) pays interest to a bank that uses this income to pay out dividends to foreign stockholders. As a consequence, national value added related to activities in the domestic economy is not the same as national income related to the same activities, just as gross domestic product (GDP) is not equal to gross national income (GNI).

For policy makers, it is relevant to know how much national income is related to activities of each industry, different types of enterprises and different types of final expenditure. For example, governments worldwide have limited resources available to stimulate the economy. They can aim to stimulate household consumption, government consumption, investments and exports. They might consider specific goods and services that are "greener" or related to specific industries. They could also attract foreign MNEs. In all cases, domestic value added in the form of wages and profits is generated, but how much of those profits remain in the country and how much leave the country in the form of income transfers? This is a difficult question; it is not surprising that there is a broad literature on fiscal multipliers and international linkages (see, for example, the literature review in Botev and Mourougane (2017[1])). Yet, an analysis using an EIOT and information about income flows would provide valuable new information for the policy debate.

This section will discuss data, methods and examples showing how to achieve this.

To set the scene, there are various types of primary income flows (codes in National Accounts in brackets):

- Interest before adjusting for implicit financial services on loans and deposits. These implicit services were called financial intermediation services indirectly measured (FISIM) in the 2008 System of National Accounts (D.41a).
- Dividends (D.421).
- Withdrawals from the income of quasi-corporations (D.422).
- Reinvested earnings on FDI (D.43).
- Investment income attributable to insurance policy holders (D.441).
- Investment income payable on pension entitlements (D.442).
- Dividends attributable to collective investment fund shareholders (D.4431).
- Retained earnings attributable to collective investment fund shareholders (D.4432).
- Rent (D.45).
- Adjustments for implicit financial services on loans and deposits (P.119C).
- Remuneration of cross-border employees (D.1, possibly including both wages and salaries in cash or in kind (D.11) and employer's actual and imputed social contributions (D.121 and D.122) (see Eurostat (2023[2])).

In practice, data on dividends, reinvested earnings on FDI and compensation of cross-border employees will be most prominent.

Public data sources

There are various public data sources for income flows. The most common is FDI statistics, such as FDI income payments about reinvested earnings by industry, as seen in OECD (2016[3]; 2016[4]; 2015[5]). The authors use the total income payments rather than only the distributed earnings, because it would better reflect how much of the domestic value added can be decided upon by foreign MNEs. Bohn, Brakman and Dietzenbacher (2021[6]) use the World Bank's *Bilateral Remittances Database* for flows of labour income. They also use bilateral data on direct and portfolio investment positions from different sources to map capital income flows. These are provided by the OECD, the International Monetary Fund (IMF) (Coordinated Portfolio Investment Survey), and UN Trade and Development (UNCTAD). UNCTAD's data concern the ultimate, not the direct, investors on a bilateral basis (Casella, 2019[7]). Meng et al. (2022[8]) use several data sources to estimate bilateral FDI flow and stock data by industry. These are the Global Trade Analysis Project bilateral multi-region multi-sector FDI stocks database; UNCTAD's bilateral FDI stocks; the IMF Coordinated Direct Investment Survey with detailed data on FDI stocks; OECD FDI stocks by country by industry; and the Chinese Statistical Bulletin with the People's Republic of China's (hereafter "China") outward FDI stocks by industry.

Meng et al. (2022[8]) estimate data for 35 economies (including "Rest of World") and 20 industries. OECD (2016[3]) and Bohn, Brakman and Dietzenbacher (2021[6]) provide results for 27 and 42 countries, respectively. Data are, thus, widely available.

Duan et al. (2021[9]) consider China alone, although their methods might be applicable to other countries. They rely on foreign capital shares in stocks by industry and by type of enterprise (domestic enterprise or foreign invested enterprise) and use this to split capital income into national and foreign capital income. Their data sources are the China Industrial Economy Statistical Yearbook, the China Economic Census Yearbook and the China Statistical Yearbook. Duan et al. (2021[9]) note that the share of labour income remaining in China is expected to be very high since the United Nations Global Migration Database shows the share of foreigners in the total population of China is very small. This might be similar in other countries.

Confidential data sources

A national statistical office will have more detailed information available, such as data used for or produced from the Sector Accounts. These describe monetary flows between different sectors in the economy and abroad, providing a quantitative description of several coherent economic processes in an economy. These economic processes are described for groups of units with a more or less homogeneous economic behaviour: the sectors. The main sectors are non-financial corporations, financial corporations, government, households and non-profit institutions serving households (NPISH). The Sector Accounts show not only the economic relations of these sectors with each other but also the transactions of the domestic sectors with the “Rest of World”. The following processes are distinguished: production, income generation, income distribution, income redistribution, income expenditure, capital formation and financing.

The compiling process of the Sector Accounts uses a large number of sources from different areas such as production, final expenditure, income and finance. Examples include statistics on balance sheets and profit and loss accounts of non-financial corporations, reports on financial corporations from the national central bank, government administration of ministries and municipalities, budget surveys, and international trade and balance of payments statistics. These data sources could be useful for income analysis in an ESUT/EIOT setting as well. It is advisable to stay as close as possible to the Sector Accounts. Their underlying system is an integration framework where the different data sources are confronted and integrated, just like the National Accounts.

This section will now describe the data sources by sector in more detail.

For non-financial corporations (S11), the most relevant flows are interest and dividends paid to or received from abroad, retained earnings on FDI, and income received from foreign subsidiaries. These may be available through surveys of statistics of finances, (corporation) tax data, annual reports of housing corporations or in declarations of listed firms.

Financial corporations (S12) often account for the majority of property income flows in an economy and with “Rest of World”. Surveys, conducted either by the national statistical office or the national central bank, can provide information about interest and dividends. Sometimes information about ownership of debt securities or quoted equity is available. Several types of income can be easily linked to industries. For example, investment income attributable to insurance policy holders is related to insurance and pension funding (industry 65 in ISIC Rev. 4). Some of the interest is related to output of services for owner-occupied dwellings.

Flows between general government (S13) and its counterparts might be found in annual reports of the ministries. Similar information might be found in annual reports of municipalities. Ideally, such information is split by policy area (e.g. energy networks, usage of public pavement, maintenance of public transport), which allows for assigning to industries.

The property income transactions of households (S14) and NPISH (S15) are mostly with financial corporations. Other relatively large flows are dividends, withdrawals from the income of quasi-corporations abroad and retained earnings as collective investment fund shareholders. It is assumed that these are received by households in their capacity as investors/consumers.

Compensation of cross-border employees (non-residents) might be estimated using a linked employer-employee database, wage information and the population register.

The general guidelines, “use what you have and use common sense”, apply. Ideally, data are available. Otherwise, discussions with experts might provide information. When the data do not fit immediately, the largest discrepancies should be solved by hand and general methods (such as the GRAS method, an iterative scaling method described in Chapter 5) should be used to solve smaller discrepancies.

Methods

When considering FDI income flows in an input-output setting, it is advised to use an EIOT, since FDI income only concerns MNEs. However, there are other ways as well.

OECD (2016[3]; 2016[4]; 2015[5]) all combine trade in value added (TiVA) data with information at industry level about output and exports by domestically owned enterprises and foreign enterprises in the domestic economy. They also use FDI income data by industry. They first estimate the export intensity of foreign-owned enterprises by dividing their exports by turnover, at industry level. They then multiply this ratio with the FDI income in that industry. This yields an estimate of the FDI income related to the direct exports of foreign-owned enterprises in that industry. This is income that a country earns from its exports but leaves the country anyway. It can be compared to the direct domestic value added of the industry to put it into perspective.

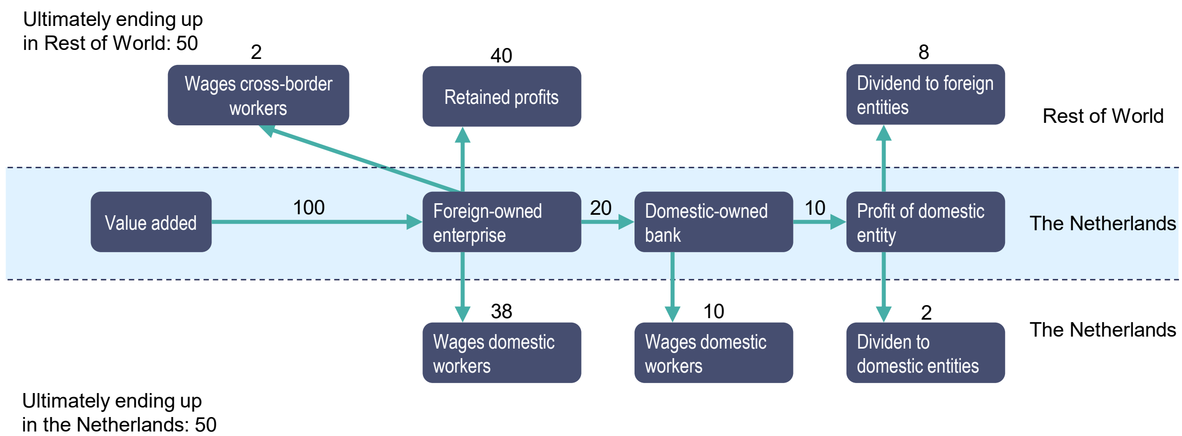
Bohn, Brakman and Dietzenbacher (2021[6]) link income in one country to consumption in others. They first construct a GDP-GNI matrix, showing how value added in country A ends up as income in country B. They do that by estimating how much value added stays in the own country, and using bilateral information about workers remittances (from the World Bank) and investment data to split the value added that leaves the country. In this way, production in country A leads to value added in country A, which leads to income in country B. After the construction of the GDP-GNI matrix, they combine it with calculations of value-added exports to estimate the income of each country that is embodied in foreign final use. In other words, consumption in country A is traced back to production (and value added) in country B, which leads to income in country C. This yields a country's "GNI footprint", showing the income that country C has due to consumption in country A.

Meng et al. (2022[8]) use the OECD Analytical Activity of Multinational Enterprises data set, a time series of multi-country IOTs where each industry is split into domestically owned enterprises and foreign-owned ones. They use it to estimate trade in value added by type of enterprise. Using different sources of FDI data, they estimate a very detailed matrix with bilateral FDI stocks and flows, by industry at country level. Given a host country and an industry, this shows the size of the investing country and its returns to capital, which allows linking production with value added and capital income, by host country, industry and investing country. Combining this information with the estimates of bilateral trade in value added, Meng et al. (2022[8]) arrive at estimates for "trade in factor income". Among others, they obtain estimates for the US-owned factor-income induced by China's final use.

Duan et al. (2021[9]) use tripartite IOTs for China. In these tables, each industry is split into three parts: 1) domestic enterprises meeting domestic demand; 2) enterprises in processing exports; and 3) enterprises involved in ordinary exports and/or foreign owned. In the third category, in each industry, capital income to output ratios and the share of "paid-in capital" (the asset value of enterprises) held by foreign shareholders are known. For RMB 1 of output in a given industry, they first derive the corresponding capital income. This is split into a foreign-owned and domestically owned part using the share of foreign shareholders in total paid-in capital. Together with an input-output analysis, this yields estimates of income related to exports that is flowing abroad/staying at home.

Lemmers (2023[10]) points out that besides income related to production, there is also income related to property, e.g. in financial services. Consequently, part of the outflow is financed by the inflow, and part of the outflow is financed with value added. Furthermore, value added due to production at a domestically owned enterprise may end up, via a bank and its profits, as dividends distributed to foreign and domestic entities. Figure 9.1 shows such income flows.

Figure 9.1. Fictitious example: which part of the value added ultimately ends up in the Netherlands or abroad?



Source: Lemmers (2023[10]).

This approach first compiles an IOT where each industry is split by type of MNE. It then compiles tables of income flows between each type of MNE in each industry, several sectors and “Rest of World”. This flow of funds table is similar to an EIOT, as shown in Table 9.1.

Table 9.1. Outline of income flow matrix

		Manufact. Non-MNE	Manufact. Dutch MNE	Manufact. Foreign MNE	Services Non-MNE	Services Dutch MNE	Services Foreign MNE	Financial services Non-split	Households	Rest of World	Total
Manufacturing	non-MNE										
Manufacturing	Dutch MNE										
Manufacturing	Foreign MNE										
Services	non-MNE										
Services	Dutch MNE										
Services	Foreign MNE										
Financial services	non-split										
Households											
Rest of World											
Total											

Note: MNE: multinational enterprise. Manufact: manufacturing.
Source: Lemmers (2023[10]).

The starting point is the integrated sector-to-sector property income matrix for 2015 from Dutch sector accounts. For both the use and supply of property income, there is limited information on counterparties on a detailed enterprise group to enterprise group basis. Therefore, in many instances, the production value (P.1) of enterprise groups was used to distribute property income flows to the counterpart industry and type of enterprise group. Since a large part of income flows occurs via the financial sector, pass through flows from Rest of World to the country and back to rest of the world that are not related to the domestic production process are problematic. These payments should, therefore, be removed from the data.

Examples of results

Table 9.2 provides an example of the results from OECD (2016[3]). It shows how much direct domestic value added in exports for six countries was expatriated via FDI payments. For example, Argentina had over USD 45 billion of direct domestic value added (DDVA) embodied in exports, i.e. by the enterprises that export directly. The total FDI income payments amounted to USD 11 billion. Since the average export intensity of enterprises was 0.18, 0.18 * 11 billion equals USD 2 billion of those FDI income payments that were related to the domestic value added of direct exporters. This means that 4% of domestic value added due to direct exports is expatriated. Note that this share is higher for countries where exports have a higher share in production and FDI income payments are relatively high compared to domestic value added (e.g. Belgium and China). For most countries (not shown in the table), the share of FDI income payments in DDVA in exports was below 10%. Exceptions were Estonia, Hungary, Ireland, Luxembourg and the Slovak Republic. The share was over 40% for Luxembourg due to its very open economy.

Table 9.2. Illustration of direct domestic value added data and foreign direct investment income adjustment calculations, 2011

	Direct domestic value added (DDVA) content of exports	Total FDI income payments	Export intensity	FDI payments associated with exports	Share of FDI income payments in DDVA in exports
	(1)	(2)	(3)	(4) = (2) * (3)	(5) = (4) / (1)
	Million USD			Million USD	
Argentina	45 534	10 811	0.18	1 946	0.04
Austria	80 184	11 566	0.24	2 797	0.03
Belgium	91 894	32 270	0.30	9 538	0.10
Brazil	131 985	31 716	0.03	888	0.01
Canada	259 112	37 246	0.12	4 347	0.02
China (People's Republic of)	586 455	204 476	0.23	46 211	0.08

Note: FDI: foreign direct investment.
Source: OECD (2016[3]).

Lemmers (2023[10]) uses information for the Netherlands in 2015 and obtained three main messages. First, a substantial part of value added, 15%, flows abroad. Second, a substantial part first flows to a domestic entity and only then leaves the country. It is not only value added of foreign MNEs, but also of domestically owned enterprises. Third, there are substantial differences between industries and types of enterprises. It is necessary to accommodate this heterogeneity in the analysis.

Table 9.3. Value added by final use category and destination, by type of enterprise, 2015

	Domestic final use		Foreign final use		Total
Destination value added	Netherlands	RoW	Netherlands	RoW	
	x billion EUR				
Non-MNE	120	3	74	2	199
Dutch owned MNE	34	3	46	5	88
Foreign owned MNE	25	12	48	25	110
Non-split	164	31	19	10	224
Total	344	49	186	42	621

Note: RoW: Rest of World; MNE: multinational enterprise.
Source: Lemmers (2023[10]).

As shown in Table 9.3, non-MNEs had a total value added of EUR 199 billion. Of this, EUR 120 billion was embodied in domestic final use and ultimately ended up in the Netherlands. EUR 3 billion was embodied in domestic final use and was transferred abroad via income transfers. EUR 74 billion was embodied in exports and ultimately ended up in the Netherlands. EUR 2 billion was embodied in exports and transferred abroad via income transfers. Note that there is substantial heterogeneity between the different types of enterprises. Of the value added of foreign-owned MNEs, about a third ultimately ends abroad. It is only about 2.5% for non-MNEs and 10% for domestically owned MNEs. This is not surprising as foreign MNEs will transfer profits abroad to the parent enterprise. Domestically owned enterprises do not have foreign parent enterprises. Dutch MNEs might pay dividends to foreign entities, but non-MNEs are less likely to do so. However, domestically owned enterprises, whether MNEs or not, will pay interest to banks that may pay dividends to foreign entities.

Employment

There is considerable interest in globalisation's impact on jobs, especially in developed countries where labour costs can be high relative to developing economies. A key concern in this respect reflects labour-intensive activities in developed economies, where higher use of capital to compensate for relative price differences in labour costs can have only a marginal impact. The initial wave of global value chains (GVCs) saw many firms capitalise on labour savings through international outsourcing, resulting in declines in the labour-intensive, and typically lower skilled, parts of their workforces. More recent years have seen an acceleration of these trends to other, higher, parts of the value chain, often affecting higher skilled workers. Export-oriented enterprises typically hire more highly skilled workers, and their exports engage disproportionally higher skilled employees from upstream enterprises. Accessing foreign markets is not only costly due to existing export barriers, but enterprises are also subject to more competition and need to invest significant resources to stay ahead of the game, their workforce being a pivotal resource in this regard. Outsourcing enterprises have been able to improve their international competitiveness, increase exports and, consequently, generate jobs through specialisation in higher parts of the value chain. New enterprises have been created precisely because they were able to specialise in niche activities that international fragmentation has provided. Within this churning of jobs, there have been winners and losers. Even if the losers may only be temporary, as workers reskill to engage in new activities, this churning is an important element behind the broad backlash against globalisation. This is an important reason why better information on the effects of GVCs on employment is needed.

There are significant differences in how workers of different genders or different skills participate in the labour force. In addition to the segregation being seen as a problem in itself, it also affects, for example, how different types of employees take part in GVCs, how well different employees can take advantage of the benefits of globalisation and how economic shocks will affect employees.

Country example: Belgium

In a small open economy like Belgium, precise information on the contribution of exports to employment is of great value for policy makers. This contribution encompasses jobs in export-producing enterprises as well as jobs in domestic suppliers in the export value chain. Within this framework, a precise estimation of employment embodied in exports should account for heterogeneity between exporters and non-exporters, particularly in terms of employment intensity, productivity and input structures. Furthermore, this provides an estimate of the bias that would appear if one does not account for this heterogeneity.

Data and methods

Michel and Hambÿe (2022[11]) present calculations of export-related employment based on an export-extended IOT and employment data for Belgium in 2010.[1] These data break down manufacturing industries into export-oriented enterprises and domestic market enterprises. Export-oriented enterprises are those that sell at least 25% of their output to foreign markets.

The disaggregation of industry-level manufacturing employment from the national accounts into export- and domestically oriented enterprises is based on enterprise-level data from the National Social Security Office. This administrative data source provides near-comprehensive information on the number of employees, which make up the bulk of manufacturing employment (more than 95%). When linked to the business register through a unique identifier for all manufacturing enterprises, it allows to determine the shares of export-oriented enterprises in total industry-level employment. Hence, for this disaggregation, it is implicitly assumed that the distribution of self-employed by exporting intensity is the same as for employees in each manufacturing industry. An additional disaggregation by skill category is obtained through enterprise-level data on educational attainment from the "social balance sheet", which is a separate section of the annual accounts.

Results

According to the calculations with the exporter-extended IOT, export-related employment amounted to 1.32 million jobs, or 29.5% of total employment in Belgium. Manufacturing exports sustained 0.59 million jobs in Belgium, of which about half were directly in the exporting enterprises and half were indirectly in domestic supplier enterprises. With regular IOT and employment data, the number of jobs sustained by manufacturing exports would have been overestimated by 4%. This is essentially an overestimation of low-skilled jobs sustained by exports. The underlying reason for this overestimation is that the labour intensity, value -added-to-output ratio and import propensity are higher for domestically oriented manufacturing enterprises than for export-oriented manufacturing enterprises.

Digging deeper into the extended data, and presenting results by type of enterprise, reveals that exports of export-oriented manufacturers generate a substantial number of jobs in non-manufacturing enterprises. These are, in particular, the service providers (229 000 jobs). The reverse relationship does not hold, as exports of enterprises in service industries generate jobs almost exclusively in these industries and only 6 000 jobs at export-oriented manufacturers. This is illustrated in Table 9.4.

Table 9.4. Employment embodied in exports by industry and enterprise types, 2010

Exports of / Employment in	Export-oriented manufacturers *Number of persons*	Domestically oriented manufacturers	Service industries
Export-oriented manufacturers	237 572	2 493	5 797
Domestically oriented manufacturers	32 943	52 516	15 096
Service industries	228 905	30 731	715 976
Total	499 420	85 739	736 870

Source: Michel and Hambÿe (2022[11]).

Overall, the results show that the combination of an EIOT and employment data allows us to confirm that within industries, the production process of export-oriented manufacturers is different from that of other enterprises and to improve the estimation of export-related employment.

Country example: Finland

Finland is a small open economy with significant exposure to foreign trade. Better knowledge of how trade affects the domestic economy is pivotal to ensure good policy making. For example, the Ministry of Economic Affairs and Employment faces questions regarding employment and economic growth. It is, therefore, necessary to delve deeper into employment structures and GVC dependencies of enterprises and employees. For instance, does every type of gender or every type of skill benefit in the same way from domestic and foreign demand?

Data and methods

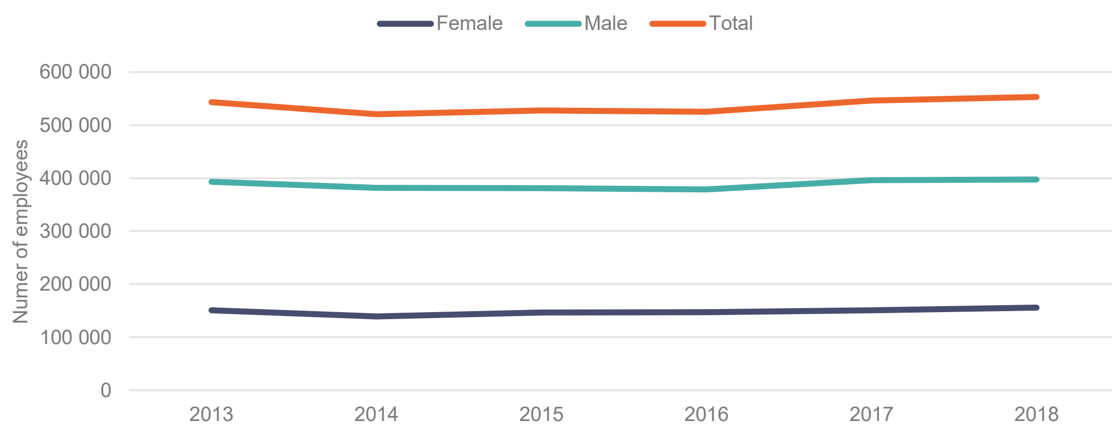
During a co-operative project in 2019-20, Statistics Finland and the OECD developed more information on employment and GVCs. First, they set up a system to compile regularly EIOTs. This facilitated calculating standard trade in value added indicators by type of enterprise. They incorporated employment statistics in the same system by creating a linked employer-employee database. The necessary data come from employee-level register data, containing employee characteristics such as age, gender and level of education. This enables detailed analyses, e.g. allowing for estimations of GVC dependencies of different groups of employees by enterprise type. Such employment indicators are included in Statistics Finland's experimental trade in value added publication (Statistics Finland, 2024[12]).

Employees are divided into three groups based on their level of education: low skill, medium skill and high skill. The groupings are based on the International Standard Classification of Education maintained by the UNESCO Institute for Statistics. The education classifications are explained in detail in UIS (2012[13]). Employees with education levels in early childhood education (code 0), primary education (code 1), lower secondary education (code 2) or unknown level of education (code 9 or no code) are considered low-skilled employees. Employees with education levels in upper secondary education (code 3) or post-secondary non-tertiary education (code 4) are considered medium-skilled employees. Employees with education levels in short-cycle tertiary education (code 5), Bachelor's or equivalent level (code 6), Master's or equivalent level (code 7), or doctoral or equivalent level (code 8) are considered high-skilled employees.

Results

Finland has one of the smallest gender gaps in employment rates among OECD countries (OECD and Statistics Finland, 2020[14]), but sectoral and industrial segregation is a common topic in public discussions. The traditionally important role of manufacturing enterprises in GVC integration, simultaneously a reason for the discussion on gender segregation in the labour market, is reflected in the GVC dependency of employees. Over 70% of the employees dependent on exports are men (Figure 9.2). In total, more than 500 000 Finnish workers are either directly or indirectly dependent on foreign demand for their employment. The number remained fairly stable between 2013 and 2018, declining slightly at the beginning of the period but climbing back up over the last two years.

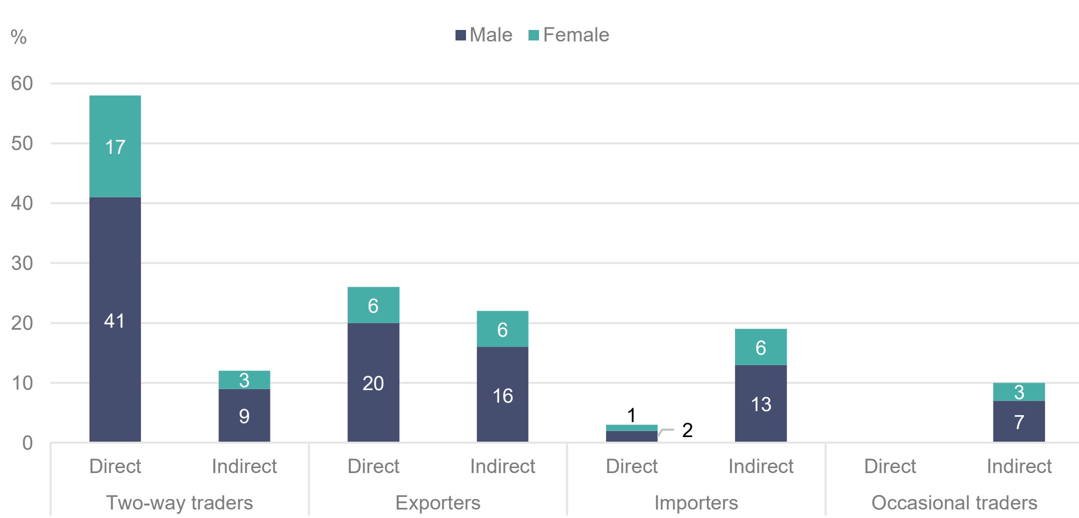
Figure 9.2. Male, female and total employment embodied in exports, Finland, 2013-2018



Source: Lindroos and Myllymäki (2021[15]).

The difference in participation rates between male and female workers in different sectors and industries is not only reflected in how many men and women participate in GVCs, but also in the way they participate (Figure 9.3). As women are disproportionately employed in non-exporting enterprises, their direct contribution to Finland´s exports is significantly lower than that of their male counterparts. However, non-exporting enterprises employ relatively more female workers. These enterprises provide upstream goods and services to exporting enterprises, which leads to jobs of female employees embodied in indirect exports.

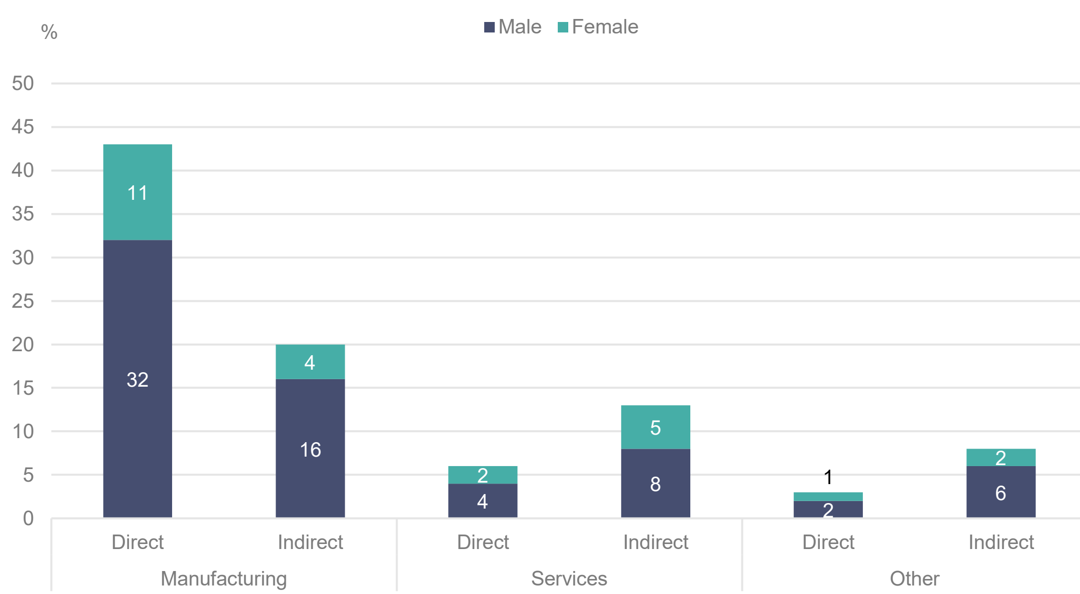
Figure 9.3. Jobs embodied in exports by gender and enterprise trading status, Finland, 2018



Note: Private sector excluding agriculture (A), finance and insurance (K), real estate (L), education (P), health and social work (Q), and part of other service activities (S).
Source: Lindroos and Myllymäki (2021[15]).

Manufacturing remains the most important gateway to foreign markets, but service industries provide pivotal inputs through domestic value chains. This is also reflected in the export dependencies of employees by industry, as can be seen in Figure 9.4. But the Finnish economy has steadily transitioned towards a stronger dependency on service production over the last decade. Employment has decreased in several manufacturing industries while service industries are well represented among the industries showing strong employment growth (OECD and Statistics Finland, 2020[14]). The transition towards more service-based production indicates an upcoming change in GVC participation by gender. In 2018, women represented 57% of the workforce in service industries.

Figure 9.4. Jobs embodied in exports, by gender and industry, Finland, 2018

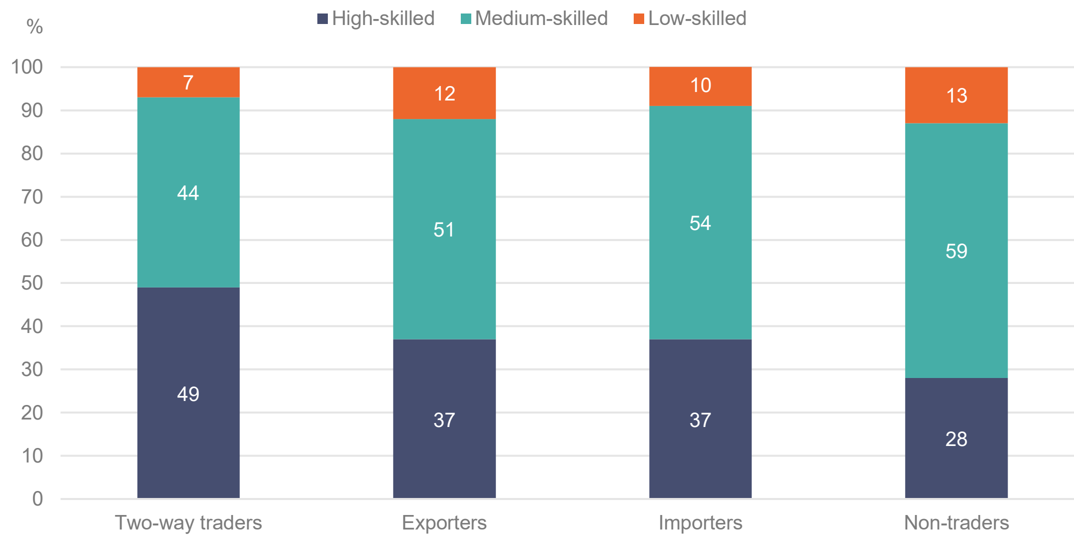


Source: Lindroos and Myllymäki, (2021[15]).

Besides the gender dimension of employment, the skill dimension is relevant as well. The Finnish labour force has undergone a steady transition towards more medium- and high-skilled employees. In 2018, about 35% of the Finnish labour force was high-skilled and 54% medium-skilled, having seen increases of about 3 and 5 percentage points since 2008, respectively. During the ten-year period, the number of employees classified as low-skilled declined by more than 100 000 in the private sector and the decline was spread broadly across industries.

The lean towards more educated workers is especially visible in Finnish two-way traders, but the workforce structure in exporters and importers is also significantly different from enterprises that do not participate in foreign markets. Two-way traders employed, at 49%, proportionally more high-skilled workers as a share of their workforce than other enterprises in 2018. The share of low-skilled employees in two-way traders was also noticeably small compared to other enterprises. The share of low-skilled employees is fairly even in other enterprises, but exporters and importers hire proportionally more high-skilled employees than non-traders.

Figure 9.5. Employment by enterprise trading status and employee skill, Finland, 2018



Note: Private sector excluding agriculture (A), finance and insurance (K), real estate (L), education (P), health and social work (Q), and part of other service activities (S).
Source: Lindroos and Myllymäki, (2021[15]).

The transition towards more service-based production is also likely to affect the skills composition of exporting enterprises in the coming years. Knowledge-based activities such as information technology and information services, which accounted for over 15% of growth in value-added exports between 2013 and 2019 hired proportionally more highly educated employees than many traditional manufacturing industries. The contribution of service industries to exports is mostly indirect. But these industries continue to strengthen their role in Finnish direct exports as well.

Physical extended supply and use tables

International institutions such as the United Nations and the European Union see the transition to a more circular economy as a means to achieve a more sustainable economy (UNECE, 2021[16]; European Commission, 2021[17]). However, moving part of the production process abroad via international trade might lead to a less sustainable economy. It might lead to more pressure on natural resources and more pollution. It is also possible, however, that globalisation could lead to more efficient production processes, development and diffusion of new resource-friendly technologies (Fortanier and Maher, 2001[18]). The question is what net effect will these developments have on the economy? It is then necessary to know which materials are used by which industries and in what quantities.

Besides environmental policies, policies concerning secured supply of and dependency on materials are on many agendas as well. Materials such as lithium, cobalt, gallium and germanium are necessary for the energy and/or digital transition. Some countries might extract these materials themselves; many others are dependent on imports. The COVID-19 pandemic and growing geopolitical instabilities showed vulnerabilities and dependencies of countries when it concerned materials. The European Commission (2023[19]) developed policies to diminish the dependency on critical raw materials from certain countries. Again, it is necessary to know which materials are used by which industries and in what quantities.

Physical supply and use tables contain exactly that information. They capture extraction, imports, production, consumption, exports and other use at product level. They also contain flows of emissions and waste, while covering the entire economy. The System of Environmental Economic Accounting (United Nations, 2012[20]), describes how to compile such tables. Since it is firmly embedded in national accounts, it allows the development of indicators using both the physical and the monetary information such as resource efficiency and resource dependency. Among others, it enables effective monitoring of the circular economy and other resource policies at macro and meso level, which is necessary, since policies can be very product-specific. This leads to a better understanding of the location of inefficiencies/dependencies and how material use drives other environmental fields such as emissions.

It is meaningful to compile physical ESUTs as well, for several reasons. First, international trade plays an important role, and large enterprises, MNEs and traders are more involved in international trade than SMEs (small and medium-sized enterprises), non-MNEs and non-traders. Second, it is expected that different types of enterprises have different production processes. If certain types of enterprises are less resource-intensive, there might be best practices to be learnt for the other types of enterprises towards more dematerialisation. Third, it is relevant to know which type of enterprise is involved with each product since it may indicate vulnerabilities. For example, Germany and Poland nationalised natural gas firms tied to the Russian Federation (AP, 2022[21]).

Country experience: The Netherlands

Graveland (2016[22]) describes an approach to derive ESUTs in physical terms for the Netherlands for the reporting year 2012. He uses the existing material accounts for the Netherlands, a SUT in physical terms, as the starting point. Subsequently, he uses employment of domestically owned and foreign-owned enterprises to split material supply and use in an industry by ownership. While this approach is generally not recommended, as it relies on strong assumptions that will be explained in the methodological section, this example provides information about the magnitude of the involvement of foreign MNEs. Graveland estimated that about a third of material supply and use for Dutch production is by foreign-owned enterprises. This is concentrated in specific industries and corresponding products. The following sections describe his data, methods and results in more detail.

Data

The starting point of the analysis is the material flow monitor of the Netherlands in 2012. These are SUTs in physical (kilogramme) instead of monetary (EUR) terms. The tables contain about 300 products and 125 industries. The material flow monitor is based on existing national economic-environmental accounting statistics and is updated every two years.

The information about employment, production and foreign ownership was obtained in a similar way as described in the earlier chapters. The General Business Register provided the industry classification and the employment of each enterprise. Production was derived from the Structural Business Statistics (SBS) survey (for the enterprises in the survey), from estimates using this survey (for the enterprises in the SBS domain but outside the survey) and by combining employment with the ratio employment by production for enterprises outside the SBS. The delineation between domestically owned/foreign-owned enterprises was obtained from the Inward FATS (Foreign Affiliates Statistics). It compiles the UCI, the Ultimate Controlling Institutional Unit, which is the enterprise, up the chain of the Dutch enterprise's control, which is not under the control of another enterprise, and the country of the UCI. If the country tagging is the Netherlands, the enterprise is domestically owned, if this country is not the Netherlands, the enterprise is foreign-owned. Sources for the country of the UCI are Statistics Netherlands' surveys (such as the financial statistics of large non-financial enterprises or the Community Innovation Survey) and external sources (such as the *Dunn & Bradstreet Database*).

Methods

The previous chapters have shown how to compile ESUTs using a bottom-up approach (similar to the compilation of the regular SUTs) and a top-down approach (using information about production, value added, imports and exports at total level). The approach used in this study uses yet another method, namely splitting an industry into foreign-owned and domestically owned parts by employment or production. For example, if the foreign-domestic proportion in employment at metal manufacturing is 40/60, this method splits the material supply and use in metal manufacturing of each product by 40/60 as well. To arrive at the proportions, employment and production were aggregated by industry and ownership.

This method is not recommended, as it uses two very strong assumptions about input and output for the production process. First, it assumes that the inputs for production of the two types of enterprises are the same (with a possible exception for value added) in each industry. They use the same products in the same proportions. Second, they are assumed to produce the same products in the same proportions as well. If one were to compile an extended physical IOT from these ESUTs, without any extra information, even the origin and destination (domestic/foreign) of input and output of the two types of enterprises would be the same in each industry. Therefore, results only show the possibilities of physical ESUTs and a rough order of magnitude.

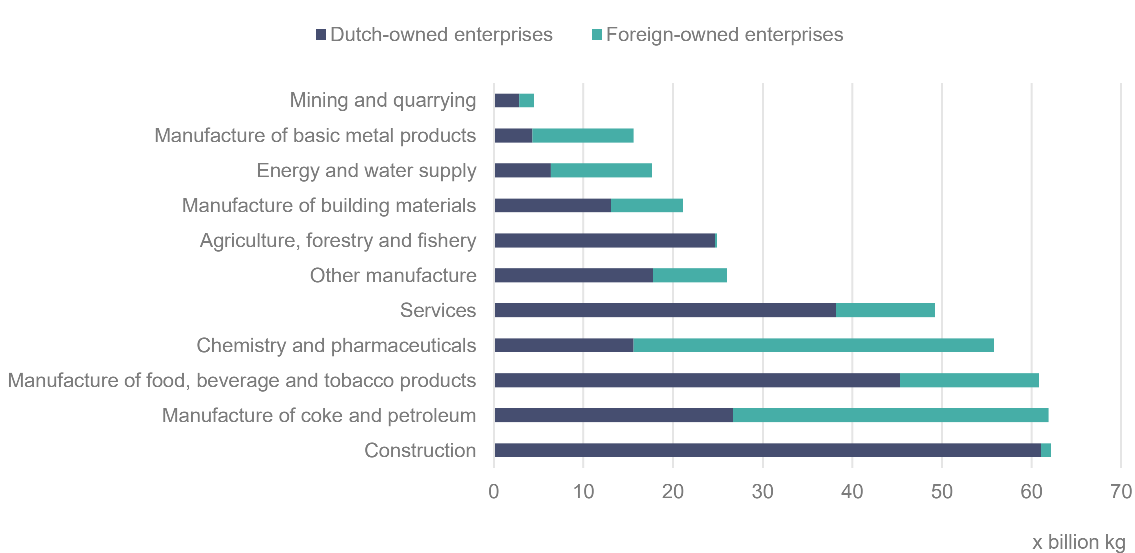
Results

This section contains two examples of the results. See Graveland (2016[22]) for more examples.

Figure 9.6 shows that material use is concentrated in a few industries. These are construction; manufacture of coke and petroleum; manufacture of food, beverages and tobacco products; chemistry; and pharmaceuticals. The service industry uses a large quantity of materials as well, but this is not surprising given that the industry encompasses 80% of the Dutch economy.

Ownership of the materials varies significantly among industries. There are hardly any foreign-owned construction enterprises in the Netherlands, hence the foreign share of material use in this industry is low. However, in manufacture of coke and petroleum, and of chemistry and pharmaceuticals, foreign-owned enterprises have a majority. This holds for several other industries as well, e.g. the manufacture of basic metals and the supply of energy and water.

Figure 9.6. Use in the Dutch economy, by industry and ownership, 2012



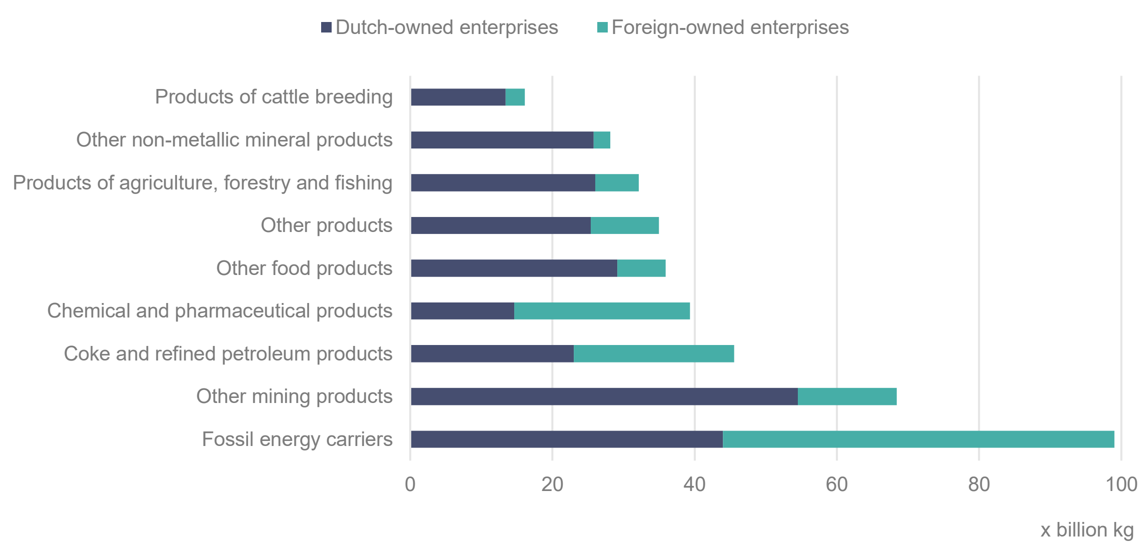
Source: adapted from Graveland (2016[22]).

The total share of foreign-owned enterprises in Dutch material use was 36%. This is much greater than their shares in domestic production and employment. The reason is that they have substantial shares in material-intensive industries, whereas they are relatively small in material non-intensive industries such as services. Services also include government services, education and healthcare services, all with a low (or zero) share of foreign ownership and a low material intensity.

The total share of foreign-owned enterprises in Dutch material supply was 39%. As explained previously, foreign-owned enterprises have large shares in several material-intensive industries. They use a sizeable share of total materials in the Dutch economy, and therefore produce (supply) a large share as well. Differences in the share in supply and use are because the ESUT was not balanced. Graveland (2016[22]) provides detailed results for material supply.

The type of products used by domestically owned/foreign-owned enterprises is strongly related to the industries where they are active. Figure 9.7 shows that products with the most weight in the Dutch economy are fossil energy carriers, other mining products (such as sand and ores), coke and refined petroleum products, and chemical and pharmaceutical products. With the exception of other mining products, foreign-owned enterprises use at least half of the quantities of these four products.

Figure 9.7. Use in the Dutch economy, by product and ownership, 2012



Source: adapted from Graveland (2016[22]).

The supply of Dutch-produced materials is similar, since this is related to the industries as well. For example, a large part of the manufacture of coke and petroleum is foreign-owned. In the Netherlands, this industry transforms fossil energy carriers to coke and refined petroleum products. Hence, supply of coke and refined petroleum products will be foreign-owned for a large part as well.

Other possible indicators

Following Delahaye et al. (2015[23]); Hanemaaijer et al. (2021[24]); and Delahaye, Tunn and Tukker (2022[25]), this section points out other indicators related to resource efficiency, resource dependency, material substitution, recycling and environmental impact, respectively.

- Using natural resources efficiently is necessary since they are limited, and extraction might cause harm. For enterprises, efficiency is necessary since it reduces costs and dependencies. It is considered best to consider resource efficiency at industry level. Material intensity is defined as the ratio of material use (in kilogrammes [kg]) to value added. Material productivity is defined as the ratio of the quantity that is produced with 1 kg of materials. Differences between types of enterprises can be due to, among others, different production processes or use of different materials. Both types of differences can lead to sharing best practices.

- Countries will usually not produce every single product; they may lack ores or fossil fuels and therefore be resource-dependent. Sometimes substitution is possible, but often it is not. For a given product, a country is independent from others when import plus extraction minus export is covered completely by domestic material extraction and/or production. It is relevant to distinguish between imports of raw materials, intermediate products and final goods, since this indicates which stage of the production process takes place in the own country. A material footprint of imports is calculated as the amounts of raw materials necessary to produce imported goods. A physical SUT will show which industry is dependent on which critical raw material to produce. An ESUT will show whether there are differences in this respect between different types of enterprises. A time series will show whether part of the production process is moved abroad or not.
- Measuring substitution of non-organic materials (such as fossil fuels) by biomass to produce the same product monitors the transition to a circular economy. For example, it could concern producing plastic from plant-based oil instead of from fossil oil. Another way to monitor the transition is by defining biotic materials as those that come from renewable biological resources and abiotic materials as “the rest”. Combining this with bio-based products allows to estimate the size of the bio-based economy and monitor it over time. An ESUT will indicate whether there are differences between types of enterprises and whether there is potential for one of them to improve.
- Recycling mitigates the depletion of natural resource reserves and reduces dependencies on countries which supply materials. It is not meaningful to compare industries since they have very different material use/supply and production processes. For example, electricity suppliers will use recycled biomass whereas paper producers will use recycled paper. Comparing the use of recycled materials by different types of enterprises in the same industry may lead to sharing best practices.
- One can estimate which material flows to and via a country have the most environmental impact abroad. Since different types of enterprises in the same industry will differ in their use of domestic/foreign materials, their environmental impact abroad will differ as well. This is why Guilhoto and Howell (2024[26]) recommend using an extended IOT or an extended multi-country IOT when estimating the carbon dioxide (CO_2) footprint of FDI. For the same reason, it is recommended to use an extended IOT or multi-country IOT when estimating the material footprint of MNEs, SMEs, etc.

Emissions

Input-output models have been widely used in studying trade-related economic and environmental issues. However, the traditional input-output model fails to capture enterprise heterogeneity. As mentioned in Chapter 2, production structure, technology and trade (Bernard et al., 2012[27]; Chong et al., 2019[28]) vary substantially among different types of enterprises. This is also the case for energy consumption and carbon emissions. Only by taking this heterogeneity into account can proper estimates of the economic gains and environmental costs related to exports of different types of enterprises be obtained.

Country example: China

This section is based on Zhang and Yang (2022[29]). One typical feature of China’s economy is the enormous number of SMEs, accounting for 99% of its total number of enterprises in 2018. SMEs contributed to more than 60% of GDP, 50% of taxation, 70% of technological innovation and 80% of urban employment, demonstrating that they are a dominant force in the Chinese economy. At the same time, SMEs also have a considerable environmental impact. Recent evidence by Meng et al. (2018[30]) shows that more than half of China's total CO_2 emissions were attributed to SMEs in 2010.

Policies are aimed at enterprises, but a one-size-fits-all policy is bound to fail. Zhang and Yang's work provides scientific insights for policy makers to choose effective industrial structure adjustment strategies. Different policies for different types of enterprises can lead to China's trade progress while mitigating trade-related emissions.

Data

The data sets used to compile the EIOT can be divided into three categories: 1) a regular non-competitive IOT; 2) enterprise-level data; and 3) other official statistics.

- China's regular IOT from the National Bureau of Statistics (NBS) is the basis for the compilation of the EIOT.
- Enterprise-level data include the Chinese Annual Survey of Industrial Firms (CASIF) and Chinese Customs Trade Statistics. Specifically, the CASIF data obtained from the NBS covers more than 300 000 enterprises each year, accounting for approximately 95% of total Chinese industrial output. At enterprise level, the CASIF provides information of industrial output; value added; export value; and other basic characteristics such as enterprise code, industry code, etc. The data from the Chinese Customs Trade Statistics are compiled by the General Administration of Customs of China, which records all transactions (imports and exports) passing through Chinese customs. It contains enterprise identification (name, address, ownership), product code (eight-digit Harmonized Commodity Description and Coding System [HS] code), value of imports and exports, etc.
- China's National Economic Census and other official statistics from NBS are also used for the total constraints.

Methods

Zhang and Yang (2022[29]) constructed an extended non-competitive input-output model for China that distinguishes between large, medium and small-sized enterprises. The classification of an enterprise into the different enterprise size categories is based on the NBS' "Division Standard of Large/Medium/Small Sized Enterprises", which varies across sectors. Table 9.5 shows the criteria for the industrial sector. These are related to the number of employees and an enterprise's revenue. To be classified as large or medium-sized, enterprises should meet both the number of employees and revenue criteria. Otherwise, the enterprise will be classified into the next lower category of enterprise size.

Table 9.5. The division criteria of enterprise size in China

Sector	Variable	Unit	Large	Medium	Small
Industrial	Employees (X)	Persons	X≥1 000	300≤X＜1 000	Other
	Revenue (Y)	RMB 104	Y≥40 000	2 000≤Y＜40 000	Other

Source: Zhang and Yang (2022[29]).

Emissions by size class are estimated using their dependence on the intermediate inputs from energy sectors. The study distinguishes five energy sectors: 1) coal mining and processing; 2) crude petroleum and natural gas extraction; 3) petroleum processing and coking; 4) electricity and steam production and supply; and 5) gas production and supply. Note that other emissions, for example at the enterprise itself, are not taken into account. It is recommended to include such information if it is available.

Results

Table 9.6 shows the share of each size class in output, value added, export and CO_2 emissions in the industrial sector for 2012. Overall, the total output and value added of SMEs accounted for more than 60% in the industrial sector, demonstrating that SMEs play a crucial role in China's economic development. In terms of exports, large enterprises accounted for half of China's industrial sector's total exports, indicating that large enterprises have certain advantages over SMEs in international trade.

Table 9.6. Contribution to China's economy and CO_2 emissions of industrial sector, 2012

	Value added share	Output share	Export share	CO_2 emissions share
Large enterprises	33%	37%	48%	39%
Medium-sized enterprises	29%	26%	29%	21%
Small enterprises	38%	37%	23%	40%

Source: Zhang and Yang (2022[29]).

Next, the value added and CO_2 emissions generated per unit export of different size classes are calculated. This enables comparing economic gains and environmental costs related to exports of different size classes in China. The results imply that considering the heterogeneity of enterprise size matters when measuring the exports-related value added and CO_2 emissions in China. Table 9.7 shows that the value added per RMB 1 000 of exports of large enterprises is the lowest (RMB 627), while that of small enterprises is the highest (RMB 791), and the ratio of medium-sized enterprises lies in between. The pattern of embodied CO_2 emissions per RMB 1 000 of exports by size class is similar to that of value added. Large enterprises exported cleaner than SMEs. Possible explanations may be the difference in export product structure and the import intensity of intermediate inputs across different sized enterprises.

Table 9.7. Value-added and CO_2 emissions per unit export of different sized enterprises in China, 2012

	Value-added (RMB)	CO_2 emissions (tonne)
Large enterprises	627	0.135
Medium-sized enterprises	771	0.154
Small enterprises	791	0.171
Average	706	0.149

Source: Zhang and Yang (2022[29]).

The study found apparent disparities in the export structure among different size classes. Specifically, large enterprises mainly export high-tech or sophisticated products, such as "electronic and telecommunication equipment" and "electric equipment and machinery". These amounted to 45% and 10%, respectively, of total industrial exports for large enterprises in 2012. These sectors tend to use relatively more imported intermediates and therefore usually have a lower value added per unit of exports ratio. Meanwhile, they also have a very low CO_2 emissions intensity compared with resource-intensive and labour-intensive sectors.

Furthermore, in 2012, 22% of the total intermediate input of large enterprises consisted of imported products. For medium-sized and small enterprises this was only 16% and 7%, respectively. This indicates that larger enterprises use more imported intermediate products, which leads to a higher intensity of foreign raw materials and intermediate input products. Thus, these enterprises would create lower domestic value added and lower embodied domestic CO_2 emissions in exports.

Integrating extended supply and use tables and productivity statistics

This section, based on Samuels (2021[31]), motivates integrated ESUTs and KLEMS (capital, labour, energy, materials and services; see, for example, O'Mahony and Timmer (2009[32])) productivity statistics. Merging the two approaches with TiVA analysis yields insights into the economic forces driving the origins and evolution of GVCs; the sources of cross-country economic competitiveness; and improves the analytical usefulness of the ESUTs, KLEMS and TiVA statistics. This section first highlights the benefits of integrating KLEMS and TiVA statistics (without ESUTs). Subsequently, it briefly discusses the data needs for and the advantages of integrating KLEMS with ESUTs.

There has been substantial progress in the international statistical community in the production of broadly comparable (across countries) KLEMS statistics and IOTs for TiVA decompositions. Merging the two parses TiVA estimates from total trade in value added to its origins across factors of production. This is useful for analysing the origins of value chains across countries, instead of taking them as given. It provides estimates of underlying factor flows that are not evident in standard TiVA estimates without the integrated KLEMS detail.

When a country engages in GVCs, its trade in value added reflects and is driven by its production structure relative to others in the GVC. When a country exports value added, this value added embeds contributions from different types of labour and capital services. Integrating KLEMS with TiVA allows identifying these different sources of value-added trade. For example, a more advanced country that may be intensive in educated labour and research and development (R&D) likely has a different trade structure from a country intensive in production that does not require highly educated labour and R&D.

Taking a concrete example, consider the identification of the role of R&D in US value-added exports. Using standard TiVA estimates, R&D has a limited apparent role in US trade even though the United States is relatively R&D-intensive. On the other hand, US KLEMS statistics include information on the role of R&D services in US production (BEA, 2023[33]). R&D embedded in US value-added exports can be measured by identifying the share of R&D directly embedded in each value-added export and combining this with the R&D embedded in the contributions of US upstream industries that participate in the domestic supply chain. Table 9.8 shows a preliminary estimate of the factor content of US value-added exports in 2019 and demonstrates the usefulness of integrating KLEMS and TiVA statistics. The results show that embedded R&D is a significant contributor to US exports that would not be evident in traditional trade or TiVA trade measures. With existing data, producing KLEMS and TiVA-integrated statistics is relatively straightforward.

Table 9.8. Factor content of US value added exports, 2019

	Level (in billion USD)	Share (%)
Entertainment originals	11.2	0.7
IT equipment	32.3	1.9
Software	60.7	3.5
Research and development	148.6	8.6
Non-college labour	360.8	21.0
Other capital	551.1	32.0
College labour	555.5	32.3
Total	1 720.3	100.0

Source: Samuels (2021[31]).

A promising future direction is to integrate KLEMS and ESUTs. The premise of the ESUTs is that further decomposing industries in the supply-use tables (e.g. into exporters and non-exporters) helps understand the origins of TiVA. It refines the TiVA estimates as well by isolating the input structure of globally engaged producers from other producers.

Integrating KLEMS with ESUTs has the same basic motivation as integrating KLEMS and the standard TiVA estimates discussed above. However, it is even more powerful, because the exporters and non-exporters are separated, thus providing refined TiVA estimates, and more detailed origins and sources of value added across the global value chain.

The data necessary for such an account that includes KLEMS-type productivity estimates would be demanding. Investigative work would have to be done to evaluate the prospects for estimating the necessary components. The basic components would be output prices that reflect differences in prices charged by globally engaged versus other producers. On the input side, comparable information would need to be assembled: the number and compensation rates for workers classified by demographic group (e.g. workers with a college and non-college degree and other dimensions) along with the capital stock, asset composition and rates of return in globally engaged versus purely domestically engaged producers. While the data challenges are significant, the benefits of such an account are important in understanding the sources of economic competitiveness as the global value chain and its evolution dominates much of economic development throughout the world.

Regional extended supply and use tables

One of the primary factors behind the development of TiVA-type indicators was to better understand the impact of globalisation, in particular in relation to the fragmentation of GVCs. An important focus of that work centres on “who benefits” and, in particular, the evidence that trade is not a zero-sum game. However, while there is significant evidence that trade has been, and remains, an important driver of growth across the globe, within countries the evidence, albeit largely anecdotal, suggests that those gains are not always spread equally, potentially exacerbating what have become known as geographies of discontent (OECD, 2023[34]). Regional ESUTs provide a powerful tool that can shed insights on how regions within countries have benefited, or otherwise, from globalisation, and to inform policies, especially emerging new industrial policies, many of which have a strong place-based focus. The Inflation Reduction Act and the CHIPS and Science Act in the United States, as well as the European Chips Act and Korea’s K-Chips Act, are recent examples of efforts to foster supplier diversification and partial onshoring of production processes through a mix of industrial and innovation policies.

This section is based on Horvát and Amann (2025[35]). It provides more information on various types of regional SUTs along with challenges and possible solutions pertaining to their construction. The fact that regional SUTs are rare, and regional ESUTs even rarer, illustrates the nature of the challenges involved, particularly the considerable challenge of measuring transactions concerning institutional units across regional borders. As such, the focus below is mostly on regional SUTs, with a more theoretical discussion on the possibility of extending them to regional ESUTs.

The spatial scale matters for measuring interdependencies between markets. Larger regions typically possess more of the necessary resources, infrastructure and capacities to meet many of their internal needs effectively and rely less on external resources. Conversely, smaller regions are more likely to concentrate on specific activities or tasks where they have a comparative advantage, making them more reliant on trade and co-operation. To illustrate, the latest OECD TiVA estimates show that 17% of European Union domestic value added is embodied in its gross exports (outside the European Union), which is, on average, half the size of domestic value added embodied in gross exports of individual member states. There are sizeable differences between larger economies such as France and smaller ones such as Ireland.

Another motivation for considering regions is the large variety in socio-economic and environmental performance between regions. This is because, for example, their demographic make-up, their industry agglomeration and specialisation, as well as their links within and across regions (Monsalve et al., 2020[36]). Furthermore, they can determine a region's position in GVCs (Meng et al., 2016[37]) and, ultimately, how regions are affected by global economic developments.

Typologies for regional supply and use tables

Typologies underpinning the construction of regional SUTs can broadly be categorised in three ways:

Administrative typologies (ARSUTs) are generally based on historical, economic, statistical and political boundaries representing some form of subnational government, such as a US state, German *Länder,* Spanish Autonomous Community or any other form of subnational government. Administrative typologies enable a more accurate and detailed depiction of regional characteristics and link the potential analysis with local stakeholders. Examples of such typologies are the OECD territorial grids, the territorial levels classification (OECD, 2023[38]) or the Nomenclature of territorial units for statistics (NUTS) (Eurostat, 2022[39]) classification for EU member countries. ARSUTs improve the understanding of regional impacts and dependencies by increasing the spatial granularity and accuracy of the relationships between and within regions.

Analytical typologies are based on descriptive categories that follow more functional forms of areas, e.g. metropolitan and non-metropolitan within countries (UNSD, 2020[40]; Dijkstra, Poelman and Veneri, 2019[41]), which may result in spatial aggregations of regions that cross regional administrative boundaries. These can help better understand specific spatial factors that drive economic performance, such as agglomeration effects. Examples of functional forms include labour market areas (OECD, 2020[42]) and functional urban areas (OECD, 2018[43]). Functional urban areas, sometimes called "metropolitan areas", encompass cities along with their adjacent commuter regions.

Combined typologies blend administrative and characteristic typologies. They combine administrative boundaries with descriptive categories with spatial dimensions (Monsalve et al., 2020[36]; Sato and Narita, 2023[44]; Zheng et al., 2019[45]).

Compiling regional supply and use tables

Methodological approaches

Subnational statistics can either be derived top-down from national aggregates using economic indicators or econometric and mathematical models (European Commission: Joint Research Centre, Rueda-Cantuche, J., López-Alvarez, J. and Galiano Bastarrica, 2025[46]), or obtained bottom-up from microdata sources. Hybrid approaches, which blend top-down tools with available microdata, are most frequently used in practice.[2] Similarly, compiling regional ESUTs can be done using bottom-up tools or can be derived from national tables (using top-down methodologies) or a combination of the two.[3] Top-down methodologies can produce distorted or inaccurate regional projections resulting from modelling constraints. In turn, bottom-up methods are complex and more data-intensive (Davidson et al., 2022[47]).

Ideally, regional ESUTs would be constructed bottom-up. However, no country has complete regional SNA accounts (European Commission et al., 2009[48]), and the availability of economic measures usually decreases with increasing regional granularity. A particular challenge relates to the unit for analysis that may be used for surveys. In many countries, this is the level of the enterprise and not the establishment, which means that underlying data for the production and consumption of a multi-establishment enterprise may not always be available. While National Statistical Offices try to apportion activity across regions in constructing regional national accounts data, this phenomenon can give rise to headquarters biases in regional statistics, especially with respect to activities with a high dependence on knowledge-based capital.

Whether using a bottom-up or top-down approach, breakdowns of regions that are equivalent to single or collections of administrative units are simpler to compile than those based on functional areas, given the data availability.

Challenges compiling regional supply and use tables bottom-up

The central challenges when compiling regional SUTs bottom-up relate to subnational production accounts, interregional trade, central government activity and sampling.

Subnational production accounts

As noted above, identifying and measuring economic activity (and the location where they originate) may be complicated whenever the enterprise has multiple establishments located in different regions, which can be further complicated if the establishments produce significant secondary products or services that differ from the enterprise's primary activity. If production accounts at the establishment level are not available or exploited, apportionment methods are typically used to assign measures of the economic activity of enterprises to establishments using secondary information such as the number of employees or any other available measures.[4] Table 9.9 describes preferred apportionment indicators for production and generation of income account measures, by decreasing level of precision and anticipated complexity of implementation.

Table 9.9. Types of apportionment methods by decreasing level of precision and anticipated complexity of implementation

Type of data	Description/assumption	Need to apply apportion methods
Establishment-level surveys	Collecting information on production and generation of income accounts; administrative collection of establishment-level data.	No
Business Census	Regular Census on the establishment level.	Yes (for non-Census years but using Census weights if enterprise data are available in non-Census years)
Business registry surveys or multilocation surveys	Proportion of wages or wage bill associated with establishment.	Yes
Employment survey	Most commonly available; assumes equal productivity of output, wages, imports and exports across all establishments within an enterprise.	Yes

Source: Horvát and Amann (2025[35]).

Interregional trade

Interregional transfers of goods and services are a central feature of any interregional framework at the subnational level: goods and services can cross regional borders at multiple stages of the production process, yet such regional transfers are generally not captured, at least readily, in the national statistical system. Consistent trade flows between regions can, however, be obtained or estimated by populating trade flow matrices using initial flow information sourced from either one or a combination of different sources (Table 9.10). These commodity flows are then balanced using information on regional production and use of products and services together with final consumption. Note that Table 9.10 only contains the possible sources for flows that can identify the type of enterprise. All sources in the table can, therefore, be related to the enterprise level.

Table 9.10. Possible data sources of interregional trade flows

Type of data	Advantages	Potential limitations	Country examples
Value added tax transactions/ e-invoices	Rich source of information on various characteristics of enterprises covering a high share of the formal economy. No need for additional data collection, thus reducing the burden on enterprises. Possible mapping of international flows and business-to-business and government flows.	Confidential data, often out of reach of competitors of national accounts, matching with a business registry, headquarter bias, bias since the personal data protection regulation can impede the regionalisation of B2C transactions on the consumer side.	Value-added tax: Belgium (Avonds, Hertveldt and Van den Gruyce, 2021[49]). E-invoicing: B2G for procurement is mandatory at the EU level; B2B and B2C are mandatory in Italy (European Commission, 2013[50]) and optional in other countries but many plan to make it compulsory
B2B payment transactions	Rich source of information on enterprises covering a high share of the formal economy of already collected data, thus reducing the burden on enterprises, Possible mapping of international flows and to B2B and government flows.	Confidential data, classification of payment, identification of financial sector (recipient vs. payment intermediary), collected in only a few countries, matching with business registry, headquarter bias, bias since the personal data protection regulation can impede the regionalisation of B2C transactions on the consumer side. As these are country-specific instruments, there are no international flows.	Mexico; United Kingdom (ONS, 2023[51]).
Trade survey on origin of purchases and destination of sales	Provides a clear picture of the origins and destinations of trade flows.	Increased burden on enterprises, potentially low response rate. Countries may reduce the burden on enterprises by only asking about the destination of sales or purchases, as it may be easier for enterprises to provide information on the location of their customers. Similarly, in some sectors, enterprises have a limited number of suppliers, so it may be easier to learn about the location of purchases rather than the location of sales.	Canada (Généreux and Langen, 2002[52]), United Kingdom (Trade Survey for Wales, Exports statistics Scotland, Northern Ireland Economic Trade Statistic).

Notes:
1: Headquarter bias refers to the potential allocation of the disproportionate activity to headquarters as they are considered as owning knowledge-based capital of the enterprise.
2: B2G corresponds to business to government, B2B business to business and B2C business to consumer transactions.
3: The list of country examples is non-comprehensive and includes current as well as past projects and initiatives.
Source: Horvát and Amann (2025[35]).

Central government activity

While the location of production of central government can be readily determined (as well as its consumption) through administrative data, this is less trivial with respect to the location of consumption. In this sense, distribution on a per-capita basis is imperfect, as it assumes homogeneous regional demand for central government activity. Another approach would be to allocate it based on the location of production, as in the case of Canada (Davidson et al., 2022[53]), recognising that this would have little impact on input-output coefficients. However, regardless of how consumption is allocated, identifying from which regions central government purchased its intermediate consumption would still be necessary. Advancements in electronic government procurement systems are, however, helping to make these data more readily available (Cocciolo, Samaddar and Fazekas, 2023[54]).

Sampling

Available microdata are typically sampled to guarantee representative results at the national level. Therefore, the data may be ill-suited to produce representative regional SUTs, especially for regions with specific industry profiles. Furthermore, the availability of regional surveys and administrative or commercial data sets to remedy these challenges will vary on a case-by-case basis. In some cases, the lack of data may render a bottom-up construction of regional SUTs infeasible.

Digital supply and use tables

Digital SUTs are technically not ESUTs, since they do not split industries by type of enterprise. However, they do split SUTs by type of industry and by type of product, and several of the methods and data sources may be of use to compilers of ESUTs. This section is based on Mitchel (2022[55]) and Sakuramoto (2022[56]) and presents digital SUTs. First, it explains the general background and history of digital SUTs. Subsequently, it introduces the general framework, addressing the where (within or outside the production boundary), how (digitally ordered/delivered or not), what (digital/non-digital products) and who (digital/non-digital industries). It then presents the most sought-after indicators, concluding with three country examples.

Why do we need the digital supply and use tables

Digitalisation has fundamentally altered the production and consumption of goods and services worldwide. Enterprises have been able to leverage digitalisation to disrupt established markets while also improving the efficiency of their production processes. At the same time, the digital transformation has permitted consumers to access a wider variety of goods and services while exercising greater control over the characteristics of the transaction processes.[5] Despite the rise of digitalisation, and the inclusion of digital transactions within the SNA production boundary, many of the digital trends occurring within the economy are not explicitly observable in the national accounts.

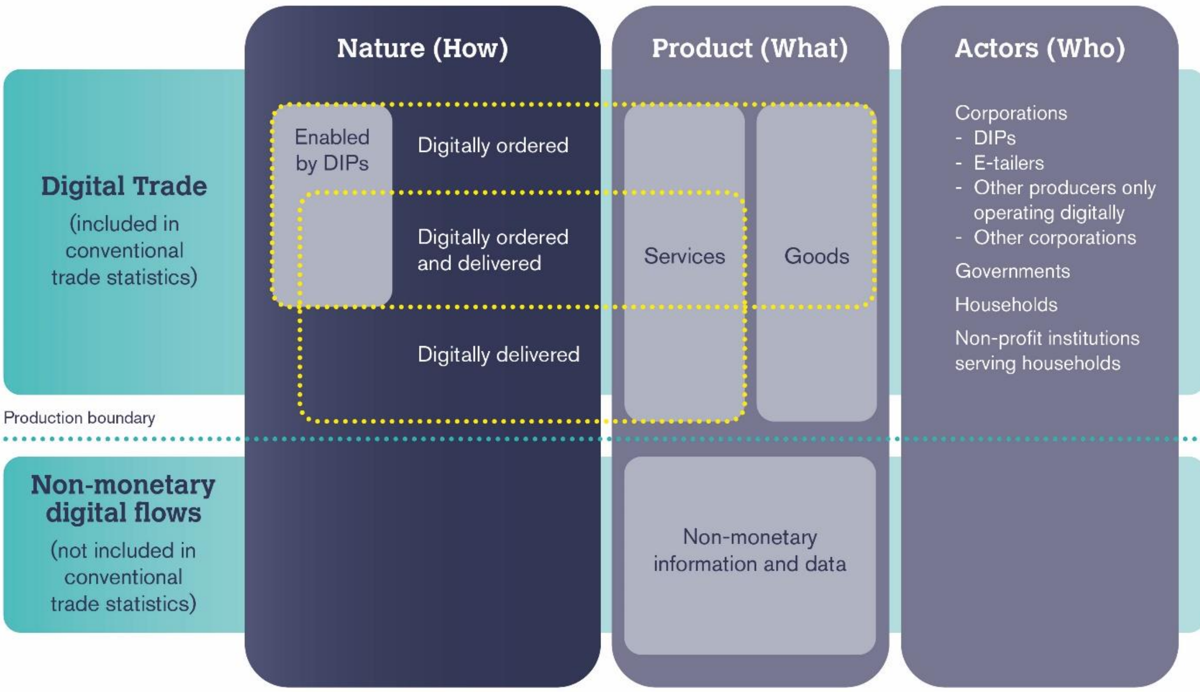
This absence of these key trends associated with digitalisation within the national accounts has, at times, caused confusion about what is (and is not) included in the production boundary of the national accounts[6] and who is (or is not) benefiting from the digitalisation taking place. This need for more information has been recognised by other international groupings. For example, the G20 Digital Economy Task Force (DETF) requested a greater focus on measuring digitalisation and its impact on the economy. This includes a direct call to develop "satellite national accounts" focusing on the digital economy (G20 DETF, 2018[57]), creating the "G20 Roadmap toward a Common Framework for Measuring the Digital Economy" that explicitly included the digital SUTs as a method to improve the visibility of digitalisation in the national accounts (G20 DETF, 2020[58]; OECD, 2020[59]). The G20 DETF (2021[60]) reaffirmed and emphasised the need for co-operation and sharing of best practices among national statistical offices.

There is currently no single, generally accepted definition of what the digital economy entails. This absence of agreement could be attributed to its multi-dimensional nature, since digitalisation has affected the production, ordering, delivery and consumption of almost all goods and services. From a measurement point of view, one can derive a picture of the digital economy by aggregating certain products or industries, e.g. the ICT products in the Central Product Classification (UNSD, 2015[61]) or the ICT sector in the International Standard Industrial Classification of All Economic Activities, Revision 4 (UNSD, 2008[62]). From a policy point of view, however, these definitions are often considered to be too narrow, insomuch that they miss digitalisation's impact on the production of traditional goods and services. Therefore, it is likely that the output of these "narrow" interpretations of the digital economy understates the overall impact of digitalisation on the economy.

The digital SUT framework

To improve the visibility of increasing digitalisation in macroeconomic statistics, a digital SUT framework was developed (Figure 9.8). The framework's fundamental point of delineation is the nature of transaction ("how"). However, to provide outputs that highlight the points of policy interest, the framework also includes additional variables. These include the good or service being ordered and delivered ("what"), the actor/sector involved in the transaction ("who"). The Figure clarifies which interactions/transactions are within the SNA production boundary (shown by a dotted line separating digital production from non-monetary digital flows).

Figure 9.8. Framework of digital supply and use tables



Note: 1. DIPs = Digital Intermediation Platforms.
2. There are currently seven new digital industries; the last column in Figure 9.8 shows examples. The full list is provided later in the chapter.
Source: OECD, (2023[63]).

The multi-dimensional nature of the digital economy requires a framework that can produce outputs reflecting both the production and consumption of digital products as well as the production and consumption of non-digital products obtained through digital means, whether they are digitally ordered, digitally delivered or both. The SUTs are uniquely positioned to do this as the regular SUTs record not only what was produced and consumed but also who produced and consumed it. The SUTs are also flexible enough that additional products and industries can be added to provide more detail on specific topics without disrupting the balance already occurring within the SUTs.

With this in mind, digital SUTs contain the following additions from regular SUTs:

- Five additional rows under each product (and aggregate), separating transactions by whether they are digitally or non-digitally ordered, with digitally ordered transactions further broken down into ordered directly from the counterparty, ordered via a resident digital intermediation platform and ordered via a non-resident platform.
- Two additional columns delineating the nature of the delivery of the service as either digitally delivered or not digitally delivered.
- Seven additional industry columns, aggregating enterprises based on characteristics related to the transaction nature or how they are leveraging the digitalisation.
- Four additional rows representing the explicitly identified digital products of cloud computing services and digital intermediation services as well as an aggregation of all ICT goods and digital services that fall within the SNA production boundary.
- Three additional rows representing data and digital service products that are currently outside the SNA production boundary.

More detailed definitions within the framework

Nature of the transaction (How)

In the digital SUTs, transactions in goods and services are broken down into five types, as shown in Table 9.11, which presents an example for the product row representing accommodation services. Theoretically, such a breakdown is conceivable for each product in the SUTs, but it is unlikely that such a breakdown will be compiled at the detailed level for all products.

Table 9.11. Nature of transaction under product row

Accommodation services	Description
A	Digitally ordered
Ai	Direct from a counterparty
Aii	Via a digital intermediation platform
Aii,1	Via a resident digital intermediary platform
Aii,2	Via a non-resident digital intermediary platform
B	Not digitally ordered

Source: (OECD, 2023[63]).

The product ("What")

While all goods and services produced in the economy are theoretically included in the digital SUTs, the framework focuses on ICT goods and digital services and non-digital goods and services that are most likely to be digitally ordered and/or digitally delivered. Examples of this include travel services, transport, accommodation and food services. Therefore, while non-digital products that are rarely if ever transacted digitally (i.e. trade in primary commodities, wholesale business services, etc.) are within scope of the digital SUTs, splitting the nature of transaction for these products is a lower priority.

The alternative product perspective within the framework relates to aggregates of ICT goods and digital services. Simply put, this includes all products that "must primarily be intended to fulfil or enable the function of information processing and communication by electronic means, including transmission and display" (UNSD, 2015[61]). As such, it coincides with the alternative classification of ICT products, as included in the Central Product Classification 2.1 (UNSD, 2015[61]). Like units that will populate the new digital industries, the production of these products is likely recorded in a large number of product rows. Ideally, portions of these product rows will be aggregated together to form two high-level rows: ICT goods and digital services.[7] The exceptions to this aggregation are the two digital products explicitly identified in the digital SUTs, i.e. digital intermediation services (DIS) and cloud computing services (CCS). These two products, both of which are not explicitly identified in existing product classifications, are of particular interest to users, as they both represent the production and consumption of a digital service that has fundamentally altered the way businesses operate.

A final inclusion from the product perspective within the digital SUTs framework concerns three products that are outside the current SNA production and asset boundary. These are data, zero-priced digital services provided by enterprises and zero-priced digital services provided by the community. The measurement of these products is addressed as part of the overall revision of the SNA.

Digital industries (Who)

Like its absence in regular SUTs, there is no sector perspective set within the digital SUT framework. Rather, the additional ("who") perspective provided in the digital SUTs relates to the creation of seven new digital industries:

1. digitally enabling industries
2. digital intermediation platforms charging a fee
3. data- and advertising-driven digital platforms
4. producers dependent on intermediation platforms
5. e-tailers
6. financial service providers predominantly operating digitally
7. other producers only operating digitally.

The industries have been separated out from their conventional industry columns to quantify specific aspects of digital activity currently unidentifiable within the existing industry allocation of SUTs. Importantly, the new industries identified include enterprises that are classified based on how they use digital technologies within their business models or to interact with consumers, rather than the fundamental type of economic activity undertaken,[8] which is the basis for classification in the regular SUTs.[9] For example, a retailer becomes an e-tailer if it receives most of its orders digitally. In practice, this means that two economic entities that are currently classified in two separate ISIC industries, due to their fundamental activity, may be placed in the same digital industry within the digital SUTs if they are leveraging digitalisation in the same manner. For example, a bookmaker (gambling services) and a tertiary education provider (education services) would be classified in separate columns in the regular SUTs but would be placed together in "other producers operating digitally" in the digital SUTs if they are both only delivering their services digitally.

High-priority indicators of the digital SUT

The digital SUT framework is highly ambitious, and while the additional rows and columns mentioned previously in this chapter are added to all products for consistency, it is not expected that any country will be populating all rows and columns associated with every product.[10] Because of this, the advisory group proposed that a set of high-priority indicators should be considered as a first set of targets for countries compiling digital SUTs, focusing on the most important outputs of the digital SUTs from a user perspective:

- Expenditures split by nature of the transaction. The following indicators are proposed to monitor their developments:
  - total household final consumption expenditure digitally ordered
  - total imports digitally ordered
  - total exports digitally ordered.
- Output and/or intermediate consumption of DIS, CCS and total ICT goods and digital services. The indicators show the evolution of the digital transformation across industries. An increasing percentage of intermediate consumption of ICT goods and digital services relative to other products provides a good indicator for increasing digitalisation. Intermediate consumption of CCS and DIS is of relevance to better understand which industries are being most disrupted by the use of intermediation platforms or require the use of more flexible data storage to undertake their business.
- Output, gross value added and its components, of digital industries, preferably in basic prices.

Current examples by countries

Although ambitious, countries are still making significant strides in the development and publication of outputs consistent with the digital SUTs. A clear example is the initial set of digital SUTs published by Statistics Canada (2021[64]). The experimental estimates (Table 9.12) revealed insights into digital activity such as estimates of total value of production that was digitally ordered and digitally delivered, as well as the gross value added of several "digital industries".

Table 9.12. Gross domestic product of digital industries in Canada, 2017-2019

	2017	2018	2019
	Million CAD	Million CAD	Million CAD
Total, all industries	**1 991 534**	**2 079 869**	**2 157 352**
Total digital industries	103 298	111 384	117 788
Information and communications technology			
Hardware	6 536	7 012	7 243
Software	41 891	45 726	48 013
Telecommunications	36 166	37 175	37 460
Other services	9 912	10 669	11 511
Digital intermediary platforms	1 728	2 374	3 183
Data- and advertising-driven digital platforms	835	846	979
Online retailers and wholesalers	3 748	4 248	5 187
Digital-only firms providing finance and insurance services	2 340	2 752	3 392
Other producers only operating digitally	448	582	821

Source: Statistics Canada (2021[64]).

Statistics Netherlands (2021[65]) has also produced an initial publication that includes outputs related to the high-priority indicators. The proportion of gross value added contributing to the economy by the digital industries (8%) is much higher than the equivalent figure in Canada (5.5%). Table 9.13 shows that this is reflected in the higher share from both digital intermediation platforms (10% compared to 2.7% in Canada) and e-tailers (23% in the Netherlands compared to 4.4% in Canada).

Table 9.13. Digital industries in the Netherlands, 2018

	Size		Share	
	Output	GVA	Output	GVA
	Million EUR	Million EUR	%	%
Total digital industries	**137.4**	**55.3**	**9**	**8**
Digitally enabling industries	95.4	36.4	69	66
Digital intermediary platforms	16.3	5.4	12	10
Firms dependent on platforms	1.0	0.7	1	1
e-tailers (retail)	3.4	1.7	2	3
e-tailers (wholesale)	20.7	10.8	15	20
Digital-only firms providing finance and insurance services	0.7	0.4	0	1

Note: GVA: gross value added.
Source: Statistics Netherlands (2021[65]).

Japan (ESRI, 2021[66]) published a preliminary digital SUT which classified the entire Japanese economy into digital/non-digital industries and digital/non-digital products. It capitalised on the existing benchmark SUT and the Economic Census for Business Activity, which directly covered e-commerce, as well as the Survey of the Household Economy, the E-commerce Market Survey and the Basic Survey on the Information and Communications Industry. ESRI (2021[66]) points out the lack of information sources about smaller transactions in digital services. These are needed to capture, for example, intermediaries in Ireland, Airbnb intermediate services, YouTube rewards and advertising, etc.

Table 9.14. Digital industries in Japan, 2018

	Size		Share	
	Output	GVA	Output	GVA
	Trillion JPY			
Total digital industries	**81**	**41**	**100**	**100**
Digitally enabling industries (manufacturing)	21	9	26	22
Digitally enabling industries (services)	38	22	46	54
Digital intermediary platforms charging a fee	5	1	6	2
Firms dependent on intermediary platforms (including direct order)	15	8	18	20
E-tailer (retail)	2	1	2	2
Digital only providing financial services/insurance	1	0	1	0

Note: GVA: gross value added.
Source: Derived from ESRI (2021[66]).

The results for Japan are more comparable to those of the Netherlands. The size of the total digital industry is similar (also 8% of gross value added), as is the size of the main contributor: digitally enabling industries.

The comparison that is available between these three publications is evidence of the benefit of compiling estimates in a manner consistent with an agreed-upon framework. Users will know that they are comparing similar concepts and be able to quantify clear digital trends that are impacting the economy.

Overall, it is useful to look upon the compilation of digital SUTs as a continually evolving process in which countries can complete elements of the tables as source data become available. Countries are, therefore, encouraged to complete what they can, as soon as they can, with the idea of continually sharing emerging practices. In this way, digital SUTs can act as a roadmap, providing clear targets for countries to aim for when dealing with the challenges of making digital transformation more visible in economic statistics. These targets also provide a shared frame of reference when developing data sources that can be comparable across countries.

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Notes

[1] The project of compiling the corresponding EIOT started in 2016, based on the official Belgian SUT and IOT for 2010, which was then the most recent input-output reference year. This compilation used the full set of individual enterprise-level data sources underlying the construction of Belgium's official input-output reference year SUT and IOT.

[2] OECD (2024[67]) provides a discussion on how these challenges can be addressed in the context of the United Kingdom.

[3] For example, using regional indicators per multi-regional unit for regionalisation; see Eurostat (2013[69]).

[4] Some statistical institutions collect data on establishment-level for wages, production or capital; each can be better suited for apportion of different measures.

[5] The terms "digitisation", "digitalisation" and "digital transformation" may sometimes appear to be used interchangeably; however, they each represent something slightly different to each other. "Digitisation" is the conversion of analogue data and processes into a machine-readable format. "Digitalisation" is the use of digital technologies and data as well as interconnection that results in new or changes to existing activities. "Digital transformation" refers to the economic and societal effects of digitisation and digitalisation (OECD, 2019[68]).

[6] The production boundary of the national accounts includes "all production actually destined for the market, whether for sale or barter. It also includes all goods or services provided free to individual households or collectively to the community by government units or NPISHs" (2008 SNA §1.40). What is not included are goods or services provided for free by private enterprises.

[7] Goods are still considered to be delivered on a non-digital basis only.

[8] The exception is the digitally enabling industries, where units are classified based on the products they are producing.

[9] This basis for classification in the SUTs follows similar practices in the classification of groups, sections and divisions in the international industry classification, whereby the "actual production process and technology used become less important as a criterion for grouping activities" (UNSD, 2008[62]).

[10] For example, the OECD *SUT database* presents countries SUTs with over 90 products. But many of the rows represent goods that by assumption are unable to be digitally delivered.

Handbook on Extended Supply and Use Tables and Extended Input-Output Tables

This Handbook is a step bridging the gap between macroeconomic (national accounts) and microeconomic (business statistics and trade statistics, at enterprise level or by type of enterprise). It provides methodological guidance to combine the strengths of both. The macroeconomic statistics relate to GDP and employment, and they are internally consistent. They are also complete, containing estimates for difficult to survey production such as some activities of micro enterprises and illegal activities. The microeconomic statistics provide a wealth of detail, with all kinds of types of enterprises such as small- and medium sized enterprises, multinationals, and exporters/non-exporters that policymakers are interested in. Combining macroeconomic and microeconomic statistics has many benefits. It relates production, value added, imports, and exports of types of enterprises to GDP, total employment and other macroeconomic data in a proper way. It adds heterogeneity to statistics and indicators such as the domestic value added content of exports. This is desirable, since the aggregate might mask important information related to the diversity of the components. It also provides new indicators about direct and indirect linkages, of types of enterprises with each other and of types of enterprises with foreign and domestic supply and use. For example, it is well-known that SMEs generally have a lower propensity to export than large enterprises. The new information shows that due to their sizeable indirect exports, supplying large exporters with goods and services, SMEs still benefit from foreign markets.

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