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Mirror data asymmetry in international trade by commodity group: the case of intra-Community trade

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Keywords: *intra-Community trade; mirror data; Comext; quality of data*

Abstract

Research background: Transactions in international trade of goods are recorded in two sources, on the side of the seller's country and on the side of the buyer's country. The confrontation of such data makes it possible to measure their quality. An inconsistency between the data is called mirror data asymmetry.
Purpose of the article: The aim of the paper is to adapt the methods developed by the Authors to study mirror data asymmetry to commodity group markets examination. The quality of data on trade within specific commodity groups (CN chapters) in intra-Community trade was compared. The data were aggregated by country. The indicators used allow for the indication of commodity groups with high mirror data compatibility and those with data asymmetry between intra-Community supplies (ICS) and acquisitions (ICA). Moreover, the commodity groups for which the value-based and quantity-based approaches give different results have been identified.
Methods: Based on the literature on the subject and their own research, the Authors have developed a group of methods for studying the asymmetry of mirror data. The proposed indicator formulas are based on various data aggregation approaches. The research used data on intra-

Community supplies and acquisitions of goods broken down into 97 chapters of the Combined Nomenclature (CN). Differences between the ICS and ICA in particular commodity groups were aggregated for all pairs of EU countries. The data comes from the Comext database, provided by Eurostat.
Findings & value added: The results of the analysis are rankings of the Combined Nomenclature (CN) chapters by the quality of data on ICS and ICA. Lists of CN chapters have been created for discrepancies both in value and weight of goods. Thus, areas of necessary intensification of the work of public statistics services to improve data reliability were identified.

Introduction

International trade is an important factor affecting the dynamics of overall economic development. In a narrower sense, it is the paid exchange of raw materials, goods and services with foreign partners. In a broader sense, it also includes the movement of capital, labour, and the transfer of intellectual property. The benefits of foreign trade affect a society's standard of living and contribute to the creation of its wealth. Trade in goods is the primary form of cooperation with foreign countries. Foreign trade of a country affects the size of GDP (gross domestic product) and its structure, the development of entrepreneurship, competitiveness, specialization, expansion of markets, access to new products and technologies, etc. It is, therefore, a very important economic category influencing economic decisions. Thus, it is very important to obtain reliable data on the exchange of goods of individual countries, as well as groups of countries (e.g. EU) and on global trade turnover in general. Foreign trade statistics have a mirrored character. This means that information about the exchange of goods is recorded in the supplier country (as exports) and in the recipient country (as imports). The literature uses the terms ‘mirror data’ (Javorcik & Narciso, 2008; Markowicz & Baran, 2020a), ‘bilateral trade statistics’ (Hong & Pak, 2016) often additionally warning against ‘misreporting trade’ (Kellenberg & Levinson, 2018). This form of information collection allows the comparison of two quantities concerning the same event (a trade transaction as an export quantity on the one hand and an import quantity on the other). By definition, these two quantities should be equal. However, this is not the case. There are greater or lesser differences in these quantities. There are many reasons for this situation. These include, for example, errors in data aggregation (at the level of the economic entity or the country), incorrect coding of the country of the supplier or the recipient, inaccurate coding of goods, failure to distinguish between the invoice value and the statistical value, etc. In addition to these unintentional errors, there are also intentional errors in reporting. We are talking about the under- or over-estimation of mer-

chandise exchanges with foreign counterparts. These are the result of tax fraud.

For several years, the authors have been studying the discrepancy of mirror data in intra-Community trade in goods and ways to assess the quality of such data. The methodology developed so far has been used to assess the quality of data by EU countries. In Markowicz and Baran (2019a), we used data asymmetry indices, both proposed by Eurostat (the 'general' index) and the Authors' own proposals (the 'aggregated' index). The study resulted in a ranking of EU countries according to the quality of data on the exchange of goods between them. Our approach using absolute differences between exports and mirror imports allows for including all discrepancies (positive and negative differences). For the research, we proposed a new approach — a value-weighted quantity-based aggregated index of data quality. We used the proposed method to analyze differences in data recorded in trading partner countries (Markowicz & Baran, 2020a).

The aim of this paper is to adapt these methods to the study of asymmetry of mirror data by commodity groups. In this study, the quality of data on trade within specific commodity groups (HS chapters) in intra-Community trade was compared. The data were aggregated by country. The indicators used allow for the indication of commodity groups with high mirror data compatibility and those with data asymmetry between intra-Community supplies (ICS) and acquisitions (ICA). Moreover, the commodity groups for which the value-based and quantity-based approaches give similar results have been identified.

The article consists of an introduction, a literature review, followed by the research methodology description, results of the data analysis, a discussion of the results and conclusions. The first part presents an introduction to the topic and is followed by the literature review on the issue under consideration — the study of data quality in international trade. In research methodology section we presented our methodology proposal. We propose a methodology to study the quality of data expressed not only in terms of value, but also in terms of quantity (weight of goods). We also propose an original index of data discrepancy, combining both approaches. Our new proposal is a value-weighted quantity-based aggregated index of data quality with weights based on net value in distinct commodity groups (HS chapters).

The next section presents the results of data quality assessment for 96 HS chapters. We compared the results for the two indices. The results are also presented graphically.

In the discussion section, we indicate our contribution to the discussion in literature. In concluding remarks, we provided our results in a synthetic manner.

Presented paper is both of methodical and practical character. We are searching for appropriate research tools and will use the results to create practical applications (for use by statistical and tax services). The results of the research indicate the commodity groups with the largest errors in data.

We argue that previous research on mirror data asymmetry focuses in the spatial domain. The literature presents results indicating countries with misreported data. We aim to fill the research gap and focus on commodity groups and identifying those groups with poor data quality.

Literature review

Differences in official data on international trade have been written about for a long time. These are mirror data — recorded by trading counterparties. Already in 1996, the US recorded a $39.5 billion trade deficit with China (the world's two largest economies). However, China reported that value to be $10.5 billion (Feenstra, *et al.* 1999; Farhad, *et al*. 2018). Another example is the difference in trade data between Canada and the US, two of the richest OECD countries (Feenstra, *et al.* 1999).

We believe that the first researcher of the phenomenon of data asymmetry in foreign trade was Morgenstern (1963), who not only covered the analysis of world export and import data, but also proposed tools to study the differences between them. These differences are of great importance, especially for decision makers. Based on correct or incorrect data, economic analyses are conducted and decisions are made at various levels (region, country, group of countries). Incorrect data may result in inappropriate state intervention in economic processes. In the literature, we find e.g. many works on the topic of underreporting to avoid paying duties and taxes (Fisman & Wei, 2004; Javorcik & Narciso, 2008; Ferrantino *et al*. 2012; Mantusov & Tebekin, 2016). It was also studied by Morgenstern (1963). In his opinion, misreported bilateral transactions are evidence of concealment of illicit financial flows. Farhad *et al*. (2018) acknowledge positive correlations for both tariff and VAT rates with import under-reporting. Hien and Hung (2020) analyse Vietnam's mirror statistics and study the significant disparities of cross-border trade statistics in 2013–2016 between Vietnam and its trade partners. Hayakawa (2020) explores another problem. He argues that trade values are recorded in different years between export and

import statistics, when exports leave the port of origin in the latter months of the year.

Much attention seems to have been paid to explaining the motives for misreporting exports or imports, while less work has been done on methods for measuring differences in international trade statistics (Farhad, *et al*. 2018). Different methodological approaches are presented by both researchers and public statistics. The offices responsible for data collection are concerned about the reliability of the data. For example, Statistical Office of Montenegro (2015) describes different ways to measure asymmetry in foreign trade data: relative, absolute, weighted and depicts use of various indicators: statistical value, net mass, supplementary quantity and at different levels (country, chapter, 8-digit product code, etc.). In official statistics the MOD application provided by the Eurostat has been used (Liapis, *et al*., 2009; Statistics Poland, 2018). With a view of improving the quality of European statistics, Eurostat carries out monthly analysis of statistical sets transmitted by the Member States to the Comext database. This analysis results in reports on outliers presented at the level of individual Combined Nomenclature (CN) commodity codes, which Eurostat distributes monthly to the Member States for reconciliation. Eurostat uses MOD (Mirror Outlier Detection) using a measure of dispersion known as MAD (Median Absolute Deviation).

Different approaches to the study of discrepancies in international trade mirror data can be found in literature. Various authors propose different scopes of investigation and different methods. Carton and Slim (2018) highlight trade reporting errors in OECD countries and propose a method for examining the intensity of irregularities. Grigoriou (2019) states that mirror analyses feature prominently among the data analysis methods used to support customs administrations. In his opinion 'a major challenge of mirror analysis lies in the precise identification of the origin of the observed deviations. These differences can indeed prove legitimate and be attributed to various logistical causes'.

Another research method is proposed in Farhad *et al*. (2018). The authors propose three indices: the overall export misreporting index, the export under-reporting index and the export over-reporting index. All of the indices were calculated after aggregating data on commodity groups (to the HS 4-digit level).

Mantusov and Tebekin (2016) consider including specific data on individual imports and exports at the 6-digit level of HS in order to fill the gaps in data (these include fuels, fish traded abroad, as well as cars imported by natural persons). Unfortunately, as long as such improvements may work at country level or perhaps during bilateral reconciliation rounds, it is rather

unlikely to improve data on a group of countries automatically. However, these authors make a very strong point of the need to recognize and unify the transportation costs, and they propose an explicit deduction of a fixed amount (namely 5%) of total value of imported goods to account for the CIF vs. FOB gap (Incoterms abbreviations meaning cost of imported goods including the freight and insurance vs. pure cost of goods delivered to a vessel). It is an implementation of an idea present in literature at least since Morgenstern's work. The problem of overstating the trade value because of included freight costs has been tackled several times by various authors. And even if the problem is theoretically recognized, there still exists no general framework to bring the comparability back to such flawed mirror data. The Authors (Markowicz & Baran, 2020b) have also undertaken research on establishing a norm for correcting the excess transportation cost (CIF) included in foreign trade data in a manner following that of Morgenstern. In our study, however, the amount was varying, but for extra-Community trade it usually exceeded 10%.

The discussion on mirror data asymmetry in international trade is still ongoing in the literature. We note two streams of this discussion. The first focuses on considering the reasons for the discrepancies in data (e.g. Federico & Tena, 1991; Javorcik & Narciso, 2008). The second stream, on the other hand, focuses on the methodology for investigating these discrepancies, that is, examining the quality of international trade data (e.g. Parniczky, 1980; Ferrantino & Wang, 2008; Markowicz & Baran, 2019a) and correcting the apparent causes of discrepancies at the measures level (Mantusov & Tebekin 2016; Markowicz & Baran 2020a).

In the literature, we also have the results of analyses on certain shares of world trade. The problem of mirror data discrepancy is also present in these studies. We can find studies concerning e.g. trade of scrap plastic (Pacini & Shi, 2021), trade among developed and developing countries in lead and waste paper (Van Beukering & Bouman, 2009), or CO2 permits trade (Ainsworth, 2009). The published research also varies in scope, covering the entire world, selected groups of countries, or pairs of countries. More recent interesting works include: Asmah *et al.* (2020), who limited their analysis on misinvoicing to sub-Saharan Africa; Day (2015) describing Chinese trade data; or The Global Coalition Against Corruption (2018) who analyse the customs corruption in Kazakhstan based on mirror data.

The authors also contributed to the discussion. We proposed a methodology to study the quality of data expressed not only in terms of value, but also in terms of quantity (weight of goods). We also proposed an original index of data discrepancy, combining both approaches (a value-weighted quantity index) (Markowicz & Baran, 2020a, 2020b).

Research on mirror data asymmetry in most cases focuses on its spatial domain. The results are supposed to identify countries as places where data errors occur. In contrast, in this paper the Authors focus on commodity groups and identification of those with poor data quality. Thus we're expanding the scope of our previous analyses (Markowicz & Baran 2020a).

Research method

The Authors' methods for studying the quality of foreign trade data have been developed for several years, based on the literature on the subject and their own research (Markowicz & Baran, 2019a, 2020a). Previous studies were based on Comext data and concerned intra-EU exchanges. The analyses were carried out in order to determine the level of data quality for individual EU countries or their groups — e.g. the so-called 'new' and 'old' EU (Markowicz & Baran, 2019b). In these studies, exports and imports of goods were aggregated by commodity groups (HS chapters).

Currently, however, we are focusing on analysing the quality of data on intra-Community trade in goods divided by commodity group. The data were aggregated by country. The indicators used allow for the indication of commodity groups with high mirror data compatibility and those with data asymmetry between intra-Community supplies (ICS) and acquisitions (ICA). Moreover, the commodity groups for which the value-based and quantity-based approaches give different results have been identified.

In our research, we propose different index formulas. They are based on data on the value of transactions (value-based formula), on the weights of goods traded (quantity-based formula) or as a quantity-based formula adjusted by the share in the value of ICS or ICA.

The research used data on intra-Community supplies and acquisitions of goods broken down into 97 chapters of the Combined Nomenclature/Harmonized System (CN/HS). Differences between the ICS and ICA in distinct commodity groups were aggregated for all pairs of EU countries.

In the article, we used two types of indicators of mirror data quality — an aggregated value-based index (1) and a new proposal by the Authors, called a value-weighted quantity-based aggregated index of data quality (2).

An aggregated value-based data quality index for exports of goods (from *k*-th HS chapter) is given by:

$$ {}_{Z}W_{E}^{AU}(k) = \frac{\sum_{i=1}^{n}\left|E_{AB_i}^{k} - I_{B_iA}^{k}\right|}{K} \tag{1}$$

where:

$E_{AB_i}^{k}$ declared value of exports of goods classified in *k*-th HS chapter from country *A* to the country B_i,,

I_{B_iA} declared mirror value of acquisitions of goods shipped from country *A* to country B_i, as reported in the receiving country (B_i) statistics,

$K = \sum_{i=1}^{n}\frac{\left(E_{AB_i}^{k} - I_{B_iA}^{k}\right)}{2}$ a hypothetical true value of the above said exports.

Our newly proposed aggregated index with value-based weights (value-weighted quantity-based quality index) is calculated following the formula:

$$ {}_{Z}W_{{}_{m}E}^{AU}(k) = \frac{\sum_{i=1}^{n}\left|{}_{m}E_{AB_i}^{k} - {}_{m}I_{B_iA}^{k}\right| \cdot L_i}{K} \tag{2}$$

where:

${}_{m}E_{AB_i}^{k}$ declared weight of exports of goods classified in *k*-th HS chapter from country *A* to the country B_i,

${}_{m}I_{B_iA}^{k}$ declared mirror value of acquisitions of goods shipped from country *A* to country B_i,

$L_i = \frac{E_{AB_i}^{k} + I_{B_iA}^{k}}{\sum_{j=1}^{n}\left(E_{AB_j}^{k} + I_{B_jA}^{k}\right)}$ correction factor – the share of the value of exports of country *A* to country B_i in total ICS.

$K = \sum_{i=1}^{n}\frac{\left({}_{m}E_{AB_i}^{k} + {}_{m}I_{B_iA}^{k}\right)}{2} \cdot L_i$ the sum of average (hypothetical) quantity of exports and mirror imports from country *i* to countries *j* corrected with L_i factors.

The study was conducted according to the following steps:

1. selection of EU countries whose export value of goods exceeds the threshold (10% of the turnover of the country with the highest turnover)
2. aggregation of both value and weight of exports from selected countries (cf. point 1 above) to all EU member states for each HS chapter (96 chapters from 1 to 97 considered, specific chapters 98 and 99 excluded),
3. calculating index (1) for each HS chapter and ranking the chapters, then indicating the chapters with the highest and the lowest data quality,

4. calculating index (2) for each HS chapter and ranking the chapters, then indicating the chapters with the highest and the lowest data quality according to such modified index,
5. comparing indices (1) and (2) for every HS chapter in selected countries (graphical presentation included).

To exclude from consideration results that are random instead of being the result of the sought regularity, the study was limited to countries with the largest turnover in intra-Community trade. The selection was made in such a way that the study included countries whose turnover in the examined period exceeded 10% of the turnover of the country with the largest volume, i.e. Germany. Under this condition, the study group consisted of 12 countries, Germany itself accompanied by the Netherlands, Belgium, France, Italy, Poland, Spain, the United Kingdom (it was a member of the EU in the period under consideration), Czechia, Austria, Hungary, and Sweden The order of countries listed corresponds with their respective declared ICS volumes. We used Eurostat's Comext data on intra-Community trade in 2017 in our numerical example.

Results

We calculated all values of index (1) for every country from our list, obtaining vectors of 96 indices for every country. We continued by adding up the indices for the same *k*-th chapter in 12 countries which provided us with an aggregate. Then these 96 aggregates have been sorted in order to find out which HS chapters data can be considered of best and worst quality in every country. Eventually, we present the distributions of the actual indices among the 12 countries ordered by the average level (Fig. 1 shows ten HS chapters with best and ten with worst data quality among the 12 considered countries). We repeated the procedure with indices given by (2) and obtained another ordering of chapters, resulting in a chart analogous to the previous one (Fig. 2).

Although the selection of HS chapters in each diagram is different, we can still observe chapters that are among those with best/worst data quality regardless of the method, i.e. calculating data quality index based on weight can help in spotting those commodity groups that are reported correctly throughout the EU and those reported erroneously in many countries regardless of the method; the former group includes chapters 4, 18, 19, 39, 48, and 72, the latter — includes chapters 13, 36, 50, 89, and 97. In particular, the latter is a list of commodity groups that needs special attention from the official statistics services.

We calculated indices for every chapter in every country from our study group, so we could compare values of index (1) and index (2) correspondingly. In order to compare the indices, we simply draught scatterplots for every country from the group in which index (1) is put along the x-axis and index (2) — along y-axis (Fig. 3). We also counted the HS chapters for which index (1) takes a value higher than index (2) and those, for which index (2) > index (1). It appears, that Poland, Czechia and the Netherlands are the only countries for which the values of index (1) are higher than values of index (2) in most chapters while for most countries it is index (2) that has higher values in most of HS chapters.

For huge-turnover countries like Germany, the Netherlands, Belgium, or France the discrepancies in most of the HS chapters are low and rarely exceed 0.6 for index (1) and 0.8 for index (2), so the points in diagrams tend to cluster in bottom-left corner. For other economies, we observe a growing number of points indicating huge values of both indices. One interesting feature is that index (2) values tend to grow faster in most cases.

Discussion

The rare occurrence of countries for which index (2) has values lower than index (1) described in previous section seems to be counterintuitive as index (2) was introduced to overcome the high volatility of index (1). However, the explanation of this might be straightforward. Perhaps the main reason is the existence of value-oriented statistical thresholds introduced in intra-Community statistics. Trade of low value may well be under the reporting threshold and thus not reported, leading to small discrepancies between mirror data. The same does not hold for the weight of goods, because there exist many commodities that are both heavy and inexpensive. According to Eurostat's rules, covered by *National Requirements for the Intrastat System* (Eurostat, 2021), there exist several measures to simplify the reporting process and to lower the burden imposed on trading entities. These include the above mentioned main reason for discrepancies between mirror data, i.e. exemption thresholds under which an entity has no obligation to report Intrastat data, different for importers and for exporters and varying across the EU. But there are also other measures active, like the simplification threshold under which entities are allowed to combine their transactions and report them under an umbrella CN code 9950 0000 for small transactions, or the exemption of the net mass reporting. All of these and especially the latter may affect the net mass of reported trade on a greater scale than they affect the net worth of the same transactions.

The above explanation may seem plausible, however it is only speculative and we need further investigation based not only on Intrastat but also on Extrastat and/or World data to prove it. Although index (2) proved no particular advantage over index (1) for Intrastat data in terms of lower volatility, we presume it will perform better in other circumstances, i.e. when customs data will be used instead of Intrastat declarations. Nevertheless, we still consider formula (2) better than the previous one in terms of accuracy: index' (2) most important advantage lies in the proper treatment of huge commodity groups and not in its value itself.

We also observed that for huge economies the discrepancies in all chapters are low (points in diagrams tend to cluster in bottom-left corner) regardless of the method of calculating data quality, which is both an expected and desired result.

As we stated in previous sections, in this paper we added a commodity-oriented perspective to our previous work containing a value-oriented approach (Markowicz & Baran, 2020a). In both cases, we recommend using aggregate indices thus agreeing with Ferrantino and Wang (2008). The construction of such indices makes it impossible for positive and negative differences to cancel each other out which is an obvious advantage. However, the most promising is the simultaneous use of indices that cover the trade values with those taking into account the trade quantity. In the Authors' opinion it widens the scope of analysis and sheds light on some of the most important commodity groups.

No previous study providing analysis of international trade data with more or less sophisticated indices, including works of Morgenstern (1963), Federico and Tena (1991), Ferrantino and Wang (2008), used indicators that combine net worth and net mass of traded goods. Most of them focus only on countries and not commodity groups as sources of data discrepancies. We have filled both of these gaps.

The study of the quality of international trade data is important for the tax system in any country (Betz, 2019). A very important factor in increasing tax collection is institutional quality (Bird & Zolt, 2008). The results of our study may have implications for increasing this quality. Our goal was to provide a better tool for assessing the mirror data asymmetry and for indicating the most affected directions of trade or commodity groups that suffer from inaccurate data.

Conclusions

The results of the study lead to the following conclusions. It seems that the most important is a relative consistency of badly reported groups, regardless of the method of calculating data quality indicator — either based on the value or the quantity of goods. Thus, there is an easily identifiable group of goods that should be monitored as closely as possible.

The second important finding is the non-intuitive nature of the relationship between the classical index (1) and index (2) — while index (2) was supposed to eliminate differences between mirrored data, it appears that in most cases it rather sharpens them. We explained it in the previous section in detail. One possible reason is the nature of Intrastat data and we will try proving this hypothesis based on World data on trade.

Therefore, at this time it seems appropriate not to use one of the proposed indices, but both, and interpret their results together.

In our opinion, the search for more precise methods to measure mirror data discrepancies is crucial in eliminating existing and future errors in such data and in providing decision makers with more reliable information. This leads to the conclusion that our results may be interesting to decision and policy makers at different levels.

References

Ainsworth, R. T. (2009). The morphing of MTIC fraud: VAT fraud infects tradable CO2 permits. *Boston University School of Law Working Paper, 09–35*.

Asmah, E. E., Andoh, F. K., & Titriku, E. (2020). Trade misinvoicing effects on tax revenue in sub-Saharan Africa: the role of tax holidays and regulatory quality. *Annals of Public and Cooperative Economics, 91*(4), 649–672. doi: 10.1111/apce.12289.

Betz, T. (2019). Tariff evasion and trade policies. *International Studies Quarterly*, *63*(2), 380–393. doi: 10.1093/isq/sqz008.

Bird, R. M., & Zolt, E. M. (2008). Tax policy in emerging countries. *Environment and Planning C: Government and Policy*, *26*(1), 73–86. doi: org/10.1068/cav3.

Carton, C, & Slim, S. (2018). Trade misinvoicing in OECD countries: what can we learn from bilateral trade intensity indices? *MPRA Paper, 87695*.

Day, I. (2015). Assessing China's merchandise trade data using mirror statistics. *Reserve Bank of Australia, Bulletin, December Quarter*. Retrieved from https://www.rba.gov.au/publications/bulletin/2015/dec/3.html (10.01.2021).

Eurostat (2021). *National requirements for the Intrastat system*. Publications Office of the European Union, Luxembourg

Farhad, M, Jetter, M, Siddique, A, & Williams, A. (2018). Misreported trade. *CESifo Working Paper Series, 7150*.

Federico, G., & Tena, A. (1991). On the accuracy of foreign trade statistics (1909–1935). Morgenstern revisited. *Explorations in Economic History*, *28*(3), 259–273. doi: 10.1016/0014-4983(91)90007-6.

Feenstra, R. C., Hai, W., Woo, W. T., & Yao, S. (1999). Discrepancies in international data: an application to China-Hong Kong entrepot trade. *American Economic Review, 89*(2), 338–343. doi: 10.1257/aer.89.2.338.

Ferrantino, M. J., Liu, X., & Wang, Z. (2012). Evasion behaviors of exporters and importers: evidence from the U.S.–China trade data discrepancy. *Journal of International Economics*, *86*(1), 141–157. doi: 10.1016/j.jinteco.2011.08.006.

Ferrantino, M. J., & Wang, Z. (2008). Accounting for discrepancies in bilateral trade: the case of China, Hong Kong, and the United States. *China Economic Review*, *19*(3), 502–520. doi: 10.1016/j.chieco.2008.02.002.

Fisman, R., & Wei, S-J. (2004). Tax rates and tax evasion: evidence from 'missing imports' in China. *Journal of Political Economy*, *112*(2), 471–496. doi: 10.108 6/381476.

Grigoriou, C. (2019). Mirror analysis as a support for risk management and valuation: a practical study. *World Customs Journal, 13*(2), 91–104.

Hayakawa, K. (2020). Departure months and discrepancy in mirror trade data. *Institute of Developing Economies. Ide Discussion Paper, 795*.

Hien, P. T. T., & Hung, N. V. (2020). Applying 'mirror statistics' in cross-border trade administration: case of general department of Vietnam customs. *World Customs Journal, 14*(1), 41–54.

Hong, K. P., & Pak, S. J. (2016). Estimating trade misinvoicing from bilateral trade statistics: the devil is in the details. *International Trade Journal, 31*(1), 3–28. doi: 10.1080/08853908.2016.1202160.

Javorcik, B. S., & Narciso, G. (2008). Differentiated products and evasion of import tariffs. *Journal of International Economics, 76*(2), 208–222.

Kellenberg, D., & Levinson, A. (2018). Misreporting trade: tariff evasion, corruption, and auditing standards. *Review of International Economics, 27*(1), 106–129. doi: 10.1111/roie.12363.

Liapis, S., Ashbrook, M., Fragkakis, M., & Petrakos, G. (2009). Mirror outlier detection in foreign trade data. *Conference Paper, New Techniques and Technologies for Statistics NTTS*. Retrieved from https://ec.europa.eu/eurostat/documents/1001617/4398385/S4P1-MIRROROUTLIERDETECTION-LIAPIS.pdf (8.01.2021).

Mantusov, V. B., & Tebekin, A. V. (2016). Perfecting methodological recommendations on conducting comparative analysis of foreign trade data of Russian federation. *Vestnik of Russian Customs Academy 1*, 7–19.

Markowicz, I., & Baran, P. (2019a). ICA and ICS-based rankings of EU countries according to quality of mirror data on intra-Community trade in goods in the years 2014-2017. *Oeconomia Copernicana*, *10*(1), 55–68. doi: 10.24136/oc.201 9.003.

Markowicz, I., & Baran P. (2019b). Quality of Intrastat data. Comparison between "old" and "new" EU member states. *Acta Universitatis Lodziensis. Folia Oeconomica*, *2*(341), 69–80. doi: 10.18778/0208-6018.341.05.

Markowicz, I., & Baran, P. (2020a). A new method for calculating mirror data asymmetry in international trade. *Oeconomia Copernicana, 11*(4), 637–656. doi: 10.24136/oc.2020.026.

Markowicz I., & Baran P. (2020b), Discrepancies between mirror data on intra-Community trade: the case of Poland. *Econometrics. Ekonometria, 24*(1), 1-11, doi: 10.15611/eada.2020.1.01.

Morgenstern, O. (1963). *On the accuracy of economic observations*. Princeton University Press, New Jersey.

Pacini, H., & Shi, G. (2021). Network analysis of international trade in plastic scrap. *Sustainable Production and Consumption*, *27*, 203–216. doi: 10.1016/j.spc.2020.10.027.

Parniczky, G. (1980). On the inconsistency of world trade statistics. *International Statistical Review*, *48*(1), 43–48. doi: 10.2307/1402404.

Statistical Office of Montenegro – MONSTAT (2015). Mirror analysis summary report. International trade in goods statistics. IPA 2012, Multi-beneficiary statistical co-operation programme.

Statistics Poland (2018). Foreign trade. Mirror and asymmetry statistics.

The Global Coalition Against Corruption (2018). The customs corruption in Kazakhstan: the trade mirror analysis. White book. Almaty.

Van Beukering, P., & Bouman, M. (2009). Empirical evidence on recycling and trade of paper and lead in developed and developing countries. *World Development, 29*(10), 1717–1737.

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Annex

Figure 1. Distributions of HS chapters positions in quality rankings based on index (1) calculated for individual countries (10 best and 10 worst chapters)

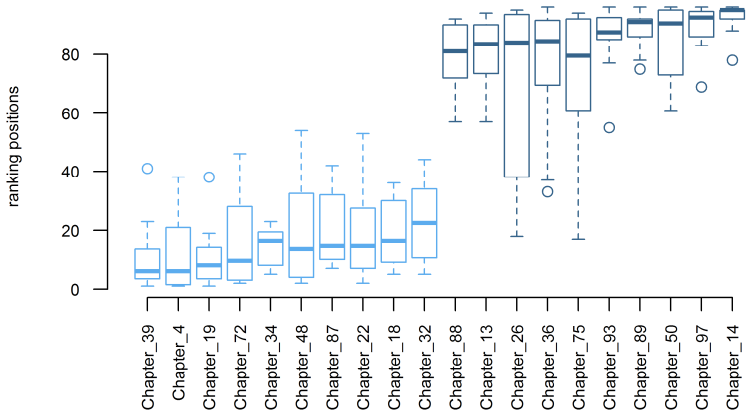


Figure 2. Distributions of HS chapters positions in quality rankings based on index (2) calculated for individual countries (10 best and 10 worst chapters)

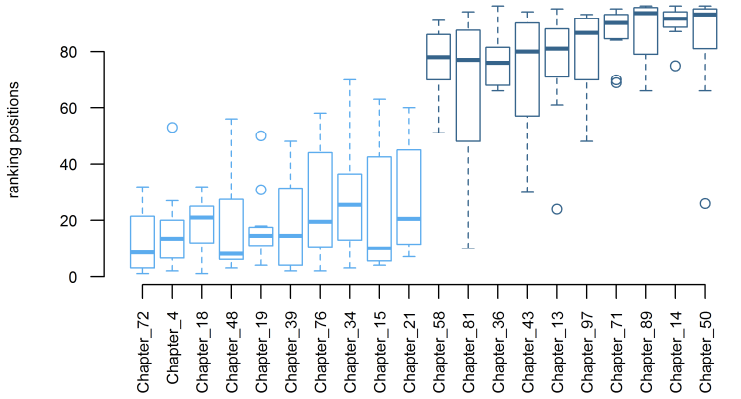
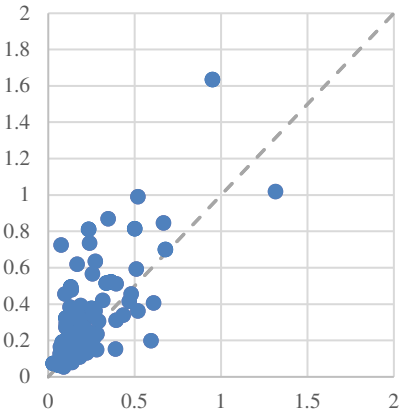
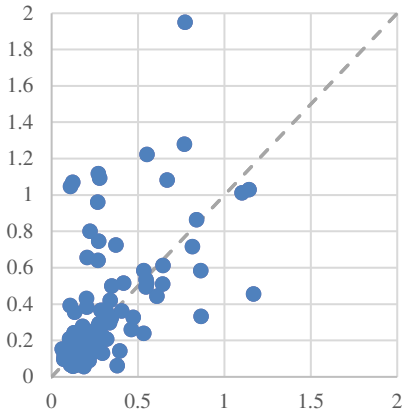


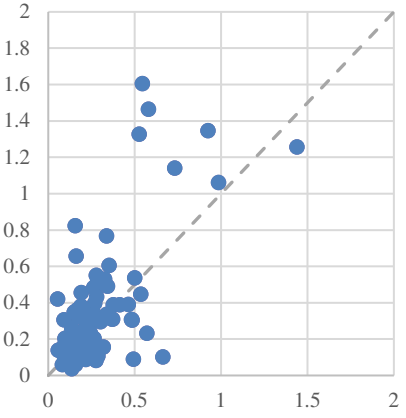
Figure 3. Values of index (1) vs. index (2) for every HS chapter in countries under examination (a-l)



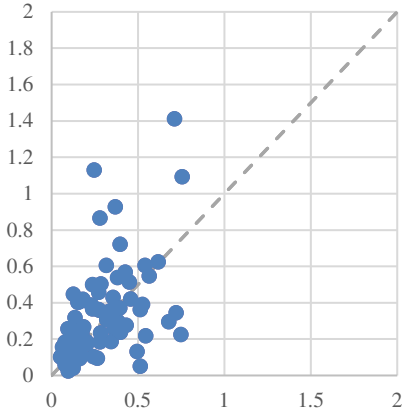
a) Germany (34 below the line, 62 above)



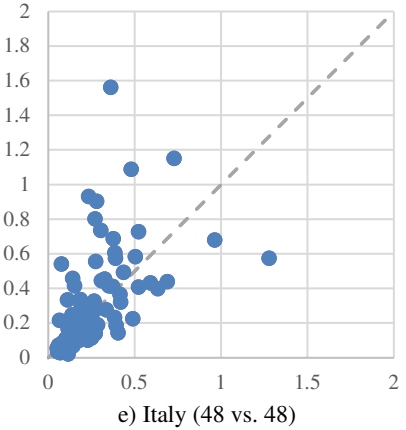
b) The Netherlands (50 vs.46)



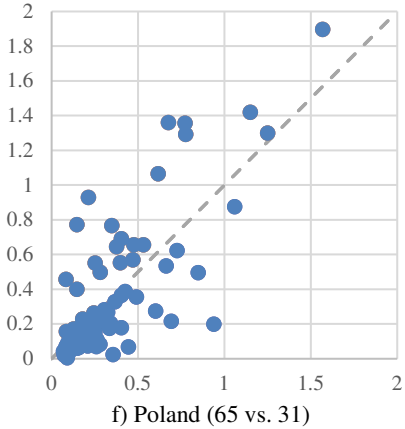
c) Belgium (44 vs. 52)



d) France (37 vs. 59)

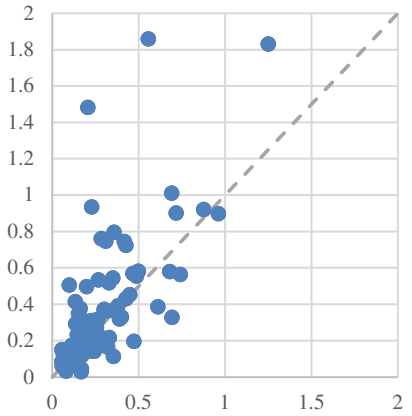


e) Italy (48 vs. 48)

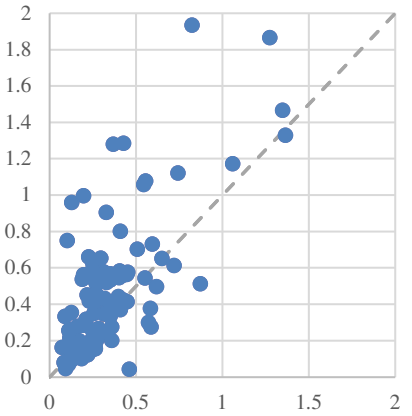


f) Poland (65 vs. 31)

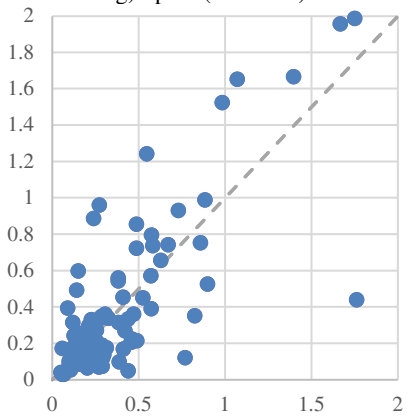
Figure 3. Continued



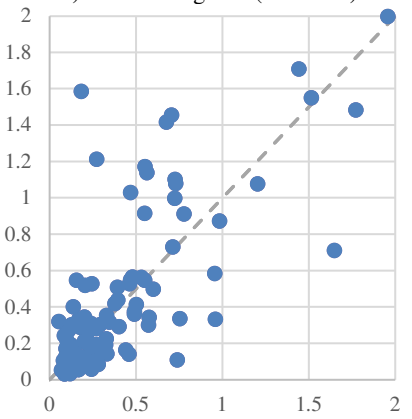
g) Spain (40 vs. 56)



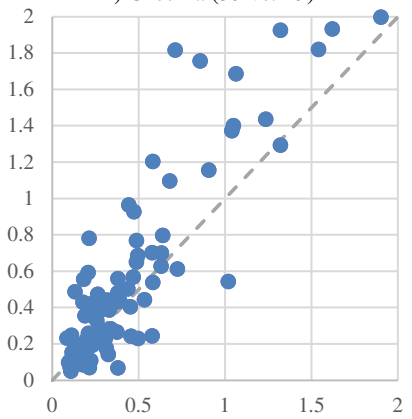
h) United Kingdom (39 vs. 57)



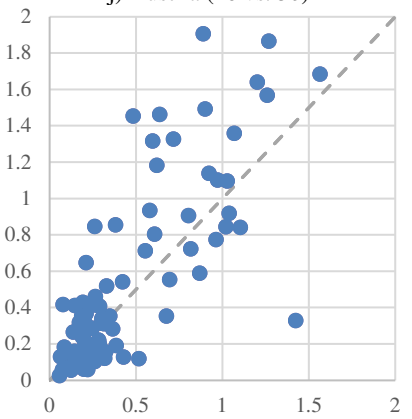
i) Czechia (53 vs. 43)



j) Austria (46 vs. 50)



k) Hungary (41 vs. 55)



l) Sweden (47 vs. 49)