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PHARMACEUTICAL EXPORT PROFILES AND BILATERAL CUSTOMS REPORTING DISCREPANCIES ACROSS MAJOR ECONOMIES IN INTERNATIONAL TRADE NETWORKS

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Abstract:

This analysis examines whether pharmaceutical export scale and composition distinguish bilateral customs reporting disagreement in international trade. UN Comtrade records provide a balanced panel of 60 annual observations across 12 directed trading relationships among China, Germany, the United Kingdom and the United States from 2010 to 2014. Descriptive distributions, ranked groups, Spearman correlations and exploratory sample restrictions characterize absolute symmetric discrepancies between exports and mirror imports. Mean discrepancy is 0.3225, with substantial variation across opposite trade directions. Bulk medicament share exhibits the clearest positive association, with a correlation of 0.4005 and positive correlations across every annual and country omission comparison. Export scale shows weak monotonic correspondence, while retail medicament share produces contrasting mean and rank patterns sensitive to sample composition. These findings distinguish persistent descriptive correspondence from composition dependent patterns without identifying causal mechanisms. The contribution is a pharmaceutical trade measurement framework that preserves direction, product composition and sensitivity when interpreting reporting disagreement. Statistical authorities and trade analysts can use these distinctions to prioritize reconciliation of corresponding records before drawing conclusions from aggregate balances.

Key Words: Pharmaceutical Trade; Mirror Statistics; Reporting Discrepancies; Export Composition; Rank Correlation

1. Introduction:

Pharmaceutical trade statistics can assign different values to the same international flow depending on whether the exporter or importer records it. This disagreement complicates comparisons of market size, trading relationships and export composition because conclusions may depend on the reporting perspective selected. Linsi, Burgoon and Mügge, 2023, demonstrate that discrepancies between mirror trade records can strengthen, weaken or overturn substantive findings about economic interdependence. For pharmaceutical trade, the relevant question therefore extends beyond how much countries exchange to how consistently those exchanges are recorded, and whether disagreement varies with the scale and composition of exports. The measurement problem arises because an international transaction enters separate national recording systems. Export and import values can differ through valuation conventions, shipment timing, partner attribution and commercial intermediation. Wang, Gehlhar and Yao, 2010, show that bilateral reconciliation requires attention to transport valuation, reporting reliability and trade routed through intermediary economies. These mechanisms imply that a reporting discrepancy is an outcome of multiple processes rather than a direct observation of inaccurate declarations. The distinction matters for statistical reconciliation: identifying disagreement provides a basis for examining records, but its magnitude alone cannot establish which authority reports the underlying exchange more accurately.

Existing research also establishes that reporting differences can reflect economic incentives. Ferrantino, Liu and Wang, 2012, examine simultaneous reporting behavior at exporting and importing borders and show that different incentives can contribute to the observed discrepancy in opposing directions. Kellenberg and Levinson, 2019, associate bilateral reporting differences with tariffs, auditing standards, corruption and other national characteristics. Together, these contributions establish that mirror gaps can contain economically meaningful variation while requiring additional information to identify its source. They do not establish whether pharmaceutical export scale, retail medicament share and bulk medicament share exhibit comparable descriptive relationships with reporting disagreement within the same set of trading relationships. Export scale and product composition provide distinct ways to investigate that question. A recording difference of a given monetary size represents a smaller proportional discrepancy when the underlying trade flow is larger. However, larger flows may also involve more transactions and reporting events, allowing absolute differences to accumulate. Product shares introduce a separate distinction between the monetary size of exchange and the types of medicaments recorded within it. Retail and bulk medicament shares describe different customs categories and need not exhibit the same relationship with disagreement. These competing possibilities motivate descriptive comparisons without imposing a predetermined direction or treating composition as a direct measure of reporting behavior.

Aggregation creates a further interpretive challenge. Country totals can conceal differences between individual partners, while a single country pair can contain contrasting reporting patterns across opposite trade directions. Linsi and Mügge, 2019, explain how international commercial structures challenge the correspondence between economic activity and national statistical categories. This perspective supports retaining directed trading relationships and both reporting values rather than reducing

agreement to an aggregate national balance. It also requires separating the magnitude of disagreement from its direction: an absolute discrepancy identifies distance between two records but does not indicate which value is higher. The reviewed evidence leaves a bounded empirical question unresolved: how do pharmaceutical reporting discrepancies vary across export scale and medicament composition, and how sensitive are those patterns to the economies and years included? This analysis addresses that question by examining the three dimensions separately within a common sample. Its contribution is a pharmaceutical comparison that combines directed bilateral records, product shares and explicit composition sensitivity. The approach distinguishes patterns that recur across descriptive comparisons from those that depend on aggregation or sample membership, without attributing either pattern to unmeasured institutional mechanisms.

The empirical setting comprises annual pharmaceutical trade among China, Germany, the United Kingdom and the United States from 2010 to 2014. The balanced panel contains 60 observations covering 12 directed trading relationships. United Nations Comtrade records supply pharmaceutical exports under HS30, corresponding mirror imports, and exporter reported medicament values under HS3004 and HS3003. Export scale is measured as the natural logarithm of HS30 exports. Retail and bulk medicament shares divide the respective heading values by HS30 exports. Absolute reporting discrepancy divides the absolute difference between exports and mirror imports by their arithmetic mean. Source references preserve the connection between each calculated measure and its underlying records. This analysis aims to characterize pharmaceutical customs reporting disagreement and examine how it varies with export scale, retail medicament shares and bulk medicament share. The central research question asks whether these dimensions display distinct descriptive relationships with disagreement across the observed trading relationships and years. Annual summaries, comparisons across directed relationships, ranked groups and Spearman correlations address that question. Exploratory annual and country omission comparisons assess sensitivity to sample composition. The design supports transparent description of the observed panel; it does not identify causal effects or represent all international pharmaceutical trade.

The findings distinguish the three export profile dimensions. Bulk medicament share exhibits a positive descriptive association with reporting discrepancy across the implemented annual and country omission comparisons. Export scale shows limited monotonic correspondence, while retail share produces contrasting mean and rank patterns that depend on sample composition. Substantial differences between opposite trade directions further demonstrate that agreement cannot be summarized adequately by one value for each country pair. These results contribute a basis for organizing pharmaceutical trade reconciliation around direction, product composition and sensitivity of the observed pattern. Their wider relevance lies in how mirror records are compared and interpreted, while the estimated magnitudes remain specific to the sampled economies and period.

2. Theory, Conceptual Framework and Research Questions Development:

Pharmaceutical trade connects commercial transactions with national systems of customs recording. Exporters and importers participate in the same bilateral exchange, but their authorities observe that exchange through different valuation conventions, territorial boundaries and reporting procedures. Consequently, recorded trade reflects both economic activity and the institutions that make that activity statistically observable. Linsi and Mügge, 2019, explain how international production and commercial intermediation challenge the correspondence between national statistical categories and economic transactions. This analysis therefore treats bilateral customs reporting discrepancy as a measure of disagreement between recorded trade values, rather than a direct measure of commercial misconduct. The empirical framework connects pharmaceutical export profiles with the magnitude of disagreement between exporter and importer records. Export profiles comprise three observed measures: the natural logarithm of pharmaceutical exports under HS30, the share of HS3004 medicaments in those exports, and the share of HS3003 medicaments. The outcome is the absolute difference between pharmaceutical exports and corresponding mirror imports, divided by their arithmetic mean. This normalization expresses disagreement relative to the size of the recorded flow. The framework uses these measures separately rather than combining them into an unobserved export profile index.

The available observations cover 12 directed trading relationships among China, Germany, the United Kingdom and the United States from 2010 to 2014, yielding 60 observations. Interpretation concerns these observed relationships and years. The conceptual connection is descriptive: export scale and composition provide dimensions along which reporting discrepancies can be compared. Neither the direction of a discrepancy nor the accuracy of either reporting authority can be established from its absolute magnitude. Linsi et al., 2023, demonstrate that mirror discrepancies can materially alter conclusions about economic interdependence, supporting the treatment of reporting disagreement as an empirical object requiring explicit measurement. Export value captures the scale of pharmaceutical exchange within each directed trading relationship. Under a measurement error mechanism, a recording difference of a given monetary size produces a smaller relative discrepancy when the underlying trade flow is larger. However, larger flows may also involve more transactions, intermediaries and reporting events, allowing absolute differences to accumulate. These mechanisms generate competing expectations about the relationship between export scale and proportional disagreement. Wang et al., 2010, show that reconciling bilateral statistics requires attention to reporting reliability, transport valuation and trade routed through an intermediary economy. Their framework supports interpreting scale alongside the recording environment rather than assuming that larger trade flows necessarily produce more consistent statistics. This analysis also recognizes a mathematical connection between export value and the discrepancy measure because exports enter the outcome denominator and its absolute difference. An observed pattern across export values can therefore reflect normalization as well as differences in reporting consistency. Descriptive comparison can establish how discrepancy magnitudes vary across export scale without attributing that variation to improved customs performance.

RQ1: How does the magnitude of bilateral customs reporting discrepancy vary with pharmaceutical export value across the observed trading relationships and years?

The retail medicament export share captures the proportion of pharmaceutical exports classified under HS3004. It measures composition within recorded exports, rather than medicine quality, regulatory compliance or final consumption. A larger share may concentrate trade in products with more consistent commercial descriptions, potentially facilitating correspondence between export and import records. Conversely, differences in valuation and commercial routing can sustain reporting disagreement even when product categories appear comparable. These are competing theoretical possibilities, not established

effects in the available observations. Ferrantino et al., 2012, demonstrate that discrepancies can vary across product categories and reflect incentives operating on both sides of a transaction. Their evidence establishes that product composition can matter for interpreting reporting gaps, but it does not establish a directional relationship for pharmaceutical retail shares. Accordingly, the relevant descriptive question concerns whether discrepancy magnitudes differ across the observed composition of exports.

RQ2: How does the magnitude of bilateral customs reporting discrepancy vary with the retail medicament share of pharmaceutical exports?

The bulk medicament export share captures the proportion of pharmaceutical exports classified under HS3003. Unlike the retail share, this measure identifies medicaments outside measured doses or retail packaging within the relevant customs heading. It does not represent all pharmaceutical inputs. Its theoretical relevance lies in whether differences in the commercial form of traded medicaments correspond to differences in the consistency of customs records. Institutional incentives can affect how transactions are declared and checked, but the available composition measure does not observe those incentives directly. Kellenberg and Levinson, 2019, find that bilateral reporting differences vary with tariffs, auditing standards, corruption and other national characteristics. Their findings support an institutional explanation for reporting disagreement while cautioning against interpreting product shares as direct measures of reporting behavior. Here, the bulk share provides an observed basis for comparing discrepancy magnitudes without assigning those differences to particular institutional processes.

RQ3: How does the magnitude of bilateral customs reporting discrepancy vary with the bulk medicament share of pharmaceutical exports?

Together, these questions organize descriptive comparison around export scale and product composition. The retail and bulk shares use the same pharmaceutical export denominator and do not exhaust HS30, which also contains other pharmaceutical categories. They therefore describe distinct components of the export profile rather than opposite ends of a single continuum. The framework permits increasing, decreasing or irregular patterns, including limited observable variation, while keeping interpretation within the recorded trade measures.

3. Data:

This analysis documents the provenance, coverage and construction of annual pharmaceutical trade measures and their corresponding customs reporting discrepancies. The verified dataset supports descriptive comparisons across trading relationships, export values and product shares within the observed period.

3.1 Data Sources, Population, and Sample Construction:

The source is the United Nations Comtrade database, maintained by the United Nations Statistics Division and accessed through its public preview API. The workbook preserves 387 source records, query URLs, retrieval status, classification identifiers and source row references. The extraction date is recorded in the Guide worksheet and is distinct from the observation period. No fixed provider release identifier accompanies the extraction. The dataset represents a historical API snapshot rather than information archived at each original reporting date. Access and reuse remain subject to UN Comtrade terms; public API availability does not establish an unrestricted redistribution licence. The extraction uses annual merchandise trade records with commodity codes 30, 3003 and 3004, export and import flow identifiers X and M, and reporter and partner codes 156, 276, 826 and 842. These country codes identify China, Germany, the United Kingdom and the United States. The query specifies secondary partner code 0, customs procedure code C00 and transport mode code 0. Trade values are annual flows in current United States dollars.

The conceptual target population comprises directed international pharmaceutical trading relationships. The accessible sampling frame is narrower: all 12 directed relationships among the four selected economies. Country selection is purposive, and the workbook does not provide an enumerated global population or a probability sampling design. Accordingly, the observed relationships provide comparative evidence for these economies without representing international pharmaceutical trade as a whole. The unit of analysis is a directed exporter and importer relationship observed in a calendar year. A shipment direction from China to Germany constitutes a different analytical unit from the reverse direction. The retained dataset contains five annual observations for every directed relationship from 2010 to 2014. It therefore forms a balanced panel of 12 relationships and 60 observations, with 12 observations per year and 15 observations per exporting economy. Eligibility requires different exporter and importer countries, an available HS30 export value, a corresponding HS30 mirror import value, available HS3004 and HS3003 export values, and positive HS30 exports. The workbook documents these operational rules but does not establish when they were adopted. Table 1 distinguishes incomplete retrieval from missing fields within retrieved observations.

Table 1: Sample construction and verified coverage

Stage	Units	Observations	Reason or Rule
Candidate frame for 2010 to 2025	12 directed relationships	192	Four selected economies, excluding trade with themselves
Candidate observations not retrieved	12 directed relationships	132	Annual records for 2015 to 2025 were not retrieved after the public API quota was exhausted
Retrieved analytical frame for 2010 to 2014	12 directed relationships	60	Five annual observations for each directed relationship
Exclusions for missing required fields	0 relationships lost	0	All retrieved analytical observations contain the four required trade values
Exclusions for invalid denominators	0 relationships lost	0	All retained HS30 export values and discrepancy denominators are positive
Duplicate analytical observations removed	0 relationships lost	0	No repeated combination of year, exporter and importer was found
Final descriptive sample	12 directed	60	Complete matched observations for 2010 to 2014

Stage	Units	Observations	Reason or Rule
	relationships		

The 132 observations outside the retained period are retrieval gaps, not verified instances of absent trade or unavailable national reporting. They receive no estimated values. Interpretation is restricted to the 60 observed records rather than extended to the full candidate period.

3.2 Data Integration, Cleaning, and Quality Assurance:

Integration matches exporter records with importer mirror records by calendar year, reporting country, partner country, commodity code and trade direction. For each directed relationship, HS30 exports reported by the exporter are paired with HS30 imports reported by the importer from that exporter. HS3004 and HS3003 values come from the exporter's own records. This arrangement preserves a consistent export denominator for both composition measures. The analytical dataset contains 240 source references, comprising four inputs for each of the 60 observations. Verification against the Raw Customs worksheet found no discrepancies in the referenced years, countries, flows, commodity codes or monetary values. No duplicate analytical keys were found. The raw worksheet also contains no duplicate combinations of year, reporter, partner, flow, commodity code and classification. Records for countries trading with themselves remain in the source archive but do not enter the bilateral analytical sample. All observations use annual calendar periods. No frequency conversion, fiscal calendar adjustment or temporal interpolation is applied. Monetary values retain the provider's current dollar units, with no additional exchange rate conversion or inflation adjustment. Consequently, export value measures nominal trade scale rather than changes in pharmaceutical quantities or purchasing power. The source field primary Value supplies the monetary inputs. Export and import valuations are retained as reported, without estimating a freight or insurance adjustment. Wang et al., 2010, show that transport valuation, intermediary trade and reporting reliability matter for reconciling bilateral statistics. Here, these considerations delimit interpretation rather than enter as estimated corrections.

Classification checks show matching revisions on both sides of every retained bilateral observation. Records for 2010 and 2011 use H3, corresponding to HS2007, while records for 2012 to 2014 use H4, corresponding to HS2012. The analysis retains these identifiers and the reported chapter and heading aggregates. Matching classifications within observations does not establish complete comparability across revisions. Temporal differences therefore describe the recorded aggregates without attributing all changes to underlying commercial behavior. All four source values and all four calculated measures are complete across the retained sample. There are no variable specific coverage losses within any retained year or economy. Missing records are not replaced with zero, and no imputation or interpolation is applied. All required source values are positive in the observed sample. Verification found no negative required monetary values, nonpositive denominators, shares outside the interval from zero to one, or discrepancy values outside the interval from zero to two. The combined HS3004 and HS3003 shares remain below one throughout the sample, consistent with the presence of other pharmaceutical categories within HS30. Recalculation reproduced all four derived measures at the stored numerical precision. Extreme values remain part of the descriptive distribution unless a source inconsistency is demonstrated. These checks establish internal arithmetic consistency and traceability; they do not establish that either customs authority reports the underlying transactions without error. Linsi and Mügge, 2019, explain why international commercial structures can create persistent differences between economic activity and national statistical representations.

3.3 Variable Measurement, Construction, and Validation:

Pharmaceutical export profile is operationalized through export scale, retail medicament shares and bulk medicament share. These are separate calculated measures rather than interchangeable indicators of a latent construct. Bilateral customs reporting discrepancy measures the magnitude of disagreement between two recorded values for the same directed annual pharmaceutical flow. Equation 1 defines export scale.

$$X_{1,ijt} = \ln E_{ijt}$$

Here, $X_{1,ijt}$ denotes log export value, E_{ijt} denotes HS30 exports in current United States dollars, iidentifies the exporter, j identifies the importer and t identifies the calendar year. The logarithm is defined because every retained export value is positive. Equation 2 defines the retail medicament export share.

$$X_{2,ijt} = \frac{R_{ijt}}{E_{ijt}}$$

Here, $X_{2,ijt}$ denotes the retail share and R_{ijt} denotes HS3004 exports in current United States dollars. This heading covers relevant medicaments in measured doses or retail packaging. The measure describes export composition rather than medicine quality or actual retail consumption. Equation 3 defines the bulk medicament export share.

$$X_{3,ijt} = \frac{B_{ijt}}{E_{ijt}}$$

Here, $X_{3,ijt}$ denotes the bulk share and B_{ijt} denotes HS3003 exports in current United States dollars. This heading covers relevant mixed medicaments outside measured doses or retail packaging. It does not encompass all pharmaceutical ingredients or intermediate products. Equation 4 defines bilateral customs reporting discrepancy.

$$Y_{ijt} = \frac{2\left|M_{jit} - E_{ijt}\right|}{M_{jit} + E_{ijt}}$$

Here, Y_{ijt} denotes absolute symmetric reporting discrepancy and M_{jit} denotes HS30 imports reported by importer jfrom exporter i. The measure divides the absolute reporting difference by the arithmetic mean of the two values. Zero indicates agreement, while larger values indicate greater proportional disagreement. The absolute transformation removes information about which reported value is higher.

Table 2: Variable dictionary

Variable or Indicator	Analytical Role	Definition and Construction	Source and Identifier	Unit and Frequency	Transformation and Direction	Missing Value Rule	Coverage and Limitation
Pharmaceutical exports	Source measure	Exporter reported HS30 value	UN Comtrade, primary Value, flow X, HS30	Current USD, annual	Higher values indicate larger recorded exports	Require an observed positive value	60 observations; nominal value
Mirror pharmaceutical imports	Source measure	Importer reported HS30 imports from the exporter	UN Comtrade, primary Value, flow M, HS30	Current USD, annual	Higher values indicate larger recorded mirror imports	Require an observed value	60 observations; valuation may differ from exports
Retail medicament exports	Source measure	Exporter reported HS3004 value	UN Comtrade, primary Value, flow X, HS3004	Current USD, annual	Component of the retail share	Require an observed value	60 observations; customs category rather than consumption
Bulk medicament exports	Source measure	Exporter reported HS3003 value	UN Comtrade, primary Value, flow X, HS3003	Current USD, annual	Component of the bulk share	Require an observed value	60 observations; excludes other pharmaceutical inputs
Log export value	Export profile dimension	Equation 1	HS30 exports	Natural log of USD, annual	Higher values indicate larger export scale	Positive export denominator required	60 observations; shares an input with the outcome
Retail medicament share	Export profile dimension	Equation 2	HS3004 and HS30 exports	Fraction, annual	Higher values indicate a larger retail component	Both source values required	60 observations; not a growth rate
Bulk medicament share	Export profile dimension	Equation 3	HS3003 and HS30 exports	Fraction, annual	Higher values indicate a larger bulk component	Both source values required	60 observations; does not complement the retail share to one
Absolute reporting discrepancy	Descriptive outcome	Equation 4	HS30 exports and mirror imports	Ratio, annual	Higher values indicate greater disagreement	Both values and a positive sum required	60 observations; does not identify reporting direction or cause

Table 3 reports unweighted descriptive statistics, giving each directed relationship and year equal weight. Standard deviations use the sample denominator. Shares and discrepancy are displayed as ratios, so a retail share of 0.5306 corresponds to 53.06 percent.

Table 3: Descriptive statistics for the retained sample

Variable	Valid Observations	Mean	Standard Deviation	Median	Minimum	Maximum
Pharmaceutical exports, USD billions	60	3.0671	2.9243	2.1188	0.0998	12.9591
Mirror pharmaceutical imports, USD billions	60	3.3593	3.2490	2.2737	0.1129	14.0885
Retail medicament exports, USD billions	60	1.9612	2.2993	0.9943	0.0235	10.9832
Bulk medicament exports, USD billions	60	0.1462	0.4074	0.0420	0.0011	2.2393
Log export value	60	21.2828	1.2085	21.4736	18.4182	23.2851
Retail medicament share	60	0.5306	0.2654	0.6097	0.0518	0.9296
Bulk medicament share	60	0.0428	0.0651	0.0204	0.0007	0.3446
Absolute reporting discrepancy	60	0.3225	0.2868	0.2473	0.0098	1.1326

The discrepancy ratio can exceed one because its denominator is the mean of exports and mirror imports, rather than the larger value. Such observations remain within its permitted range. Its sample mean is the mean of individual normalized discrepancies, not a discrepancy calculated from aggregate trade totals. Ferrantino et al., 2012, demonstrate that reporting differences can reflect several mechanisms operating simultaneously, reinforcing the distinction between measured disagreement and its underlying causes.

3.4 Analytical Framework, Identification, and Reproducibility:

The analytical framework is descriptive. It characterizes recorded pharmaceutical trade scale, product composition and customs reporting disagreement within the observed panel. The implemented summaries comprise valid counts, arithmetic means, sample standard deviations, medians and ranges. They describe the retained observations without estimating causal effects or population parameters. Export scale and both composition measures share the HS30 export value with the discrepancy calculation. Consequently, patterns between these measures can reflect mathematical dependence as well as commercial or reporting differences. The same trading relationships also recur annually, while different relationships share exporting and importing economies. The 60 records therefore do not constitute 60 independent country samples. Reporting discrepancy is not assigned to either authority as an error estimate. Linsi et al., 2023, show that choosing one side of mirror trade records can affect substantive conclusions about international exchange. Retaining both reported values and their source references preserves this measurement distinction.

The interpretation also remains separate from institutional explanations that are not directly measured. Kellenberg and Levinson, 2019, identify relationships between reporting differences and tariffs, auditing standards and national institutional characteristics. The present data contain trade values and classifications rather than direct observations of those mechanisms. Accordingly, descriptive differences are interpreted as patterns in recorded trade, without attributing them to particular incentives or administrative practices. Reproducibility rests on the workbook's linked documentation. Raw Customs preserves source values and reporting metadata. Coverage distinguishes included observations from retrieval gaps. Dataset records the four monetary inputs, calculated measures, classification identifiers and source row references. Guide documents variable definitions, eligibility rules and query URLs. These elements permit reconstruction of the retained sample and verification of Equations 1 to 4 against the archived inputs. The aligned calendar periods, country identifiers, commodity definitions and units provide a consistent basis for the descriptive comparisons. Interpretation remains bounded by the purposive geographical frame, the observed period,

nominal valuation and the classification change. Arithmetic verification supports the reproducibility of the measures while preserving the distinction between internally consistent calculations and independently verified transaction values.

4. Methods:

4.1 Research Design and Analytical Scope:

This analysis uses a descriptive panel design to examine how pharmaceutical customs reporting disagreement varies with export scale and medicament composition. The unit of analysis is a directed trading relationship observed annually. The balanced sample contains 60 observations across 12 relationships among China, Germany, the United Kingdom and the United States from 2010 to 2014. Table 1 documents sample construction, while Table 2 defines the source measures and calculated indicators. The analytical targets are the distribution of absolute reporting discrepancies and their unadjusted correspondence with three export profile dimensions. Variation arises across trading relationships and across years within each relationship. The pooled comparisons combine these sources of variation without separating them into independent effects. Opposite trade directions remain distinct because their reported values and product compositions differ. The design describes the retained observations rather than estimating population effects. Country selection is purposive, and the observed records do not supply an independently assigned exposure or comparison group. Accordingly, correlations and group differences are interpreted as descriptive associations. This distinction is consequential because mirror trade records can differ systematically, and selecting one reporting perspective can affect substantive interpretation, as demonstrated by Linsi et al. (2023).

4.2 Measurement Alignment and Descriptive Comparisons:

The analysis uses the measures defined in Equations 1 to 4. Log export value represents nominal pharmaceutical export scale. Retail and bulk medicament shares describe separate components of pharmaceutical exports. Absolute symmetric discrepancy measures the distance between exporter reported exports and corresponding importer reported imports relative to their arithmetic mean. All measures refer to the same directed relationship and calendar year. The descriptive sequence first characterizes the common sample using valid counts, arithmetic means, sample standard deviations, medians and observed ranges. Standard deviations use the number of observations less one as the denominator. Monetary values are displayed in billions of United States dollars where this improves readability; calculations retain the original dollar values. Shares and discrepancies remain ratios throughout computation. Annual comparisons sum export and mirror import values separately and calculate unweighted means and medians of individual discrepancy ratios. The mean discrepancy therefore differs conceptually from a discrepancy calculated from aggregate trade totals. Counts of observations in which imports exceed exports, or exports exceed imports, retain information about reporting direction that the absolute discrepancy removes.

Comparisons across directed relationships calculate mean export values, mean product shares and discrepancy summaries over the five observed years. Each relationship contributes equally to the pooled sample because coverage is balanced. These comparisons preserve directional differences without assigning either reporting authority priority. Wang et al. (2010) identify valuation, intermediary trade and reporting reliability as distinct considerations in bilateral reconciliation; the implemented summaries measure disagreement without estimating corrections for those processes. For each export profile dimension, the 60 observations are divided independently into three groups using the empirical quantiles at one third and two thirds. The resulting lower, middle and upper groups each contain 20 observations. Means and medians of discrepancy are calculated within each group. Group membership is dimension specific, so the upper group for export scale need not contain the same observations as the upper group for either product share. These exploratory comparisons assess distributional patterns without imposing a linear relationship.

4.3 Rank Associations and Exploratory Sensitivity:

Spearman rank correlations summarize monotonic correspondence between each export profile dimension and reporting discrepancy. Each correlation uses the same 60 complete observations. Ranking reduces the direct influence of monetary magnitude on the association summary, while preserving the ordering of observations. Equation 5 specifies the implemented rank correlation.

$$\rho_s = \frac{\sum_{k=1}^{n}(r_k - \bar{r})\,(s_k - \bar{s})}{\sqrt{\sum_{k=1}^{n}(r_k - \bar{r})^2 \sum_{k=1}^{n}(s_k - \bar{s})^2}}$$

Here, ρ_s denotes the Spearman correlation, kindexes observations, n denotes the sample size, r_k denotes the rank of the selected export profile measure, s_k denotes the rank of reporting discrepancy, and $\bar{r}$and $\bar{s}$denote their respective mean ranks. Tied values receive average ranks. Positive values indicate that higher ranked profile values tend to accompany higher ranked discrepancies; negative values indicate the opposite ordering. Rank correlations complement rather than replace the grouped comparisons. Group means depend on discrepancy magnitudes, whereas rank correlations depend on relative ordering. Their directions can therefore differ without constituting a computational inconsistency. Both summaries are retained to distinguish changes in distributional magnitude from monotonic correspondence.

Two exploratory sensitivity procedures assess sample composition. First, correlations are recalculated separately for each year using 12 directed relationships. Second, all observations involving one economy as either exporter or importer are removed, and correlations are recalculated among the remaining three economies. Each omission sample contains six directed relationships and 30 observations. Ranks are recalculated within every restricted sample. Sensitivity is assessed through changes in sign and magnitude. Annual comparisons examine temporal variation in the descriptive association, while country omissions assess dependence on particular national trading relationships. These checks change the analytical sample and do not isolate an institutional effect. Their exploratory status distinguishes them from prespecified confirmatory tests. Correlations are reported without conventional significance tests or confidence intervals. Repeated observations share trading relationships, exporters and importers, so treating all records as independent would provide an unsuitable basis for routine correlation inference. Moreover, pharmaceutical exports enter both the profile measures and the discrepancy calculation. Rank transformation does not remove this mathematical dependence. The resulting coefficients therefore describe observed correspondence rather than independently identified commercial mechanisms.

4.4 Verification, Implementation and Reproducibility:

Verification begins with the cleaned analytical records and their source references. Each observation's four monetary inputs is checked against the Raw Customs worksheet for year, reporting country, partner country, commodity code, trade direction and recorded value. Analytical uniqueness is assessed using year, exporter and importer. Raw record uniqueness additionally includes trade direction, commodity code and classification. The calculated measures are independently recomputed from their monetary inputs and compared with the stored values. Domain checks assess positive export denominators, positive discrepancy denominators, nonnegative monetary values, product shares within zero and one, and discrepancies within zero and two. Classification identifiers are inspected across reporting perspectives and years. These procedures assess traceability and arithmetic consistency without treating agreement with archived inputs as independent verification of the underlying transactions.
The common sample contains complete values for all required measures. No imputation, interpolation, trimming or winsorization is applied. Observed extreme discrepancies remain in the calculations. Means, medians, ranked groups and composition checks provide complementary descriptions of their influence without introducing discretionary deletion thresholds.

Calculations use Python 3.12.14, pandas 2.2.3, NumPy 2.3.5 and openpyxl 3.1.5. Workbook values are read with cached formula results available, and derived measures are recalculated from the source inputs. The implementation uses pandas' descriptive summaries, empirical quantile grouping and Spearman correlation routines. All procedures are deterministic and require no random seed. Replication is supported by the Raw Customs, Dataset, Coverage and Guide worksheets. Together, these preserve source values, analytical identifiers, observation status, query URLs, definitions and source row references. The processing sequence proceeds from source verification to measure reconstruction, pooled summaries, annual and relationship comparisons, grouped comparisons, rank correlations and sensitivity calculations. This alignment permits reconstruction of the reported descriptive evidence while maintaining its geographical, temporal and measurement boundaries.

5. Findings:

This analysis examines how pharmaceutical customs reporting discrepancies vary with export scale and product composition. The findings combine annual comparisons, trading relationship profiles and exploratory descriptive associations across 60 observations. Interpretation distinguishes observed reporting disagreement from causal effects and the accuracy of either reporting authority.

5.1 Distribution and Temporal Variation in Reporting Discrepancies:

The analytical sample comprises 12 directed trading relationships among China, Germany, the United Kingdom and the United States, observed annually from 2010 to 2014. Each relationship contributes five observations. All retained observations contain the monetary inputs required to calculate export scale, retail medicament share, bulk medicament share and absolute reporting discrepancy. The comparisons therefore use a common sample without variable specific losses. Across the 60 observations, mean absolute reporting discrepancy is 0.3225, compared with a median of 0.2473 and a standard deviation of 0.2868. The mean exceeds the median, indicating that observations with larger discrepancies raise the average above the distribution's midpoint. Fourteen observations exceed 0.5000, while four exceed 1.0000. These values measure disagreement relative to the average of exporter and importer records, rather than relative to exports alone.

Table 4: Annual pharmaceutical trade values and reporting discrepancies

Year	Observations	Reported Exports, USD Billions	Mirror Imports, USD Billions	Mean Discrepancy	Median Discrepancy
2010	12	33.117	35.956	0.2428	0.2116
2011	12	32.586	37.093	0.3250	0.2382
2012	12	37.296	41.272	0.3403	0.2203
2013	12	37.266	40.673	0.3583	0.2473
2014	12	43.759	46.564	0.3462	0.2723

Mean discrepancy rises from 0.2428 in 2010 to 0.3462 in 2014, an increase of 0.1033 ratio units. The trajectory is not continuous: the mean reaches 0.3583 in 2013 before declining in 2014. Median discrepancy follows a different path, declining in 2012 while the mean increases. This divergence indicates that changes in the distribution's upper values contribute to the annual mean pattern. Reported exports total USD 184.023 billion across the sample, compared with USD 201.558 billion in mirror imports. Nevertheless, imports exceed exports in exactly 30 observations, while exports exceed imports in the other 30. The aggregate excess of imports therefore reflects the monetary magnitude of reporting differences rather than a greater frequency of import values exceeding export values. Aggregate balance and observation level agreement capture different properties of the records. The evidence supports retaining both reporting perspectives. Linsi, Burgoon and Mügge, 2023, demonstrate that mirror discrepancies can affect substantive conclusions drawn from international trade statistics. Here, the equal frequency of opposite reporting directions coexists with a substantial aggregate difference.

5.2 Concentration Across Directed Trading Relationships:

Reporting disagreement varies substantially across trading relationships. Table 5 presents the mean discrepancy for each direction separately, preserving the distinction between exports from one economy and exports in the reverse direction.

Table 5: Reporting discrepancies by directed trading relationship

Exporter	Importer	Observations	Mean Discrepancy	Minimum	Maximum
China	Germany	5	0.2010	0.1034	0.3540
China	United Kingdom	5	0.0804	0.0098	0.1234
China	United States	5	0.0516	0.0252	0.0905
Germany	China	5	0.4566	0.3704	0.5922
Germany	United Kingdom	5	0.0661	0.0125	0.1030

Exporter	Importer	Observations	Mean Discrepancy	Minimum	Maximum
Germany	United States	5	0.1657	0.0835	0.2998
United Kingdom	China	5	0.3015	0.1907	0.4359
United Kingdom	Germany	5	0.3450	0.0266	0.5522
United Kingdom	United States	5	0.5361	0.3037	0.6517
United States	China	5	0.5667	0.4404	0.6170
United States	Germany	5	0.9569	0.3619	1.1326
United States	United Kingdom	5	0.1428	0.0787	0.1826

Exports from the United States to Germany exhibit the largest mean discrepancy, at 0.9569, whereas exports from China to the United States exhibit the smallest, at 0.0516. The difference between these relationship means is 0.9053 ratio units. The largest individual discrepancy occurs for United States exports to Germany in 2012, when reported exports are approximately USD 2.558 billion and mirror imports are USD 9.238 billion. The corresponding discrepancy is 1.1326. Opposite trade directions display markedly different reporting profiles. Mean discrepancy is 0.9569 for United States exports to Germany but 0.1657 for German exports to the United States. Likewise, the United Kingdom to United States direction records a mean of 0.5361, compared with 0.1428 in the reverse direction. Reporting agreement is therefore a property of the directed flow rather than a uniform characteristic of a country pair. These differences establish heterogeneity without identifying its source. Wang, Gehlhar and Yao, 2010, distinguish valuation, intermediary trade and reporting reliability in bilateral reconciliation. The present relationship comparisons measure their possible combined expression in recorded values without separating those mechanisms.

5.3 Export Profiles and Reporting Discrepancies:

To address the three research questions, observations are ranked separately by log export value, retail medicament share and bulk medicament share. Each ranking is divided into three equal groups of 20 observations. These exploratory groups summarize distributional patterns rather than represent predetermined commercial thresholds. Spearman rank correlations provide complementary descriptions of monotonic association across the full sample.

Table 6: Reporting discrepancies across export profile groups

Export Profile Dimension	Ranked Group	Observations	Mean Discrepancy	Median Discrepancy
Log export value	Lower third	20	0.2329	0.1297
Log export value	Middle third	20	0.4578	0.3709
Log export value	Upper third	20	0.2769	0.1737
Retail medicament share	Lower third	20	0.3476	0.1297
Retail medicament share	Middle third	20	0.3308	0.3257
Retail medicament share	Upper third	20	0.2892	0.2943
Bulk medicament share	Lower third	20	0.2180	0.1302
Bulk medicament share	Middle third	20	0.2945	0.2191
Bulk medicament share	Upper third	20	0.4551	0.4527

For export scale, mean discrepancy is greatest in the middle third rather than the upper third. The upper third exceeds the lower third by 0.0440 ratio units, but both fall below the middle group. The pooled Spearman correlation is 0.0884. RQ1 is therefore answered by a weak monotonic association alongside a more pronounced middle group concentration. The observed comparisons do not support a uniform increase or decrease in reporting disagreement across export scale. For retail medicament share, mean discrepancy declines from 0.3476 in the lower third to 0.2892 in the upper third. However, median discrepancy is substantially higher in the upper third than in the lower third. The pooled rank correlation is positive, at 0.1328. These summaries are compatible because group means reflect the magnitude of large discrepancies, whereas rank correlation reflects ordering across individual observations. RQ2 therefore reveals a distribution dependent pattern rather than a consistent directional relationship.

For bulk medicament share, both mean and median discrepancy increase across the three groups. Mean discrepancy rises from 0.2180 in the lower third to 0.4551 in the upper third, a difference of 0.2370 ratio units. Median discrepancy rises from 0.1302 to 0.4527. The pooled Spearman correlation is 0.4005, exceeding the corresponding correlations for export scale and retail share. RQ3 therefore identifies the clearest positive descriptive association among the three export profile dimensions. These patterns concern product composition and reporting disagreement, not the conduct of exporters or importers. Ferrantino, Liu and Wang, 2012, show that reporting gaps can reflect several incentives operating simultaneously and differently across product categories. The observed bulk share association does not isolate any particular behavioral explanation.

5.4 Exploratory Sensitivity and Answers to the Research Questions:

Exploratory sensitivity checks assess whether pooled associations depend on the year or the inclusion of particular economies. Annual correlations use 12 observations each. Country omission checks remove every relationship involving the omitted economy, leaving six directed relationships and 30 observations in each comparison.

Table 7: Sensitivity of descriptive rank associations

Export Profile Dimension	Full Sample Correlation	Annual Correlation Range	Correlation Range After Omitting One Economy
Log export value	0.0884	Negative 0.1538 to positive 0.2867	Negative 0.2814 to positive 0.4051

Export Profile Dimension	Full Sample Correlation	Annual Correlation Range	Correlation Range After Omitting One Economy
Retail medicament share	0.1328	Positive 0.0070 to positive 0.2657	Negative 0.3584 to positive 0.5092
Bulk medicament share	0.4005	Positive 0.1608 to positive 0.5594	Positive 0.2044 to positive 0.6739

The export scale association changes sign across annual comparisons and country omission samples. The retail share association remains positive within each year but becomes negative when all relationships involving China are removed. These changes show that pooled summaries for export scale and retail composition depend on the geographical and temporal composition of the observations. The bulk share association remains positive in every annual comparison and every country omission sample. Its magnitude nevertheless varies substantially. The smallest country omission correlation is 0.2044 after removing relationships involving the United States, while the largest is 0.6739 after removing relationships involving China. The direction is more stable than for the other dimensions, but its strength is sample dependent.

These checks assess composition sensitivity rather than causal identification. Export values enter both the profile measures and the discrepancy calculation, while repeated relationships share national reporting systems. Linsi and Mügge, 2019, identify broader difficulties in aligning international economic activity with national statistical records. The present sensitivity results reinforce the need to preserve those measurement boundaries when interpreting pooled associations. Taken together, the evidence answers the three research questions distinctly. Export scale shows limited monotonic correspondence with discrepancy. Retail share produces contrasting mean and rank patterns that depend on sample composition. Bulk share exhibits a positive descriptive association that persists across the implemented annual and country omission comparisons. None of these patterns identifies the institutional source of reporting disagreement. Kellenberg and Levinson, 2019, examine institutional determinants using additional explanatory information, whereas the present findings establish variation within recorded pharmaceutical trade values and product shares.

6. Discussion:

Agreement in aggregate pharmaceutical trade can conceal substantial disagreement within individual trading relationships. Tables 4 and 5 show that reporting discrepancies depend on trade direction, while Tables 6 and 7 distinguish the comparatively stable positive association for bulk medicament share from the weaker patterns for export scale and retail share. The bulk share correlation of 0.4005 describes an ordering of observed values rather than an estimated causal effect. Read alongside Equations 1 to 4, these results establish that export scale and composition provide different information about reporting disagreement. Linsi, Burgoon and Mügge, 2023, demonstrate how mirror discrepancies affect conclusions about international exchange. This analysis adds a pharmaceutical comparison in which directional heterogeneity and composition sensitivity remain visible within a common observation period. Its contribution is the distinction between dimensions of the export profile, rather than a general claim that larger or more specialized trade produces greater reporting inconsistency. Product composition provides the clearest descriptive differentiation, but the retail and bulk measures carry different empirical signals. In Table 6, both mean and median discrepancy increase across bulk share groups, whereas retail share produces declining group means alongside a positive pooled rank correlation. Equations 2 and 3 identify these measures as shares of recorded pharmaceutical exports, while Equation 4 measures disagreement across reporting systems. Their association therefore concerns the correspondence between commercial composition and statistical consistency. Ferrantino, Liu and Wang, 2012, show that reporting differences can reflect incentives operating simultaneously on both sides of international transactions. The present evidence refines interpretation by showing that composition patterns should be examined separately: a broad pharmaceutical category can contain dimensions with contrasting distributional relationships. The bulk pattern identifies a basis for closer reconciliation of records, while the retail pattern demonstrates why a single average comparison can misrepresent the ordering of individual observations.

The strongest descriptive pattern is not necessarily the most generalizable relationship. Table 7 shows that the bulk share association remains positive across annual comparisons and every country omission sample, although its magnitude changes. Export scale and retail share are more sensitive to the economies included. This distinction separates stability of direction from stability of strength. It also limits interpretations of theoretical dominance: the results identify the bulk dimension as the most consistent descriptive correlate among the three measured dimensions, without assigning it a proportion of explained discrepancy. Wang, Gehlhar and Yao, 2010, emphasize that bilateral reconciliation depends on valuation, intermediary trade and reporting reliability. Against that framework, the present comparisons show that product composition can organize observed disagreement even when its underlying sources remain inseparable. The theoretical implication is that export profiles should retain distinct dimensions rather than collapse scale and composition into a single measure presumed to have a uniform relationship with reporting consistency. Directionality changes the practical unit at which reporting consistency should be assessed. Table 5 shows substantial differences between opposite flows involving the same economies, while Table 4 demonstrates that aggregate mirror imports can exceed exports even when neither reporting direction predominates across observations. Equation 4 preserves the magnitude of disagreement but removes its sign, making the underlying export and import values essential for interpretation. Linsi and Mügge, 2019, explain how international commercial structures challenge national statistical representations. The present evidence makes that measurement problem concrete: a country pair cannot be assigned one reporting consistency profile without losing information about the direction of exchange. For statistical reconciliation, the findings support reviewing directed annual flows and retaining both source values before aggregating results. They also show why aggregate net differences provide an incomplete basis for prioritizing records, since opposite reporting differences can offset one another while substantial individual discrepancies persist.

The international relevance lies in distinguishing observed reporting patterns from explanations that require additional evidence. Kellenberg and Levinson, 2019, associate trade reporting differences with tariffs, auditing standards and institutional characteristics. Here, Tables 5 to 7 show heterogeneity within a sample containing both advanced and emerging economies, but

the comparisons do not establish a corresponding institutional ranking. Instead, they demonstrate that geographical composition can change the apparent relationship between export profiles and disagreement. This redirects practical attention toward transparent reconciliation priorities: retain directional records, compare both means and medians, and examine flows with higher bulk medicament shares without treating that characteristic as evidence of misconduct. Equations 1 to 4 also expose shared monetary inputs across measures, reinforcing the need to distinguish commercial relationships from mathematical dependence. Beyond pharmaceuticals, the contribution is an approach to interpreting mirror trade evidence that preserves product composition, direction and sample sensitivity before drawing broader conclusions about reporting systems.

7. Conclusion and Implications:

International pharmaceutical trade cannot be interpreted reliably through aggregate totals alone. This analysis reveals that reporting disagreement varies across trade directions and commercial composition, while relationships involving scale and finished product concentration depend on how observations are grouped. The core contribution is an empirical distinction between persistent descriptive patterns and associations sensitive to sample composition. This refines the interpretation of customs statistics by showing that agreement belongs to directed trading relationships rather than to countries or country pairs uniformly. The evidence supports treating recorded discrepancies as measurement outcomes requiring reconciliation, without attributing them automatically to misconduct or institutional failure. For managers and statistical authorities, the findings support directing reconciliation resources toward flows with sustained disagreement and examining composition alongside monetary size. Operationally, retaining both reporting perspectives, preserving commodity classifications and comparing distributional summaries can prevent aggregate balances from concealing substantial individual differences. Policy practice should emphasize transparent documentation and coordinated review of corresponding records before discrepancies inform assessments of market exposure or reporting performance. The broader contribution is a transferable approach to interpreting international trade evidence that preserves direction, composition and sensitivity. Applied carefully, this approach can strengthen the statistical basis for commercial decisions and public assessments of pharmaceutical exchange.

The purposive coverage of four economies over five years creates opportunities to assess transferability through broader geographical and temporal replication. Additional commodity detail could establish whether the observed composition pattern persists within narrower pharmaceutical categories. Shipment records, freight valuations and intermediary routing information would permit direct examination of mechanisms that aggregate customs values cannot distinguish. Alternative discrepancy measures could assess sensitivity to shared monetary inputs and normalization choices. Designs incorporating documented reporting reforms or administrative changes could investigate causal relationships. These extensions would clarify which patterns generalize across institutional settings and which reflect particular trading relationships or recording conventions.

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