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# Advancing UN Comtrade for Physical Trade Flow Analysis: Addressing the Issue of Outliers

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# ABSTRACT

The UN Comtrade is one of the most widely used data sources for physical trade analysis. However, the issue of outliers would result in misleading interpretations and biased results, limiting its applications. Assuming that no deals would be made at unreasonable prices, we define an outlier as the data record whose unit price (trade value divided by net weight) is unusually high or low. To address the outlier issue, we develop a framework of first applying the kernel density estimation method to detect outliers and then using different statistical models to handle them based on their potential causes, then develop a deviation index to assess the impacts of outliers, and present the data quality improvement and the significance of our framework; and finally evaluate its performance by comparing with previous methods to show its outperformance on adaptability to different commodities' data. Our results reveal that outliers exist for almost all reporters (207 in 209, 99%), all commodities, and all years, and most outliers (92%) are with wrong net weight values. With a higher deviation index, reporters are Canada, China, France, etc., while commodities are high-price electronic products, clocks, etc. The data quality would be greatly improved by addressing the outlier issue, thus benefiting UN-based physical trade analysis.

#### 1. Introduction

The United Nations Commodity Trade Statistics Database (UN Comtrade, https://comtrade.un.org) is the largest depository of international trade data, widely used in commodity trade analysis due to its broad coverage of commodity categories and reporters. However, as presented and discussed in our first article of this series (Chen et al., 2022), the data quality issues (i.e., outliers, missing values, and bilateral asymmetries) have seriously impeded the application of UN Comtrade. As the second one in this three-part series, this study presents the systematic method for addressing the outlier issue in UN Comtrade.

Previous studies have proved that the impacts of outliers in UN Comtrade on commodity trade analysis are nonnegligible (Chini and Peer, 2021; Giljum et al., 2014; Kharrazi et al., 2017). First, outliers might distort actual results because most parametric statistics (e.g., means, standard deviations, and correlations) and statistical analysis (e.g., linear regression and analysis of variance (ANOVA)) are susceptible to outliers (Cousineau and Chartier, 2010). The misleading statistical patterns and conclusions caused by outliers significantly increase analysis uncertainties (Rose and Stanley, 2005; Westphal et al., 2008). For example, outliers may produce a significant imbalance between both parties of a transaction in the trading network, where the estimated unit prices could be significantly out of the normal range. Consequently, when evaluating trade elasticity, the unusual unit prices may cause a massive deviation by turning a potentially normal trade flow into a dominant one, leading to significant biases and thus meaningless results (Ahmed et al., 2015). Besides, as unusually large or small observations, outliers could cause violent fluctuations of time-series data. Such

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Fig. 1. The framework for detecting and handling outliers in this study.

fluctuations might conceal and even hide vital information that reveals actual patterns, leading to a misleading interpretation (Chen and Liu, 1993). Therefore, adequate outlier preprocessing is one of the most critical points when applying UN Comtrade data.

Multiple attempts have been made to detect outliers in UN Comtrade. Statistical-based methods, such as three-sigma rules (Pukelsheim, 1994; Kharrazi et al., 2017) and boxplot (Brewer et al., 2020), are the most widely used. The method of the three-sigma rule is based on the assumption of the normal distribution, which has been adopted by Andrey A. Gnidchenko (2018) in investigating automotive products. The boxplot method was first proposed by Tukey (1977) as a tool for outliers detection, which assumes that the variable's distribution is symmetric with a light tail on both sides (Naghshin, 2020). Brewer et al. (2020) used the boxplot method to process UN Comtrade data in order to explore the flows of food among countries. However, for UN Comtrade data, almost none of the unit prices distribute normally. Skewed commodity trade data is prevalent, and the distribution of unit price is right-skewed. Thus, based on strong assumptions for data distribution, existing detection methods might be less accurate and precise in detecting outliers. Besides, these methods may be effective only in certain limited circumstances (e.g., some specific commodities and periods). For UN Comtrade data with various commodities, these methods are hard, or impossible, to be universal. In addition to the statistical-based methods, other outlier detection methods have also been extensively studied, for example, clustering-based (e.g., unsupervised classification), learning-based (e.g., deep learning), ensemble methods (e.g., extreme gradient boosting (XGB))(Sikder and Batarseh, 2021). The major limitation of these methods is a lack of explainability, i.e., it is challenging or even impossible to identify the causes of the detected outliers. By comparing multiple outlier detection methods, Kaur and Garg (2016) concluded that statistical-based outlier detection is better applicable for statistical data like UN Comtrade.

Furthermore, handling the detected outliers can be challenging (Aguinis et al., 2013; Kwak and Kim, 2017). Based on a review of methodological and substantive organizational science sources, Aguinis

et al. (2013) summarized outlier handling techniques and categorized them into modification (i.e., manually changing an outlier's value to another), replacement (i.e., replacing an outlier's value with a substituted value), removal (i.e., elimination of the data point from the analysis), keeping (i.e., acknowledging the presence but doing nothing), etc. Most studies just remove these outliers, which would result in biased conclusions (Altman and Krzywinski, 2016; Ghosh and Vogt, 2012; Kwak and Kim, 2017; Leys et al., 2019; Pollet and van der Meij, 2017). Besides, since some outliers in UN Comtrade can result from infrequent events (e.g., droughts (Collins, 1998) and money-laundry (Damerval, 2012)) containing influential information, inappropriate outlier handling may also jeopardize the analysis. Thus, adequate outlier detection and handling could significantly increase the reliability of UN Comtrade-based commodity trade studies, which is well worth the efforts.

In this regard, a framework was developed to detect and handle outliers in UN Comtrade for data of all commodities during 1988–2019. Also, the deviations of detected outliers from the handled values were calculated to investigate the impacts of outliers and quantify the data quality improvements. This article is organized as follows. Section 2 describes our framework for outlier detection and handling and methods for deviation analysis. Section 3 first presents our results of outlier distributions and deviations. Then some cases reflecting the effects of outliers and the improvements made by this study are presented. Finally, Section 4 evaluates and compares the performance of our outlier detection and handling methods with those adopted in previous studies, and Section 5 presents the conclusions.

# 2. Methods

This study detects and handles the outliers in UN Comtrade and calculates their deviations from the handled data. Our outlier handling involves manually modifying outliers after identifying their causes or correcting them with fitted values. Fig. 1 shows the methods of outlier detection and handling in this study. We apply these methods to the UN

Comtrade data during 1988–2019 for 5037 commodities based on the Harmonized System version 0 (HS0) classification (the most used). We define an outlier as the data record whose unit price is unusually high or low, assuming that no rational merchant would make deals at unreasonable prices. This unit price is in current prices derived by dividing the trade value ( $\nu$ ) in current prices by the net weight (w). Before the detection of outliers, in the concern of the effect of currency inflation, the unit price in the current price needs to be converted into the constant unit price (x) via the constant price coefficient ( $\beta$ ). The constant price coefficient ( $\beta$ ) for each year by dividing global Gross Domestic Product (GDP) in the constant price by that in the current price, where global GDP data can be directly retrieved from the World Bank database.

# 2.1. Outlier detection

The outlier detection contains two steps, which are applied to all available trade records (1988–2019) of all reporters by 6-digit HS codes. The first step is to estimate the probability distribution of the variable *x*. In this study, we use the statistical-based outlier detection method of the Kernel Density Estimation (KDE). The KDE is a non-parametric process of estimating an unknown probability density function using a kernel function. Unlike existing methods (e.g., boxplot) in previous studies, the KDE method is a distribution-free method, which does not rely on assumptions that data belong to any particular parametric family of probability distributions. Therefore, it would be more flexible (Izenman, 1991), and thus can be better applicable for detecting outliers for all commodities regardless of data distribution, which theoretically applies to UN Comtrade data. The estimated probability density function  $\hat{f}(x)$  can be computed by the Eq. (1), where *h* is the hyperparameter, and  $K(\frac{x-x_i}{h})$  is the kernel function (Terrell and Scott, 1992). We select the Gaussian kernel (Marron and Wand, 1992; Wang et al., 2003) and pick h as the 20<sup>th</sup> percentile of the interpoint distance (Silverman, 1986), whose values usually perform well in most cases.

Followingly, according to the probability distribution, we assume that the observation, whose occurrence probability is lower than 0.5%, is an outlier, i.e., if a variable (*x*) with a value of *t* satisfies the Eq. (2), where  $\alpha$  equals 99.5%, it will be regarded as an outlier. The performance of outlier detection with  $\alpha$  of 99%, 99.9%, etc., was compared, and we found that 99.5% is more applicable in this study, since it is effective in distinguishing normal data points and outliers for most commodities. The performance of outlier detection using KDE will be evaluated and discussed in Section 4. It is noteworthy that, in a specific case, this threshold can be correspondingly adjusted for a particular purpose.

$$\widehat{f}(x) = \frac{1}{nh} \sum_{i=1}^{n} K\left(\frac{x - x_i}{h}\right)$$
(1)

$$\int_{-\infty}^{t} \widehat{f}(x) dx > \alpha$$
<sup>(2)</sup>

It is worth noting that some trade records would be excluded from the estimation of the probability distribution. These trade records have abnormally large unit prices caused by artificial errors and would present significant bias in the probability distribution estimation. Therefore, we check distributions of every commodity in UN Comtrade and regard abnormally large data whose unit price exceeds 1000 times as the median as observations. Then, these observations will be handled along with the detected outliers in Section 2.2.

# 2.2. Outlier handling

For detected outliers, we first figure out potential causes of outliers. Differentiating causes of outliers helps to select appropriate methods to keep the underlying information as much as possible. With the unit price (trade value divided by net weight) as the principle of detection, the outliers are caused by either wrong net weight or wrong trade value (as shown in the determination in Fig. 1), so we develop handling methods for each cause. Previous studies have proved that trade values are more reliable than net weight values because the trade values are reported in a standard unit (Gaulier and Zignago, 2010; United Nations, 2010; Brewer et al., 2020). Therefore, to be consistent with the original data as much as possible, we first identify and handle outliers with obviously wrong trade values. Then the rest are considered caused by wrong net weight, whose trade value data are considered reliable.

(1) Identification of outliers with wrong trade values. By manually checking the detected outliers, some outliers are found to have abnormally high or low trade values, which could be attributed to the errors. For example, South Africa reported only 1 U.S. dollar (USD) in the transaction with Iraq for commodity 732,620 (Articles of iron or steel wire, nes) in 2018. As reporters usually have rules that only transactions over specific monetary thresholds (i.e., low-value limits) would be reported to UN Comtrade, these unusually small trade values could be mistakes (Gaulier et al., 2008). For the United States, transactions with greater than 2500 USD (exporting) or 250 USD (importing) would be recorded and reported (U.S.-China JCCT, 2009). Also, South Africa reported a 3 billion trade with China for product 860,120 (Rail locomotives powered by electric accumulators) in 2015, more significant than the sum of all other records of this commodity in that year, which is also unrealistic. Based on the fact that the transaction price usually lies in a normal range, an outlier is defined to be caused by a wrong trade value if it satisfies one of the following criteria:

*Criterion 1*: The trade value is smaller than 0.01 quantiles of the trade values of all records while the net weight is greater than 0.1 quantiles of the net weights of all records.

*Criterion 2*: The trade value is larger than 0.99 quantiles of the trade values of corresponding commodities, while its net weight is between 0.1 and 0.8 quantiles of the net weights of corresponding commodities.

To identify outliers with wrong trade values, the thresholds in *Criterion 1* and *Criterion 2* are determined to ensure that an outlier has abnormally low (i.e., below the value limit) or abnormally large, but meanwhile its net weight value is real. That is because, if both trade value and net weight value of an outlier are likely to be wrong, the trade value is believed to be more reliable (Gaulier and Zignago, 2010; United Nations, 2010; Brewer et al., 2020), and this outlier is attributed to be caused by the wrong net weight value. These thresholds are determined based on official statistics. For example, given the low-value limit of \$2500 for the United States' exports and \$250 for imports, we can derive its corresponding quantiles. The thresholds for Criterion 2 were also determined in the same way.

To handle records with outliers with wrong trade values, the net weight values will be kept, and the trade values will be replaced with fitted values. These fitted values are estimated by a model employing seven statistical models, which is developed by us and will be described in the next article of this series.

(2) Identification of outliers with wrong net weight values. As discussed in our first article of this series (Chen et al., 2022) and other existing studies, the erroneous data are most likely caused by unit issues (Brewer et al., 2020; FAO, 2019). Reporters may adopt different units, which would lead to errors at orders of magnitudes. For example, some reporters use tons instead of kilograms as the net weight units of transported commodities by mistake, which results in approximately 1000 times differences in the net weights and consequently unit prices. Take the transaction between Chile and Argentina as an example. As reported by Chile, it exported 125 kgs (kg) of trout (a kind of fish, with HS0 6-digit code 030,211) to Argentina with a trade value of 552,645 USD, and the unit price is 4421.16 USD/kg. Meanwhile, Argentina reported an import of 122,350 kg and a trade value of 554,047 USD with a unit price of just 4.53 USD/kg. It can be observed that the unit price of data reported by Chile is approximately 1000 times larger than that reported by its partners, although the trade values from both sides are almost the same. This situation often appears in Chile's reported

Some records of Chile's transactions for the commodity with code 030211.

Reporter	Partner	Net weight (Kilograms, kg)	Trade value (U.S. dollars, \$)	Unit Price (\$/kg)
Chile	Argentina	125	552645	4421.16
Argentina	Chile	122350	554047	4.53
Chile	Brazil	18	65198	3622.11
Brazil	Chile	18344	64298	3.51
Chile	USA	46	184801	4017.41
USA	Chile	40267	295940	7.35
Chile	Uruguay	3	15690	5230
Uruguay	Chile	2789	17196	6.17
Chile	Cuba	72	218334	3032.42
Cuba	Chile	91840	400997	4.37
Chile	Germany	133	713810	5366.99
Germany	Chile	151800	875000	5.76
Chile	Mexico	1638	5124922	3128.77
Mexico	Chile	1483754	4257234	2.87
Chile	Netherlands	3	24282	8094.00
Netherlands	Chile	2801	31109	11.11
Chile	United	102	550349	5395.58
	Kingdom			
United	Chile	112268	568766	5.07
Kingdom				
Chile	Spain	35	332522	9500.63
Spain	Chile	34383	397615	11.56

transactions with Brazil, the United States of America (USA), Uruguay, etc. (complete list of countries in Table A1).

Therefore, to keep the data as original as possible, we first distinguish the outliers caused by unit misuse in those with wrong net weights. For each set of trade data of one commodity reported by one reporter in one year (e.g., the transaction records of 030,310 in HS0 between China and all the other reporters in 2018 reported by China), we assume that the outliers are considered to be caused by using tons instead of kilograms as the net weight units if the trade data satisfy the following criteria:

**Criterion 1:** No less than half of records satisfy Eq. (3), where *netweight*<sub>r</sub> is the net weight value reported by this reporter, and *netweight*<sub>p</sub> is the net weight value reported by the partner:

$$\frac{netweight_r \times 1000 - netweight_p}{netweight_p} < 0.4$$
(3)

*Criterion 2:* No less than three records in that year are considered outliers, i.e., satisfying Eq. (4), where  $\tilde{N}_{rt}$  is the number of outliers reported by this reporter in this year:

$$\widetilde{N}_{rt} \ge 3$$
 (4)

*Criterion 3:* No less than half of the records are considered outliers, i. e., satisfying Eq. (5), where  $N_{rt}$  is the total number of records reported by this reporter this year:

$$\frac{N_n}{N_n} \ge 0.5 \tag{5}$$

*Criterion 1* is designed to ensure that the outliers are caused by the misuse of net weight units rather than other reasons by comparing with the partner's data. For example, if the original net weight times 1000 approximately equals its partner's data, this outlier is most likely caused by the wrong net weight unit. *Criterion 2* and *Criterion 3* were set up to exclude the normal data reflecting infrequent events but recognized as outliers, as unit misuse tends to be habitual. The reporter will report



Fig. 2. Percentage of outliers: (a) over the years; (b) of reporters; of commodities (c) by 6-digit code and (d) by 2-digit code. To note, results in (b) are ordered by the reporter order, which is the ascending order of reporter codes. The details of reporter orders, codes, and results are presented in Table A2.

data with the wrong unit for multiple commodities and many years.

It is worth noting that outlier detection is sometimes considered controversial as there is no strict boundary between outliers and normal data. Whether a data point is considered abnormal is closely associated with the definition of outliers. It is hard or even impossible to quantitatively evaluate the performance of these thresholds. The only way is to visually interpret identified outliers to manually determine whether they are abnormal with a subjective judgment. The process of threshold identification is 1) choosing a set of thresholds to detect outliers; 2) randomly selecting ten commodities and sorting their unit prices in ascending order; 3) comparing the range of outliers and normal data points lie in. If this set of thresholds performs well in more than eight commodities, we would then select another ten commodities. If it does not, the thresholds will be adjusted, and the above process will be repeated. The determination of the normal range of data points is presented in Fig. 5 and Section 4. By this process, the thresholds are found to be effective with 0.4, 3, and 0.5 in Eqs. (3), (4), and (5), respectively

To modify records with outliers caused by unit misuse, we keep the trade values and manually multiply the net weights by 1000 to unify the units. Then, for the rest outliers with wrong net weights, the trade values were kept and the net weights were replaced with fitted values with the model mentioned above.

#### 2.3. Deviation analysis

With the handled values, the deviations of detected outliers are calculated, which can reflect the impacts of outliers on UN Comtrade and represent data quality improvement to a certain extent. Eq. (6) gives the deviations of detected outliers from the values after handling. The larger this index, the more significant impact of this outlier, and the more critical our handling.

$$dev_{cr} = \frac{|X_{cr}^{Out} - X_{cr}^{P_{roc}}|}{T_c}$$
(6)

 $dev_{cr}$  represents the deviation of outliers for commodity *c* by reporter *r*.  $X_{cr}^{Out}$  represents the detected outlier's value of commodity *c* by reporter *r* (either net weight or trade value), while  $X_{cr}^{Proc}$  denotes the value after handling.  $T_c$  reflects the original global total amount of either net weight or trade value of commodity *c*. The total deviations of commodities or reporters are calculated with Eqs. (7) and (8), respectively.

$$dev_c = \sum_{r} dev_{cr} \tag{7}$$

$$dev_r = \sum_c dev_{cr} \tag{8}$$

# 3. Results

#### 3.1. Outlier distributions

A total of 6874,652 outliers were detected in the commodity trade data during 1988–2019 retrieved from UN Comtrade at the 6-digit level for HS0, accounting for approximately 1.9% of the total amount of data. Most outliers (6318,891 records, 92% of the total outliers) are with wrong net weight values, while 555,761 (8%) are with wrong trade values. Fig. 2(a) shows the proportions of each outlier type in all the UN Comtrade data over the years. It can be observed that the percentages of the outliers with wrong net weight in each year during 1988–2019 were between 1.2% and 2.3%, peaking at the years around 2001. In contrast, the percentages of outliers with wrong trade values have increased from 0.082% (1988) to 0.22% (2018).

Almost all reporters (207 of the 209) have reported unusual data, except Cayman Isds and Tajikistan. No outlier is detected in these two reporters because they have not reported their commodities' net weight data so far. Fig. 2(b) shows the proportions of outliers for each reporter,

#### Table A2

The number of outliers with wrong net weight or with wrong trade value for each country/area, ordered by the percentage of outliers (%).

Reporter Order	Reporter (Code)	No.of outliers with wrong net weight	No.of outliers with wrong trade value	No. of records	Percentage of outliers
71	Gambia(270)	0	0	0	31.073
165	Sierra Leone (694)	0	0	0	18.149
116	Mauritania (478)	0	0	0	17.548
83	Haiti(332)	0	0	0	13.580
199	United Rep. of Tanzania(834)	0	0	0	12.608
79	Guinea(324)	0	0	0	12.116
83	Guinea-Bissau (624)	0	0	0	11.765
88	Iraq(368)	0	0	0	11.154
51	Djibouti(262)	0	0	0	10.997
2/	(854)	0	0	0	0.566
01	(736)	0	0	0	9.300
29	Burundi(108)	0	0	0	9.501
183	Togo(768)	0	0	0	9.156
41	Comoros(1/4)	0	0	0	8.794
104	(690)	0	0	0	0.308
139	Nigeria(566)	0	0	0	8.146
171	South Africa (710)	0	0	0	7.767
17	Benin(204)	0	0	0	7.669
139	Niger(562)	0	0	0	7.160
175	Sudan(729)	0	0	0	6.629
199	Uganda(800)	0	0	0	6.4/3 6.416
113	Mali(466)	0	0	0	6.399
72	Ghana(288)	0	0	0	6.297
207	Zambia(894)	0	0	0	6.233
103	Lesotho(426)	0	0	0	6.166
143	Papua New Guinea(598)	0	0	0	6.121
191	Tuvalu(798)	0	0	0	5.878
118	Mozambique (508)	0	0	0	5.732
127	Namibia(516)	0	0	0	5.732
190	Turks and Caicos Isds	0	0	0	5.639
110	(796) Malaui(454)	0	0	0	5 500
37	Chad(148)	0	0	0	5.525
35	Central African Rep (140)	0	0	0	5.393
43	Congo(178)	0	0	0	5.205
207	Zimbabwe (716)	0	0	0	5.195
155	Rwanda(646)	0	0	0	5.127
22	Botswana(72)	0	0	0	5.103
83	Guyana(328)	0	0	0	5.078
83	Honduras(340)	0	0	0	5.005
38 1	Afghanistan(4)	0	0	0	4.880
7	Azerbaijan(31)	0	0	0	4.617
38	Chile(152)	0	0	0	4.590
205	Yemen(887)	0	0	0	4.371
32	Cameroon(120)	0	0	0	4.045
3	Algeria(12)	0	0	0	4.043
47 10	Cuba(192) Bhutan(64)	0	0	0	4.012
19 58	Fthionia(221)	0	0	0	3 992
100	Kyrgyzstan	0	0	0	3.943
5	Angola(24)	0	0	0	3.905
162	Senegal(686)	0	0	0	3.819
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able A2 (a	continued)					Table A2 (a	continued)	
Reporter Order	Reporter (Code)	No.of outliers with wrong net weight	No.of outliers with wrong trade value	No. of records	Percentage of outliers	Reporter Order	Reporter (Code)	No.of outlie with wrong net weigh
201	Vanuatu(548)	0	0	0	3 742	107	Luxembourg	0
160	Sao Tome and	0	0	0	3.500	100	(442)	0
110	Principe(6/8)	0	0	0	2 4 4 2	199	United Arab	0
20	China Macao	0	0	0	3.442	1	Andorra(20)	0
39	SAR(446)	0	0	0	3.412	7 202	Venezuela(862)	0
52	Dominica(212)	0	0	0	3 408	94	Janan(392)	0
31	Cambodia(116)	0	0	0	3.310	131	Nepal(524)	0
159	Samoa(882)	0	0	0	3.299	27	Bulgaria(100)	0
118	Mexico(484)	0	0	0	3.247	177	Suriname(740)	0
182	Timor-Leste	0	0	0	3.237	18 6	Bermuda(60) Australia(36)	0
2	Albania(8)	0	0	0	3 232	131	Neth Antilles	0
159	Saint Vincent	0	0	0	3.202	10	(530)	0
	Grenadines					13	Other Asia, nes	0
- 4	(670)	0	0	0	0.100	15	(490)	0
54 190	Egypt(818)	0	0	0	3.123	15	Belarus(112)	0
180	Switzerland	U	U	U	3.116	12	Banrain(48)	0
154	(757) Russian	0	0	0	3 111	130 130	North	0
101	Federation (643)	0	Ū	Ū	0.111	109	Macedonia (807)	0
109	Madagascar (450)	0	0	0	3.086	78	Guatemala (320)	0
95	Kazakhstan (398)	0	0	0	3.075	157	Saint Kitts and Nevis(659)	0
146	Philippines	0	0	0	3.052	111	Malaysia(458)	0
	(608)					114	Malta(470)	0
151	Qatar(634)	0	0	0	3.010	61	Finland(246)	0
151	Rep. of	0	0	0	2.960	181	Syria(760)	0
	Moldova(498)					44	Cook Isds(184)	0
139	Oman(512)	0	0	0	2.935	118	Mongolia(496)	0
97	Kenya(404)	0	0	0	2.915	72	Greece(300)	0
/1	Georgia(268)	0	0	0	2.884	161	Saudi Aradia	0
199	Kingdom(826)	0	0	0	2.004	153	(002) Romania(642)	0
158	Saint Lucia	0	0	0	2.870	155	Rep. of Korea	0
	(662)						(410)	
71	Gabon(266)	0	0	0	2.844	139	Norway(579)	0
6	Armenia(51)	0	0	0	2.820	163	Serbia and	0
60 E0	F1J1(242)	0	0	0	2.806		Montenegro	
30	(384)	0	0	0	2.004	172	(091) Spain(724)	0
94	Jordan(400)	0	0	0	2.766	40	Colombia(170)	0
57	Eritrea(232)	0	0	0	2.749	185	Trinidad and	õ
201	Uzbekistan	0	0	0	2.718		Tobago(780)	
	(860)					21	Bosnia	0
144	Paraguay(600)	0	0	0	2.669		Herzegovina	
20	Bolivia	0	0	0	2.648		(70)	
	(Plurinational					6	Aruba(533)	0
	State of)(68)					51	Denmark(208)	0
54	Ecuador(218)	0	0	0	2.571	187	Tunisia(788)	0
55	El Salvador	0	0	0	2.571	172	Sri Lanka(144)	0
0.2	(222) Jamaica (200)	0	0	0	2 550	106	Lithuania(440)	0
95 169	Slovakia(703)	0	0	0	2.530	73	(304)	0
135	Nicaragua(558)	0	0	0	2.512	141	Palau(585)	0
86	Indonesia(360)	0	õ	õ	2.505	11	Bahamas(44)	õ
6	Antigua and	0	0	0	2.500	76	Grenada(308)	0
	Barbuda(28)					23	Brazil(76)	0
199 24	Ukraine(804) Brunei	0 0	0 0	0 0	2.471 2.466	118	Montenegro (499)	0
	Darussalam (96)				-	118 49	Morocco(504) Czechia(203)	0 0
45	Costa Rica(188)	0	0	0	2.435	91	Italy(381)	0
15	Barbados(52)	0	õ	õ	2.401	101	Latvia(428)	0
112	Maldives(462)	0	0	0	2.391	58	Estonia(233)	0
87	Iran(364)	0	0	0	2.383	131	Netherlands	0
30	Cabo Verde (132)	0	0	0	2.380	63	(528)	0
								-

Reporter Order	Reporter (Code)	No.of outliers with wrong net weight	No.of outliers with wrong trade value	No. of records	Percentage of outliers
107	Luxembourg	0	0	0	2.360
199	United Arab Emirates(784)	0	0	0	2.341
4	Andorra(20)	0	0	0	2.323
202	Venezuela(862)	0	0	0	2.297
94	Japan(392)	0	0	0	2.283
.31	Nepal(524)	0	0	0	2.255
./	Bulgaria(100)	0	0	0	2.245
8	Bermuda(60)	0	0	0	2.223
.0	Australia(36)	0	0	0	2.200
31	Neth. Antilles (530)	0	0	0	2.190
.3	Bangladesh(50)	0	0	0	2.187
39	Other Asia, nes (490)	0	0	0	2.161
5	Belarus(112)	0	0	0	2.142
2	Bahrain(48)	0	0	0	2.111
30	Kuwait(414)	0	0	0	2.109
39	Macedonia (807)	0	0	0	2.106
8	Guatemala (320)	0	0	0	2.076
57	Saint Kitts and Nevis(659)	0	0	0	2.069
11	Malaysia(458)	0	0	0	2.059
14	Malta(4/0)	0	0	0	2.052
1 81	Svria(760)	0	0	0	2.049
4	Cook Isds(184)	0	0	0	1.901
18	Mongolia(496)	0	0	0	1.962
2	Greece(300)	0	0	0	1.956
61	Saudi Arabia (682)	0	0	0	1.950
53	Romania(642)	0	0	0	1.943
20	Rep. of Korea (410)	0	0	0	1.919
.39 63	Serbia and	0	0	0	1.901
00	Montenegro (891)	0	0	0	1.001
72	Spain(724)	0	0	0	1.847
0	Colombia(170)	0	0	0	1.838
85	Trinidad and Tobago(780)	0	0	0	1.770
1	Bosnia Herzegovina (70)	0	0	0	1.754
,	Aruba(533)	0	0	0	1.748
1	Denmark(208)	0	0	0	1.739
87	Tunisia(788)	0	0	0	1.732
72	Sri Lanka(144)	0	0	0	1.712
00 5	Lithuania(440) Greenland	0	0	0	1.707
41	(304) Palau(585)	0	0	0	1.075
1	Bahamas(44)	0	0	0	1.666
6	Grenada(308)	0	0	0	1.653
3	Brazil(76)	0	0	0	1.652
18	Montenegro (499)	0	0	0	1.629
18	Morocco(504)	0	0	0	1.615
9	Czechia(203)	0	0	0	1.605
1	Italy(381)	0	0	0	1.530
8	Estonia(222)	0	0	0	1.519
21	Netherlande	0	0	0	1.453

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## Table A2 (continued)

Reporter Order	Reporter (Code)	No.of outliers with wrong net weight	No.of outliers with wrong trade value	No. of records	Percentage of outliers
	French Guiana				
	(254)				
102	Lebanon(422)	0	0	0	1.442
46	Croatia(191)	0	0	0	1.442
203	Wallis and	0	0	0	1.441
	(876)				
48	Cvprus(196)	0	0	0	1.429
182	Thailand(764)	0	0	0	1.361
117	Mayotte(175)	0	0	0	1.347
163	Serbia(688)	0	0	0	1.320
89	Ireland(372)	0	0	0	1.302
168	Solomon Isds	0	0	0	1.293
118	(90) Montserrat	0	0	0	1 274
110	(500)	0	0	0	1.2/ 4
149	Portugal(620)	0	0	0	1.251
184	Tonga(776)	0	0	0	1.226
168	So. African	0	0	0	1.216
	Customs Union				
17	(711) Balaium	0	0	0	1 204
17	Luxembourg	0	0	0	1.204
	(58)				
53	Dominican Rep.	0	0	0	1.198
	(214)				
6	Argentina(32)	0	0	0	1.185
145	Peru(604)	0	0	0	1.151
115	Martinique	0	0	0	1.110
85	(4/4) Iceland(352)	0	0	0	1 084
200	USA(842)	0	0	0	1.074
168	Slovenia(705)	0	0	0	1.064
147	Poland(616)	0	0	0	1.064
16	Belgium(56)	0	0	0	1.041
97 50	Kiribati(296)	0	0	0	1.036
59	(234)	0	0	0	1.034
132	New Caledonia	0	0	0	1.031
	(540)				
77	Guadeloupe	0	0	0	1.018
	(312)				
39	China(156)	0	0	0	0.998
200	Singapore(702)	0	0	0	0.992
84	Hungary(348)	0	0	0	0.909
132	New Zealand	0	0	0	0.882
	(554)				
62	France(251)	0	0	0	0.877
33	Canada(124)	0	0	0	0.874
157	R矛union(638)	0	0	0	0.857
141	Pakistan(586)	0	0	0	0.816
101	Dem. Rep. (418)	0	0	0	0.801
6	Austria(40)	0	0	0	0.776
5	Anguilla(660)	0	0	0	0.760
39	China, Hong	0	0	0	0.752
	Kong SAR(344)	0	0	0	0.510
71	French Polymeria(258)	0	0	0	0.713
142	Panama(591)	0	0	0	0.668
188	Turkey(792)	0	0	0	0.643
117	Mauritius(480)	0	0	0	0.625
179	Sweden(752)	0	0	0	0.610
85	India(699)	0	0	0	0.558
61	Fmr Fed. Rep.	0	0	0	0.505
	(280)				
71	Germany(276)	0	0	0	0.449
105	Libya(434)	0	0	0	0.405
90	Israel(376)	0	0	0	0.139

Tuble III (c	(constant)					
Reporter Order	Reporter (Code)	No.of outliers with wrong net weight	No.of outliers with wrong trade value	No. of records	Percentage of outliers	
202	Vietnam(704)	0	0	0	0.074	
71	FS Micronesia (583)	0	0	0	0.033	
172	State of Palestine(275)	0	0	0	0.030	
189	Turkmenistan (795)	0	0	0	0.004	

Table A2 (continued)

and the reporters who have high ratios of unusual data are mostly least developed countries/areas. For example, the average percentage of outliers is around 3.32%, and the median is 2.30% for Venezuela. The Gambia has the highest outlier rate, with over 30% of the data detected as unusual, followed by Sierra Leone (18.15%) and Mauritania (17.55%). Particularly, Gambia has the highest rates for both outliers with wrong net weight (26.3%) and those with wrong trade value (4.7%). For outliers with wrong net weight, the outlier percentages of both Mauritania and Sierra Leone exceed 15%, ranking second and third, respectively. For outliers with wrong trade value, the secondhighest rate is for Tanzania (3.3%), followed by Sierra Leone (3.0%). Also, this issue of outliers is serious for developed countries. In the top 10 critical economies with the most reported records, Switzerland has the largest percentage of outliers (3.12%), followed by the United Kingdom (2.88%), which both exceed the median. Germany has the lowest percentage of outliers, with only 0.45%. The rests range from 0.87% (Canada) to 1.85% (Spain). The complete results are given in Table A2.

Data outliers exist for all categories of commodities. Fig. 2(c) shows the percentages of outliers in commodities by 6-digit code in HSO, while Fig. 2(d) shows the results by 2-digit code. It can be observed that most commodities categories have approximately 2% of data detected as outliers. Results by 2-digit code show that the commodities, such as ores (3.31%), the pulp of wood (2.85%), stone (2.77%), products originated from animals (2.59%), etc., have a large proportion of outliers. In contrast, the outliers in commodities of clocks and watches are less, around 1.6%. More specifically, results by 6-digit code show that the data of precious metal ores and concentrates (10.32%), ambergris (6.63%), waste or scrap containing gold (5.41%), etc., include relatively more outliers. In comparison, data of commodities such as watch movements (0.20%), the clock of metal (0.34%), the parking meters (0.60%) have less. For some commodities, such as materials containing precious metals, pharmaceutical materials, etc., this issue is more severe. These results indicate that trade data concerning critical resources and materials are more likely to be misreported as outliers. The complete results are given in Table A3.

It is also uncovered that in outliers with the wrong net weight, there are 11,015 records identified as using different net weight units (i.e., using tons rather than kilograms). In total, 14 reporters have this issue. It is worth noting that Chile (9946 records) and Other Asia (877) have the most outliers caused by using the wrong units. For commodities, outliers with wrong net weight due to unit misuse exist in 256 types (HS0 6-digit), especially those related to organic chemicals, copper and articles, and food products (complete results in Table A4). Previous studies might have significantly biased results with the underestimation of these commodities' net weight.

# 3.2. Outlier deviations

The results of the deviations between the outliers and the handled data reveal the impacts of outliers and estimate the data quality

Percentage of outliers in each chapter, ordered by total percentage. Percentage1 is the percentage of outliers with wrong net weight while Percentage2 is for those with wrong trade value.

Chaj	oter	Percentage1 (%)	Percentage2 (%)	Total (%)
26	Ores, slag and ash	3.133	0.180	3.314
47	Pulp of wood, fibrous cellulosic material, waste etc.	2.719	0.133	2.852
25	Salt, sulphur, earth, stone, plaster, lime and cement	2.631	0.137	2.768
05	Products of animal origin, nes	2.424	0.171	2.595
27	Mineral fuels, oils, distillation products, etc.	2.369	0.110	2.479
31	Fertilizers	2.394	0.085	2.479
49	Printed books, newspapers, pictures etc.	2.035	0.440	2.475
23	Residues, wastes of food industry, animal fodder	2.292	0.090	2.382
72	Iron and steel	2.283	0.093	2.375
10	Cereals	2.203	0.159	2.362
11	Milling products, malt, starches, inulin, wheat glute	2.169	0.190	2.359
89	Ships, boats and other floating structures	2.245	0.106	2.351
48	Paper & paperboard, articles of pulp, paper and board	2.055	0.262	2.317
14	Vegetable plaiting materials, vegetable products nes	2.146	0.143	2.288
12	Oil seed, oleagic fruits, grain, seed, fruit, etc.	2.132	0.151	2.283
07	Edible vegetables and certain roots and tubers	2.114	0.159	2.273
20	Vegetable, fruit, nuts, etc.	2.112	0.158	2.270
15	Animal, vegetable fats and oils, cleavage products, etc.	2.102	0.163	2.265
08	Edible fruit, nuts, peel of citrus fruit, melons	2.131	0.131	2.262
04	Dairy products, eggs, honey, edible animal product nes	2.090	0.170	2.260
66	Umbrellas, walking-sticks, seat-sticks, whips, etc.	1.904	0.354	2.257
17	Sugars and sugar confectionery	2.101	0.154	2.255
78	Lead and articles thereof	2.082	0.164	2.246
35	Albuminoids, modified starches, glues, enzymes	2.093	0.150	2.243
28	Inorganic chemicals, precious metal compound, isotope	2.139	0.097	2.236
22	Beverages, spirits and vinegar	2.093	0.142	2.235
21	Miscellaneous edible preparations	2.060	0.173	2.232
09	Coffee, tea, mate and spices	2.034	0.194	2.228
73	Articles of iron or steel	2.040	0.187	2.226
29	Organic chemicals	2.113	0.113	2.226
68	Stone, plaster, cement, asbestos, mica, etc.	2.072	0.153	2.224
76	Aluminium and articles thereof	2.052	0.169	2.220
16	Meat, fish and seafood food preparations nes	2.062	0.156	2.217
03	Fish, crustaceans, molluscs, aquatic invertebrates ne	2.096	0.121	2.217
19	Cereal, flour, starch, milk preparations and products	2.061	0.156	2.217
34	Soaps, lubricants, waxes, candles, modelling pastes	2.045	0.171	2.217
69	Ceramic products	2.037	0.176	2.212
63	Other made textile articles, sets, worn clothing etc.	1.957	0.255	2.212
45	Cork and articles of cork	1.969	0.241	2.210
44	Wood and articles of wood, wood charcoal	2.022	0.187	2.209
79	Zinc and articles thereof	2.082	0.124	2.206
39	Plastics and articles thereof	2.027	0.178	2.206
74	Copper and articles thereof	2.025	0.178	2.203
13	Lac, gums, resins, vegetable saps and extracts nes	2.067	0.133	2.200
38		2.067	0.131	2.198

Table A3 (continued)

Chaj	pter	Percentage1 (%)	Percentage2 (%)	Total (%)
	Miscellaneous chemical			
18	Cocoa and cocoa preparations	2.050	0.145	2.195
56	Wadding, felt, nonwovens,	1.996	0.195	2.191
02	Meat and edible meat offal	2.114	0.077	2 1 9 1
24	Tobacco and manufactured	2.055	0.132	2.187
	tobacco substitutes			
96	Miscellaneous manufactured	1.927	0.259	2.186
36	Explosives, pyrotechnics, matches, etc	2.025	0.160	2.184
65	Headgear and parts thereof	1.902	0.277	2,179
94	Furniture, lighting, signs,	1.944	0.231	2.175
32	Tanning, dyeing extracts,	2.020	0.151	2.171
46	tannins, derivs, pigments etc. Manufactures of plaiting	1.918	0.250	2.168
83	material, basketwork, etc. Miscellaneous articles of base	1.950	0.214	2.165
87	metal Vehicles other than railway,	2.062	0.102	2.164
	tramway			
81	Other base metals, cermets, articles thereof	2.032	0.126	2.158
80	Tin and articles thereof	1.971	0.182	2.153
30	Pharmaceutical products	1.960	0.188	2.148
82	Tools, implements, cutlery,	1.905	0.240	2.145
	etc.			
70	Glass and glassware	1.949	0.192	2.141
59	Impregnated, coated or	1.968	0.163	2.131
75	laminated textile fabric	1.005	0.125	2 1 2 0
73 51	Wool animal bair borsebair	1.993	0.155	2.130
51	varn and fabric thereof	1.975	0.151	2.120
88	Aircraft, spacecraft, and parts	2.004	0.120	2.125
33	Essential oils, perfumes,	1.963	0.156	2.119
40	Rubber and articles thereof	1.961	0.155	2.117
95	Toys, games, sports requisites	1.876	0.240	2.116
53	Vegetable textile fibres nes, paper varn, etc.	1.976	0.138	2.113
06	Live trees, plants, bulbs, roots,	1.978	0.130	2.108
86	Railway, tramway	1.993	0.113	2.106
61	Articles of apparel, accessories,	1.960	0.144	2.104
60	knit or crochet	1.067	0.100	0 1 0 1
01	Live animals	1.967	0.133	2.101
58	Special woven or tufted fabric	1.921	0.178	2.100
57	lace, tapestry, etc.	1 873	0.223	2.096
42	coverings	1 977	0.218	2.095
44	harness, travel good	1.0//	0.210	2.095
54	manmade filaments	1.966	0.116	2.082
67	Bird skin, feathers, artificial flowers, human hair	1.836	0.238	2.074
62	Articles of apparel, accessories,	1.929	0.134	2.064
92	Musical instruments, parts and	1.811	0.250	2.060
55	accessories	1 043	0.114	2 057
35 84	Nuclear reactors, boilers,	1.943	0.125	2.057
F 0	machinery, etc.	1.027	0.116	0.050
52	Silk	1.93/	0.110	2.053
41	Raw hides and skins (other	1.933	0.094	2.030
85	than furskins) and leather	1 867	0.153	2.02/
61	equipment	1.007	0.100	1 000
04	parts thereof	1.007	0.120	1.774

#### Table A3 (continued)

Chap	oter	Percentage1 (%)	Percentage2 (%)	Total (%)
90	Optical, photo, technical, medical apparatus, etc.	1.850	0.142	1.992
43	Furskins and artificial fur, manufactures thereof	1.852	0.133	1.985
93	Arms and ammunition, parts and accessories thereof	1.851	0.124	1.975
71	Pearls, precious stones, metals, coins, etc.	1.821	0.142	1.962
37	Photographic or cinematographic goods	1.735	0.150	1.885
97	Works of art, collectors pieces and antiques	1.538	0.283	1.821
91	Clocks and watches and parts thereof	1.412	0.202	1.614

improvements. The deviation indexes of reporters range from 0.0000001 (Turkmenistan) to 169.4 (South Africa), with an average of 2.5 and a median of 0.4 (Honduras). Fig. 3(a) shows the deviations of countries/areas, and Table A5 presents deviation indexes of the reporters and their critical commodities. Especially for South Africa, Mexico, and Malaysia, whose deviation indexes are far greater than 30, their trade data will significantly differ. South Africa's outliers are mainly related to commodities in chapters 61, 62, and 85, namely apparel and clothing accessories, electrical machinery, sound recorders, reproducers, etc. Mexico's outliers are mainly concentrated in chapter 85 (Electrical machinery and equipment and parts thereof), while Malaysia's are in chapter 28 (e.g., inorganic chemicals), 76 (e.g., Aluminium and articles), and 85 (e.g., Electrical, electronic equipment). Furthermore, outliers of the United Kingdom (13.5), China Hong Kong (10.4), and Spain (10.1) also have relatively large deviations.

Interestingly, it is observed that some reporters have large proportions of outliers but low deviations, and vice versa. For example, Gambia has the most outliers while the deviation index of these outliers is just 0.44, which is better than half of the reporters. Conversely, China Hong Kong only has 0.75% of data as outliers, but the deviation index is 10.4. This situation happens to Canada (percentage of outliers 0.87%, deviation index 7.8), USA (1.1%, 6.1), China (1.0%, 5.6), India (0.56%, 5.0), France (0.88%, 3.1), Germany (0.45%, 2.9), etc. It indicates when concerning reporters with large proportions of outliers but low deviations, uncertainties of these studies might rarely be attributed to outliers, and other potential sources (e.g., model parameters) should be thoroughly discussed. But for reporters with small proportions of outliers but high deviations, related studies should fully take into account the biases that outliers might result in. The complete results are given in Table A6.

Many commodity categories are severely affected by outliers, as shown in Fig. 3(b), especially for those in chapter 85 (Electrical, electronic equipment, deviation index 60.1), chapter 84 (Nuclear reactors, boilers, machinery, etc., 44.1). Deviation indexes of commodities in chapter 62 (Articles of apparel, accessories, not knit or crochet), chapter 61 (Articles of apparel, accessories, knit or crochet), and chapter 90 (Optical, photo, technical, medical apparatus, etc.) were 34.5, 33.1, and 32.5, respectively. The deviations are relatively less in light commodities, such as plaiting material (chapter 46, deviation index 0.14), cocoa and cocoa preparations (chapter 18, 0.24), bird skin (chapter 67, 0.26). In contrast, the data quality of huge, heavy, and expensive equipment or apparatus mentioned above can be significantly improved by handling outliers. Moreover, a significant difference between the number of outliers and the deviation index also exists for some commodity categories. As mentioned above, the commodity of clocks and watches and parts thereof (chapter 91) has the smallest number of outliers, but its deviation is significant with an index of 15.8, ranking the tenth in all 2digit commodities. These results mean that in some cases, using UN Comtrade data to monitor flows and stocks of commodities or

#### Table A4

Commodities (HS0 6-digit) with wrong net weigh due to misuse, ordered by the number of records.

Commodity code	Commodity descriptin	Number of records
081320	Prunes, dried	391
080620	Grapes, dried	334
030420	Fish fillets, frozen	286
080610	Grapes, fresh	250
081120	Rasp-, mul-berries, etc (uncooked, steam, boil), froze	210
740311	Copper cathodes and sections of cathodes unwrought	208
081330	Apples, dried	197
030321	Trout, frozen, whole	179
080212	Almonds, fresh or dried, shelled	173
130239	Mucilages and thickeners nes	162
020329	Swine cuts, frozen nes	155
080232	Walnuts fresh or dried shelled	132
080920	Cherries, fresh	142
081110	Strawberries, (uncooked steamed or boiled),	141
080940	Plums, sloes, fresh	135
080910	Apricots, fresh	125
071080	Vegetables, frozen nes, uncooked steamed or boiled	123
291812	Tartaric acid	116
741110	Pipes or tubes, refined copper	116
760200	Waste or scrap, aluminium	115
721934	Cold rolled stainless steel, w >600mm, t 0.5-1.0 mm	114
200860	Cherries, otherwise prepared or preserved	113
030212	Salmon fresh or chilled, whole	105
020442	Sheep cuts, bone in, frozen	103
740911	Plate, sheet, strip, refined copper, coil, t > 0.15mm	98
190110	Infant foods of cereals, flour, starch or milk, retai	96
200960	Grape juice or must not fermented or spirited	92
080231	Walnuts in shell, fresh or dried	92
740919	Plate, sheet, strip, refined copper, flat, t >	90
391310	Alginic acid its salts & esters in primary forms	88
040900	Honey, natural	88
740319	Refined copper products, unwrought, nes	88
080930	Peaches, nectarines, fresh	88
050400	Guts, bladders and stomachs of animals except fish	87
030759	Octopus, frozen, dried, salted or in brine	85
090420	Capsicum or Pimenta, dried, crushed or ground	84
081190	Fruits and nuts (uncooked, steamed, boiled) frozen,ne	83
130231	Agar-agar	80
040299	Milk and cream nes sweetened or concentrated	79
722100	Bar or rod, stainless steel, hot rolled, coiled	79
210120	Tea and mate extracts, essences and	78 77
200970	concentrates Apple juice not fermented or spirited	74
030379	Fish nes frozen whole	74
740811	Wire of refined copper $> 6$ mm wide	74
020443	Sheep cuts, boneless, frozen	72
200600	Fruits, nuts, fruit-peel, etc preserved by sugar	66
200980	Single fruit, veg juice nes, not fermented or spirite	66
070920	Asparagus, fresh or chilled	66
160411	Salmon prepared or preserved, not minced	65
280120	Iodine	65
283691	Lithium carbonates	65
030310	Salmon, Pacific, frozen, whole	65
200802	Fiuits, ifesil lies	0∠ 61
030410	Fish fillet or meat, fresh or chilled, not liver roe	61
081210	Cherries provisionally preserved	61
120922	Seed, clover, for sowing	57
030380	Fish livers and roes, frozen	57

# Table A4 (continued)

Commodity code	Commodity descriptin	Number of records
080440	Avocados, fresh or dried	56
200870	Peaches, otherwise prepared or preserved	55
290512	Propyl alcohol and isopropyl alcohol	55
520942	Denim cotton >85% >200g/m2	55
170410	Chewing gum containing sugar, except medicinal	54
282760	Iodides and odide oxides of metals	54
291739	Aromatic polycarboxylic acids, derivatives, nes	54
030378	Hake, frozen, whole	54
392020	Sheet/film not cellular/reinf polymers of propylene	54
200290	Tomatoes nes, prepared or preserved, not in vinegar	52
081040	Cranberries, bilberries, similar fruits, fresh	52
030322	Salmon Atlantic or Danube, frozen, whole	51
10820	Inulin	50
160231	Turkey meat, offal prepared or preserved, except live	48
290539	Diols except ethylene and propylene glycol	48
071230	Mushrooms and truffles, dried, not further prepared	47
080520	Mandarin, clementine & citrus hybrids, fresh or dried	47
291714	Maleic anhydride	46
291735	Phthalic anhydride	46
210210	Yeasts, active	45
030710	Oysters	45
080420	Figs, fresh or dried	45
282520	Lithium oxide and hydroxide	44
380820	Fungicides, packaged for retail sale	44
10210	Sheep or lamb skins, raw, wool on, except Persian etc	44
071030	Spinach, frozen, uncooked steamed or boiled	44
283325	Copper sulphates	43
10101	Saits & esters of tartaric acid	43
721660	Sections, nes, iron or non-alloy steel, nfw than	43 43
120230	Bovine cuts honeless frozen	41
740721	Bars rods & profiles of copper-zinc base allows	41
91732	Dioctyl orthophthalates	40
21220	Seaweeds and other algae	39
50910	Olive oil, virgin	39
030541	Salmon, smoked, including fillets	37
210130	Chicory & other coffee substitutes, roasted & product	36
392092	Sheet/film not cellular/reinf polyamides	36
10529	Wool tops & other combed wool, except combed fragment	36
20430	Lamb carcasses and half carcasses, frozen	35
110630	Flour, meal, powder of fruit/nut, citrus or melon pee	34
20741	Fowl cuts & offal, domestic, except livers, frozen	34
282739	Chlorides of metals nes	32
071090	Frozen vegetable mixtures, uncooked, boiled or steame	32
721012	Flat rolled iron or non-alloy steel, coated with tin, w $>600$ mm, t $<0.5$ m	32
500110	Long pile knit or crochet textile fabric	31
071190	Vegetables nes and mixtures provisionally preserved	31
290541	Trimethylolpropane	30
510111	Greasy shorn wool, not carded or combed	30
40500	Master alloys of copper	30
82741	Chloride oxides and chloride hydroxides of copper	29
720421	Waste or scrap, of stainless steel	29
200520	Potatoes, prepared or preserved, not frozen/ vinegar	28
)20130	Bovine cuts boneless, fresh or chilled	28
230120	Flour or meal, pellet, fish, etc. for animal feed	28
071040	Sweet corn, frozen, uncooked steamed or boiled	27
40200	Unrefined copper, copper anodes, electrolytic refinin	27
90111	Coffee, not roasted, not decaffeinated	27

Table A4 (	(continued)
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	eu )	
Commodity code	Commodity descriptin	Number of records
200570	Olives, prepared or preserved, not frozen/ vinegar	26
291712	Adipic acid, its salts & esters	26
150420	Fish oils except liver, not chemically modified	25
200310	Mushrooms, prepared or preserved, not in vinegar	25
190219	Uncooked pasta, not stuffed or prepared, without eggs	24
290513	N-butyl alcohol	24
7/1011	Foil of refined conner not backed $t < 0.15$ mm	24
080211	Almonds in shell fresh or dried	24
281520	Potassium hydroxide (caustic potash)	27
201520	Butanols nes	23
201731	Dibutyl orthophthalates	23
040221	Milk and cream powder unsweetened $< 1.5\%$ fat	23
200880	Strawberries otherwise prepared or preserved	20
441820	Doors frames and thresholds of wood	22
730820	Towers and lattice masts iron or steel	22
283421	Potassium nitrate	21
071021	Peas frozen uncooked steamed or boiled	21
740710	Bars, rods & profiles of refined copper	21
360200	Prepared explosives except propellent powders	20
510121	Degreased shorn wool not carded combed or	20
010121	carbonize	20
290122	Propene (propylene)	19
480620	Paper, greaseproof	19
071029	Legumes, except peas and beans, frozen	19
390311	Polystyrene, expansible in primary forms	18
391723	Tube pipe or hose rigid of polyvinyl chloride	18
170290	Sugar nes, invert sugar, caramel and artificial	17
020722	Turkeys domestic whole frozen	17
290121	Ethylene	17
291711	Oxalic acid, its salts & esters	17
550932	Yarn >85% acrylic staple fibres, multiple not retail	17
721912	Hot rolled stainless steel coil, w >600mm, t 4.75-10m	17
110520	Potato flakes, granules and pellets	16
160250	Bovine meat, offal nes, not livers, prepared/ preserve	16
290124	Buta-1, 3-diene and isoprene	16
030549	Smoked fish & fillets other than herrings or salmon	16
030729	Scallops other than live, fresh or chilled	16
740929	Plate/sheet/strip, copper-zinc alloy, flat, t > 0.15m	16
722810	Bar/rod of high speed steel not in coils	15
080221	Hazelnuts and filberts in shell fresh or dried	15
284890	Phosphides of other metals or of non-metals	14
340520	Polishes, creams etc. for maintenance of woodwork	14
410390	Raw hide/skins except bovine/equine/sheep/ goat/reptil	14
410429	Bovine and equine leather, tanned or retanned, nes	14
060491	Foliage, branches, for bouquets, etc fresh	14
720270	Ferro-molybdenum	14
722920	Wire of silico-manganese steel	14
731420	Net/fencing, welded, iron or non-alloy steel <3mm wire, <100cm mesh	14
081020	Raspberry, blackberry, mulberry and loganberry, fresh	14
190220	Stuffed pasta	13
290220	Benzene	13
030760	Snails, edible (except sea snails)	13
120921	Seed, lucerne (alfalfa), for sowing	12
190211	Uncooked egg pasta not stuffed or prepared	12
020322	Hams, shoulders and cuts, of swine, bone in, frozen	12
290243	P-xylene	12
290516	Octanol(octyl alcohol), isomers	12
291/13	Azerarc aciu, sepacic acid, ineir saits & esters	12
721240	front, fresh of chilled, whole	12

# Table A4 (continued)

Commodity	Commodity descriptin	Number of
code		records
	Flat rolled iron or non-allov steel, <600mm,	
	painted/plastic coated	
081010	Strawberries, fresh	12
290123	Butene (butylene) and isomers thereof	11
291733	Dinonyl or didecyl orthophthalates	11
481620	Paper, self-copy, except in rolls $>$ 36 cm wide	11
240120	Tobacco, unmanufactured, stemmed or stripped	10
260300	Copper ores and concentrates	10
270820	Chlorobenzene o-dichlorobenzene and n-	10
290001	dichlorobenzen	10
290517	Dodecan-1-ol, hexadecan-1-ol and octadecan-1-	10
	ol	
310510	Fertilizer mixes in tablets etc or in packs $< 10 \text{ kg}$	10
380520	Pine oil	10
440122	Wood in chips, non-coniferous	10
720260	Ferro-nickel	10
722691	Hot rolled alloy-steel nes nfw, <600mm wide	10
950640	Articles equipment for table-tennis	10
270750	Aromatic hydrocarbon mixtures from coal tar	9
2,0,00	nes	-
280490	Selenium	9
284170	Metallic molybdates	9
290129	Unsaturated acyclic hydrocarbons nes	9
290241	O-xylene	9
030229	Flatfish, fresh/chilled not halibut/plaice/sole,	9
	whol	
740110	Copper mattes	9
842542	Hydraulic jacks/hoists except for garages	9
151190	Paim oil or fractions simply refined Boying edible offal frozen except livers and	8
02002)	tongues	0
021090	Meat and edible meat offal cured, flours, meals	8
	nes	
280910	Diphosphorus pentaoxide	8
282630	Sodium hexafluoroaluminate (synthetic	8
	cryolite)	
030375	Dogfish and other sharks, frozen, whole	8
040891	Eggs, bird, not in shell, dried	8
480920	Paper, self-copy, width $> 36$ cm	8
481031	Paper, kraft,>95% chem puip,<150 g,dieached,	8
550931	Varn $>85\%$ acrylic staple fibres single not retail	8
681310	Asbestos brake linings and pads	8
701010	Ampoules of glass for conveyance or packing	8
070930	Aubergines(egg-plants), fresh or chilled	8
081310	Apricots, dried	8
190120	Mixes and doughs for bread, pastry, biscuits, etc.	7
030269	Fish nes, fresh or chilled, whole	7
590800	Textile wicks, gas mantles	7
070320	Garlic, fresh or chilled	7
200360	Bovine cuts bone in, irozen Halogenated derivatives of aromatic	6
2)030)	hydrocarbons nes	0
321511	Printing ink, black	6
321519	Printing ink, other than black	6
040700	Birds eggs, in shell, fresh, preserved or cooked	6
440500	Wood wool, wood flour	6
071022	Beans, frozen, uncooked steamed or boiled	6
071120	Olives, provisionally preserved	6
120600	Sunflower seeds	5
200840	Pears, otherwise prepared or preserved	5
293010	Crustageone nos frozon	5
470200	Crustaceans nes, nozen, Chemical wood pulp, dissolving grades	5
060310	Cut flowers and flower buds for bouquets etc.	5
-00010	fresh	0
070200	Tomatoes, fresh or chilled	5
720291	Ferro-titanium and ferro-silico-titanium	5
842549	Jacks and hoists except hydraulic and garage	5
	hoists	
200911	Orange juice, frozen, not fermented or spirited	4
020690	Sheep, goat, ass, mule, hinnie edible offal, frozen	4
282410	Lead monoxide (itharge, massicot)	4

Table A4 (continued)

Commodity code	Commodity descriptin	Number of records
290311	Chloromethane and chloroethane	4
290313	Chloroform (trichloromethane)	4
290319	Chlorinated derivs saturated acyclic	4
	hydrocarbons, ne	
290323	Tetrachloroethylene (perchloroethylene)	4
291737	Dimethyl terephthalate	4
300210	Antisera and other blood fractions	4
030721	Scallops, live, fresh or chilled	4
320620	Pigments and preparations based on chromium	4
	compounds	
470610	Cotton linters pulp	4
480240	Paper, wallpaper base, uncoated	4
600122	Looped pile knit or crochet fabric, of manmade	4
	fibres	
720292	Ferro-vanadium	4
730230	Railway/tramway switch/crossing material,	4
	iron/steel	
780110	Lead refined unwrought	4
080240	Chestnuts, fresh or dried	4
842630	Portal or pedestal jib cranes	4

commodity-related materials/substances may have significant uncertainties, since a small number of outliers might contribute to substantial deviations. The complete results are given in Table A7.

# 3.3. Effects of addressing the outlier issue

The deviation analysis proves that the data quality of UN Comtrade has been substantially improved. The improved data can benefit analyses using UN Comtrade by avoiding data-related bias and reducing uncertainties, thus promoting their accuracy and reliability. Addressing the outlier issue can benefit practical applications of UN Comtrade in the following aspects.

First, data with outliers handled is more statistically credible. Previous statistical studies using UN Comtrade using methods including mean (Benkovskis and Wörz, 2013; Péidy, 2005) and linear regression (Dittrich and Bringezu, 2010) are usually sensitive to outliers, which may cause biases in analysis results (Osborne and Overbay, 2004). Take the data of fish, Pacific salmon, etc., as an example, as shown in Fig. 4(a). The average unit price of this commodity is approximately 33.6 USD/kg in original data, while that calculated with the handled data is 6.6 USD/kg. According to statistics of the last 30 years from the International Monetary Fund (IMF), the average monthly unit prices of this commodity ranged from 2 to 9 USD/kg. It can be observed that the estimated average unit price seems apparently out of the normal range, and the corrected value is consistent with the market price. It shows that statistical analysis with the corrected unit price would be more reliable than the data containing outliers.

Besides, addressing the outlier issue helps to reflect more realistic effects of a certain policy, which is an important application of UN Comtrade data. Various time-series models, such as the detrended fluctuation analysis (Herzer and Nowak-Lehnmann D, 2006; Usman and Faruque, 2019; Ji et al., 2020), were established using UN Comtrade data to evaluate policies effects (Brooks et al., 2018; Qu et al., 2019; Wang et al., 2020). These models would be significantly affected by data fluctuation resulting from outliers (Hargreaves, 1994; Huang et al., 1998; Nason, 2006), which stresses the significance of data quality (Costanza et al., 1992; Pullin and Knight, 2009; Salemdeeb et al., 2021; von Bahr et al., 2003). For example, the total net weights of trees, edible fruit or nut, shrubs and bushes (HS0 code 060,220) are stable from 1988 to 2009 but have fluctuated wildly since 2010 (Fig. 4(b)). The total net weight of this commodity rose dramatically from 2017 to 2018 by 295% and has a sharp decline in 2019 by 22.76%. By comparing abnormal records, we found that these abnormal data points are mostly transactions between South Africa and Morocco, Morocco, Mozambique,



Fig. 3. Deviation Index of (a) reporters and (b) 2-digit commodities.

Namibia, and Zimbabwe, which are all reported by South Africa using the unit of 'Number of items' or 'Volume in liters' to report quantity. The details can be found in Table A8. These outliers may be caused by two reasons: misuse of the quantity unit and mistaken conversion between quantity and net weight. For example, the transaction of South Africa's imports from Namibia records the same value (391,314,900) of quantity and net weight. However, the quantity unit was adopted as 'Volumes in liters', which is an obvious error. As mentioned in our first article (Chen et al., 2022), the United Nations Statistical Division or the reporter would usually use an empirical conversion factor to convert the reported quantity to the net weight. For the transactions reported by South Africa, this factor ranges from 300 to 2000. However, among transactions reported by other countries to South Africa (all using the unit of 'Number of items'), this factor is no greater than 5 with an average of 0.98. Complete results are presented in Table A9. However, sometimes, these dramatic changes caused by outliers may be attributed to the effect of policies, such as applying physical quantity quotas to particular goods. These outliers, if not addressed, may lead to false estimation and judgment. Processing outliers could smooth the abnormal fluctuations in net weight values caused by outliers, which can promote the reliability and efficiency of physical trade analysis concerning temporal factors.

Furthermore, commodity trade flows, especially the physical flows, between countries or areas can be more accurately quantified with the outlier-handled UN Comtrade data, which provides data-based evidence for addressing environmental issues (Rougieux et al., 2017; Pan et al., 2021; Wen et al., 2021) and for developing sustainable development strategies (Dialga and Ouoba, 2022; Rahim et al., 2021; Tenaw and Hawitibo, 2021). One of the major causes of uncertainties in these studies is bilateral asymmetries, i.e., the reporter's record is not equal to its partner's for the same transaction. Bilateral asymmetries greatly limit

The deviation index of each reporter and main contributions of commodities, ordered by deviation index values of each reporter. Commodity 1, 2 and 3 are the commodities with top3 large deviation index.

Reporter	Dev <sub>r</sub>	Commo	dity1 and deviation index	Commo	dity2 and deviation index	Commo	dity3 and deviation index
South Africa	169.377	61	29.5862	85	29.3198	62	28.6903
Mexico	63.680	85	15.3854	84	4.9682	90	4.6251
Malaysia	34.127	28	6.4563	85	5.2543	76	2.1967
Netherlands	15.049	84	7.9921	29	0.8972	85	0.8878
United Kingdom	13.541	85	1.5714	84	1.1460	90	1.0778
China, Hong Kong SAR	10.383	71	1.8774	28	1.1231	85	1.0481
Spain	10.078	84	1.6155	90	0.6227	29	0.5806
Egypt	9.217	72	2.1066	73	1.5315	29	0.7280
Nigeria	8.843	84	1.5964	87	0.6321	85	0.5820
Canada	7.770	28	1.9473	71	1.6254	29	0.5866
USA	6.056	29	1.1795	28	0.7238	33	0.5238
Indonesia	5.857	25	0.5329	28	0.5280	29	0.3555
Saudi Arabia	5.703	29	2.1087	71	0.7089	28	0.4973
China	5.592	22	0.6622	12	0.5223	82	0.4758
India	5.044	71	0.4021	85	0.4012	69	0.3261
Papua New Guinea	4.803	72	1.4761	73	1.2240	12	0.9020
Japan	4.391	71	2.6144	29	0.5236	26	0.1230
Philippines	4.373	28	0.5115	81	0.4121	55	0.3323
Mozambique	4.160	84	0.7929	71	0.4434	63	0.4422
Greece	3.735	71	0.4329	25	0.3846	84	0.2960
Slovakia	3.731	72	0.6371	84	0.4542	58	0.2412
Australia	3.665	24	0.7469	84	0.2654	28	0.2652
United Arab Emirates	3.665	84	0.5910	71	0.3505	25	0.3213
Belgium	3.537	29	0.7458	28	0.4317	84	0.4200
France	3.096	28	0.4386	29	0.3700	25	0.3493
Thailand	3.061	71	0.5994	68	0.3166	44	0.2896
Russian Federation	2.908	27	0.2900	84	0.2394	72	0.1599
Germany	2.866	29	0.7523	28	0.5612	25	0.2378
Bangladesh	2.813	72	0.8979	68	0.3057	57	0.2847
Czechia	2.730	84	0.4449	85	0.1651	82	0.1425
Italy	2.521	84	0.5457	29	0.3067	28	0.2566
Rep. of Korea	2.32/	/1	0.3639	89	0.1588	41	0.1291
Lampan	2.244	27	0.7349	72	0.4918	73	0.1357
Angola	2.22/	4 9/	0.3412	73 63	0.1527	29 73	0.1258
Pomania	1 827	30	0.2215	52	0.1527	25 25	0.1238
Other Asia nes	1.037	20	0.4141	72	0.3120	81	0.1587
Kenva	1.770	84	0 4991	48	0.1515	85	0 1394
Ireland	1.727	29	0 4742	71	0.1451	84	0.1146
Pakistan	1.718	37	0.5734	53	0.1542	68	0.1312
Georgia	1.661	64	0.2280	62	0.2068	85	0.1988
Brazil	1.543	29	0.1887	84	0.1138	54	0.1086
Chile	1.454	8	0.1534	28	0.1446	48	0.1184
Sweden	1.431	28	0.2080	37	0.1099	38	0.1018
Oman	1.409	29	0.3834	25	0.1039	41	0.0769
Norway	1.346	38	0.4837	28	0.1983	89	0.1451
United Rep. of Tanzania	1.340	85	0.0920	62	0.0797	7	0.0751
So. African Customs Union	1.338	44	0.3575	71	0.0921	81	0.0870
Denmark	1.325	28	0.1409	91	0.1196	90	0.1047
Ghana	1.317	3	0.2001	12	0.0845	15	0.0824
Ukraine	1.215	52	0.1761	84	0.1192	55	0.1140
Qatar	1.198	72	0.1953	68	0.1929	28	0.1379
Kazakhstan	1.181	94	0.0998	76	0.0786	59	0.0782
Algeria	1.176	28	0.1121	84	0.0986	62	0.0887
Poland	1.157	70	0.1026	84	0.0846	85	0.0834
Ecuador	1.131	84	0.1499	29	0.1443	90	0.1092
Hungary	1.126	85	0.2932	84	0.2434	28	0.0444
Namibia	1.059	/1	0.2996	01 71	0.1434	2	0.0483
Guyana	1.049	44 80	0.3358	71 25	0.1820	02 30	0.0569
Israel	1.040	21	0.4835	23 72	0.1901	20	0.1128
Myanmar	0.978	52	0 1 3 4 0	96	0 1322	17	0.0992
Fmr Sudan	0.971	71	0.1246	28	0.0895	82	0.0714
Kyrgyzstan	0.953	55	0.2551	6	0.1662	25	0.1510
Bulgaria	0.943	89	0.4900	84	0.0548	96	0.0374
Brunei Darussalam	0.935	25	0.1578	3	0.1525	28	0.0955
Costa Rica	0.897	41	0.0918	72	0.0736	29	0.0714
Portugal	0.866	89	0.2154	28	0.1727	84	0.1011
Finland	0.862	28	0.1859	29	0.1478	71	0.1458
Luxembourg	0.833	28	0.1592	84	0.1119	25	0.0891
Trinidad and Tobago	0.814	62	0.0852	84	0.0756	47	0.0634
Switzerland	0.793	91	0.1964	29	0.0742	28	0.0687
Albania	0.783	96	0.3418	69	0.1975	93	0.0749

Z. Jiang et al	Ζ.	Jiang	et	al.
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# Table A5 (continued)

Demonster	Davi	Comm	aditus and deviation index	Comm	aditu 9 and daviation indav	Commo	ditu? and doviation indov
Reporter	Dev <sub>r</sub>	Comm	odity1 and deviation index	Comm	odity2 and deviation index	Commo	dity3 and deviation index
Belarus	0.769	84	0.1213	29	0.0891	55	0.0813
Nepal	0.759	49	0.0736	96	0.0664	33	0.0586
Malta	0.744	84	0.1462	27	0.1418	85	0.0764
Iran	0.725	29	0.2349	28	0.0784	93	0.0475
Seychelles	0.721	82	0.0880	84	0.0534	3	0.0510
Mauritania	0.710	17	0.0728	62	0.0587	43	0.0566
Venezuela	0.695	81	0.1025	29	0.0920	85	0.0598
Kuwait	0.692	43	0.1624	71	0.1131	25	0.0966
Eswatini	0.692	48	0.0734	47	0.0626	29	0.0514
Malawi	0.680	1	0.1670	84	0.0601	85	0.0471
Morocco	0.673	44	0.4895	84	0.0184	3	0.0172
Guatemala	0.668	29	0.1586	72	0.0728	28	0.0471
Austria	0.646	71	0.1210	28	0.0636	29	0.0626
Colombia	0.629	37	0.0630	91	0.0453	84	0.0448
Azerbaijan	0.620	62	0.1655	84	0.0850	59	0.0714
Zimbabwe	0.616	27	0.1559	17	0.0744	84	0.0739
Burkina Faso	0.593	61	0.0863	55	0.0688	3	0.0683
Belgium-Luxembourg	0.568	29	0.1395	28	0.1209	25	0.0577
Jamaica	0.567	71	0.1494	72	0.0742	55	0.0579
Suriname	0.552	29	0.2426	28	0.1396	84	0.0672
Mongolia	0.542	29	0.3330	30	0.0582	6	0.0375
Sri Lanka	0.538	74	0 1008	28	0.0601	53	0.0459
Togo	0 531	63	0.1566	55	0.0542	52	0.0451
Bolivia (Plurinational State of	0.526	Q/	0.0541	55	0.0480	36	0.0367
Central African Pan	0.520	04 71	0.4476	33 AA	0.0404	30	0.0080
Botswana	0.525	/1	0.4470	44 04	0.0404	39 60	0.0009
Combodia	0.504	/1	0.0000	04 40	0.0073	02	0.0449
Callibodia	0.496	/3	0.0597	49	0.0005	8/	0.0219
Yemen	0.487	84	0.2230	96	0.0305	62	0.0266
Bahrain	0.478	30	0.0654	55	0.0652	61	0.0427
Fiji	0.466	58	0.0464	85	0.0440	52	0.0410
Honduras	0.444	84	0.1061	28	0.0496	9	0.0404
Gambia	0.438	54	0.1215	61	0.0248	85	0.0174
Slovenia	0.423	62	0.1056	90	0.0572	65	0.0405
Uganda	0.413	87	0.0470	41	0.0435	82	0.0254
Croatia	0.413	27	0.0971	25	0.0349	52	0.0275
Cyprus	0.405	12	0.1455	84	0.0640	85	0.0238
North Macedonia	0.393	52	0.2182	6	0.0706	84	0.0482
Estonia	0.389	84	0.1132	27	0.0889	68	0.0132
Maldives	0.386	25	0.1020	54	0.0418	56	0.0237
Serbia and Montenegro	0.370	52	0.2492	30	0.0660	84	0.0064
Gabon	0.368	82	0.1498	55	0.0870	26	0.0276
Bhutan	0.366	44	0.0867	9	0.0629	72	0.0517
Jordan	0.361	28	0.0623	84	0.0469	68	0.0415
Syria	0.355	81	0.0533	58	0.0429	20	0.0270
Guinea	0.349	71	0.1157	52	0.0351	96	0.0342
Tunisia	0.340	28	0.0917	27	0.0346	84	0.0184
Lithuania	0.319	84	0.0793	4	0.0227	86	0.0121
Senegal	0.316	52	0.0524	71	0.0413	54	0.0333
Paraguay	0.308	44	0.0635	27	0.0357	55	0.0315
Latvia	0.298	68	0.0563	86	0.0448	84	0.0187
Mali	0.258	71	0.0413	37	0.0188	90	0.0167
Fmr Fed Rep of Germany	0.256	28	0.0738	25	0.0366	11	0.0347
Belize	0.248	63	0.0667	85	0.0340	84	0.0262
China, Macao SAR	0.243	22	0.0635	25	0.0387	54	0.0128
Argentina	0.241	20	0.0476	23	0.0264	28	0.0151
Iraa	0.241	68	0.0433	19	0.0204	20	0.0278
Benin	0.220	Q/	0.0207	52	0.0189	27	0.0155
Côte d'Ivoire	0.223	04 Q	0.0207	92 Q1	0.0198	20	0.0102
Niger	0.219	50	0.0203	62	0.0195	94	0.0192
Ethionia	0.207	52	0.0447	02	0.015/	04	0.0120
Etniopia	0.203	55	0.0260	53	0.0155	90	0.0146
Peru Fl Color de r	0.200	3	0.0511	25	0.0162	41	0.0123
EI SAIVAUOF	0.200	25	0.0001	14		30	0.01/1
Dominican Rep.	0.198	28	0.0221	/1	0.0193	30	0.0181
Cameroon	0.193	94	0.0389	84	0.0273	57	0.0240
Burundi	0.164	63	0.0383	81	0.0274	37	0.0236
Lebanon	0.162	87	0.0194	69	0.0186	55	0.0127
Barbados	0.161	84	0.0301	32	0.0232	64	0.0125
Nicaragua	0.160	9	0.0259	54	0.0228	29	0.0218
Armenia	0.157	84	0.0332	73	0.0253	16	0.0173
New Zealand	0.145	28	0.0207	29	0.0185	89	0.0177
Panama	0.143	29	0.0869	91	0.0120	90	0.0067
Madagascar	0.143	37	0.0176	71	0.0138	52	0.0116
Bahamas	0.132	22	0.0378	76	0.0192	73	0.0146
Iceland	0.130	88	0.0678	85	0.0131	41	0.0112
Antigua and Barbuda	0.121	89	0.0441	95	0.0295	63	0.0232
Rwanda	0.121	54	0.0251	56	0.0180	71	0.0123

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#### Table A5 (continued)

Reporter	Dev <sub>r</sub>	Commo	dity1 and deviation index	Commo	dity2 and deviation index	Commo	dity3 and deviation index
Sierra Leone	0.116	22	0.0383	11	0.0128	48	0.0063
Congo	0.115	52	0.0129	84	0.0129	62	0.0121
Saint Kitts and Nevis	0.108	1	0.0430	84	0.0207	78	0.0126
Uruguay	0.108	23	0.0265	63	0.0130	86	0.0118
Tonga	0.105	27	0.0757	68	0.0195	69	0.0036
Cuba	0.094	44	0.0129	87	0.0117	33	0.0067
Vietnam	0.090	54	0.0469	40	0.0158	72	0.0128
Rep. of Moldova	0.083	84	0.0092	68	0.0079	23	0.0064
Neth. Antilles	0.076	63	0.0405	96	0.0188	28	0.0100
Kiribati	0.071	12	0.0356	3	0.0293	11	0.0043
Afghanistan	0.070	26	0.0356	58	0.0074	41	0.0066
Mauritius	0.070	52	0.0110	39	0.0110	24	0.0091
New Caledonia	0.063	73	0.0258	84	0.0088	26	0.0083
Lao People's Dem. Rep.	0.063	28	0.0278	48	0.0123	44	0.0051
Serbia	0.057	84	0.0087	28	0.0060	14	0.0052
Lesotho	0.053	70	0.0113	84	0.0067	61	0.0049
Saint Lucia	0.051	84	0.0189	68	0.0102	91	0.0056
Sudan	0.050	2	0.0102	88	0.0090	29	0.0053
Vanuatu	0.050	85	0.0149	56	0.0111	96	0.0075
Comoros	0.041	9	0.0234	85	0.0020	74	0.0013
Andorra	0.040	25	0.0151	71	0.0090	39	0.0021
Haiti	0.038	23	0.0239	56	0.0062	83	0.0021
Uzbekistan	0.037	55 60	0.0076	25	0.0053	12	0.0021
Bospia Herzegovina	0.037	84	0.0082	23 71	0.0035	60	0.0025
Libuo	0.037	04 20	0.0082	71	0.0030	42	0.0023
LiDya Bormudo	0.028	20 67	0.0054	73	0.0040	43	0.0039
Semon	0.024	17	0.0062	2 10	0.0042	11	0.0020
Sallioa Timor Losto	0.023	17	0.0034	10	0.0048	01	0.0037
Timor-Leste	0.021	90	0.0106	48	0.0021	91	0.0012
Entrea	0.019	81	0.0037	/3	0.0023	59	0.0021
Dominica	0.018	84	0.0084	48	0.0015	63	0.0009
Solomon Isds	0.018	15	0.0102	24	0.0039	16	0.0028
Montenegro	0.015	14	0.0029	84	0.0021	48	0.0009
Saint Vincent and the Grenadines	0.014	62	0.0022	25	0.0010	63	0.0010
Greenland	0.014	3	0.0091	48	0.0029	61	0.0004
Palau	0.011	85	0.0039	76	0.0032	39	0.0010
Cabo Verde	0.011	71	0.0026	62	0.0012	72	0.0011
Aruba	0.010	91	0.0035	25	0.0028	48	0.0013
Faeroe Isds	0.008	5	0.0044	3	0.0014	15	0.0005
Djibouti	0.007	84	0.0009	87	0.0009	73	0.0005
Grenada	0.007	62	0.0015	90	0.0004	85	0.0004
Sao Tome and Principe	0.006	67	0.0024	20	0.0007	84	0.0004
FS Micronesia	0.005	81	0.0050	3	0.0001	97	0.0000
Mayotte	0.003	84	0.0011	96	0.0007	85	0.0003
Guinea-Bissau	0.003	93	0.0012	10	0.0002	17	0.0002
Cook Isds	0.002	11	0.0020	31	0.0002	27	0.0000
French Polynesia	0.002	85	0.0007	90	0.0003	84	0.0002
Anguilla	0.002	90	0.0006	5	0.0006	2	0.0005
French Guiana	0.002	93	0.0012	88	0.0002	82	0.0001
Turks and Caicos Isds	0.001	6	0.0002	91	0.0002	30	0.0001
Montserrat	0.001	90	0.0005	25	0.0001	87	0.0001
Chad	0.001	88	0.0004	72	0.0001	84	0.0001
Réunion	0.001	72	0.0004	51	0.0003	85	0.0000
Guadeloupe	0.001	25	0.0002	29	0.0001	89	0.0001
Tuvalu	0.001	31	0.0003	24	0.0001	21	0.0000
Martinique	0.0004	33	0.00010	28	0.00007	29	0.00004
State of Palestine	0.0003	85	0.00021	1	0.00006	84	0.000004
Wallis and Futuna Isds	0.0003	89	0.00013	90	0.00003	73	0.00002
Turkmenistan	0.000001	85	0.000001	-	-	-	-

this kind of research because selecting different sides' data would lead to different results (Gehlhar, 1996; Bahmani-Oskooee et al., 2013; Javorsek, 2016; Pfister, 2018). It has been uncovered that outliers due to misreporting are critical causes of the bilateral asymmetry issue (Farhad et al., 2019). As shown in Fig. 4(c), there are some huge differences in global total net weights between imports and exports. For example, in 1988 the global total net weight of imports was 2.11 times larger than that of exports, and the difference was 2.48 times in 2014, 1.86 times in 2018, and 1.99 times in 2019. The most severe difference occurs in 2014 when the original net weight of imports is approximately three times the export. As Fig. 4(d) shows, the total net weight value of imports and exports in the global trading system is significantly more balanced, especially for the data during 2013–2019. This suggests that outlier processing in this study has substantially weakened the impacts of bilateral asymmetries in the physical flows caused by misreported data. There are still narrow gaps between imports and exports, which might be caused by missing values which will be further discussed in the next article of our series.

# 4. Comparison with previous methods

This study uses KDE to detect outliers instead of previous ones with strong distribution assumptions, as almost no data of the unit prices in UN Comtrade distribute normally. The KDE is based on data distribution estimation, so it can be used to detect outliers for all commodities regardless of their data distribution and provide better results. To prove that, a case study is conducted to compare the performance of these three methods, namely the three-sigma rules, the boxplot, and the KDE.

**16** (cc . tini *d*) Tabl

Reporter	Dercentage of outling	Deviation index	Kenya
Reporter	Percentage of outliers	Deviation index	Georgia
Gambia	31.073	0.438	United Kingd
Sierra Leone	18.149	0.116	Gabon
Mauritania	17.548	0.71	Armenia
Haiti	13.58	0.038	Fiii
United Rep. of Tanzania	12.608	1.34	Côte d'Ivoire
Guinea	12.110	0.349	Jordan
Guillea-Bissau Iroa	11.705	0.003	Eritrea
Diibouti	10.007	0.220	Uzbekistan
Burkina Faso	10.337	0.503	Paraguay
Emr Sudan	9 566	0.971	Bolivia (Pluri
Burundi	9 501	0.164	Ecuador
Togo	9.156	0.531	El Salvador
Comoros	8.794	0.041	Jamaica
Sevchelles	8.508	0.721	Slovakia
Nigeria	8 1 4 6	8 843	Nicaragua
South Africa	7.767	169.377	Indonesia
Benin	7 669	0 223	Antigua and
Niger	7.005	0.223	Ukraine
Sudan	6 629	0.05	Brunei Darus
Uganda	6 473	0.413	Costa Rica
Belize	6 416	0.248	Barbados
Mali	6.399	0.258	Maldives
Ghana	6 297	1 317	Iran
Zambia	6.232	2.244	Cabo Verde
Lesotho	6 166	0.053	Luxembourg
Danua New Guinea	6 1 2 1	4 803	United Arab
Tuvalu	5.878	0.001	Andorra
Mozembique	5.732	4.16	Venezuela
Namibia	5.732	1.059	Japan
Turke and Caicos Jeds	5.732	0.001	Nepal
Malawi	5 523	0.68	Bulgaria
Chad	5.325	0.001	Suriname
Central African Ren	5 303	0.523	Bermuda
Congo	5.353	0.115	Australia
Zimbabwe	5.205	0.616	Neth. Antilles
Bwanda	5.127	0.121	Bangladesh
Botswana	5.103	0.504	Other Asia, n
Guyana	5.078	1 049	Belarus
Honduras	5.005	0.444	Bahrain
Fewatini	4 886	0.692	Kuwait
Afghanistan	4 675	0.07	North Maced
Azerbaijan	4.617	0.62	Guatemala
Chile	4.50	1.454	Saint Kitts an
Vemen	4 371	0.497	Malaysia
Cameroon	4.045	0.407	Malta
Algeria	4.043	1 176	Finland
Cuba	4.012	0.004	Svria
Bhutan	4.012	0.094	Cook Isds
Ethiopio	4.012	0.300	Mongolia
Ethiopia Kurguraton	2.042	0.203	Greece
Angolo	2,005	0.933	Saudi Arabia
Aligola	3.905	2.21/	Romania
Venuetu	3.819	0.510	Rep. of Korea
Vanualu	3.742	0.05	Norway
	3.5	0.000	Serbia and M
Myanmar Okina Maasa CAD	3.442	0.9/8	Snain
Cillia, Macao SAR	3.412	0.243	Colombia
	3.408	0.018	Trinidad and
Cambodia	3.31	0.496	Bosnia Herze
Samoa	3.299	0.023	Aruba
Wexico	3.247	03.08	Denmark
1 Imor-Leste	3.237	0.021	Tunisia
	3.232	0.783	Sri Lanka
Saint Vincent and the Grenadines	3.202	0.014	Lithuania
Egypt	3.123	9.217	Greenland
Switzerland	3.116	0.793	Dalan
Russian Federation	3.111	2.908	r didu Bahamaa
Madagascar	3.086	0.143	Gronodo
Kazakhstan	3.075	1.181	Grenada
Philippines	3.052	4.373	Masteria
Qatar	3.01	1.198	Morecee
Rep. of Moldova	2.96	0.083	Crochio
Oman	2.935	1.409	Czecnia
Rep. of Moldova Oman	2.96 2.935	0.083 1.409	Czech Italy

le A6 (continued)		
porter	Percentage of outliers	Deviation index
enya	2.915	1.77
eorgia	2.884	1.661
nited Kingdom	2.884	13.541
int Lucia	2.87	0.051
lbon menia	2.844	0.368
i	2.806	0.466
te d'Ivoire	2.804	0.219
rdan	2.766	0.361
itrea	2.749	0.019
bekistan	2.718	0.037
raguay Jivia (Durinational State of)	2.669	0.308
uador	2.571	1.131
Salvador	2.571	0.2
maica	2.55	0.567
ovakia	2.534	3.731
caragua	2.512	0.16
donesia	2.505	5.857
raine	2.5	1 215
unei Darussalam	2.466	0.935
osta Rica	2.435	0.897
rbados	2.401	0.161
aldives	2.391	0.386
in	2.383	0.725
bo Verde	2.38	0.011
xembourg	2.36	0.833
nited Arab Emirates	2.341	3.005 0.04
mezuela	2.323	0.695
pan	2.283	4.391
epal	2.255	0.759
lgaria	2.245	0.943
riname	2.225	0.552
rmuda	2.206	0.024
Istralia	2.2	3.665
ngladesh	2.19	0.070
her Asia. nes	2.161	1.776
larus	2.142	0.769
hrain	2.111	0.478
ıwait	2.109	0.692
orth Macedonia	2.106	0.393
atemala	2.076	0.668
alaysia	2.069	0.108
alta	2.059	0 744
nland	2.049	0.862
ria	1.981	0.355
ook Isds	1.972	0.002
ongolia	1.962	0.542
eece	1.956	3.735
udi Arabia	1.95	5.703
nialita n of Korea	1.943	2 327
prway	1.901	1.346
rbia and Montenegro	1.861	0.37
ain	1.847	10.078
lombia	1.838	0.629
inidad and Tobago	1.77	0.814
snia Herzegovina	1.754	0.037
uDa	1.748	0.01
inisia	1.732	0.34
i Lanka	1.712	0.538
huania	1.707	0.319
reenland	1.675	0.014
lau	1.673	0.011
hamas	1.666	0.132
renada	1.653	0.007
azii	1.052	1.543
orocco	1.029	0.013
echia	1.605	2.73
ıly	1.53	2.521

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# Table A6 (continued)

Latvia1.5190.298Estonia1.4710.389Prench Guiana1.445315.049Prench Guiana1.4420.162Lebanon1.4420.161Croatia1.4420.413Wallis and Futuna Isds1.4140.0003Cyprus1.4290.405Thailand1.3613.061Mayotte1.3470.003Serbia1.320.057Ireland1.3021.727Solomon Isds1.2930.018Montserrat1.2740.001Portugal1.2510.866Tonga1.2260.105So. African Customs Union1.2161.338Belgium-Luxembourg1.2040.568Dominican Rep.1.1980.241Peru1.1510.0241Peru1.1510.004Iceland1.0640.423Poland1.0640.433USA1.0746.056Slovenia1.0310.063Guadeloupe1.0180.001China0.9921.126New Caledonia0.8570.001Parce0.8773.096Canada0.8747.77Réunion0.8570.001Parce0.8747.76Réunion0.8570.001Palistan0.7650.058Singapore0.8720.038Virugal0.6461.431Turkey0.6431.044Austri	Reporter	Percentage of outliers	Deviation index
Estonia1.4710.389Netherlands1.44315.049French Guiana1.4420.162Lebanon1.4420.1162Croatia1.4420.413Wallis and Futuna Isds1.4410.0003Cyprus1.4290.405Thailand1.3613.061Mayotte1.3470.003Serbia1.320.057Ireland1.3021.727Solomon Isds1.2930.018Montserrat1.2740.001Portugal1.2510.866Tonga1.2260.105So. African Customs Union1.2161.338Belgium-Luxembourg1.2040.568Dominican Rep.1.1980.198Argentina1.1850.241Peru1.1510.241Peru1.110.0004Iceland1.0640.13USA1.0746.056Slovenia1.0340.018Viruguy0.9920.108New Caledonia1.0310.063Guadeloupe1.0180.001China0.9972.227Hungary0.9091.126Viruguy0.9920.108Singapore0.8170.001China0.8570.001Patistan0.8161.718Lao People's Dem. Rep.0.8170.002China, Hong Kong SAR0.7520.383French Polynesia0.7430.002Austria	Latvia	1.519	0.298
Netherlands1.45315.049French Guiana1.4420.162Croatia1.4420.413Wallis and Futuna Isds1.4420.405Thailand1.3613.061Mayotte1.3470.003Serbia1.320.057Ireland1.3021.727Solomon Isds1.2930.018Montserrat1.2740.001Portugal1.2510.866Tonga1.2260.105So. African Customs Union1.2161.338Belgium-Luxembourg1.2040.568Dominican Rep.1.1850.241Perru1.1510.2Martinique1.110.0004Iceland1.0640.13USA0.0711.537Faeroe Isds1.0310.063Guadeloupe0.9985.592Uruguay0.9920.108Singapore0.3773.096Canada0.8773.096Canada0.8773.096Canada0.8773.096Canada0.8747.77Painion0.8570.001Paistan0.8161.718Lao People's Dem. Rep.0.8010.063Austria0.75210.383Frence Polynesia0.7130.002Pahanaa0.6680.143Turkey0.6431.044Hungary0.8011.044Hungary0.8570.001Paistan0.8161.	Estonia	1.471	0.389
Prench Guiana1.4460.002Lebanon1.4420.162Croatia1.4420.413Wallis and Futuna Isds1.4410.0003Cyprus1.4290.405Thailand1.3613.061Mayotte1.3470.003Serbia1.320.057Ireland1.3021.727Solomon Isds1.2930.018Montserrat1.2740.001Portugal1.2510.866Tonga1.2161.338Belgium-Luxembourg1.2040.568Dominican Rep.1.1980.198Argentina1.850.241Peru1.1510.2Martinique1.110.0004Iceland1.0641.433USA1.0746.056Slovenia1.0640.423Poland1.0640.423Poland1.0640.423Poland0.0630.071Facro Isds1.0310.063Guadeloupe0.180.001China0.9995.592Uruguay0.9920.108Singapore0.8070.777Reinion0.8570.001China0.7670.646Austria0.7670.646Austria0.7670.646Austria0.7670.646Austria0.7610.443Pere Polynesia0.7130.002Piakistan0.6550.071Verken0.64	Netherlands	1.453	15.049
Lebanon1.4420.162Croatia1.4420.413Wallis and Futuna Isds1.4410.0003Cyprus1.4290.405Thailand1.3613.061Mayotte1.3470.003Serbia1.320.057Ireland1.3021.727Solomon Isds1.2930.018Montserrat1.2740.001Portugal1.2510.866Tonga1.2260.105So. African Customs Union1.2161.338Belgium-Luxembourg1.2040.568Dominican Rep.1.1980.198Argentina1.1850.241Peru1.110.0004Iceland1.0840.13USA1.0746.056Slovenia1.0640.423Poland1.0413.537Kiribati1.0360.071Faeroe Isds1.0310.063Guadeloupe1.0180.001China0.9920.108Singapore0.9372.227Uruguay0.9920.108Singapore0.9372.227Vitugay0.9920.108Singapore0.8770.001Pahana0.8770.001Pahana0.75210.383France0.8770.001Pahasian0.6630.446Austria0.75210.383French Polynesia0.7130.002Pahasian0.6550.071	French Guiana	1.446	0.002
Croatia1.4420.413Wallis and Futuna Isds1.4420.4005Cyprus1.4290.4005Ihalland1.3613.061Mayotte1.3470.003Serbia1.320.057Ireland1.3021.727Solomon Isds1.2930.018Montserrat1.2740.001Portugal1.2510.866Tonga1.2260.105So. African Customs Union1.2161.338Belgium-Luxembourg1.2040.568Dominican Rep.1.1980.241Peru1.1510.2Martinique1.110.0004Iceland1.0640.13USA1.0746.056Slovenia1.0641.157Belgium1.0413.537Kirlbati1.0360.071Faeroe Isds1.0340.008New Caledonia1.0310.663Guadeloupe0.9985.592Uruguay0.9920.108Singapore0.8770.001Patada0.8770.001China0.8770.002Prance0.8770.002China0.7760.646New Zealand0.8747.77Réunion0.8570.001Patasta0.7760.646Austria0.7760.646Austria0.7760.646Austria0.5780.041Patasta0.6431.04Mauri	Lebanon	1.442	0.162
Wallis and Putuna Isds         1.441         0.0003           Cyprus         1.429         0.405           Thailand         1.361         3.061           Mayotte         1.347         0.003           Serbia         1.322         0.057           Ireland         1.302         1.727           Solomon Isds         1.293         0.018           Montserrat         1.274         0.001           Portugal         1.251         0.866           Tonga         1.226         0.105           So. African Customs Union         1.216         1.338           Delgium-Luxembourg         1.198         0.198           Argentina         1.855         0.241           Peru         1.11         0.0004           Iceland         1.084         0.13           USA         1.074         6.056           Slovenia         1.064         0.423           Poland         1.064         1.517           Belgium         1.031         0.063           Guadeloupe         1.034         0.008           Uruguay         0.992         0.108           Singapore         0.937         2.227	Croatia	1.442	0.413
Cyprus1.4290.405Thailand1.3613.061Mayotte1.3470.003Serbia1.320.057Ireland1.3021.727Solomon Isds1.2930.018Montserrat1.2740.001Portugal1.2510.866Tonga1.2161.338Belgium-Luxembourg1.2040.568Dominican Rep.1.1980.198Argentina1.1850.241Peru1.1510.2Martinique1.110.0004Iceland1.0840.13USA1.0746.056Slovenia1.0641.157Belgium1.0413.537Kiribati1.0360.071Faeroe Isds1.0310.663New Caledonia1.0310.663Cuadeloupe1.0180.001China0.9985.592Uruguay0.9991.126New Zealand0.8820.145France0.8773.096Canada0.8747.77Réunion0.8570.001Pakistan0.75210.383Lao Pople's Dem. Rep.0.8161.718Lao Pople's Dem. Rep.0.8161.718Lao Pople's Dem. Rep.0.8161.718Lao Pople's Dem. Rep.0.8161.431India0.5585.044Turkey0.6431.041Mauritius0.6585.044France0.6730.02	Wallis and Futuna Isds	1.441	0.0003
Thailand1.3613.061Mayotte1.3470.003Serbia1.320.057Ireland1.3021.727Solomon Isds1.2930.018Montserrat1.2740.001Portugal1.2510.866Tonga1.2260.105So. African Customs Union1.2161.338Belgium-Luxembourg1.2040.568Dominican Rep.1.1980.198Argentina1.1850.241Peru1.1510.2Martinique1.110.0004Iceland1.0640.423Poland1.0640.423Poland1.0640.423Poland1.0640.423Poland1.0640.001China0.9985.592Uruguay0.9020.108Singapore0.9372.227Hungary0.9920.108Singapore0.8773.096Canada0.8747.77Réunion0.8570.001Pakistan0.8161.718Lao People's Dem. Rep.0.8010.063Austria0.75210.383Turkey0.6431.041Austria0.5580.071Palenda0.8570.001Pakistan0.8161.718Lao People's Dem. Rep.0.8010.0623China0.6250.072Sweden0.611.431India0.5585.044Fure	Cyprus	1.429	0.405
Mayotte         1.347         0.003           Serbia         1.322         0.057           Ireland         1.302         1.727           Solomon Isds         1.293         0.018           Montserrat         1.274         0.001           Portugal         1.251         0.866           Tonga         1.226         0.105           So. African Customs Union         1.216         1.338           Belgium-Luxembourg         1.204         0.568           Dominican Rep.         1.198         0.198           Argentina         1.185         0.241           Peru         1.151         0.20           Martinique         1.11         0.0004           Iceland         1.064         0.423           Poland         1.064         0.423           Poland         1.064         0.423           Poland         1.064         0.001           Kiribati         1.031         0.063           Guadeloupe         1.013         0.001           China         0.998         5.592           Uruguay         0.992         0.108           Singapore         0.877         0.001 <td< td=""><td>Thailand</td><td>1.361</td><td>3.061</td></td<>	Thailand	1.361	3.061
Serbia         1.32         0.057           Ireland         1.302         1.727           Solomon Isds         1.293         0.018           Montserrat         1.274         0.001           Portugal         1.251         0.866           Tonga         1.226         0.105           So. African Customs Union         1.216         1.338           Belgium-Luxembourg         1.204         0.568           Dominican Rep.         1.198         0.198           Argentina         1.185         0.241           Peru         1.151         0.2           Martinique         1.11         0.00044           Iceland         1.084         0.13           USA         1.074         6.056           Slovenia         1.064         1.157           Belgium         1.041         3.537           Kiribati         1.036         0.071           Faeroe Isds         1.031         0.063           Guadeloupe         1.018         0.001           China         0.999         5.592           Urugay         0.992         0.108           Singapore         0.937         2.227 <t< td=""><td>Mayotte</td><td>1.347</td><td>0.003</td></t<>	Mayotte	1.347	0.003
Ireland         1.302         1.727           Solomon Isds         1.293         0.018           Montserrat         1.274         0.001           Portugal         1.251         0.866           Tonga         1.226         0.105           So. African Customs Union         1.216         1.338           Belgium-Luxembourg         1.204         0.568           Dominican Rep.         1.198         0.198           Argentina         1.185         0.241           Peru         1.151         0.2           Martinique         1.11         0.0004           Iceland         1.084         0.13           USA         1.074         6.056           Slovenia         1.064         1.157           Belgium         1.041         3.537           Kiribati         1.036         0.071           Faeroe Isds         1.031         0.063           Guadeloupe         1.018         0.001           China         0.999         1.126           New Caledonia         0.874         7.77           Mungary         0.909         1.126           New Zealand         0.8857         0.001      C	Serbia	1.32	0.057
Solomon Isds         1.293         0.018           Montserrat         1.274         0.001           Portugal         1.251         0.866           Tonga         1.226         0.105           So. African Customs Union         1.216         1.338           Belgium-Luxembourg         1.204         0.568           Dominican Rep.         1.198         0.198           Argentina         1.185         0.241           Peru         1.151         0.2           Martinique         1.11         0.0004           Iceland         1.084         0.13           USA         1.074         6.056           Slovenia         1.064         1.157           Belgium         1.041         3.537           Kiribati         1.036         0.071           Faeroe Isds         1.031         0.063           Guadeloupe         1.018         0.001           China         0.999         5.592           Urruguy         0.909         1.126           New Zealand         0.877         3.096           Canada         0.874         7.77           Réunion         0.816         1.718	Ireland	1.302	1.727
Montserrat         1.274         0.001           Portugal         1.251         0.866           Tonga         1.226         0.105           So. African Customs Union         1.216         1.338           Belgium-Luxembourg         1.204         0.568           Dominican Rep.         1.198         0.198           Argentina         1.185         0.241           Peru         1.151         0.2           Martinique         1.11         0.0004           Iceland         1.084         0.13           USA         1.074         6.056           Slovenia         1.064         0.423           Poland         1.064         0.423           Poland         1.064         0.037           Kiribati         1.036         0.071           Faeroe Isds         1.034         0.008           Guadeloupe         1.018         0.001           China         0.998         5.592           Urruguay         0.909         1.126           New Zealand         0.877         3.096           Canada         0.874         7.77           Réunion         0.857         0.001           Pa	Solomon Isds	1.293	0.018
Portugal         1.251         0.866           Tonga         1.226         0.105           So. African Customs Union         1.216         1.338           Belgium-Luxembourg         1.204         0.568           Dominican Rep.         1.198         0.198           Argentina         1.185         0.241           Peru         1.151         0.2           Martinique         1.11         0.0004           Iceland         1.084         0.13           USA         1.074         6.056           Slovenia         1.064         0.423           Poland         1.064         0.423           Poland         1.064         0.008           Kiribati         1.036         0.071           Faeroe Isds         1.031         0.063           Guadeloupe         1.018         0.001           China         0.998         5.592           Uruguay         0.990         1.126           New Zealand         0.882         0.145           France         0.877         3.096           Canada         0.874         7.77           Réunion         0.857         0.001           Pakista	Montserrat	1.274	0.001
Tonga         1.226         0.105           So. African Customs Union         1.216         1.338           Belgium-Luxembourg         1.204         0.568           Dominican Rep.         1.198         0.198           Argentina         1.185         0.241           Peru         1.151         0.2           Martinique         1.11         0.0004           Iceland         1.084         0.13           USA         1.074         6.056           Slovenia         1.064         1.157           Belgium         1.041         3.537           Kiribati         1.036         0.071           Faeroe Isds         1.031         0.063           Guadeloupe         1.018         0.001           China         0.998         5.592           Uruguay         0.992         0.108           Singapore         0.937         2.227           Hungary         0.909         1.126           New Zealand         0.882         0.145           France         0.877         3.096           Canada         0.874         7.77           Réunion         0.857         0.001           Paki	Portugal	1.251	0.866
So. African Customs Union         1.216         1.338           Belgium-Luxembourg         1.204         0.568           Dominican Rep.         1.198         0.198           Argentina         1.185         0.241           Peru         1.151         0.2           Martinique         1.11         0.0004           Lecland         1.084         0.13           USA         1.074         6.056           Slovenia         1.064         0.423           Poland         1.064         0.423           Poland         1.064         0.071           Fareoe Isds         1.031         0.063           Guadeloupe         1.018         0.001           China         0.998         5.592           Uruguay         0.992         0.108           Singapore         0.937         2.227           Hungary         0.909         1.126           New Zealand         0.882         0.145           France         0.877         3.096           Canada         0.874         7.77           Réunion         0.857         0.001           Pakistan         0.752         10.383           Ita	Tonga	1.226	0.105
Belgium-Luxembourg         1.204         0.568           Dominican Rep.         1.198         0.198           Argentina         1.185         0.241           Peru         1.151         0.2           Martinique         1.11         0.0004           Iceland         1.084         0.13           USA         1.074         6.056           Slovenia         1.064         0.423           Poland         1.064         0.423           Poland         1.064         0.071           Faeroe Isds         1.031         0.063           Guadeloupe         1.018         0.001           China         0.998         5.592           Urruguy         0.992         0.108           Singapore         0.937         2.227           Hungary         0.992         0.108           Singapore         0.827         3.096           Canada         0.877         3.096           Canada         0.874         7.77           Réunion         0.857         0.001           Pakistan         0.752         10.383           French Polynesia         0.752         0.033           Austria	So. African Customs Union	1.216	1.338
Dominican Rep.         1.198         0.198           Argentina         1.185         0.241           Peru         1.151         0.2           Martinique         1.11         0.0004           Iceland         1.084         0.13           USA         1.074         6.056           Slovenia         1.064         1.157           Belgium         1.041         3.537           Kiribati         1.036         0.071           Faeroe Isds         1.031         0.063           Guadeloupe         1.018         0.001           China         0.998         5.592           Uruguay         0.992         0.108           Singapore         0.937         2.227           Hungary         0.909         1.126           New Zealand         0.882         0.145           France         0.877         3.096           Canada         0.876         0.001           Pakistan         0.816         1.718           Lao People's Dem. Rep.         0.801         0.663           Austria         0.76         0.646           Anguilla         0.625         0.07           Sweden	Belgium-Luxembourg	1.204	0.568
Argentina       1.185       0.241         Peru       1.151       0.2         Martinique       1.11       0.0004         Iceland       1.084       0.13         USA       1.074       6.056         Slovenia       1.064       0.423         Poland       1.064       0.157         Belgium       1.041       3.537         Kiribati       1.036       0.071         Faeroe Isds       1.034       0.008         New Caledonia       1.031       0.063         Guadeloupe       1.018       0.001         China       0.992       0.108         Singapore       0.937       2.227         Hungary       0.909       1.126         New Zealand       0.882       0.145         France       0.877       3.096         Canada       0.877       0.001         Pakistan       0.816       1.718         Lao People's Dem. Rep.       0.801       0.663         Austria       0.752       0.383         French Polynesia       0.713       0.002         Panama       0.668       0.143         India       0.558       5.044<	Dominican Rep.	1.198	0.198
Peru         1.151         0.2           Martinique         1.11         0.0004           Iceland         1.084         0.13           USA         1.074         6.056           Slovenia         1.064         0.423           Poland         1.064         1.157           Belgium         1.041         3.537           Kiribati         1.036         0.071           Faeroe Isds         1.034         0.008           New Caledonia         1.031         0.663           Guadeloupe         1.018         0.001           China         0.992         0.108           Singapore         0.937         2.227           Hungary         0.909         1.126           New Zealand         0.882         0.145           France         0.877         3.096           Canada         0.874         7.77           Réunion         0.857         0.001           Pakistan         0.816         1.718           Lao People's Dem. Rep.         0.801         0.063           Anstria         0.776         0.646           Anguilla         0.625         0.07           Sweden	Argentina	1.185	0.241
Martinique         1.11         0.0004           Iceland         1.084         0.13           USA         1.074         6.056           Slovenia         1.064         0.423           Poland         1.064         1.157           Belgium         1.041         3.537           Kiribati         1.036         0.071           Faeroe Isds         1.034         0.008           New Caledonia         1.031         0.063           Guadeloupe         1.018         0.001           China         0.998         5.592           Uruguay         0.992         0.108           Singapore         0.937         2.227           Hungary         0.909         1.126           New Zealand         0.882         0.145           France         0.877         3.096           Canada         0.874         7.77           Réunion         0.857         0.001           Pakistan         0.766         0.646           Anguilla         0.76         0.646           Anguilla         0.76         0.002           China, Hong Kong SAR         0.752         10.383           French Polynesi	Peru	1.151	0.2
Iceland     1.084     0.13       USA     1.074     6.056       Slovenia     1.064     0.423       Poland     1.064     1.157       Belgium     1.041     3.537       Kiribati     1.036     0.071       Faeroe Isds     1.034     0.063       Guadeloupe     1.018     0.001       China     0.998     5.592       Uruguay     0.992     0.108       Singapore     0.937     2.227       Hungary     0.909     1.126       New Zealand     0.882     0.145       France     0.877     3.096       Canada     0.877     3.096       Canada     0.877     0.001       Pakistan     0.816     1.718       Lao People's Dem. Rep.     0.801     0.663       Austria     0.776     0.646       Anguilla     0.76     0.002       China, Hong Kong SAR     0.752     10.383       French Polynesia     0.61     1.431       India     0.558     5.044       Fur Fed. Rep. of Germany     0.505     0.025       Germany     0.449     2.866       Libya     0.074     0.09       Fis Micronesia     0.033     0.00	Martinique	1.11	0.0004
USA         1.074         6.056           Slovenia         1.064         0.423           Poland         1.064         1.157           Belgium         1.041         3.537           Kiribati         1.036         0.071           Faeroe Isds         1.034         0.008           New Caledonia         1.031         0.063           Guadeloupe         1.018         0.001           China         0.992         0.108           Singapore         0.937         2.227           Hungary         0.909         1.126           New Zealand         0.882         0.145           France         0.877         3.096           Canada         0.874         7.77           Réunion         0.857         0.001           Pakistan         0.816         1.718           Lao People's Dem. Rep.         0.801         0.063           Austria         0.752         10.383           French Polynesia         0.713         0.002           Panama         0.668         0.143           Turkey         0.643         1.04           Mauritius         0.558         0.544           Fur Fed	Iceland	1.084	0.13
Slovenia         1.064         0.423           Poland         1.064         1.157           Belgium         1.041         3.537           Kiribati         1.036         0.071           Faeroe Isds         1.034         0.008           New Caledonia         1.031         0.663           Guadeloupe         1.018         0.001           China         0.992         0.108           Singapore         0.937         2.227           Hungary         0.909         1.126           New Zealand         0.882         0.145           France         0.877         3.096           Canada         0.877         3.096           Canada         0.877         0.001           Pakistan         0.857         0.001           Pakistan         0.861         1.718           Lao People's Dem. Rep.         0.801         0.663           Austria         0.752         10.383           French Polynesia         0.713         0.002           Panama         0.668         0.143           Turkey         0.643         1.04           Mauritius         0.555         0.256           Ge	USA	1.074	6.056
Poland         1.064         1.157           Belgium         1.041         3.537           Kiribati         1.036         0.071           Faeroe Isds         1.034         0.068           New Caledonia         1.031         0.063           Guadeloupe         1.018         0.001           China         0.998         5.592           Uruguay         0.992         0.108           Singapore         0.937         2.227           Hungary         0.909         1.126           New Zealand         0.882         0.145           France         0.877         3.096           Canada         0.877         0.001           Pakistan         0.816         1.718           Lao People's Dem. Rep.         0.801         0.063           Austria         0.776         0.646           Anguilla         0.76         0.002           China, Hong Kong SAR         0.752         10.383           French Polynesia         0.713         0.002           Panama         0.668         0.143           India         0.558         5.044           Fmr Fed. Rep. of Germany         0.505         0.256 </td <td>Slovenia</td> <td>1.064</td> <td>0.423</td>	Slovenia	1.064	0.423
Belgium         1.041         3.537           Kiribati         1.036         0.071           Faeroe Isds         1.034         0.008           New Caledonia         1.031         0.663           Guadeloupe         1.018         0.001           China         0.998         5.592           Uruguay         0.992         0.108           Singapore         0.937         2.227           Hungary         0.909         1.126           New Zealand         0.882         0.145           France         0.877         3.096           Canada         0.874         7.77           Réunion         0.857         0.001           Pakistan         0.816         1.718           Lao People's Dem. Rep.         0.801         0.063           Austria         0.776         0.646           Anguilla         0.76         0.002           China, Hong Kong SAR         0.752         10.383           French Polynesia         0.713         0.002           Panama         0.668         0.143           India         0.558         5.044           Fmr Fed. Rep. of Germany         0.505         0.256 </td <td>Poland</td> <td>1.064</td> <td>1.157</td>	Poland	1.064	1.157
Kiribati     1.036     0.071       Faeroe Isds     1.034     0.008       New Caledonia     1.031     0.063       Guadeloupe     1.018     0.001       China     0.998     5.592       Uruguay     0.992     0.108       Singapore     0.937     2.227       Hungary     0.909     1.126       New Zealand     0.882     0.145       France     0.877     3.096       Canada     0.874     7.77       Réunion     0.857     0.001       Pakistan     0.816     1.718       Lao People's Dem. Rep.     0.801     0.663       Austria     0.776     0.646       Anguilla     0.76     0.002       China, Hong Kong SAR     0.752     10.383       French Polynesia     0.713     0.002       Panama     0.668     0.143       Turkey     0.643     1.04       Mauritius     0.625     0.07       Sweden     0.61     1.431       India     0.558     5.044       Fmr Fed. Rep. of Germany     0.505     0.256       Germany     0.405     0.028       Israel     0.139     1.025       Vietnam     0.074     0	Belgium	1.041	3.537
Faeroe Isds         1.034         0.008           New Caledonia         1.031         0.063           Guadeloupe         1.018         0.001           China         0.998         5.592           Uruguay         0.992         0.108           Singapore         0.937         2.227           Hungary         0.909         1.126           New Zealand         0.882         0.145           France         0.877         3.096           Canada         0.877         0.001           Pakistan         0.816         1.718           Lao People's Dem. Rep.         0.801         0.063           Austria         0.76         0.646           Anguilla         0.76         0.646           Anguilla         0.752         10.383           French Polynesia         0.713         0.002           Panama         0.668         0.143           Turkey         0.643         1.04           Mauritius         0.558         5.044           Fmr Fed. Rep. of Germany         0.505         0.256           Germany         0.449         2.866           Libya         0.074         0.09	Kiribati	1.036	0.071
New Caledonia         1.031         0.063           Guadeloupe         1.018         0.001           China         0.998         5.592           Uruguay         0.992         0.108           Singapore         0.937         2.227           Hungary         0.909         1.126           New Zealand         0.882         0.145           France         0.877         3.096           Canada         0.877         0.001           Pakistan         0.857         0.001           Pakistan         0.816         1.718           Lao People's Dem. Rep.         0.801         0.063           Austria         0.776         0.646           Anguilla         0.76         0.002           China, Hong Kong SAR         0.752         10.383           French Polynesia         0.713         0.002           Panama         0.668         0.143           Turkey         0.643         1.04           Mauritius         0.555         0.07           Sweden         0.61         1.431           India         0.558         5.044           Fmr Fed. Rep. of Germany         0.505         0.256	Faeroe Isds	1.034	0.008
Guadeloupe         1.018         0.001           China         0.998         5.592           Uruguay         0.992         0.108           Singapore         0.937         2.227           Hungary         0.909         1.126           New Zealand         0.882         0.145           France         0.877         3.096           Canada         0.874         7.77           Réunion         0.857         0.001           Pakistan         0.816         1.718           Lao People's Dem. Rep.         0.801         0.063           Austria         0.776         0.646           Anguilla         0.76         0.002           China, Hong Kong SAR         0.752         10.383           French Polynesia         0.713         0.002           Panama         0.668         0.143           Turkey         0.643         1.044           Mauritius         0.625         0.07           Sweden         0.61         1.431           India         0.558         5.044           Fmr Fed. Rep. of Germany         0.405         0.028           Israel         0.139         1.025	New Caledonia	1.031	0.063
China         0.998         5.592           Uruguay         0.992         0.108           Singapore         0.937         2.227           Hungary         0.909         1.126           New Zealand         0.882         0.145           France         0.877         3.096           Canada         0.877         3.096           Canada         0.874         7.77           Réunion         0.857         0.001           Pakistan         0.816         1.718           Lao People's Dem. Rep.         0.801         0.663           Austria         0.776         0.646           Anguilla         0.76         0.002           China, Hong Kong SAR         0.752         10.383           French Polynesia         0.713         0.002           Panama         0.668         0.143           Turkey         0.643         1.04           Mauritius         0.625         0.07           Sweden         0.61         1.431           India         0.558         5.044           Fmr Fed. Rep. of Germany         0.505         0.256           Germany         0.405         0.028	Guadeloupe	1.018	0.001
Uruguay         0.992         0.108           Singapore         0.937         2.227           Hungary         0.909         1.126           New Zealand         0.882         0.145           France         0.877         3.096           Canada         0.877         3.096           Canada         0.877         3.096           Canada         0.874         7.77           Réunion         0.857         0.001           Pakistan         0.816         1.718           Lao People's Dem. Rep.         0.801         0.063           Austria         0.776         0.646           Anguilla         0.76         0.002           China, Hong Kong SAR         0.752         10.383           French Polynesia         0.713         0.002           Panama         0.668         0.143           Turkey         0.643         1.04           Mauritius         0.625         0.07           Sweden         0.61         1.431           India         0.558         5.044           Fmr Fed. Rep. of Germany         0.505         0.256           Germany         0.449         2.866	China	0.998	5.592
Singapore         0.937         2.227           Hungary         0.909         1.126           New Zealand         0.882         0.145           France         0.877         3.096           Canada         0.874         7.77           Réunion         0.857         0.001           Pakistan         0.816         1.718           Lao People's Dem. Rep.         0.801         0.663           Austria         0.776         0.646           Anguilla         0.76         0.002           China, Hong Kong SAR         0.752         10.383           French Polynesia         0.713         0.002           Panama         0.668         0.143           Turkey         0.61         1.431           India         0.558         5.044           Fmr Fed. Rep. of Germany         0.505         0.256           Germany         0.405         0.028           Ibya         0.139         1.025           Vietnam         0.074         0.99           FS Micronesia         0.033         0.0003           State of Palestine         0.03         0.00031	Uruguay	0.992	0.108
Hungary         0.909         1.126           New Zealand         0.882         0.145           France         0.877         3.096           Canada         0.877         0.001           Pakistan         0.857         0.001           Pakistan         0.816         1.718           Lao People's Dem. Rep.         0.801         0.063           Austria         0.776         0.646           Anguilla         0.76         0.646           Anguilla         0.752         10.383           French Polynesia         0.713         0.002           China, Hong Kong SAR         0.668         0.143           Turkey         0.643         1.04           Mauritius         0.625         0.07           Sweden         0.61         1.431           India         0.558         5.044           Fmr Fed. Rep. of Germany         0.505         0.256           Germany         0.449         2.866           Libya         0.074         0.09           Israel         0.139         1.025           Vietnam         0.074         0.09           FS Micronesia         0.033         0.0003 <tr< td=""><td>Singapore</td><td>0.937</td><td>2.227</td></tr<>	Singapore	0.937	2.227
New Zealand         0.882         0.145           France         0.877         3.096           Canada         0.874         7.77           Réunion         0.857         0.001           Pakistan         0.816         1.718           Lao People's Dem. Rep.         0.801         0.063           Austria         0.776         0.646           Anguilla         0.76         0.002           China, Hong Kong SAR         0.752         10.383           French Polynesia         0.713         0.002           Panama         0.668         0.143           Turkey         0.643         1.04           Mauritius         0.625         0.07           Sweden         0.61         1.431           India         0.558         5.044           Fmr Fed. Rep. of Germany         0.505         0.256           Germany         0.405         0.028           Israel         0.139         1.025           Vietnam         0.074         0.09           FS Micronesia         0.033         0.0003           State of Palestine         0.03         0.00031	Hungary	0.909	1.126
France         0.877         3.096           Canada         0.874         7.77           Réunion         0.857         0.001           Pakistan         0.816         1.718           Lao People's Dem. Rep.         0.801         0.063           Austria         0.776         0.646           Anguilla         0.76         0.002           China, Hong Kong SAR         0.752         10.383           French Polynesia         0.713         0.002           Panama         0.668         0.143           Turkey         0.643         1.04           Mauritius         0.625         0.07           Sweden         0.61         1.431           India         0.558         5.044           Fmr Fed. Rep. of Germany         0.505         0.256           Germany         0.405         0.028           Israel         0.139         1.025           Vietnam         0.074         0.09           FS Micronesia         0.033         0.005           State of Palestine         0.03         0.0003           Turkmenistan         0.004         0.00001	New Zealand	0.882	0.145
Canada         0.874         7.77           Réunion         0.857         0.001           Pakistan         0.816         1.718           Lao People's Dem. Rep.         0.801         0.063           Austria         0.776         0.646           Anguilla         0.76         0.002           China, Hong Kong SAR         0.752         10.383           French Polynesia         0.713         0.002           Panama         0.668         0.143           Turkey         0.643         1.04           Mauritius         0.625         0.07           Sweden         0.61         1.431           India         0.558         5.044           Fmr Fed. Rep. of Germany         0.505         0.256           Germany         0.405         0.028           Israel         0.139         1.025           Vietnam         0.074         0.99           FS Micronesia         0.033         0.0003           State of Palestine         0.03         0.0003	France	0.877	3.096
Réunion         0.857         0.001           Pakistan         0.816         1.718           Lao People's Dem. Rep.         0.801         0.063           Austria         0.776         0.646           Anguilla         0.76         0.002           China, Hong Kong SAR         0.752         10.383           French Polynesia         0.713         0.002           Panama         0.668         0.143           Turkey         0.643         1.04           Mauritius         0.625         0.07           Sweden         0.61         1.431           India         0.558         5.044           Fmr Fed. Rep. of Germany         0.505         0.256           Germany         0.449         2.866           Libya         0.139         1.025           Vietnam         0.074         0.09           FS Micronesia         0.033         0.005           State of Palestine         0.03         0.00031           Turkmenistan         0.004         0.000001	Canada	0.874	7.77
Pakustan         0.816         1.718           Lao People's Dem. Rep.         0.801         0.063           Austria         0.776         0.646           Anguilla         0.76         0.002           China, Hong Kong SAR         0.752         10.383           French Polynesia         0.713         0.002           Panama         0.668         0.143           Turkey         0.643         1.04           Mauritius         0.625         0.07           Sweden         0.61         1.431           India         0.558         5.044           Fmr Fed. Rep. of Germany         0.505         0.256           Germany         0.449         2.866           Libya         0.074         0.028           Israel         0.139         1.025           Vietnam         0.074         0.09           FS Micronesia         0.033         0.005           State of Palestine         0.03         0.00031	Reunion	0.857	0.001
Lao People's Dem. Rep.         0.801         0.063           Austria         0.776         0.646           Anguilla         0.76         0.002           China, Hong Kong SAR         0.752         10.383           French Polynesia         0.713         0.002           Panama         0.668         0.143           Turkey         0.643         1.04           Mauritius         0.625         0.07           Sweden         0.61         1.431           India         0.558         5.044           Fmr Fed. Rep. of Germany         0.505         0.256           Germany         0.449         2.866           Libya         0.139         1.025           Israel         0.133         0.005           State of Palestine         0.03         0.0003           Turkmenistan         0.004         0.00001	Pakistan	0.816	1.718
Austria         0.776         0.646           Anguilla         0.76         0.002           China, Hong Kong SAR         0.752         10.383           French Polynesia         0.713         0.002           Panama         0.668         0.143           Turkey         0.643         1.04           Mauritius         0.625         0.07           Sweden         0.61         1.431           India         0.558         5.044           Fmr Fed. Rep. of Germany         0.505         0.256           Germany         0.405         0.028           Israel         0.139         1.025           Vietnam         0.074         0.09           FS Micronesia         0.033         0.005           State of Palestine         0.03         0.00001	Lao People's Dem. Rep.	0.801	0.063
Anguila         0.76         0.002           China, Hong Kong SAR         0.752         10.383           French Polynesia         0.713         0.002           Panama         0.668         0.143           Turkey         0.643         1.04           Mauritius         0.625         0.07           Sweden         0.61         1.431           India         0.558         5.044           Fmr Fed. Rep. of Germany         0.505         0.256           Germany         0.405         0.028           Libya         0.139         1.025           Vietnam         0.074         0.09           FS Micronesia         0.03         0.0003           Turkmenistan         0.004         0.00001	Austria	0.776	0.646
China, Hong Kong SAR         0.752         10.383           French Polynesia         0.713         0.002           Panama         0.668         0.143           Turkey         0.643         1.04           Mauritius         0.625         0.07           Sweden         0.61         1.431           India         0.558         5.044           Fmr Fed. Rep. of Germany         0.505         0.256           Germany         0.405         0.028           Israel         0.139         1.025           Vietnam         0.074         0.09           FS Micronesia         0.03         0.0003           Turkmenistan         0.004         0.00001	Anguilla	0.76	0.002
French Polynesia         0.713         0.002           Panama         0.668         0.143           Turkey         0.643         1.04           Mauritius         0.625         0.07           Sweden         0.61         1.431           India         0.558         5.044           Fmr Fed. Rep. of Germany         0.505         0.256           Germany         0.449         2.866           Libya         0.139         1.025           Vietnam         0.074         0.09           FS Micronesia         0.033         0.005           State of Palestine         0.03         0.00001	China, Hong Kong SAR	0.752	10.383
Panama         0.668         0.143           Turkey         0.643         1.04           Mauritius         0.625         0.07           Sweden         0.61         1.431           India         0.558         5.044           Fmr Fed. Rep. of Germany         0.505         0.256           Germany         0.449         2.866           Libya         0.139         1.025           Israel         0.139         0.09           FS Micronesia         0.033         0.005           State of Palestine         0.03         0.00001	French Polynesia	0.713	0.002
Turkey         0.643         1.04           Mauritius         0.625         0.07           Sweden         0.61         1.431           India         0.558         5.044           Fmr Fed. Rep. of Germany         0.505         0.256           Germany         0.449         2.866           Libya         0.405         0.028           Israel         0.139         1.025           Vietnam         0.074         0.09           FS Micronesia         0.033         0.005           State of Palestine         0.03         0.00003           Turkmenistan         0.004         0.000001	Panama	0.668	0.143
Mauritus         0.625         0.07           Sweden         0.61         1.431           India         0.558         5.044           Fmr Fed. Rep. of Germany         0.505         0.256           Germany         0.409         2.866           Libya         0.405         0.028           Israel         0.139         1.025           Vietnam         0.074         0.09           FS Micronesia         0.03         0.0003           Turkmenistan         0.004         0.000001	Turkey	0.643	1.04
Sweden         0.61         1.431           India         0.558         5.044           Fmr Fed. Rep. of Germany         0.505         0.256           Germany         0.449         2.866           Libya         0.405         0.028           Israel         0.139         1.025           Vietnam         0.074         0.09           FS Micronesia         0.03         0.0003           Turkmenistan         0.004         0.000001	Mauritius	0.625	0.07
India         0.558         5.044           Fmr Fed. Rep. of Germany         0.505         0.256           Germany         0.449         2.866           Libya         0.405         0.028           Israel         0.139         1.025           Vietnam         0.074         0.09           FS Micronesia         0.03         0.0003           Turkmenistan         0.004         0.000001	Sweden	0.61	1.431
Fmr Fed. Rep. of Germany         0.505         0.256           Germany         0.449         2.866           Libya         0.405         0.028           Israel         0.139         1.025           Vietnam         0.074         0.09           FS Micronesia         0.033         0.005           State of Palestine         0.03         0.00001	India	0.558	5.044
Germany         0.449         2.866           Libya         0.405         0.028           Israel         0.139         1.025           Vietnam         0.074         0.09           FS Micronesia         0.033         0.005           State of Palestine         0.03         0.0003           Turkmenistan         0.004         0.00001	Fmr Fed. Rep. of Germany	0.505	0.256
Libya         0.405         0.028           Israel         0.139         1.025           Vietnam         0.074         0.09           FS Micronesia         0.033         0.005           State of Palestine         0.03         0.0003           Turkmenistan         0.004         0.00001	Germany	0.449	2.866
Israel         0.139         1.025           Vietnam         0.074         0.09           FS Micronesia         0.033         0.005           State of Palestine         0.03         0.0003           Turkmenistan         0.004         0.00001	Libya	0.405	0.028
Vietnam         0.074         0.09           FS Micronesia         0.033         0.005           State of Palestine         0.03         0.0003           Turkmenistan         0.004         0.00001	Israel	0.139	1.025
FS Micronesia         0.033         0.005           State of Palestine         0.03         0.0003           Turkmenistan         0.004         0.00001	Vietnam	0.074	0.09
state of Palestine         0.03         0.0003           Turkmenistan         0.004         0.00001	FS Micronesia	0.033	0.005
1urkmenistan 0.004 0.000001	State of Palestine	0.03	0.0003
	i urkmenistan	0.004	0.000001

Fig. 5 shows the relationship of unit prices (after log transformation) and their rankings (in ascending order), the records were extracted from UN Comtrade with HS0 code 521,213. For example, if a record's unit price is 2 USD/kg and ranks 65<sup>th</sup> largest unit price among all these unit prices, its coordinate in Fig. 5 will be (65,log(2)). It should be mentioned that the slope in Fig. 5 measures the degree of density of unit price. If two points are lined in the figure, for example (x1, y1) and (x2, y2), the slope of this line equals to  $\frac{y_2-y_1}{x_2-x_1}$ . If the difference between y1 and y2 is big, the slope will be large, indicating that the first data's unit price is considerably larger than the second data. In this situation, if  $(x_2 - x_1)$  is small, it indicates that the density near such unit price is small because even the nearest point is considerably larger than that value. Therefore, the higher slope indicates lower density in that value; conversely, the lower slope indicates higher density. For example, when  $x \in (10,000, 40,000)$ ,

Table A7

The deviation index of commodities in HS0 2-digit, ordered by deviation index.

Chapte	er	Deviation index
85	Electrical, electronic equipment	60.129
84	Nuclear reactors, boilers, machinery, etc	44.065
62	Articles of apparel, accessories, not knit or crochet	34.456
00 01	Articles of apparel, accessories, knit or crochet	33.080
28	Inorganic chemicals, precious metal compound, isotope	21.547
29	Organic chemicals	18.976
71	Pearls, precious stones, metals, coins, etc	16.797
96	Miscellaneous manufactured articles	16.575
91 70	Clocks and watches and parts thereof	15.836
73 72	Iron and steel	11.904
25	Salt, sulphur, earth, stone, plaster, lime and cement	8.747
82	Tools, implements, cutlery, etc of base metal	8.627
95	Toys, games, sports requisites	7.102
52	Cotton	6.218
39	Plastics and articles thereof	5.707
55 27	Mineral fuels oils distillation products etc	5 359
40	Rubber and articles thereof	5.298
68	Stone, plaster, cement, asbestos, mica, etc articles	4.830
74	Copper and articles thereof	4.784
30	Pharmaceutical products	4.646
48	Paper & paperboard, articles of pulp, paper and board	4.502
44 81	Other base metals, cermets, articles thereof	4.394
38	Miscellaneous chemical products	4.009
54	manmade filaments	3.993
12	Oil seed, oleagic fruits, grain, seed, fruit, etc, ne	3.914
76	Aluminium and articles thereof	3.913
42	Articles of leather, animal gut, harness, travel good	3.817
87 37	Photographic or cinematographic goods	3.592
58	Special woven or tufted fabric, lace, tapestry etc	3.495
63	Other made textile articles, sets, worn clothing etc	3.249
03	Fish, crustaceans, molluscs, aquatic invertebrates ne	3.095
83	Miscellaneous articles of base metal	3.036
70	Glass and glassware	2.854
33	Essential oils, perfumes, cosmetics, toileteries	2.683
32	Tanning, dyeing extracts, tannins, derivs, pigments et	2.613
89	Ships, boats and other floating structures	2.569
26	Ores, slag and ash	2.308
92	Musical instruments, parts and accessories	2.260
69	Ceramic products	2.140
93	Arms and ammunition, parts and accessories thereof	2.016
94	Furniture, lighting, signs, prefabricated buildings	1.964
15	Animal, vegetable fats and oils, cleavage products, et	1.898
22	Beverages, spirits and vinegar	1.778
49	Printed books newspapers nictures etc	1.639
65	Headgear and parts thereof	1.639
01	Live animals	1.614
41	Raw hides and skins (other than furskins) and leather	1.549
80 E6	Tin and articles thereof	1.447
50 31	Fertilizers	1.435
66	Umbrellas, walking-sticks, seat-sticks, whips, etc	1.401
20	Vegetable, fruit, nut, etc food preparations	1.388
11	Milling products, malt, starches, inulin, wheat glute	1.352
04	Dairy products, eggs, honey, edible animal product nes	1.349
05	Products of animal origin, nes	1.337
97 08	Edible fruit nuts peel of citrus fruit melons	1.320
86	Railway, tramway locomotives, rolling stock, equipmen	1.296
43	Furskins and artificial fur, manufactures thereof	1.287
59	Impregnated, coated or laminated textile fabric	1.206
09	Coffee, tea, mate and spices	1.171
75 24	NICKEI AND ATLICIES INFREDI Tobacco and manufactured tobacco substitutes	1.059
64	Footwear, gaiters and the like, parts thereof	1.029
13	Lac, gums, resins, vegetable saps and extracts nes	0.998
34	Soaps, lubricants, waxes, candles, modelling pastes	0.990

#### Table A7 (continued)

Chapt	Deviation index	
53	Vegetable textile fibres nes, paper yarn, woven fabri	0.989
51	Wool, animal hair, horsehair yarn and fabric thereof	0.977
17	Sugars and sugar confectionery	0.973
57	Carpets and other textile floor coverings	0.942
14	Vegetable plaiting materials, vegetable products nes	0.914
02	Meat and edible meat offal	0.867
47	Pulp of wood, fibrous cellulosic material, waste etc	0.860
10	Cereals	0.850
79	Zinc and articles thereof	0.850
78	Lead and articles thereof	0.812
21	Miscellaneous edible preparations	0.745
36	Explosives, pyrotechnics, matches, pyrophorics, etc	0.697
23	Residues, wastes of food industry, animal fodder	0.661
16	Meat, fish and seafood food preparations nes	0.649
35	Albuminoids, modified starches, glues, enzymes	0.581
60	Knitted or crocheted fabric	0.559
50	Silk	0.496
45	Cork and articles of cork	0.485
19	Cereal, flour, starch, milk preparations and products	0.466
67	Bird skin, feathers, artificial flowers, human hair	0.255
18	Cocoa and cocoa preparations	0.237
46	Manufactures of plaiting material, basketwork, etc.	0.142

the slope is slight, and the value of y is about in the range (2,3). This indicates that there are 30,000 data whose logarithm of trade values falls into the range (2,3).

The performance evaluations were conducted on these three methods, and KDE shows its outperformance over others. Intuitively, the method with high performance should ideally choose the point where the slope changes the most, i.e., the blue line in Fig. 5. The black points

and red points are the normal data and outliers after detection, respectively. The three-sigma rule, shown in Fig. 5(a), can only detect those whose unit prices are unusually high due to their violation of the normal distribution assumption. The boxplot method (Fig. 5(b)) can detect both extremely high and low values, but it regards too many observations as outliers. In contrast, the KDE (Fig. 5(c)) more precisely finds the best dividing point separating normal data and outliers. This evaluation for detection methods has been applied to all commodities in UN Comtrade, and all cases show that KDE outperforms the other two.

Existing outlier handling methods mainly include (1) directly removing outliers and (2) replacing outliers with the median unit price. The first method was used, for example, in Gaulier et al. (2008), in which detected outliers are removed. The removed data is nearly 30% of the total amount for calculating International Trade Price Indices. This is effective in calculating the price index because the remaining 70% is still enough to estimate the unit price and show the relative price change. However, it would lose 30% of the weight/trade value if this method is applied to study the trading network. The second was used, for example, in Brewer et al. (2020) to build the food database. In order to test the performance of this method, we randomly chose a part of normal data as outliers and used the median unit price to replace them. The results show that the differences between the replaced and the actual values are enormous for some commodities. This method could be suitable for particular commodities, such as food, but cannot be applied to all. The performance of this method as well as the comparative analysis with other methods can be found in our third manuscript.

Compared with directly removing all the detected outliers, our approach retains a large amount of physical and monetary information. The corrected outliers contain 52 billion tons of net weight and 58



**Fig. 4.** Effects of addressing the outlier issue, by (a) comparing the averaged unit price among original, handled, and monthly market values for the commodity 030,310 in HS0; (b) comparing the original and the handled data over years for the commodity 060,220 in HS0; and comparing net weight values of imports and exports between data (c) with outliers and (d) with outlier-handled.

Outliers with large contributions, which are all reported by South Africa

Period	Flow	Partner	Original Quantity	Net Weight	Trade Value	Handled Net Weight	Contribution to the total changes	Conversion factor
2019	Export	Morocco	133316	258375000	523061	26522	28.83%	1938.06
2019	Export	Mozambique	109595	171541284	429995	123071	19.13%	1565.23
2019	Export	Namibia	366931	122873769	1439642	380097	13.67%	334.87
2019	Export	Zimbabwe	294729	98028588	1156362	201872	10.92%	332.61
2018	Import	Namibia	391314900	391314900	65526	18203	30.19%	1.00
2018	Export	Mozambique	133948	189073101	486339	135100	14.58%	1411.54
2018	Export	Morocco	86876	164247000	315430	87623	12.67%	1890.59
2018	Export	Zimbabwe	165019	139628076	599151	166438	10.76%	846.13

#### Table A9

Transactions reported by other countries to South Africa

Period	Reporter	Flow	Original Quantity Net		Conversion
			Quantity	Weight	luctor
2018	Angola	Import	32233	21905	0.68
2018	Belgium	Import	3522	1154	0.33
2018	Botswana	Import	5030	10555	2.10
2018	China	Import	30	13	0.43
2018	Czechia	Import	35	175	5.00
2018	Germany	Import	250	2	0.01
2018	Italy	Export	244210	1513	0.01
2018	Lebanon	Import	3799	400	0.11
2018	Madagascar	Import	650	50	0.08
2018	Mozambique	Import	549468	161102	0.29
2018	Namibia	Import	59267	49614	0.84
2018	Netherlands	Import	84	56	0.67
2018	Peru	Import	5000	350	0.07
2018	Saudi Arabia	Import	1261	3280	2.60
2018	Zimbabwe	Import	283074	244526	0.86
2018	Spain	Import	10204	9801	0.96
2018	Spain	Export	2159	59	0.03
2018	Eswatini	Import	-	356515	-
2018	United Rep. of	Import	61	20	0.33
	Tanzania				
2018	USA	Export	5600	9512	1.70
2018	Zambia	Import	252776	211874	0.84
2019	Botswana	Import	10430	22849	2.19
2019	Chile	Import	191	345	1.81
2019	China	Import	1549	1617	1.04
2019	Czechia	Import	13	65	5.00
2019	Ghana	Import	-	150	-
2019	Kenya	Import	19498	207	0.01
2019	Rep. of Korea	Import	74	30	0.41
2019	Malawi	Import	106850	53114	0.50
2019	Mauritius	Import	4500	944	0.21
2019	Morocco	Import	183551	6523	0.04
2019	Namibia	Import	230647	194814	0.84
2019	Portugal	Import	50	20	0.40
2019	India	Import	34	1	0.03
2019	Zimbabwe	Import	333199	357839	1.07
2019	Spain	Import	6864	2945	0.43
2019	Spain	Export	875	20	0.02
2019	Eswatini	Import	51229	133022	2.60
2019	Eswatini	Export	4587	18500	4.03
2019	United Arab Emirates	Import	117027	152080	1.30
2019	Tunisia	Import	638	9	0.01
2019	Egypt	Import	52650	50410	0.96
2019	United Kingdom	Import	1232	84	0.07
2019	USA	Export	5325	6672	1.25
2019	Zambia	Import	495492	659643	1.33
2019	Zambia	Export	9109	13500	1.48
2019	United Arab	Export	11897	94	0.01
2019	Peru	Import	139802	443	0.00

billion USD of trade value in total. Simply removing the outliers will lose a great amount of information. The comparison of our method and the median unit price method will be presented in the next article discussing the missing value issue of UN Comtrade. Although our methods have been proved effective and efficient, there still are some limitations that have to be noted in practical applications. First, despite an overall improvement in data quality, it is possible that our method may introduce a marginal level of errors. Specifically, some identified outliers might be trade value errors rather than weight value errors and vice versa, because the exact causes are unlikely to be covered just based on data values. More supporting information (e.g., raw data) is required. Besides, there may exist some detected outliers that are not caused by misreporting but related to actual events, for example, war, disaster, pandemic, etc. Ideally, to further improve the data quality, the detected outliers should be analyzed by trying to consider their real causes.

Second, for the handling method, there are several substantive thresholds in the decision criteria (e.g., 0.4 in Eq. (5)), which may omit a small number of data that uses ton as the net weight units. Moreover, for transaction data that are only provided by one side (i.e., exporter or importer), *criterion 3* is not able to determine whether the outliers are caused by the unit. In other words, *criterion 3* is only applicable for a small portion of the detected outliers, as only less than 50% of the commodity trade data are reported by both the importer and exporter in UN Comtrade. For a specific purpose, the detected outlier should be manually and thoroughly checked if it is precisely caused by unit misuse.

#### 5. Conclusions

This study develops a general framework to address the outlier issue in UN Comtrade. By this framework, the results show that, from 1988 to 2019, 1.9% of the total amount of data are outliers, which may be few in numbers but cause significant biases, especially in physical trade flow analysis. The proportion of outliers is higher in the data reported by least developed countries/areas. Fourteen reporters have misused the unit of net weight, in which Chile and Other Asia have the most outliers caused by unit misuse. The results also uncover that outliers in data reported by South Africa, Mexico, and Malaysia have the highest deviation index, indicating their significant impacts and substantial data quality improvement. Furthermore, at the 2-digit level, chapters 85, 84, 62, 61, and 90 are the commodity that is most severely affected by outliers.

After the outlier detection and handling, substantial data quality improvement can be observed. Our work benefits practical applications of UN Comtrade by providing more credible statistical information, reflecting more realistic effects of policies, and offering more accurate trade flows. For example, the original unit price of pacific salmon is abnormally large, but the unit price estimated with handled data is corrected and lies in a normal range. The original unit price and the corrected one differ by approximately 500%.

Compared with previous methods, one of the main advantages of our approach is that it is based on estimating the distribution of data, which can better distinguish outliers from normal data for various commodities. In addition, during handling, we use different methods for different causes of outliers, which could retain both physical and monetary information as much as possible, and could be more applicable than previous methods. As a result, the data quality of UN Comtrade has been improved, which increases the reliability of physical trade analysis.

![](_page_19_Figure_2.jpeg)

Fig. 5. Comparison of three detection methods: (a) three-sigma rules; (b) boxplot; (c) kernel density estimation. Data points in red color are outliers, while those in black color are normal observations. The blue dash line highlights the points with the higher degree of unit price density, which differentiates the outliers and the normal ones.

Based on these results, four primary conclusions can be drawn as follows:

- Outliers exist in UN Comtrade for almost all reporters (207 in 209), all commodities, and all years.
- For some reporters (e.g., China Hong Kong, Canada, USA, China, India, France, Germany) and some commodities with high prices(e. g., electrical or electronic equipment, nuclear reactors, clocks), outliers may be few in numbers but may cause significant biases in analysis.
- The framework of detection and handling adopted in this work is effective and efficient for addressing the issue of outliers in UN Comtrade, although there are some inevitable limitations.
- Our work of handling outliers greatly improves the data quality of UN Comtrade, which could benefit trade flow analyses, especially of physical trade flow, by avoiding data-related bias and uncertainties, and thus benefit policy-maker who would like to make the decision with the data of UN Comtrade.

As the second of our three-part series, this article aims to address the data quality issue of outliers in UN Comtrade. In the next article (Zhang et al., 2022), we will present our procedures for missing values fitting based on the dataset without outliers. With these issues addressed, the improved dataset can be accessed online via https://www.macycle.org/improved-un-comtrade-data/.

#### CRediT authorship contribution statement

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#### **Declaration of Competing Interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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#### Resources, Conservation & Recycling 186 (2022) 106524

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#### Z. Jiang et al.

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