



INSTITUTE FOR ENERGY AND
ENVIRONMENTAL RESEARCH
HEIDELBERG

UNDERSTANDING SYSTEM CHALLENGES IN INTERNATIONAL TRADE STATISTICS FOR MATERIAL FLOW ANALYSIS



ifeu Working Paper 02/2018

Monika Dittrich (ifeu), Birte Ewers (ifeu),
Maren Lundhaug (NTNU), Daniel Müller (NTNU)

Heidelberg, Oktober 2018

Die ifeu working paper sollen Zwischenergebnisse und vorläufige Ergebnisse von Projektarbeiten, die am ifeu durchgeführt werden, der Öffentlichkeit zugänglich machen und damit den wissenschaftlichen Diskurs fördern. Die ifeu working paper werden von den Autoren und Autorinnen verantwortet und spiegeln deren Meinung wider. Die Autoren und Autorinnen begrüßen Rückmeldungen zu den Inhalten.

ifeu Working Papers disseminate interim and preliminary results of research projects implemented by ifeu to encourage scientific discussion. The authors are responsible for the content of the paper and appreciate comments on its contents. Any opinions expressed in this paper are those of the author(s).

Corresponding author:

Dr. Monika Dittrich: Monika.Dittrich@ifeu.de

Suggested citation: Dittrich, M., Ewers, B., Lundhaug, M., Müller, D. (2018): Understanding System Challenges in international Trade Statistics for Material Flow Analysis. ifeu Working Paper. Heidelberg.

The authors would like to thank Jan Weinzettel (CUEC), Mark Simonis (Geological Survey Norway) for their critical and helpful comments.

Title image source: harvepino / fotolia

Content

List of Figures	4
List of Tables	5
1 Abstract	6
2 Introduction	7
2.1 The MinFuture framework	7
2.2 Import dependencies of the European Union	9
3 Classifications and data availability	10
3.1 Trade databases and classification systems	10
3.2 Data availability for metals and minerals	12
3.2.1 Example: Aluminium	12
4 Bilateral trade data: challenges	19
5 Reasons for mismatches	24
5.1 Conceptual reasons	24
5.1.1 Regarding the reference period	24
5.1.2 Regarding country of origin and destination	25
5.1.3 Regarding product classification	26
5.2 Further reasons	27
5.2.1 Purpose of data collection and trade policy	27
5.2.2 Compliance	27
5.2.3 Administrative procedures	28
5.2.4 Confidentiality	28
5.2.5 Errors and missing data	28
6 Options for data editing	30
6.1 With regard to bulk trade data	30
6.1.1 Prioritizing one source of information	30
6.1.2 Correcting errors	30
6.1.3 Gap filling	31
6.1.4 Balancing trade data with production statistics	31
6.1.5 Procedures to balance bilateral trade	32
6.2 With regard to selected (raw) materials	32
7 Design principles	34

Content

7.1 Trade within a free trade zone, example EU	34
7.2 Trade with a third party, without storage	35
7.3 Trade with a third party, including storage	36
7.4 Consignment: example import from third party	37
7.5 Summary of the design principles	38
8 Summary of suggestions for further development of (physical) trade statistics	39
References	41

List of Figures

Figure 1: The MinFuture Pyramid comprises the physical economy monitoring framework	8
Figure 2: Domestic extraction (DE) and net import of metals in the European Union, 2015	9
Figure 3: Asymmetries in bilateral trade data, Comtrade for France and Germany	20
Figure 4: Asymmetries in bilateral trade data, Comext for France and Germany	22
Figure 5: Asymmetries in bilateral trade data, UNComtrade for Germany and Canada	23
Figure 6: Steps of trade flows within a free trade zone, example Germany	35
Figure 7: Steps of trade flows, outside free trade zone and without storage	36
Figure 8: Steps of trade flows, including storage	37
Figure 9: Steps of trade flows including consignment	37

List of Tables

Table 1: Overview on international trade statistic systems	11
Table 2: Overview on level of disaggregation in trade statistics	12
Table 3: Information about Aluminium in trade classification systems, raw materials	13
Table 4: Information about Aluminium in trade classification systems, intermediate and final products	14
Table 5: Information about Aluminium in trade classification systems, waste and scrap	15
Table 6: Overview on information on 16 selected metals and minerals in different steps of the value chain in the HS classification system	15
Table 7: Overview on information in trade statistics on critical materials as defined by EC	16
Table 8: Matches and mismatches of reported weights in Comtrade SITC Rev. 4, example bilateral trade between France and Germany in 2010	19
Table 9: Matches and mismatches of reported weights in Comext SITC Rev. 4, example bilateral trade between France and Germany in 2010	21

1 Abstract

The EU depends on the supply of raw materials from other regions. Import dependency is particularly high with regard to metals. Experts forecast that it will increase even more with the transformation of the energy system. However, knowledge about geological metal sources, metal content of products and anthropogenic stocks, yields and losses of recycling, as well as metal content of metal traded internationally as ores, products or slags is poor. This working paper addresses the issue of international trade statistics linking extraction, processing, use and recycling.

The paper shows the particular challenges that arise when international trade data is analysed in order to monitor the physical dimension of metal and mineral flows in detail. It demonstrates the normality of mismatches of bilateral trade data and systematically explains different reasons for mismatches. Existing approaches on how to deal with the challenges are explained. From a systems perspective, exact reference points are identified for which trade data provide information. Finally, suggestions are presented for further development of international trade statistics.

2 Introduction

The EU depends critically on the supply of raw materials, particularly metals and fossil energy carriers, from regions outside of Europe (e.g. UNEP, 2016). The transformation towards an energy system based on renewable sources requires a high quantity of raw materials which are scarce and / or critical. However, knowledge about geological sources, metal content of these materials in products and anthropogenic stocks, as well as yields and losses of recycling is poor. Thus, the European Commission posed the question of how international statistics can be developed further in order to provide comprehensive material-specific information.

Based on research within the project MinFuture, this paper addresses the issue of international trade statistics linking extraction, processing, use and recycling. It deals with the particular challenges that arise when international trade data is analysed in order to monitor metal and mineral flows in detail. Thereby, not only primary metals are considered, but also semi-processed and processed products as well as secondary metals included in scraps or in slags. The paper aims at a better system understanding of trade statistics and makes suggestions for their further development.

After an introduction to the MinFuture project and an overview on European international trade dependencies, this paper starts with explaining classification systems in trade providing an overview on strengths and weaknesses of selected classification systems (Chapter 2).

In Chapter 3, the particular challenges of trade data are identified, and the empirical dimension of the challenge is quantified using examples. The challenges arise mainly due to the fact that for the majority of trade flows two sets of data are reported, one from the exporter and one from the importer. Usually, those two do not match.

Chapter 4 considers reasons for the discrepancy, and Chapter 5 provides an overview on methods how to deal with the mismatching information without changing statistical systems. Chapter 6 provides design principles and Chapter 7 gives a summary of different findings and suggestions on how to improve statistical systems.

2.1 The MinFuture framework

MinFuture aims at understanding and developing international statistics in order to improve their usefulness in material flow analysis. Therefore, the MinFuture pyramid was developed which includes essential MFA components used in the monitoring of physical flows and stocks of materials. These include: systems, data, uncertainty, models and scenarios, visualisation, indicators, and strategy support. The pyramid components are organised using a hierarchical order because the robustness of components in the upper level is impacted by the robustness of components found in the lower level.

The MinFuture framework provides an assessment of these seven components to support MFA practitioners in their work. All of the seven components are also considered along four dimensions (1) **Stages** along the material cycle, (2) International **trade**, (3) The linkages/ **layers** of the materials and (4) **time**.

Figure 1: The MinFuture Pyramid comprises the physical economy monitoring framework



Source: Müller et al., MinFuture

Systems define where materials are located (processes/stocks) and where they are moving (flows). Mathematically, systems are defined through (mass or energy) balance equations which include observed and unobserved flows. Systems can be defined using different levels of aggregation. Strong system definitions reflect the real system adequately at an aggregation level that serves the purpose of their models.

Data represent observations of either stocks (at a given point in time) or flows (over a given time period). The quality of the data depends on a robust system understanding that correctly reflects the reference points of the measurements.

Uncertainty is inherent in all MFAs due to errors in system definitions and the data used. Approaches to uncertainty analysis aim at making uncertainties transparent and reducing them. They enable the users to make more robust assumptions and to become aware of the model's strengths and limitations. A strong uncertainty analysis addresses both systematic errors (e.g., system definition) as well as the random errors (e.g., data).

Models here are mathematical representations of material cycles and their drivers which are used to simulate historical changes in material cycles or to make forecasts for future changes through the use of scenarios. Scenarios are plausible developments for the material cycles that are consistent with the mass balance principle and the assumed drivers. Strong models and scenarios therefore depend on robust system definition and data.

Visualizations here are different maps of complex systems. They can inform decision making in industry and government by visualizing current status, historical trends, and potential future developments under different conditions. Visualization tools are developed to support the recording (monitoring), exploration (analysis), and explanation (interpretation) of information. The usefulness and quality of visualizations therefore strongly depends on the quality of the underlying system definition, data, and models.

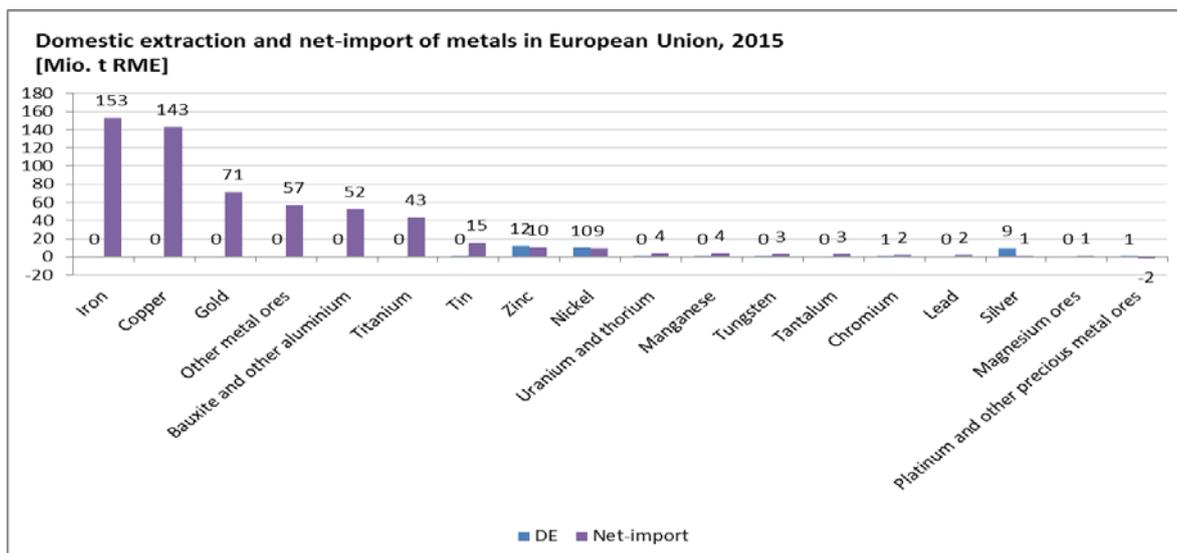
Indicators are quantitative measures that are supposed to reflect how close we are to achieving set goals. They are used to analyze and compare performance of businesses, sectors or economies across countries and to determine policy priorities. Strong indicators or indicator sets adequately reflect the system to be controlled in order to effectively reach the goals and avoid problem shifts.

Strategy support has two aspects: (i) supporting industry and government strategies for raw materials that aim at reaching different goals, such as those of the Strategic Implementation Plan (SIP) of the European Innovation Partnership on Raw Materials, the Circular Economy Action Plan, or the Sustainable Development Goals; (ii) supporting strategies for more effectively monitoring and forecasting material cycles, such as the Raw Material Information System (RMIS), through improved measurement strategies, data harmonization, and data integration.

2.2 Import dependencies of the European Union

Understanding and monitoring material flows throughout economies provides the analytical background in order to manage the flows of particular raw materials and to decrease import dependencies. This holds particularly true facing future demand of raw materials for the transformation of the energy system. Currently (2015), the European Union imported 1.4 billion tonnes of metals and exported 0.8 billion tonnes, both counted in raw material equivalents (RME¹) (Eurostat, 2017). Figure 2 shows that import dependency is high with respect to the basic metals iron, copper and aluminium as those are used in high volumes in European countries without any mining activity. The import dependency, however, is also high with regard to all other metals as domestic extraction is low or not existent. With regard to zinc, nickel and silver, domestic extraction exceeded net imports, but extraction was not sufficient to meet consumption. In 2015, there has been a net export only with regard to platinum and other precious metal ores.

Figure 2: Domestic extraction (DE) and net import of metals in the European Union, 2015



Source: Eurostat, 2017.

¹ Raw material equivalents consider the raw material required for the production of imports and exports, so that their raw material use is counted according to the same system boundary as extraction.

3 Classifications and data availability

3.1 Trade databases and classification systems

Analysing international trade relies on the availability and quality of international trade data. Fortunately, almost every country is collecting information on its foreign trade. Trade data belong to the most comprehensive and complete national statistics due to the fact that, amongst others, customs duty has been and still is an important source of income for several countries. Thus, having good information on imports and exports is part of the country's own interest.

The history of collecting and harmonizing international trade statistics goes back to the League of Nations which started the collection of harmonized trade data in 1913. The first international trade statistics was published in 1924 containing trade data for the period between 1910 and 1923 of 42 countries (League of Nation, 1924). After the Second World War, the United Nations overtook the maintenance of collecting countries' trade data in a harmonized system.

We will look at two different trade databases, namely **UN Comtrade** (United Nations International Trade Statistics Database)¹ and **Eurostat's Comext**² as well as at three different trade classifications, the Standard International Trade Classification (SITC), the Harmonized System (HS) and the Combined Nomenclature (CN).

UN Comtrade is maintained by the United Nations Statistics division and provides annual international trade statistics for 170 countries/areas. Time series data are available from 1962. Today, the database contains more than 3 billion data points.

Eurostat's Comext focuses on European trade data, but also contains statistics on a significant number of non-EU countries. Time series data are available from 1988. In comparison to UN Comtrade, Comext provides data down to a more disaggregated level.³

The level of detail in trade databases is dependent on the available positions (individual trade codes) in the corresponding trade classification. If a certain position does not exist on a disaggregated level, no data is being made available. Therefore, the trade classifications have a very strong influence on the scope of the available data. For MFA practitioners the level of disaggregation in trade data has a high impact on the possibility of creating robust detailed models that aim to monitor the physical economy.

The first classification of goods was the **Standard International Trade Classification (SITC)**. SITC is used to classify the exports and imports of a country to allow the comparison of different countries and years. SITC 1 was established in 1962 by the UN. Since then the 5-

¹ <https://unstats.un.org/unsd/tradekb/Knowledgebase/50075/What-is-UN-Comtrade>

² <http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:COMEXT>

³ <http://ec.europa.eu/eurostat/web/international-trade-in-goods/data/focus-on-comext>

digit classification was revised 4 times. In its current version (Rev. 4), it contains 2.970 positions.

Additionally, the **Harmonized Commodity Description and Coding System**, also known as the **Harmonized System (HS)** of tariff nomenclature, is used. It was introduced in 1988 and has since been developed and maintained by the World Customs Organization (WCO). The WCO is an independent intergovernmental organization based in Brussels with over 200 member countries. Updates of the classification take place every five years, the latest update being the 2017 one. It consists of approximately 5.000 positions.

Further classification systems are the **Broad Economic Categories (BEC)** and the so called **Combined Nomenclature (CN)**. BEC groups transportable goods according to their main end use and is most often used for general economic analysis of international merchandise trade data. CN was established on the basis of HS in 1987 (EEC No 2658/87) to meet the requirements of both the Common Customs Tariff and the external trade statistics of the European Union. It contains all codes of the HS classification and additional ones on an 8-digit-level. It is updated annually and with approximately 10000 positions and 8-digit codes, it is the most disaggregated classification.

The following table provides an overview of the classification systems:

Table 1: Overview on international trade statistic systems

	SITC	HS	BEC	CN
Starting year	1962	1988	1971	1987
Current version	Rev. 4	2017 (updated every 5 years)	Rev. 5	2018 (updated annually)
Transition tables to production statistics ¹	Yes (SITC Rev. 3 → ISIC Rev. 3)	Yes (HS 2007 → CPA 2008)	No	Yes (CN 2018 → CPA 2.1; CN 2017 → PRODCOM 2017/CPA 2008) ²
Number of reporting countries in 2015 (IMP/EXP)	SITC 1: 146/147 SITC4: 150/149	HS 12: 140/139	153/153	(not comparable)

Thus, the CN classification used by Eurostat is the most differentiated classification system. It is, however, available only for European countries. Both classification systems, CN and SITC can be used for material analysis as transition tables to production statistics exist. BEC has the disadvantage that transition tables are not available. As SITC was established in 1961, it is the only classification which allows historical analysis covering long term periods.

All classification systems group traded goods along (dominant) materials and along the value chain. The differentiation of the product groups have grown historically, reflecting the needs

¹ http://ec.europa.eu/eurostat/ramon/relations/index.cfm?TargetUrl=LST_REL&StrLanguageCode=EN&IntCurrentPage=1

² http://ec.europa.eu/eurostat/ramon/relations/index.cfm?TargetUrl=LST_LINK&StrNomRelCode=CN%202018%20-%20CPA%202.1&StrLanguageCode=EN

of past decades and the purpose of the particular statistic. While trade databases contain a wealth of data on traded materials, their structure is closely based on the requirements of customs declarations and tariff lines. As such, it can be challenging to extract information on traded raw materials. As supply chains has become even more globalized and the products has increased in material complexity there is a need for further refined positions in the classifications allowing a more detailed tracking of the materials.

3.2 Data availability for metals and minerals

In the MinFuture and material flow analysis context, the level of disaggregation of metals and minerals is important. Generally, the more differentiated the traded products are in the classification, the better the specific flow can be monitored.

The following table provides an overview on the number of product groups that refer to metals and minerals in the different classification systems: In general, data for commonly used metals (base metals) are much more differentiated than data for rare metals. Newer classifications are also more differentiated than older classification systems.

Table 2: Overview on level of disaggregation in trade statistics

No of differentiated product groups	SITC (Rev. 1)	SITC (Rev. 4)	HS 2012	CN
Number of codes	1913	2970	Appr. 5,000	Appr. 18,600 codes, 10,000 items
Structure	10 sections, 56 divisions, 177, groups, 625 sub-groups, 1312 items	10 sections, 67 divisions, 262 groups, 1023 sub-groups, 2970 items	21 sections, 99 chapters, appr- 1200 headings, appr. 5000 sub-headings (6 digits)	HS with an additional subdivision (CN subheading, 8 digits)
Iron and steel (primary and semi-processed)	105	appr. 200	368	1066
Copper (primary and semi-processed)	28	30	78	168
Aluminum (primary and semi-processed)	21	28	70	171
Cobalt (primary and semi-processed)	1	4	8	23
Neodymium (primary and semi-processed)	0	0	0	2

The table shows that differentiation highly varies between different metals and minerals.

3.2.1 Example: Aluminium

In the following, we give a detailed example of data availability and data requirements for Aluminium, the second most used metals worldwide in terms of both value and weight. We attempt to answer the following question:

- What are data requirements for mapping Aluminium content of trade when considering the stages of the supply chain? What data is readily available in trade databases?

Trade takes place along all stages of the supply chain. In order to be able to determine Aluminium flows crossing borders, the amount of raw material involved in a trade is required. Trade data is usually reported in weight and in monetary terms with the value in monetary terms being usually more reliable. As the traded product does not necessarily contain only Aluminium, the reported weight needs to be converted into metallic content.

Extraction and first processing

Aluminium is produced mainly from bauxite ores which are processed into Aluminium oxide at alumina plants. The main producers of ores and alumina are China and Australia.

Table 3: Information about Aluminium in trade classification systems, raw materials

HS 2017 (Comtrade)	SITC Rev. 1	CN 8 (Comext)
HS-2606 Aluminium ores and concentrates	S1-2833 Bauxite and concentrates of aluminium	CN-2606 Aluminium ores and concentrates
HS-281810 Aluminium oxide; artificial corundum	S1-51365 Aluminium oxide and hydroxide	CN-28182 Aluminium oxide (excl. Artificial corundum)
HS-28120 Aluminium oxide; other than artificial corundum		CN-281830 Aluminium hydroxide
HS-28230 Aluminium hydroxide		

In all three classifications, there are positions for both ores and Aluminium oxide allowing us to determine the amount of ores and oxide traded. However, the Aluminium content of traded ores can vary widely, and different concentrations are not distinguished within the trade classification. Therefore, the Aluminium content of traded ores has to be estimated.

Intermediate and final products

Unwrought Aluminium is produced from Aluminium oxide by an electrolytic process. The resulting Aluminium from the smelters is then mixed with scrap and alloying elements and cast into ingots. Final and intermediate products are then produced.

Here, the different level of detail of the trade classifications becomes more obvious: While SITC Rev. 1 distinguishes 13 products explicitly made of Aluminium, HS distinguishes 35 and CN approximately 100 different positions. For products not explicitly made of only Aluminium, knowledge is required on whether the product typically contains Aluminium and if yes, how much. While the Aluminium content of some products is easy to determine – e.g. Aluminium foil is very likely to contain almost 100 % Aluminium, the Aluminium content of cars, electronics or airplanes, is much more difficult to determine.

Table 4: Information about Aluminium in trade classification systems, intermediate and final products

HS 2017 (Comtrade)	SITC Rev. 1	CN 8 (Comext)
<p>HS Chapter 76: 35 categories for products of Aluminium</p> <p>e.g. powders and flakes (non-lamellar/lamellar), bars, rods and profiles (not alloyed, alloyed, hollow, other), wire (exceeding 7mm, other), foil (backed/not backed, rolled, other), tubes, pipes, household articles, reservoirs etc.</p>	<p>6841 Aluminium and aluminium alloys, unwrought</p> <p>6842 Aluminium and aluminium alloys, worked</p> <p>68421 Bars, rods, angles, shapes and wire of aluminium</p> <p>68422 Plates, sheets and strip of aluminium</p> <p>68423 Aluminium foil</p> <p>68424 Aluminium powders and flakes</p> <p>68425 Tubes, pipes & blanks, hollow bars of aluminium</p> <p>68426 Tube and pipe fittings of aluminium</p> <p>69213 Tanks, etc. for storage or manufacturing use of aluminium</p> <p>69222 Casks, drums, etc. used for transport of aluminium</p> <p>69313 Wire, cables, ropes etc. not insulated, aluminium</p> <p>69343 Expanded metal of aluminium</p> <p>69723 Domestic utensils of aluminium</p> <p>69895 Articles of aluminium, n.e.s.</p>	<p>CN Chapter 76: appr. 100 categories for products of Aluminium</p> <p>e.g. foil ((not) backed/(not) rolled/(not) further worked/thickness less than 0,2 mm/more than 0,021 mm/less than 0,021 mm/self adhesive/stamping foils/weight of foils/ excl. Christmas tree decorating material)</p>

It has to be noted that even though trade classifications are very detailed, products allocated to a certain code are not homogeneous. E.g. HS Code 8703 contains all motor cars and other motor vehicles principally designed for the transport of persons. However, the amount of Aluminium in a car can vary widely. A study commissioned by European Aluminium showed that for passenger cars traded today the Aluminium content varies from 60 kg to 600 kg.¹ In addition, the Aluminium content has changed over time as cars were built in a more and more lightweight manner. For electric vehicles, Aluminium content will increase even more. So, for each HS code, additional information is required on the type of products that are typically traded within an HS code and on their material composition.

This information has to be estimated for each product group, e.g. based on LCA lists of materials, material flow tables or extensive literature research.

¹ https://european-aluminium.eu/media/1721/european-aluminium-ducker-study-summary-report_sept.pdf

End of life: waste and scrap

Table 5: Information about Aluminium in trade classification systems, waste and scrap

HS 2017 (Comtrade)	SITC Rev. 1	CN 8 (Comext)
H4-7602 Aluminium waste and scrap	S1-28404 Aluminum waste and scrap	76020011 Turnings, shavings, chips, milling waste etc. of aluminium; waste of coloured or bonded sheets...
H4-262040 Slag, ash and residues containing mainly aluminium		76020019 Waste of Aluminium, incl. faulty workpieces
		76020090 Scrap of Aluminium
		26204000 Slag, ash and residues containing mainly Aluminium

Primary and end-of life scrap are not distinguished within the classification. For end of life data, one important problem is that at the customs declaration, trade in products without value/under certain thresholds is not registered. Also, the Aluminium content of scrap is unknown. Hence, losses have to be estimated.

Aluminium served as an example for widely used raw materials for which a large amount of data is available and for which trade classifications are fairly differentiated. Still, there are important data gaps which require estimates.

Challenges related to tracking rarer materials such as Cobalt or Neodymium are much greater as there is much less data available. For the purpose of monitoring rare metals required for e.g. renewable energy facilities, current international trade statistics are not sufficiently differentiated.

The following, table 6 provides an overview for different raw materials using the widely available classification system HS.

Table 6: Overview on information on 16 selected metals and minerals in different steps of the value chain in the HS classification system

Raw Material	Ores	Slag	Refined and semi processed	Products	Waste/Scrap
Iron	Yes	Yes	Yes (HS 72/73)	Yes (HS 73)	Yes (HS 7204)
Copper	Yes	Yes	Yes (HS 74)	Yes (HS 74)	Yes (HS 74)
Zinc	Yes	Yes	Yes (HS 79)	Yes (HS 79)	Yes (HS 79)
Nickel	Yes	No	Yes (HS 75)	Yes (HS 75)	Yes (HS 75)
Antimony	Yes	Agg.	Yes (HS 8110.10)	As other (HS 8110.90)	Yes (HS 8110.20)
Chromium	Yes	Agg.	Yes (HS 8112.21)	As other (HS 8112.29)	Yes (HS 8112.29)
Cobalt	Yes	No	Yes (HS 8105.20)	Yes (HS 8105.20/90)	Yes (HS 8105.30)
Coking coal	No	No	No (coal in general only)	No	No
Fluorspar	No	No	Yes (HS 2529)	No	No

Raw Material	Ores	Slag	Refined and semi processed	Products	Waste/Scrap
Gallium	No	No	Agg.(HS 8112.92)	Agg. & as other (HS 8112.99)	Agg. & with metal (HS 8112.99)
Platinum Group Metals	Agg.	No	Yes (Pd, Pt, Rh, agg. (Ir, Os, Ru)	Yes	Agg. (HS 7112.92)
Heavy Rare Earth Elements	No	No	Agg. (HS 2805.30)	No	No
Light Rare Earth Elements	No	No	Agg. (HS 2805.30)	No	No
Silicon Metal	No	No	Yes (HS 2804.61)	No	No
Tungsten	Yes	No	Yes (HS 8101.94)	Yes (HS 8101.96/99)	Yes (HS 8101.97)
Silver	Yes	No	Yes (HS 7106)	Yes (HS 71)	Agg.

The following Table 7 shows the materials which are defined as critical materials by the European Commission (2017) and the respective codes referring to them in the most recent SITC classification (Rev. 4) used by the UN Comtrade database.

It should be stressed that the names of the product groups mention the respective critical material. There is no information on whether the critical material is also part of another product listed in a different product group.

Table 7: Overview on information in trade statistics on critical materials as defined by EC

Material	SITC-4
Antimony	Antimony and articles thereof (including waste and scraps) (68993)
Baryte	Natural barium sulphate (barytes); natural barium carbonate (witherite), whether of not calcined (other than barium oxide of heading 522.65) (27892)
Beryllium	Beryllium, unwrought;beryllium waste and scrap; powders (68991) Beryllium, wrought, and articles of beryllium, n.e.s. (69995)
Bismuth	Bismuth and articles thereof (including waste and scrap) (68992)
Borate	Natural borates and concentrates thereof [...]; natural boric acid containing not more than 85% of H3BO3 calculated on the dry weight (27894) Borates; peroxoborates (perborates) (52384)
Cobalt	Cobalt ores and concentrates (28793) 3 further product groups with semi-processed and articles of cobalt and 3 further product groups where cobalt is mentioned besides other metals such as zinc, titanium or cadmium
Coking coal	No match
Fluorspar	Fluorspar (27854)
Gallium	No match
Germanium	No match

Hafnium	No match
Helium	No match
Indium	No match
Magnesium	Natural magnesium carbonate (magnesite) (27824) 4 further product groups: only magnesium semi-processed or final goods/waste and 2 product groups where magnesium is mentioned
Natural graphite	Graphite, natural (27822) Non-electrical articles of graphite or other carbon (66336 ¹)
Natural rubber	Natural rubber, balata, gutta-perche, guayule, chicle and similar natural gums, in primary forms or in plates, sheets or strip (231) with several sub-categories Several semi-processed and final article based on rubber without information whether rubber is natural or synthetic origin.
Niobium	Niobium, tantalum or vanadium ores and concentrates (28785)
Phosphate rock	No match, but 3 matches regarding phosphate
Phosphorus	9 product groups with phosphorus content
Scandium	Calcium, strontium and barium; rare earth metals, scandium, yttrium and alkali or alkaline-earth metals, whether or not intermixed or interalloyed (52229) Stable isotopes and their compounds; compounds, inorganic or organic, of rare earth metals, of yttrium or of scandium or of mixtures of these metals (5259)
Silicon metal	No match as such; one match Ferro-silicon (67151)
Tantalum	Niobium, tantalum or vanadium ores and concentrates (28785) Tantalum, unwrought [...]; waste and scrap; powders (68913) Tantalum, wrought, and articles of tantalum, n.e.s. (69993) Tantalum fixed capacitors (77862)
Tungsten	Tungsten (or wolfram) ores and concentrates (28792) Tungsten (wolfram), unwrought; tungsten waste and scrap (68911) Tungsten, wrought, and articles of tungsten, n.e.s. (69991)
Vanadium	Niobium, tantalum or vanadium ores and concentrates (28785)
Platinum Group Metals	Waste and scrap of platinum, including metal clad with platinum but excluding sweepings containing other precious metals (28921) 9 semi-processed and final articles containing product groups where platinum is mentioned
Heavy Rare Earth Elements	Calcium, strontium and barium; rare earth metals, scandium, yttrium and alkali or alkaline-earth metals, whether or not intermixed or interalloyed (52229)
Light Rare Earth Elements	Compounds, inorganic or organic, of rare earth metals, of yttrium or of scandium or of mixtures of these metals

Both tables show clearly that - independently from the classification system - trade classifications are not sufficiently broken down. Information required in order to monitor specific

¹ Graphite could be artificial or natural in this product group

metal flows are only insufficiently reported with regard to the majority of metals. While the basic metals (iron, copper, aluminum) are reported in a more distinguished manner, a large number of metals are reported only in conjunction with other metals or not at all.

Furthermore, the categories report the physical weight, but in most subgroups not the specific metal content. Thus, the metal content of the trade flows has to be estimated.

As an interim result, one can summarize that

- The choice of the classification system depends, amongst other, on the specific research questions.
- All classification systems break down the traded products by a combination of raw materials/dominant raw materials and by step of processing (raw material, semi-processed, final articles). This is a strength which allows the - in principle: easy - use of trade data for material flows analysis.
- However, the classification systems subdivide the traded metals differently; information on basic metals is more detailed than information on other metals; some metals are not even reported individually. This holds particularly true for the critical metals as defined by EC.
- Information is particularly fragmented or even not existent with regard to metal content in slag and scraps, but also with regard to metal content in ores, concentrates and finished products.
- Products allocated to a certain code are not homogeneous. Since the make and model of the particular products is not tracked crude assumptions must be made. Here additional metadata would help increase the robustness of the estimated metallic content.

4 Bilateral trade data: challenges

In the previous chapter, it was pointed out that international trade data has strong advantages thanks to harmonized classification systems with (at least for some metals) detailed information on traded metals and minerals. However, there is a further strength and distinctiveness regarding trade, namely the fact that trade data is reported bilaterally. This means that trade activities are reported by the importer and by the exporter - worldwide and independently. Thus, trade data can be checked systematically.

The checking of trade data leads to specific challenges: Countries are not only reporting their summarized trade with all foreign countries, but they also report their bilateral trade with the different trading partners. Thus, two original data sets from two reporter countries are describing one action: Country A reports that it exports a specific amount of product X to country B. Country B reports that it imports a specific amount of product X from country A. Theoretically, both countries should report the same amount of the traded product X.

Reality shows, that this is generally not the case. To give some examples:

Germany has exported products with a value of 89,582 billion US\$ to France, but France imported products with a value of 87,727 billion US\$ from Germany according to UN Comtrade (SITC Rev. 4). One can argue that export and import prices differ due to several reasons (explained below), but in physical terms the amount of the traded product should be the same. Checking this, Germany has exported products with a summarized weight of 344,514 tons while France has imported 403,357 tons – a difference of about 15%.

Not only aggregated quantities differ in the country data. The following examples demonstrate the dimension of the problem (Table 8): Already the number of product groups reported differs. In our example, France reports trade activities for 60 product groups for which Germany does not report any trade with France at all. Out of more than 4,500 data points on trade activity, only seven match with respect to weight. Half of the reported flows deviate by more than 50% with respect to weight. In general, weight is more interesting for material flow analysis than monetary values.

Table 8: Matches and mismatches of reported weights in Comtrade SITC Rev. 4, example bilateral trade between France and Germany in 2010

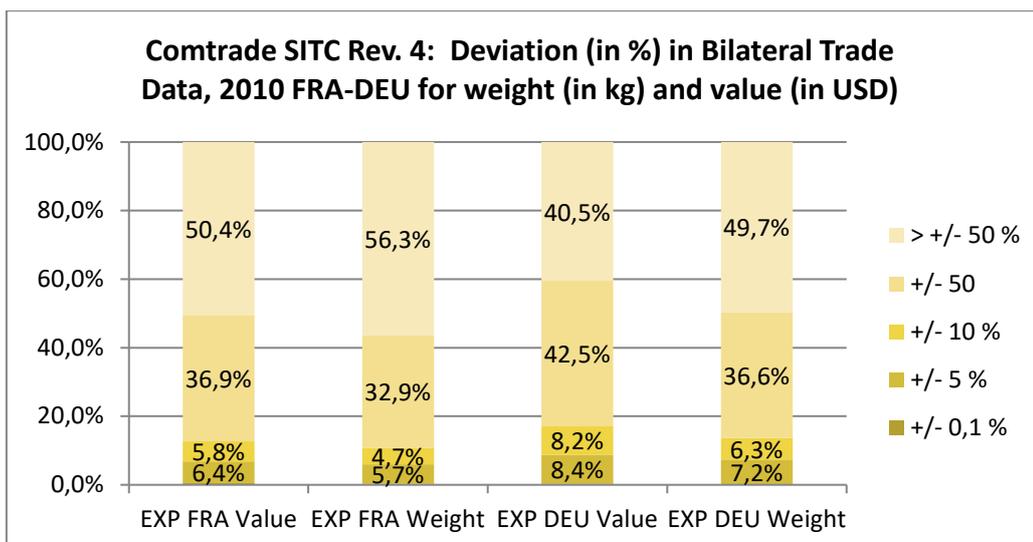
	Germany's exports to France/ France's imports from Germany	France's export to Germany/ Germany's imports from France
Product groups reported by both France and Germany*	2275	2215

	Germany's exports to France/ France's imports from Germany	France's export to Germany/ Germany's imports from France
Matches of reported values (weight)	2	5
Good concordances of reported values (weight): deviation of >0 - 5% of value	164	126
Medium concordances of reported values (weight): deviation of > 5,1 – 10% of value	143	105
Medium mismatches (deviation of 10% - <50% of value of weight)	833	729
High mismatches (deviation of more than 50% of weight)	1131	1248

*here and in the following: without aggregations at 3-,2- and 1-digit levels

The following figure shows the share of values with a deviation smaller than 0,1 %, 5 %, 10 % and 50 % between the two reporting countries by trade flow and with respect to value and weight. It can be observed that the deviation is higher with regard to weight than with respect to value for all trade flows. Only a handful of values actually match, for the vast majority of reported values deviations are larger than 10 %. For roughly half the values, the deviation is larger than 50 %. In general, the values in USD match better than the values in kg, which is surprising insofar as prices are reported according to different price concepts (FOB and CIF).

Figure 3: Asymmetries in bilateral trade data, Comtrade for France and Germany



The picture does not change much if other trade databases are used: The following table and graph show the results for Comext, the European trade database, for the same year and the same countries (Table 8). Again, France is reporting activities in more product

groups than Germany. There are few more matches, but still the number is negligible compared with the number of reported trade flows.

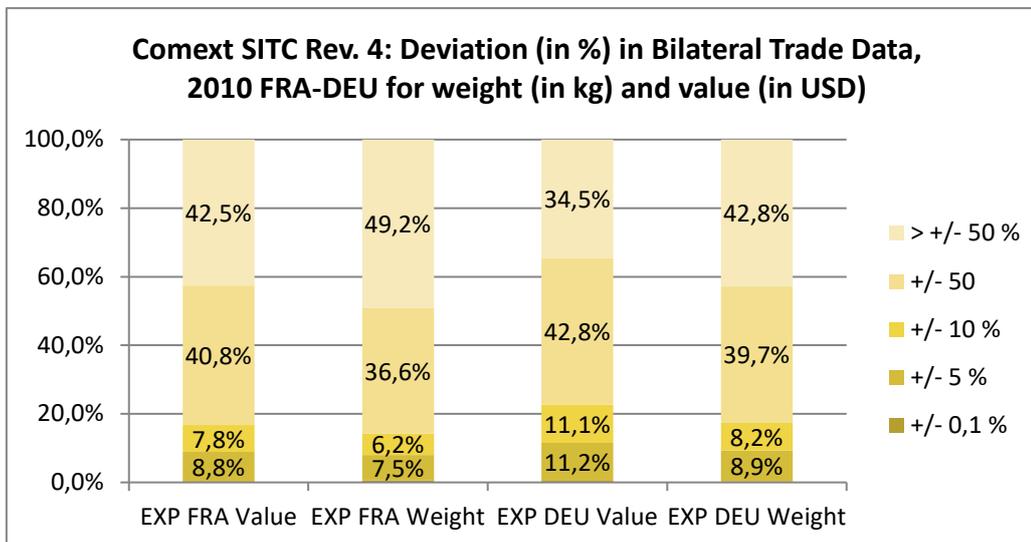
Table 9: Matches and mismatches of reported weights in Comext SITC Rev. 4, example bilateral trade between France and Germany in 2010

	Germany's exports to France/ France's imports from Germany	France's exports to Germany/ Germany's imports from France
Product groups reported by both France and Germany*	2171	2203
Matches of reported values (weight)	8	5
Good concordances of reported values (weight): deviation of less than 5% of value	194	166
Medium concordances of reported values (weight): deviation of 5,1 – 10% of value	178	137
Medium mismatches (deviation of more than 10% of weight)	861	806
High mismatches (deviation of more than 50% of weight)	930	1083

*here and in the following: without aggregations at 3,2 and 1digit levels

The figure below shows that the Comext values match slightly better than the Comtrade values, but the deviations are still very large.

Figure 4: Asymmetries in bilateral trade data, Comext for France and Germany

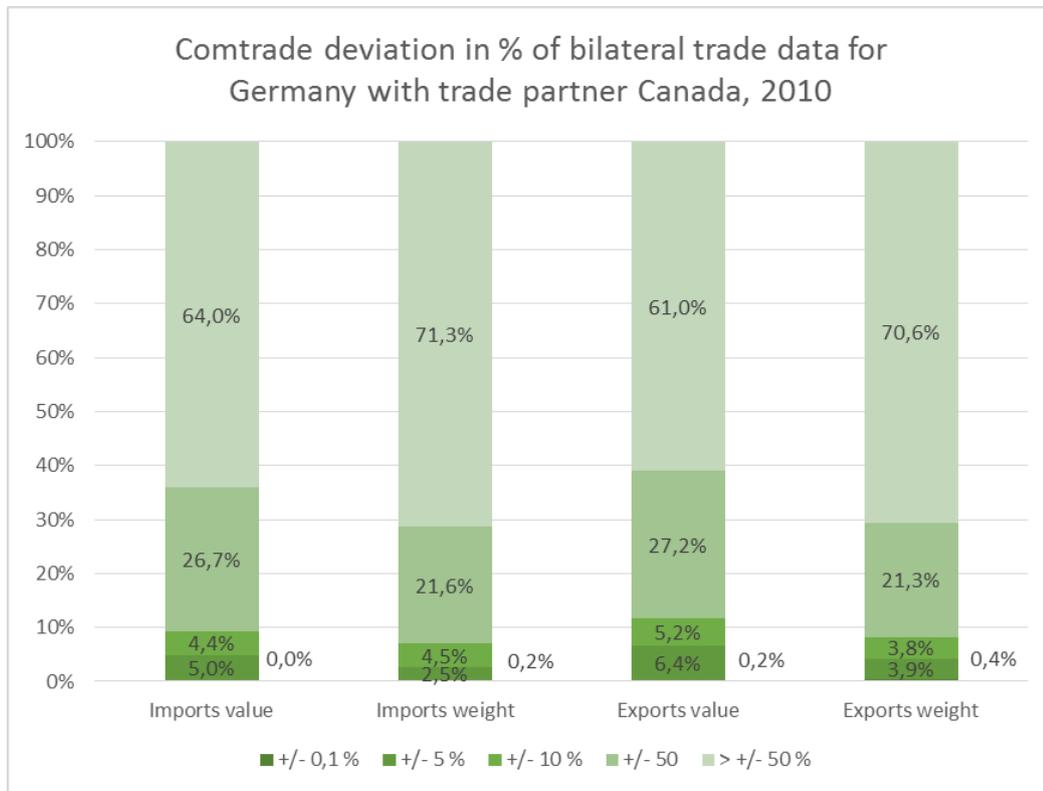


It is very important to consider that both countries, France and Germany, have good trade statistics: There are hardly any mistakes in summaries of values. There are nearly no outliers in the statistics; and nearly all product groups have reasonable values if average prices per unit product are checked. Borders between both countries are open – there is no delay due to clearing procedures.

The third example shows the results for the systematic check of the trade between Germany and Canada. The example is based on UN Comtrade data as there are no Canadian data in Comext. Again, both countries have good trade statistics, with hardly any mistakes in summaries of values and nearly no outliers in the statistics. The only difference to the example above is the distance between the countries. Thus, products require clearing and transportation mainly by ship.

As in the first example, the number of reported product groups differs: While Germany reports imports from 3026 different product groups from Canada, Canada reports exports from 3198 product groups to Germany (both including aggregates). Similar differences can be found in trade flows from Germany to Canada: Germany reports 4194 product groups, while Canada reports 5140 product groups. Again, there are only few matches: Of Germany's reported imports two values match the values reported by Canada with respect to weight, and of Canada's reported imports one matches with the exports reported by Germany. Again, the deviations are higher with respect to reported weights than with respect to reported values. The following figure provides a statistical overview of the deviations:

Figure 5: Asymmetries in bilateral trade data, UNComtrade for Germany and Canada



This example of trade between Germany and Canada shows that the differences and deviations are even higher than between Germany and France.

As an interim result, it can be summarized that

- Matches of reported bilateral trade flows are exceptions. The normality in trade statistics is that reported exports and reported imports do not match.
- Deviations with respect to monetary values are lower than with respect to physical weight. This is surprising as monetary values are supposed to be different as they are usually reported according to different price concepts such as cif and fob. Nevertheless, deviations are very high in both cases.
- The deviations are high independently from classification system, independently from free-border trade systems and independently from distance between the countries.

5 Reasons for mismatches

The reasons why bilateral trade data are mismatching can be grouped into conceptual issues and issues particular to certain data values. While conceptual issues are systematic and responsible for reoccurring mismatches, data issues describe reasons for mismatches that hold for certain values only.

5.1 Conceptual reasons

5.1.1 Regarding the reference period

Trade statistics cover trade aggregated for a defined reference period, which is usually a month, a quarter or a year. Thereby, it is important to understand that each country reports the trade flows crossing the border of the respective country within that period.

If there is no time delay between the physical crossings of the borders, the trade flow is reported in the same period for both countries.

If there is a time delay within the time period (within one month/quarter/year), the trade flow is counted for the same period in both countries. However, if there is a time delay at the end of the period, the export is counted in one period and the import is counted in the next period. Time delay may be caused by transportation including loading/unloading (e.g. between harbours), by delays in reporting, by storage “between” borders or by procedures due to customs clearances. The stronger deviation in trade reported by Germany and Canada in comparison with trade reported by Germany and France (Chapter 3) may be explained to some extent by this time delay.

What is the exact point in time a product crosses the border from a statistical perspective? This question may appear curious, but it is important to understand the procedures by the administration responsible for trade statistics.

According to §16 of Germany’s regulation of the international trade statistics (Außenhandelsstatistikdurchführungsverordnung¹), the exact point in time of crossing the border is defined as the day when the formal requirements for imports or exports are fulfilled. The responsible importer or exporter has the duty of immediate declaration. Missing documents have to be send within two weeks. Meanwhile, the declaration is predominantly sent electronically, but paper-based declarations are also still used. EU legislation defines several possible points for allocation of trade flows to a reference period². Among them are the

¹ http://www.zoll.de/DE/Fachthemen/Aussenwirtschaft-Bargeldverkehr/Aussenhandelsstatistik/aussenhandelsstatistik_node.html

² <http://ec.europa.eu/eurostat/documents/3859598/8021340/KS-02-17-333-EN-N.pdf/c6e78259-cc92-4054-b785-cc7700ee6da9>

calendar month in which the goods physically enter or leave the country, the month in which VAT is charged and the month in which the declaration is accepted by the customs office. Thus, countries can (mostly) choose which method to use, and the procedures are not harmonized within the European Union. An exception applies if the customs declaration is the source for the records. Then the reference period is the month in which the declaration is accepted by the customs.

In Germany as well as in other EU countries, there are different formalities to be executed depending on whether the trade is within the European Union or with countries outside of the European Union. The European Union is generally a custom-free trading zone with some exceptions and limitations, while trade with third countries underlies different regulations. In any case, the point in time the trade flow is reported is the day the trade formalities are met. Therefore, the responsible trader has to report the trade activity to the custom of the exporting and the importing country. If the procedure of the customs in the exporting and importing country occur in two different periods (e.g. during the change of years), the same transaction may be reported in two different years. While transportation is one important reason for a possible time lag, another reason is storage. Different types of storage can be distinguished:

- Storage in custom clearance zones: The formal procedure requires that the goods have to be presented physically at the customs. The customs office can store the goods while finalizing the procedure.
- Storage within free zones of ports: In the European Union, there are so called “free zones” where goods can be stored or transferred formally into another custom procedure. The goods are per definition in the procedure of custom clearance, thus not yet exported or imported. In Germany, for example, there are three free zones in Bremen, Bremerhaven and Cuxhaven.
- Consignment: Consignment is the act of handing over goods to another person’s or agent’s custody while retaining legal ownership until the materials or goods are sold. This may be done for the purpose of shipping the goods, placing them in an auction or in a store for sale. The moment when the ownership transfer is reported to the custom clearance (e.g. in a biweekly report summarizing all sales or shipments) and the formalities are finalized, the import is counted in trade statistics. Thus, the product can geographically be located in the importing country without a statistical recording, i.e. the statistical recording occurs later than the physical crossing of the border.

5.1.2 Regarding country of origin and destination

The issue is very similar to the issue regarding time. It is important to recognize that each country is responsible only for its own trade data. This has important implications: The first implication is that there is no systematic and globally organized system for exchanging, comparing and balancing trade data. Although from a logical point of view, each mismatch of bilateral trade data must be an error, there is not *one* correct answer, but there are always *two* answers by two official statistics.

Furthermore, statistics do not always differentiate between the country of origin (or country of departure) and the country of transit. While the country of origin is the country where

“the last substantial processing or working took place”¹, goods in transit are not being processed nor is value added. However, this very simplified definition is subject to trade agreements, as value chains are complex and materials and components are sourced from all over the world. Duty rates, preferential trade agreements, sanctions and import quotas depend on the country of origin. In addition, the country of origin is important for marketing purposes. Thus, the definition of the country of origin is crucial and detailed rules exist that are specific with respect to different products, regulated each time for each product or product group in specific trade agreements.

Similar, but not as important, the country of destination (where the product is used or further processed) and the country of transit (only transport without any processing) are not always clearly distinguished.

The already mentioned consignment (Chapter 4.1.1) also has an implication: The product can be physically in the importing country (or even in a third place), but as long as ownership has not changed, the product is not accounted for in the import statistics.

5.1.3 Regarding product classification

Trade data mismatches may have another conceptual reason, the different allocation to defined product groups.

Traded products are classified into so-called homogeneous product groups. The definition of the codes is described in manuals or explanatory rules. The scope of individual CN-codes, for example, is described in detail by EC, 2015. Similarly, there are detailed descriptions for other classifications and even for conversions between classifications. Particularly, Eurostat provides a very detailed and exhaustive information platform “Reference and Management of Nomenclatura - RAMON”². It should be mentioned that the descriptions are very detailed and clear. However, there are several cases where the assignment of the traded product to a code is ambiguous.

While most manuals and code descriptions only describe individual codes, the German handbook additionally contains rules on how to identify the correct product group, particularly in case of doubts (Destatis, 2017). Examples are:

- In case that there are two or more options, the respective product should be assigned to the more specific product group.
- Products containing different raw materials have to be assigned to the material sub group which defines the character of the product.
- Products for which raw material mixtures are not known or without any clear product group have to be assigned to the most similar product group.

Differences in handling these rules and the assignment to codes in general may explain some differences in bilateral trade data. It can also explain - to some extent - why the deviation of aggregated trade data is significantly less than the sum of all deviations.

¹ <http://ec.europa.eu/eurostat/documents/3859598/7679615/KS-GQ-16-009-EN-N.pdf/073b853a-a4f4-4c55-aaba-162671544c78>

² http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM&StrGroupCode=CLASSIFIC&StrLanguageCode=EN

5.2 Further reasons

Not only conceptual challenges can explain the frequent occurrence of mismatches in bilateral trade data. There are further reasons with regard to the purpose of the data collection, monitoring and compliance issues and individual data errors.

5.2.1 Purpose of data collection and trade policy

Trade data belong to the first data collected by countries as customs are an important income for countries. Furthermore, customs have always been and still are an instrument of promotion of business and economic development.

In Chapter 4.1.2, the crucial definition of the country of origin was already mentioned. The definition is important because the country of origin determines the tariff level, the overall import volume, import restrictions, labelling obligations, etc. Predominantly, duties and volumes are defined using the monetary value of trade and not the physical weight. Thus, the customs offices have to collect and gather accurately the monetary volume of trade flows as it matters for the implementation of the trade policy.

Information on physical weight is simply not as important as wrong information does not have any consequences. According to the information of an expert who worked several years for Germany's statistical office, this is the most important reason why monetary trade information is better than physical trade information. The examples provided in Chapter 3 have shown it very clearly: In all examples, deviations are higher with respect to physical weight than with respect to monetary values.

5.2.2 Compliance

Policies and particularly trade policies regulate and restrict trade. However, there is illegal trade. Illegal trade is defined as trade which is not respecting the rules. Illegal trade may occur with respect to all materials and product groups, including e.g. drugs, intoxicants, protected animals and animal products, hazardous substances, trade with banned countries, etc. There is no overall estimation on the magnitude of illegal trade, although there are some product-specific estimations.

Illegal trade also exists with regard to minerals and metals: Blood diamonds from Sierra Leone are sadly famous, but also other metals and minerals from conflict areas such as tantalum (coltan) from the Democratic Republic of Congo. Political answers such as the Dodd-Frank-Act and Due Dilligence Obligation¹ may reduce illegal trade, but they cannot prevent illegal trade as such.

Another issue with regard to illegal trade in metals is trade with prohibited components into banned countries and trade with electronic waste, partly declared as secondary products.

Illegal trade may have different consequences in trade statistics:

¹ According to EU regulation, importer of tin, tungsten, tantalum and gold have to check and monitor their supplier in order to secure that the raw materials have not been extracted in conflict areas.

- It does not appear in the statistics, neither in the exporting country nor in the importing country.
- It may appear in the statistics of the exporter but not of the importer, or vice versa.

In addition to illegal trade, data may also be inaccurate when exporters and importers provide 'sloppy' reports. E.g. they may only give a rough estimate instead of actually weighing the goods, or when they have a choice they may put products into the product category which has lower taxes or looser regulations.

5.2.3 Administrative procedures

Each country has different rules on the volumes and values which may enter the country without any administrative procedure and duty. This can be experienced by tourists at the borders and by individuals using postal services. Usually, countries define limits for small businesses in order to simplify custom procedures. Each country defines the limits differently, and the limits are different with respect to different products and partner countries.

Within the EU free trade zone, for example, traders with annual trade volumes below a certain threshold do not have to report any trade data at all. The threshold varies in each member state from 700 € for Malta to 1.8 Mio. € for the UK. Those exports and imports are then estimated by the statistical offices and added to the trade statistics to achieve coverage of at least 97 %.

5.2.4 Confidentiality

Due to confidentiality reasons, countries may report some trade flows only in an aggregated manner or may not publish the data under the original code, but under a special 'confidentiality' code. As regulations for confidentiality may vary between countries, this can also be a reason for differences in reported trade flows.

5.2.5 Errors and missing data

Further reasons for mismatches are errors and missing data. Processes for declaration and clearing trade products are increasingly automatized, particularly in developed countries. However, paper-based processes also still play a role. Unreadable values in documents, transmission errors, counting errors, errors due to missing values, errors due to a wrong conversion of units, errors due to ignorance of harmonized standards, and so on, do occur.

As long as these errors do not exceed any plausible range, e.g. average prices per physical volume of the product group reported in the trade statistic, scientists cannot detect these errors. Also, countries may not necessarily report trade statistics for each year, in the latest version of the classification and for all codes. The scope of data that is reported may vary from country to country leading to missing data.

In summary, there are several reasons for the frequent occurrence of asymmetries in bilateral trade data:

- There are conceptual reasons with regard to time and country of origin/destination as well as with regard to the underlying differentiation of the traded products.

- There are issues relating to the purpose of the data collection and administrative procedures as well as with compliance.
- Last but not least, errors can occur and data may be missing.

We recommend that a scientist working with trade data is aware of those reasons in order to better understand trade data and the challenges associated with it.

6 Options for data editing

After giving an insight on the reasons why bilateral trade data usually do not match, this chapter provides an overview on different options on how to solve data problems in order to get “reliable” trade data. We distinguish approaches to balance bulk trade data sets and approaches to solve raw material-specific challenges.

6.1 With regard to bulk trade data

In UN Comtrade, trade data of one exemplary country in one year may include around 4.500 codes for imports and exports with around 220 trading partners. This implies 1.98 million data points for a single country and a single year - not including re-imports and re-exports. Currently, UN Comtrade lists 294 countries and trade regions. Assuming that 200 countries report trade data of a similar scope, around 400 million data points exist for a single year. It is hence not possible to correct each single data point individually. Instead, general rules or algorithmic approaches have to be employed. In the following, some approaches are described. The choice which approach to use depends, amongst other, on the research question.

6.1.1 Prioritizing one source of information

Following the assumption that each country is the owner of its data, the country's data can be used with regard to the country without any balancing of bilateral trade data. This is the approach used within UN Comtrade and for the majority of international trade statistics. A scientist could also follow this approach and leave the data as it is.

The clear advantage is transparency and clear responsibility for the data: Data responsibility remains with the reporting country. The disadvantage is that the results may be implausible and contradictory if trade data reported from different countries are used.

6.1.2 Correcting errors

A conservative way to improve trade data is the correction of outliers. This implies that the scientist working with the data accepts that data may be wrong due to human or machine errors (see Chapter 4.2.3).

The challenge is the definition of an outlier. With regard to the large number of codes, the question arises whether one definition for outliers is sufficient or whether different definitions for different product groups have to be used. The less homogeneous the products combined in a so called homogeneous product group, the more the prices may differ: While global price differences (without freight, insurance and transport) may be small with regard

to e.g. wheat, the spread is higher within other product groups, such as e.g. “passenger vehicles”.

Thus, if this treatment of trade data is chosen, the definition and the respective limits of an outlier should be explained transparently.

6.1.3 Gap filling

Gap filling has two dimensions: missing gaps in existing statistics, and gap filling where statistics are not existent. While trade statistics are (mostly) complete with respect to monetary values, the physical data on trade flows are often not available. This is a big challenge for working with trade data from the perspective of material flows analysis.

A simple approach for filling in missing physical information is using price information. Two critical choices have to be made:

- which price to use for the correction, e.g. global average prices, global average fob-prices (commonly export prices) or regional prices.
- the level of aggregation at which the correction is done; in general, the more differentiated the product groups, the more specific the price information.

Another approach is gap filling using other bulk sources. As there is no alternative bulk source for trade in minerals, this approach is not important in the MinFuture context. The approach, however, can be relevant e.g. with respect to fossil energy carriers (using e.g. IEA as source) or with respect to trade in biomass (using e.g. FAO).

For gap filling, bilateral data can also be used. In this context, bilateral trade data are only used to estimate trade of a country that did not report at all.

6.1.4 Balancing trade data with production statistics

This approach is different to some extent as the aim is not balancing bilateral data but balancing trade with production data. This is done regularly by statistical offices for national accounts following the breakdown of product groups and economic sectors of the respective input output tables of official economic accounting.

With regard to the quantification of physical material flows, the approach of the Eurostat RME model¹ should be mentioned. The Eurostat RME model estimates raw material equivalent of trade, i.e. the raw materials required for the production of traded goods. The model assumes that, in general, trade data are of sufficiently good quality. However, trade data are aligned and complemented with an input output table, industry statistics, statistics on raw material extraction and energy use etc. in order to convert monetary flows into physical flows. A simple algorithm is used to correct for the difference between CIF and FOB prices. For gold, for which physical and monetary flows are strongly determined by speculation rather than by industry demand, smoothing algorithms are used, to reduce the volatility in supply and demand.

¹ <http://ec.europa.eu/eurostat/documents/1798247/6191533/Documentation-EU-RME-model/>

6.1.5 Procedures to balance bilateral trade

There have been several attempts to overcome bilateral mismatches. During recent years, the demand was formulated by, amongst others, multiregional input-output modellers in economy-wide material flows analysis. MRIO-approaches rely on clear and unambiguous values for bilateral trade data. However, the required trade data depend on the regional and sectoral/product specific breakdown of the used model.

The balancing of bilateral data can be done in different ways. First, a decision has to be taken whether all reporters are treated equally or whether some reporters are prioritized. Reasons for prioritizing some reporters could be, e.g. more complete data of these reporters or more reliability of their data due to fewer errors in sums or less missing/implausible values. The balancing itself is been done with more or less complex mathematical formulas. An approach based on UN Comtrade data is the BACI dataset with publicly available data until 2007¹. According to our knowledge, resulting bulk data sets from more recent approaches were not published.

Furthermore, according to our knowledge, all approaches balancing bilateral data refer to monetary trade data. As far as we know, no attempt has been made to balance physical trade data at a global level.

6.2 With regard to selected (raw) materials

In contrast to the analysis of bulk trade data, material substance analysis aims to monitor selected raw materials throughout the economy. In an interconnected economy, trade data are crucial. However, as described above, trade data provide several challenges:

- Missing/wrong/mismatching data as described above
- Data without sufficient information with respect to raw material content

The first issue was stressed above and thus all the options to solve it are relevant again: using prices/bilateral data/further sources (e.g. trade data, production statistics) to correct data or to fill data gaps. With regard to single raw materials, the effort is lower compared to bulk data sets. A comparison of production statistics and trade data is a possible manner to get reliable information on the magnitude of the data.

The second issue was already mentioned above, but should be stressed again at this point: Trade data provide aggregated information on all flows within a defined homogeneous product group within one period of time. The reported volume of e.g. exported metal ores is usually an aggregation of different charges of this metal ore. Some charges contain less and other charges contain more metal content - depending on the metal content of the metals extracted during last months in the respective mines. Metal content varies depending on geological structures and the degree of processing. A more complex issue is the raw material content of semi-processed and final articles.

Metal content of ores and concentrates is often derived by the price - following the underlying assumption that the price is higher if metal content of the ore is higher. In case a metal

¹ http://www.cepii.fr/CEPII/en/bdd_modele/presentation.asp?id=1

ore includes not only the reported metal, but also metallic by-products, the mentioned assumption and thus the result may be imprecise.

With regard to final articles, an average content of raw materials may be assumed. It is obvious that the results on traded raw materials highly depend on the assumptions of the average raw material content of the respective product.

Thus, one should be aware that the information provided by trade statistics on a traded product is always an aggregated monetary and an aggregated physical value of a series of trade activities within a period of time.

Consequently, correcting trade data and balancing trade data can take into account some of the following principles and approaches:

- correction of cif and fob prices
- checking of trade data against production data and against bilateral mirror data
- estimation of the raw material content of specific products and their mixture within the homogeneous product group, and
- awareness and knowledge of how the data on the single trade activities behind the aggregated value of annual trade is gathered and collected.

This leads to awareness and acknowledgement of the design principles presented in the following chapter.

7 Design principles

Trade statistics show trade activities that generally follow the procedures the respective country has agreed on with the partner country. One country usually has several different trade agreements with partner countries. With regard to different product groups, agreements may also differ. A fundamental difference is whether the country is part of a free trade zone or not.

In general, the procedures may have strong impacts on data collection and coverage. In the following, procedural steps will be identified in detail: When and where does the exporter/importer report to the statistical bodies? Where is the traded good located physically at this point in time?

Different procedures will be shown using EU and German regulations as an example. Information was gathered from the procedural explanations of German's customs¹ and the Eurostat manuals on European statistics on international trade in goods^{2,3}.

7.1 Trade within a free trade zone, example EU

A free trade zone is defined as a zone without limitations in terms of traded volumes and with respect to duties. In practice, even in free trade zones, there are restrictions, e.g. regarding trade with drugs or hazardous waste. In the following, the exceptions will be ignored and trade with not regulated products will be focused on. In case, no VAT is required, exporter and importer usually indicate aggregated trade to custom for statistical reasons once in a month. In case, product requires VAT, the steps are as following:

In the exporting country:

- (1) The first step is that exporter indicates the trade activity in advance and shows the product physically to the custom. In Germany, this has to be done at least 24 h before the trade activity is scheduled.
- (2) The customs provide the required documents within 24 hours.
- (3) The custom indicates trade flow to the statistical body after document procedures has been accomplished.
- (4) The product is transported and crosses the border (in transit).

¹ http://www.zoll.de/EN/Home/home_node.html;jsessionid=34E3565224E19B24ABF8DDAC27128DA2.live4402

² Eurostat, 2017b: Compilers guide on European statistics on international trade in goods, 2017 edition, DOI: 10.2785/724104.

³ Eurostat, 2016: User guide on European statistics on international trade in goods, 2016 definition, DOI: 10.2785/080339.

Thus, the physical flow of the traded good and the flow of statistical information happen on the same day. In case of delays in transport, the statistical information is recorded before the physical flow happens.

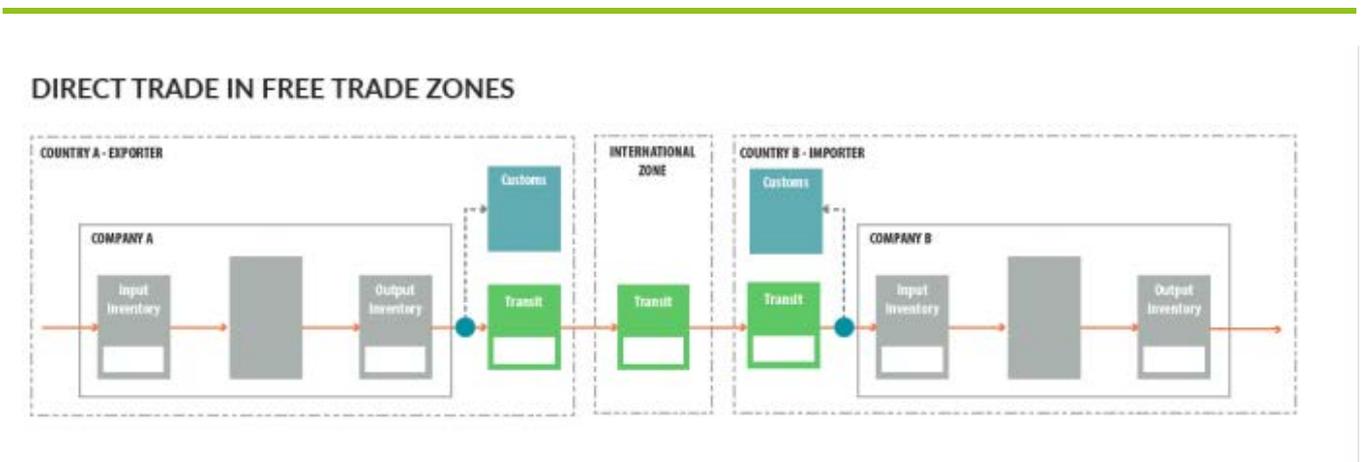
In the importing country:

- (1) After the traded good crosses the border (leaving transit zone), the importer indicates the flow and presents the goods to the customs offices.
- (2) The customs provide the documents within 24 hours.
- (3) The customs indicate trade flow to the statistical body after it has been accepted.

Thus, the flow of statistical information is a bit later (up to one day) than the physical flow.

The following figure 5 shows the steps and procedures:

Figure 6: Steps of trade flows within a free trade zone, example Germany



7.2 Trade with a third party, without storage

As a free trading zone is rather an exception at a global level, the standard case is the trade with clearance at the customs. In the following, the steps are explained using exports by ship from Germany to a country outside of Europe as an example. The steps are as following:

- (1) The exporter announces the trade to the customs (nearby).
- (2) The customs provide the required documents.
- (3) The exporter transports the goods to the port and shows the documents and products to the customs at the port.
- (4) The customs office finalizes the formalities and reports the trade flow to the statistical body.
- (5) The exporter loads the product onto the ship
- (6) The product is transported into the transit zone.

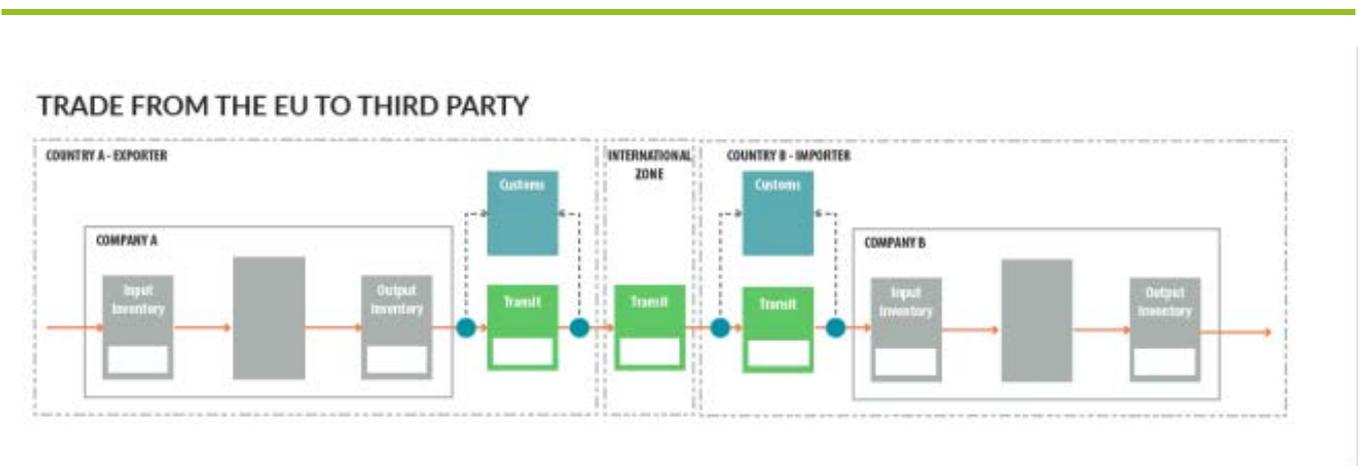
Thus, the trade flow is reported and included in the trade statistic for the reference period in which the customs office indicates the flow to the statistical body. The reference period the traded product physically crosses the border can be a different one. The length of the stay in the transit zone, e.g. at the ship, depends, amongst other, on the distance between the trade partners.

The import is to some extent a mirror image:

- (1) The traded product physically crosses the border.
- (2) The importer unloads the traded product, declares the intended import to the customs and shows the product to the customs.
- (3) The custom provides the required documents.
- (4) After finalizing the formalities the customs office reports the trade flow to the statistical bodies.

As before, the trade flow enters the statistics after all formalities are accomplished. This can occur after the physical crossing of the border. The following figure shows the steps.

Figure 7: Steps of trade flows, outside free trade zone and without storage



7.3 Trade with a third party, including storage

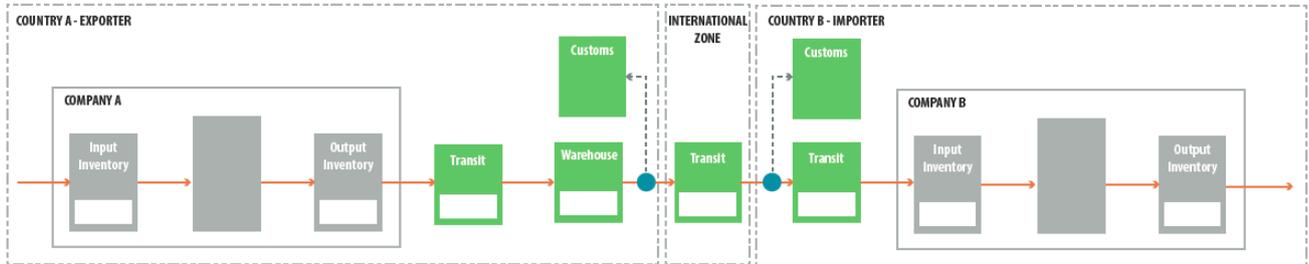
The next case, namely trade including storage, is also very widespread. The example below assumes that the storage room or the warehouse belongs to the exporter and does not have any special status. The procedural steps are:

- (1) The exporter indicates trade and shows the goods to the customs office.
- (2) The customs office provides the required documents.
- (3) The exporter stores the product in the storage room/ warehouse.
- (4) The exporter show the documents and articles to the custom
- (5) The customs accept the declaration and report the trade flow to statistical bodies.
- (6) The exporter transports the goods to the ship/medium of transport.

Thus, as long as the warehouse is in the country, export is included in the statistics after storage and after accomplishing all formalities. The physical crossing of the border can have a larger delay as in the previous examples. The import procedure is the same as in the previous examples. The following figure shows the steps.

Figure 8: Steps of trade flows, including storage

TRADE FROM THE EU TO THIRD PARTY INCLUDING STORAGE WITHIN THE EU



7.4 Consignment: example import from third party

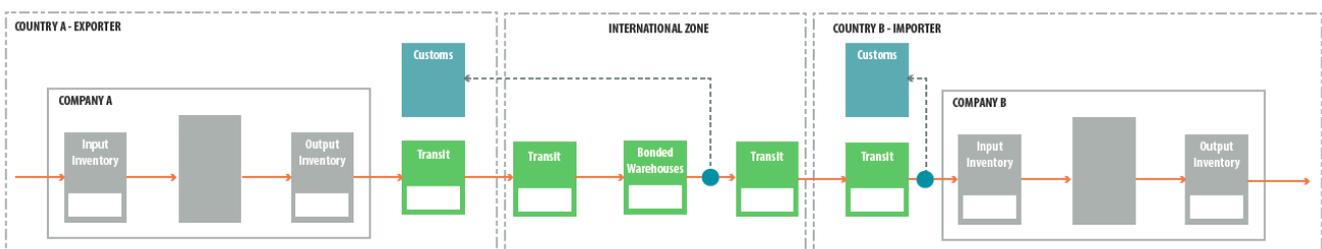
The next case is also very common as goods are often imported on a large scale without them being bought directly. Consignment means that the products are physically imported without an ownership transfer. The goods are in a storage room or warehouse and sold - depending on the agreement – one after another. As export steps are in principal not different to the examples before, only the steps for import are explained in the following:

- (1) The traded good physically crosses the border.
- (2) The importer announces the trade flow and shows the product to the customs.
- (3) The customs office checks the import goods and processes the documents.
- (4) The importer stores the traded goods in the warehouse.
- (5) The importer in country B retrieves the traded goods over time. Depending on the agreement, the importer reports the imported goods directly or in an aggregated manner for a fixed period.
- (6) The customs finalize the documents and indicate the trade flow to the statistical body.

Thus, in this case, the physical flow of the traded good and the information flow indicating the trade differ in time. Goods may even be stored for extended periods, e.g. several years, especially when they are used for price speculation or as reserves. The following figure illustrates the steps.

Figure 9: Steps of trade flows including consignment

TRADE FROM THE EU TO THIRD PARTY INCLUDING STORAGE IN A FREE TRADE ZONE/CONSIGNMENT



7.5 Summary of the design principles

The different steps have shown that the physical flows (crossing the border) and the information flows (entering the statistics) can differ with respect to the point in time. The design principles help to understand the different procedures of international trade and show what exactly enters when into the trade statistics. It has to be taken into account, however, that procedures vary from country to country. We used Germany as an example. In other countries, the reference periods might be defined differently. Also, it is important to consider that the periods for which goods are in warehouses or in transit can be quite extensive. Recorded trade flows only report flows, not stocks in warehouses or storage.

8 Summary of suggestions for further development of (physical) trade statistics

Trade data are indispensable for monitoring global flows of materials. Trade statistics subdivide trade flows by materials and steps of processing (raw material/semi-processed/final good). There are different classification systems with different purposes and differentiations of traded products. UN Comtrade provides global trade data for 220 countries/areas covering several decades and different classifications. This is a good starting point for material flow analysis.

However, the analysis has shown that the classification systems do not cover all the required information for the scientific community of material flow analysis.

Looking forward and acknowledging the need for a deeper and complete monitoring of abiotic mineral trade it is advisable to choose one or two classification systems and further develop it/them in terms of required disaggregation by materials or material contents. We suggest working with the HS-classification at a global level as it is the most common and most differentiated classification system globally. For longer time series (starting earlier than 1988), however, the SITC classification is the only classification that can be used. For trade with EU partners, we further suggest using the CN classification from Comext as much as possible as the level of disaggregation is higher than in HS.

With respect to materials, we suggest [start](#) to work with the European list of critical materials. We suggest a further differentiation of the homogeneous product groups, so that each critical material can be monitored as:

- raw material (ore, concentrate, but also as by-product),
- as semi-processed material (bars, wires, etc.),
- as far as possible, as part in a final article, and
- as slag and waste.

We further suggest including a new unit in trade statistics: metal content. Currently, there are several additional units such as m³ for timber or karat for diamonds. The additional unit metal content could be introduced, in a first step with regard to ores and concentrates and in following steps with regard to waste, scrap and slags. According to our knowledge, several reporters already provide this information to international trade statistics internally. This shows that an implementation is feasible.

As far as possible, the inclusion of more descriptive metadata should also be included especially when it comes to final products.

As it is now, commodities that have no value, most often waste and scrap is not tracked. To be able to follow the materials throughout their entire cycle and for instance give indications

on the potential for metal recycling, metal containing scrap that seems to have no value also needs to be tracked.

The analysis has shown that mismatches in bilateral trade data are the normal case - and matching bilateral trade data is the exception. There are several reasons why bilateral trade data do not match. Nevertheless, the magnitude of the deviations is alarming. In order to improve the quality of bilateral trade data, especially the physical values, the reasons for mismatches should systematically be addressed, e.g. by

- rising awareness for the political need of complete and good information on physical trade flows
- regular and systematic checking by statistical bodies, including e.g. support for less advanced statistical bodies in developing countries,
- regular and systematic comparison and checking of trade data by international bodies which are gathering information (UN Comtrade), and the
- development of standards for gap filling, error correction and balancing of bilateral trade data with respect to monetary and physical data.

As the scientific community has only a limited influence on the procedures for trade statistics, in the short term common guidelines could be developed on how to cope with data gaps and publicly available lists of materials for a large number of (representative) products could be created.

References

Arrobas, D.; Hund, K. L., McCormick, M. S., Ninghoujam, J., Drexhage, J. R. 2017: The Growing Role of Minerals and Metals for a Low Carbon Future. Washington, D.C.: World Bank Group. <http://documents.worldbank.org/curated/en/207371500386458722/The-Growing-Role-of-Minerals-and-Metals-for-a-Low-Carbon-Future>

Destatis, 2017: Warenverzeichnis für die Aussenhandelsstatistik, Ausgabe 2018. Wiesbaden. <https://www.destatis.de/DE/Publikationen/Verzeichnis/WarenverzeichnisAussenhandel2018.html>

Eurostat, 2017: Documentation of the EU RME Model. <http://ec.europa.eu/eurostat/documents/1798247/6191533/Documentation-EU-RME-model/>

Eurostat, 2017b: Compilers guide on European statistics on international trade in goods, 2017 edition, DOI: 10.2785/724104.

Eurostat, 2016: User guide on European statistics on international trade in goods, 2016 definition, DOI: 10.2785/080339.

European Commission, 2015: Explanatory notes to the Combined Nomenclature of the European Union. In: Official Journal of the European Union: Information and Notices. C 76, Volume 58. <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:C:2015:076:FULL&from=EN>

European Commission, 2017: Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the 2017 list of Critical Raw Materials for the EU. COM/2017/0490 final. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52017DC0490>

League of Nations, 1924: Memorandum of Balance of Payments and Foreign Trade Balances 1910 – 1923. Genf.

Eurostat, Comext: <http://epp.eurostat.ec.europa.eu/newxtweb/>

UNComtrade: <https://comtrade.un.org/>