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ANTIBIOTIC SUPPLIER CONCENTRATION AND IMPORT UNIT VALUES IN GLOBAL TRADE: EVIDENCE FROM ANNUAL CUSTOMS RECORDS

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Abstract:

This analysis examines whether increasing geographic concentration in global antibiotic exports corresponds to higher import unit values. UN Comtrade supplies 3,769 customs records covering 191 reporting economies, aggregated into fifteen annual observations from 2010 to 2024. Descriptive comparisons, Pearson and Spearman correlations, and exploratory sensitivity checks evaluate three complementary concentration measures. The Herfindahl Hirschman index increased by 92.42 percent, while the largest exporter share rose by 19.09 percentage points. However, correlations between concentration and import unit values remained modest, ranging from 0.221 to 0.253. Rank correlations were slightly negative, and excluding the initial observation largely eliminated positive linear alignment. Restricting imports to records without estimated weights likewise produced correlations near zero or negative. These patterns distinguish persistent geographic consolidation from an expenditure relationship sensitive to timing and record composition. The contribution is an empirical qualification of interpretations equating geographic dominance with rising antibiotic prices. International procurement monitoring should assess concentration alongside expenditure composition and weight coverage before drawing affordability conclusions.

Key Words: Antibiotic Trade; Geographic Concentration; Import Unit Values; Descriptive Correlation; Measurement Sensitivity.

1. Introduction:

Geographic concentration in antibiotic trade raises a question that expenditure data cannot answer automatically: does increasing dependence on leading exporting economies coincide with higher import unit values? The distinction matters because antibiotic access depends on sustainable supply as well as affordability. Laxminarayan and colleagues, 2016, identify access to effective antimicrobials as a worldwide health challenge. More recently, Pandey and colleagues, 2025, identify manufacturing disruptions, ingredient availability and economic viability among the drivers of antibiotic shortages. These findings establish the importance of supply structure, but they do not establish that increasing geographic concentration produces a consistent increase in expenditure per kilogram of internationally traded antibiotic chemicals. Concentration and expenditure can move together through competing economic processes. A narrower distribution of export origins may accompany reduced competitive constraints, while production advantages may allow leading exporters to expand without increasing unit values. Industrial organization research distinguishes these possibilities. De Loecker, Eeckhout and Unger, 2020, document changes in firm markups, whereas Autor and colleagues, 2020, examine reallocation toward productive firms alongside increasing concentration. Neither finding implies that concentration across exporting economies directly measures supplier market power. Syverson, 2019, emphasizes that concentration requires interpretation within the relevant market and competitive setting. For antibiotic trade, the theoretical expectation is therefore ambiguous: concentration may accompany higher, lower or relatively stable import unit values.

The closest antibiotic supply literature also cautions against treating geographic dependence as a complete account of economic outcomes. Pandey and colleagues, 2025, synthesize evidence on antibiotic shortages and responses, identifying reliance on single source ingredients and economic viability as relevant conditions. Their review addresses shortages, clinical consequences and management strategies rather than annual relationships between global export shares and customs unit values. Baldwin and Freeman, 2022, similarly distinguish supply chain risks from the outcomes generated through exposure and adjustment. Together, this evidence motivates examining concentration and expenditure separately before interpreting their relationship. Outcome measurement is central to that examination. Customs unit values divide recorded trade expenditure by physical weight; they do not identify the price of an identical product across transactions. Hallak and Schott, 2011, demonstrate that observed unit values combine quality and price components. Manova and Zhang, 2012, document systematic export price differences across firms and destinations, further showing why changes in trading composition affect aggregate comparisons. An increase in antibiotic expenditure per kilogram may therefore reflect changes in the mixture of chemicals and reporting economies rather than a uniform increase in supplier prices. Conversely, stable aggregate unit values may coexist with substantial redistribution of export activity.

The reviewed evidence does not establish whether increasing geographic concentration in antibiotic exports exhibits a consistent descriptive relationship with global import unit values across alternative concentration measures and record inclusion rules. Firm markup research addresses producer behavior, shortage research examines supply interruptions, and trade quality research establishes limitations of unit value interpretation. This analysis connects these concerns through a bounded empirical comparison of export structure and recorded expenditure. Its contribution concerns the consistency of the observed relationship across measurements and temporal comparisons, without equating geographic concentration with firm dominance or customs unit

values with transaction prices. This analysis aims to determine how antibiotic exporting country concentration evolved alongside global import unit values from 2010 to 2024. It asks whether concentration across the full export distribution, dominance by the largest exporting economy and the collective share of the four largest exporters display similar or contrasting relationships with expenditure per kilogram. These dimensions are measured through the Herfindahl Hirschman index, the largest exporter share and the combined share of the four largest exporters. They summarize complementary features of the same export distribution rather than independent causal mechanisms.

The empirical setting comprises UN Comtrade records for antibiotic chemicals under HS heading 2941. The dataset contains 3,769 annual customs records covering 191 reporting economies and produces fifteen global annual observations. Concentration calculations use positive export values, while import unit values use matching positive import values and net weights. The analysis compares annual trajectories, Pearson and Spearman correlations, consecutive annual changes, exclusion of the initial observation and an exploratory restriction to imports without estimated weights. These comparisons assess whether the descriptive relationship persists when timing and record inclusion change. The findings show increasing export concentration alongside an unstable relationship with import unit values. Positive correlations in annual levels weaken or reverse under alternative comparisons, including removal of the initial year and exclusion of records carrying estimated weights. The resulting contribution is a measurement-based qualification of how geographic concentration informs antibiotic trade monitoring. Concentration identifies where recorded export value accumulates, while unit values describe expenditure within a changing basket of imports. For international procurement and trade surveillance, the evidence supports interpreting these indicators together with denominator coverage rather than treating concentration alone as evidence of increasing antibiotic import prices.

2. Theory, Conceptual Framework and Research Questions Development:

This analysis draws on industrial organization and international trade theory to examine how antibiotic exporting country concentration varies alongside global import unit values. Export concentration describes the distribution of recorded export value across reporting economies, rather than the distribution of sales across individual suppliers. The distinction matters because a dominant exporting economy may contain competing producers. Syverson, 2019, explains that concentration alone cannot establish market power because market boundaries, competitive conduct and production efficiency shape its interpretation. Accordingly, the framework treats geographic concentration as an observable trade structure rather than a direct measure of supplier pricing power. The theoretical relationship permits opposing mechanisms. Concentration may accompany weaker competitive constraints, allowing suppliers to sustain higher margins. De Loecker, Eeckhout and Unger, 2020, document rising aggregate markups in firm data, providing evidence that changes in competitive conditions can affect pricing outcomes. Their findings motivate a possible positive relationship between concentration and unit values, but do not establish that relationship for antibiotic exporting economies. The available customs records therefore support examining whether the variables move together, without attributing observed movements to supplier conduct.

An alternative mechanism links concentration to productive advantage. Export activity may shift toward economies whose producers achieve lower costs, larger production volumes or stronger commercial capabilities. Autor and colleagues, 2020, show how reallocation toward more productive firms can accompany increasing concentration. Applied as a theoretical possibility to antibiotic trade, this mechanism allows concentration to increase while unit values decline or remain stable. These competing expectations make descriptive research questions more appropriate than a predetermined directional hypothesis. The outcome is the annual antibiotic import unit value, calculated by dividing aggregate import value by aggregate net weight for records containing positive values and weights. It measures recorded expenditure per kilogram within HS heading 2941, which covers antibiotic chemicals. It does not measure the price of an identical antibiotic product across transactions. Hallak and Schott, 2011, demonstrate that observed trade unit values combine quality and price components. Consequently, changes in the composition of imported antibiotic chemicals can alter the aggregate outcome even when individual product prices remain unchanged.

Destination composition provides a further interpretive boundary. Manova and Zhang, 2012, document systematic variation in export prices across firms and destinations, consistent with differences in product quality and market characteristics. In the present analysis, annual changes in reporting economies and the composition of recorded imports can therefore influence aggregate unit values. The analytical period comprises the fifteen observed years from 2010 to 2024. Interpretation remains anchored to those observations and the workbook's measures of import value coverage and estimated weight exposure. The conceptual framework represents exporting country concentration through three calculated indicators: the Herfindahl Hirschman index, the largest exporter share and the combined share of the four largest exporters. These indicators describe complementary features of the same export distribution. They are neither separate causal mechanisms nor components of an additional composite score. The outcome remains the annual import unit value in USD per kilogram. The framework connects each concentration indicator to the outcome through descriptive temporal comparison, without assigning a causal direction. The Herfindahl Hirschman index captures the distribution of export value across all observed exporting economies by summing their squared annual shares and multiplying the result by 10,000. It gives greater weight to larger exporters while retaining information about the wider distribution. An increase can reflect stronger dominance at the top, declining participation among smaller exporters or both. Comparing its trajectory with import unit values establishes whether broader geographic concentration and recorded expenditure per kilogram display similar, opposing or inconsistent movements.

RQ1: How does exporting country concentration measured by the Herfindahl Hirschman index evolve alongside global antibiotic import unit values from 2010 to 2024?

The largest exporter shares isolates leadership within the export distribution. Unlike the broader index, it identifies how much recorded export value belongs to the leading reporting economy in each year. A rising share indicates greater geographic dominance, although the identity of the leading economy may change. Examining this measure separately distinguishes movements centered on the largest exporter from changes involving the wider export distribution.

RQ2: How does the largest exporting economy's share evolve alongside global antibiotic import unit values from 2010 to 2024?

The combined share of the four largest exporters captures the collective prominence of leading exporting economies. It can rise even when the largest exporter loses share, provided the other leading exporters gain sufficient ground. Comparison with

the largest exporter share therefore distinguishes increasing dominance by one economy from increasing concentration across several leading economies. Its relationship with import unit values remains descriptive because the records identify neither coordination among exporters nor competitive conduct within exporting economies.
RQ3: How does the combined share of the four largest exporting economies evolve alongside global antibiotic import unit values from 2010 to 2024?

Together, these questions organize the analysis around observed trade structure and unit value movements. Their resolution requires reporting annual trajectories and comparing patterns across the three concentration indicators. Similar movements identify descriptive alignment; opposing or irregular movements identify divergence. Neither pattern establishes that geographic concentration determines antibiotic prices.

3. Data:

This analysis uses annual customs records to document antibiotic exporting country concentration and import unit values. Data provenance, sample construction, measurement rules and verification procedures establish the basis for descriptive comparisons across fifteen observed years.

3.1 Data Sources, Population, and Sample Construction:

UN Comtrade, maintained by the United Nations Statistics Division, provides the underlying merchandise trade records. The extraction covers HS heading 2941, antibiotics, with annual frequency, imports and exports, partner World, second partner World, all customs procedures and all transport modes. The corresponding query identifiers are C, A, HS, 2941, M and X, partner codes 0, customs code C00 and transport code 0. The source records use the original reporting classification rather than a single retrospectively harmonized HS revision. Merchandise trade values represent flows recorded during each calendar year, consistent with the statistical framework described by the United Nations Statistics Division, 2011. The target population comprises reporting economies participating in international trade in antibiotic chemicals. The accessible frame consists of records returned by the documented public preview API queries. Finished antibiotic medicines classified outside heading 2941 fall outside the empirical boundary. Selection uses available eligible records rather than probability sampling. The workbook specifies exclusion of reporter groups and reporter code 0, while retaining individual reporting economies and territories. Gross exports include embedded reexports. The underlying record unit is an economy, calendar year and trade flow. The retained source data form an unbalanced collection of annual reporting records covering 191 economies. Aggregation produces a global annual time series with fifteen observations from 2010 to 2024. The intended endpoint of 2025 contains no retrieved observations and does not enter the analytical sample. Export concentration uses 1,370 export records from 142 economies, while import unit values use 2,046 records from 184 economies with positive import values and net weights.

Table 1: Verified sample construction

Stage	Units	Observations	Reason or Rule
Returned source frame	Distinct reporter count not preserved	3,799 records	Sum of documented API response counts across fifteen successful annual queries
Source frame reduction	Excluded reporter identities not preserved	30 records	Difference between response counts and retained records; workbook documents reporter group and code 0 exclusions
Retained source records	191 economies	3,769 records	Individual reporting economies with annual import or export records
Export concentration input	142 exporting economies	1,370 export records	Positive recorded export value
Import records before weight screening	191 importing economies	2,399 import records	Positive recorded import value
Import records excluded for missing weight	Not separately enumerated	285 import records	Net weight unavailable
Import records excluded for zero weight	Not separately enumerated	68 import records	Zero denominator
Import unit value input	184 importing economies	2,046 import records	Positive import value and positive net weight
Final descriptive sample	One aggregate trade series	15 annual observations	All three concentration indicators and import unit value available

The workbook preserves exact query URLs and extraction timestamps in its Sources worksheet. It identifies a live database extraction without an immutable release identifier. The chronology of initial selection decisions and subsequent revisions is not recorded. Consequently, the documented rules describe the supplied dataset without establishing that they were prespecified.

3.2 Data Integration, Cleaning, and Quality Assurance:

Integration consists of appending annual query outputs and aggregating eligible records within calendar years. No external economic dataset or bilateral trade matching enters the construction. Reporter codes identify economies, year identifies the observation period, and flow distinguishes imports from exports. Verification found no duplicate combinations of year, reporter code and flow among the 3,769 retained records. Import and export records for the same economy and year represent distinct flows rather than duplicates. The retained classifications comprise H1, H2, H3, H4, H5 and H6, with 6, 92, 675, 1,235, 1,136 and 625 records, respectively. These source labels remain unchanged. The analysis aggregates the common heading 2941 without claiming that its internal product composition is constant across classifications or years. Trade values remain in current USD, and net weights remain in kilograms. The workbook applies no additional currency conversion, inflation adjustment,

deflation or calendar conversion. Import and export totals remain separate because valuation, reporting coverage and recording practices can differ. The United Nations Statistics Division, 2013, discusses these compilation differences and their implications for comparisons between trade flows.

All retained import records contain positive trade values. Missing net weight affects 285 records, while another 68 report zero weight. These 353 records remain in the source worksheet and the denominator used to assess import value coverage, but contribute neither value nor weight to the import unit value calculation. No missing observation is replaced by zero, interpolated or imputed. Source flags identifying estimated weights remain available, and records carrying those flags are retained. Annual export coverage ranges from 86 to 98 reporting economies. Import reporting ranges from 144 to 171 economies, while the unit value calculation includes between 126 and 145 economies annually. Matched records account for 71.50 to 88.80 percent of observed annual import value. Within that matched value, the proportion attached to estimated weights ranges from 45.82 to 88.29 percent. These indicators describe denominator availability and estimation exposure within the retrieved records, rather than completeness of global trade reporting. Verification reproduced the four principal annual indicators from the retained records, with numerical differences below 0.000000001. All fifteen annual observations have defined concentration indicators and positive aggregate import weight. No outlier trimming or winsorization is documented or introduced. The records represent the historical values available at extraction, rather than archived information vintages for each observation year.

3.3 Variable Measurement, Construction, and Validation:

Exporting country concentration is represented by the Herfindahl Hirschman index, the largest exporter share and the combined share of the four largest exporters. These are alternative summaries of the observed export distribution. They are not combined into an additional index. Equation 1 defines each exporter's annual value share.

$$s_{it} = \frac{x_{it}}{\sum_{j \in E_t} x_{jt}}$$

Here, s_{it} denotes economy i's export share in year t, x_{it} denotes its positive export value in current USD, E_t denotes the set of eligible exporting economies, and jindexes members of that set. Equation 2 defines the Herfindahl Hirschman index.

$$HHI_t = 10000 \sum_{i \in E_t} s_{it}^2$$

Here, HHI_t denotes annual concentration on a scale approaching zero for highly dispersed exports and reaching 10,000 when one economy accounts for all observed export value. Equation 3 defines the largest exporter share.

$$CR1_t = \max_{i \in E_t} s_{it}$$

Here, $CR1_t$ denotes the largest observed export share in year t. Equation 4 defines the combined share of the four largest exporters.

$$CR4_t = \sum_{i \in T_t} s_{it}$$

Here, $CR4_t$ denotes the combined leading exporter share, and $T_t$denotes the four economies with the largest export values in year t. Equation 5 defines the aggregate import unit value.

$$UV_t = \frac{\sum_{i \in M_t} v_{it}}{\sum_{i \in M_t} w_{it}}$$

Here, UV_t denotes import value per kilogram, M_t denotes importing economies with positive import value and net weight, v_{it} denotes import value in current USD, and w_{it}denotes net weight in kilograms. The numerator and denominator use identical eligible records. This construction produces a ratio of aggregate value to aggregate weight rather than an unweighted average of economy unit values.

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
Herfindahl Hirschman index	Concentration indicator	Equation 2	UN Comtrade, HS 2941, X, primary Value	Index, annual	Squared value shares multiplied by 10,000; higher values indicate greater concentration	Positive export values enter the annual denominator	Fifteen years; geographic concentration
Largest exporter share	Concentration indicator	Equation 3	UN Comtrade, HS 2941, X, primary Value	Ratio, annual	Largest export share; higher values indicate stronger geographic dominance	Same export eligibility rule	Leader identity may change
Four largest exporters' share	Concentration indicator	Equation 4	UN Comtrade, HS 2941, X, primary Value	Ratio, annual	Sum of four leading shares; higher values indicate greater collective concentration	Same export eligibility rule	Membership may change
Import unit value	Descriptive outcome	Equation 5	UN Comtrade, HS 2941, M, primary Value and netWgt	Current USD per kilogram, annual	Aggregate value divided by matched aggregate weight	Exclude missing or zero weight from both sums	Reflects composition and valuation
Import value coverage	Quality indicator	Matched import value divided by all retained import value	UN Comtrade, HS 2941, M	Ratio, annual	Higher values indicate greater value coverage by usable weights	All retained import values remain in the denominator	Does not measure global reporting completeness
Estimated weight value share	Quality indicator	Matched import value attached to estimated weights divided by all matched import value	UN Comtrade, is NetWgt Estimated	Ratio, annual	Higher values indicate greater exposure to estimated weights	Retain the source flag and matched records	Measures value exposure rather than estimation error
Reporting	Coverage	Counts of eligible	UN Comtrade	Economy	Higher values indicate	Count only records	Reporting

Variable or Indicator	Analytical Role	Definition and Construction	Source and Identifier	Unit and Frequency	Transformation and Direction	Missing Value Rule	Coverage and Limitation
economy counts	indicators	exporters, importers and matched importers	reporter code and flow	counts, annual	broader observed participation	meeting each indicator's eligibility rule	composition varies annually

All four principal measures have fifteen valid annual observations. Table 3 reports descriptive statistics calculated from the supplied annual series. Concentration shares are expressed as percentages for presentation; the workbook stores them as ratios.

Table 3: Descriptive statistics for principal variables

Variable	Valid Years	Mean	Standard Deviation	Median	Minimum	Maximum
Herfindahl Hirschman index	15	1,599.28	443.18	1,430.54	1,094.12	2,368.37
Largest exporter share, percent	15	33.12	7.77	31.43	22.82	45.53
Four largest exporters' share, percent	15	63.57	5.70	61.57	55.00	71.70
Import unit value, USD per kilogram	15	78.89	11.26	81.86	42.25	87.08

Standard deviations use the sample denominator. Share dispersion is expressed in percentage points. Higher import unit values indicate greater recorded expenditure per kilogram, without establishing higher prices for identical products. Hallak and Schott, 2011, demonstrate that trade unit values combine price and quality variation, supporting this measurement boundary.

3.4 Analytical Framework, Identification, and Reproducibility:

The analytical framework is descriptive. It compares annual movements in each concentration indicator with movements in aggregate import unit values across the same fifteen years. The relevant variation is temporal variation in the observed global aggregates. The three concentration measures receive separate interpretation because each summarizes the same export share distribution. No regression, causal estimator, interaction, fixed effect or statistical inference procedure enters the reported data construction and verification. The descriptive statistics therefore characterize the available annual observations without identifying the effect of concentration on import unit values. Geographic aggregation, changing reporter coverage, estimated weights and product composition constrain interpretation of temporal alignment. The workbook separates source records, annual aggregates, variable definitions and query provenance across the Records, Annual, Dictionary and Sources worksheets. Record level contributions permit reconstruction of export shares and matched import totals. The verification described here independently recalculated the principal measures from those retained inputs. This separation between source data and calculated outputs supports the traceability emphasized by Sandve and colleagues, 2013. No independent benchmark comparison or alternative eligibility sensitivity analysis is reported. The available materials do not contain the original extraction script, an immutable source release or a complete log of excluded reporter identities. Reproducibility therefore extends to recalculating the supplied aggregates and identifying the documented access queries, while exact reconstruction of the original live download remains limited by source revisions and incomplete extraction documentation.

4. Methods:

4.1 Research Design and Analytical Scope:

This analysis adopts a descriptive longitudinal design to examine whether antibiotic exporting country concentration moves consistently with global import unit values. The analytical unit is the calendar year, with fifteen observations covering 2010 to 2024. The sample construction process and measurement definitions appear in Tables 1 and 2. Individual customs records provide the inputs for annual aggregation rather than independent observations for the correlation analysis. The quantities of interest are contemporaneous correlations and the direction of annual movements between each concentration indicator and import unit value. Useful variation arises from changes over time in the distribution of recorded exports and aggregate expenditure per kilogram. The analysis examines each concentration indicator separately because the three measures summarize related features of the same export distribution. The design identifies descriptive alignment within the observed annual series. Changes in reporting participation, product composition and weight availability can influence that alignment. Accordingly, the coefficients are interpreted as sample associations without attributing expenditure movements to geographic concentration. Geographic shares also remain distinct from firm market power, consistent with the interpretive distinction emphasized by Syverson, 2019.

4.2 Measurement Alignment and Association Specification:

Equations 1 to 5 define exporter shares, concentration indicators and import unit values. All principal comparisons align concentration and expenditure within the same calendar year. Export shares use positive export values, while import unit values divide aggregate import value by aggregate net weight among identical eligible import records. The outcome therefore retains the composition of the observed antibiotic chemical basket. Hallak and Schott, 2011, establish why such unit values require interpretation separately from prices for comparable products. Equation 6 specifies the Pearson correlation used for each concentration indicator.

$$r_{k,U} = \frac{\sum_{t\in T}[C_{kt} - \bar{C}_k]\,[U_t - \bar{U}]}{\sqrt{\sum_{t\in T}[C_{kt} - \bar{C}_k]^2 \sum_{t\in T}[U_t - \bar{U}]^2}}$$

Here, $r_{k,U}$ denotes the sample correlation between concentration indicator kand import unit value; C_{kt} denotes that indicator in year t; U_t denotes import unit value; T denotes the included years; and $\bar{C}_k$and $\bar{U}$ denote their sample means. The index k identifies the Herfindahl Hirschman index, largest exporter share or combined share of the four largest exporters. Spearman correlations apply the same standardized covariance calculation to the ranks of the annual observations. Pearson coefficients summarize linear alignment in measured levels, whereas Spearman coefficients summarize monotonic alignment in their ordering. Comparing these measures helps assess whether the interpretation depends on numerical distances between observations, following the distinction examined by de Winter, Gosling and Potter, 2016. Each calendar year receives equal weight in the correlation calculations. This differs from the construction of import unit values, which uses aggregate value divided by aggregate

weight. Concentration shares remain ratios during calculation and are multiplied by 100 for percentage presentation. Changes in those percentages are reported in percentage points.

4.3 Processing, Calculation and Verification:

The analytical sequence begins with the retained customs records and their annual identifiers. Export values are aggregated within years to reconstruct exporter shares and concentration indicators. Import records enter the unit value calculation only when both trade value and net weight are positive. Records with unavailable or zero weight remain outside both its numerator and denominator. No interpolation, imputation or replacement of missing values with zero is applied. Annual series are ordered chronologically before calculation. Descriptive summaries comprise valid observation counts, arithmetic means, sample standard deviations, medians, minima and maxima. Endpoint comparisons distinguish proportional changes from absolute differences. Consecutive annual movements are compared by subtracting each preceding observation from the following observation; agreement in direction requires both changes to have the same sign. Verification checks the uniqueness of year, reporter code and flow combinations, reconciles retained record counts, and independently reconstructs the four principal annual indicators. The recalculated indicators are compared with the supplied Annual worksheet. Pairwise correlations among concentration indicators assess their empirical overlap and inform their separate interpretation. These checks assess internal arithmetic consistency rather than agreement with an independent data source. Calculations use Python 3.12.14, openpyxl 3.1.5, NumPy 2.3.5 and SciPy 1.17.0. Workbook values are read using openpyxl. NumPy supplies descriptive calculations and consecutive differences; SciPy functions pearsonr and spearmanr supply the principal correlation coefficients. Sample standard deviations use one degree of freedom. Calculations retain numerical precision until presentation.

4.4 Exploratory Sensitivity and Interpretive Limits:

Three exploratory comparisons examine specific sources of sensitivity. First, Pearson correlations are recalculated after excluding 2010, leaving fourteen annual observations. This comparison assesses dependence on the initial observation rather than treating its low unit value as a verified error. Second, correlations between consecutive annual changes use fourteen transitions. This comparison distinguishes alignment in annual movements from alignment in levels; differencing does not establish causal identification. Third, import unit values are reconstructed after excluding matched import records flagged as carrying estimated net weights. Eligible value and weight are removed together, preserving denominator consistency. The alternative outcome remains available for all fifteen years and is correlated with the unchanged concentration indicators. Because this restriction changes both weight estimation exposure and reporter composition, its results describe sensitivity to inclusion rules rather than isolated measurement error. The full sample remains the baseline, without outlier trimming or winsorization. The comparisons reported in Table 5 assess coefficient direction and magnitude across clearly identified samples and constructions. They are exploratory rather than prespecified tests. No significance thresholds, confidence intervals or population inference are attached to the coefficients, and the analysis does not assume that annual observations are independent. The fifteen-year series support descriptive comparisons without resolving temporal dependence or confounding through formal inference. The Records, Annual, Dictionary and Sources worksheets document retained inputs, calculated measures, definitions and access queries. Together with the equations and software details, they support reconstruction of the reported calculations from the supplied workbook. This documentation serves the traceability principles discussed by Sandve and colleagues, 2013. The methodological contribution rests on transparent application of established descriptive tools and explicit measurement boundaries.

5. Findings:

This analysis examines how antibiotic exporting country concentration evolved alongside global import unit values from 2010 to 2024.The findings address three research questions through annual comparisons, descriptive correlations and sensitivity checks. Interpretation distinguishes changes in trade structure from changes in recorded expenditure per kilogram. The analytical sample contains fifteen annual observations constructed from 3,769 customs records covering 191 reporting economies. Concentration measures use 1,370 export records, while import unit values use 2,046 import records with positive trade values and net weights. Another 353 import records lack usable weights and therefore do not contribute to unit values. The empirical outcome represents current USD per kilogram of antibiotic chemicals within HS heading 2941.

Table 4: Annual antibiotic export concentration and import unit values

Year	Herfindahl Hirschman Index	Largest Exporter Share, Percent	Four Largest Exporters' Share, Percent	Import Unit Value, USD per Kilogram
2010	1,145.12	23.98	58.43	42.25
2011	1,230.96	22.82	61.05	87.07
2012	1,113.54	24.41	55.58	86.46
2013	1,094.12	23.93	55.00	87.08
2014	1,397.91	30.66	61.36	77.32
2015	1,430.54	31.43	61.57	72.97
2016	1,338.50	30.11	60.02	71.68
2017	1,345.18	30.92	58.63	79.59
2018	1,521.53	33.00	63.52	83.65
2019	1,624.60	33.75	67.08	81.91
2020	1,823.42	37.41	69.13	85.45
2021	2,368.37	45.53	71.70	77.93
2022	2,310.97	45.11	69.63	86.69
2023	2,041.00	40.70	70.19	81.86

Year	Herfindahl Hirschman Index	Largest Exporter Share, Percent	Four Largest Exporters' Share, Percent	Import Unit Value, USD per Kilogram
2024	2,203.47	43.07	70.62	81.51

Exporting country concentration increased across all three indicators, but import unit values did not exhibit a comparable sustained increase. The Herfindahl Hirschman index rose by 1,058.35 points, equivalent to 92.42 percent. The largest exporter share increased by 19.09 percentage points, while the combined share of the four largest exporters increased by 12.19 percentage points. Import unit value increased by 92.95 percent between the endpoints, but this comparison depends heavily on the low initial observation. The increase from 2010 to 2011 alone reached 106.11 percent. Across the remaining years, unit values ranged from USD 71.68 to USD 87.08 per kilogram. The first research question concerns concentration across the full export distribution. Table 4 shows that the Herfindahl Hirschman index reached its minimum of 1,094.12 in 2013 and its maximum of 2,368.37 in 2021. Import unit value moved in the opposite direction between those observations, declining from USD 87.08 to USD 77.93 per kilogram. Across fourteen annual transitions, the index and unit value moved in the same direction seven times. Thus, increasing concentration across the export distribution did not consistently coincide with increasing expenditure per kilogram.

The second research question concerns the leading exporting economy. China accounted for 23.98 percent of recorded export value in 2010 and 43.07 percent in 2024. The largest exporter share peaked at 45.53 percent in 2021, when import unit value fell from USD 85.45 to USD 77.93 per kilogram. Conversely, unit value increased to USD 86.69 in 2022 as the largest exporter share declined. These contrasting movements establish that stronger geographic leadership and higher aggregate unit values did not follow a uniform annual relationship. Geographic leadership also remains distinct from firm market power, consistent with the measurement caution developed by Syverson, 2019. The third research question concerns collective concentration among leading exporters. Their combined share increased from 58.43 percent to 70.62 percent, with a maximum of 71.70 percent in 2021. The composition of this group changed: China, Panama, Switzerland and the United States occupied the leading positions in 2010, compared with China, India, Switzerland and Italy in 2024. The increase in the largest exporter share exceeded the increase in the combined leading group share by 6.90 percentage points. This arithmetic indicates that rising concentration involved a stronger leading economy alongside a reduced combined share for the next three ranked exporters.

Table 5: Descriptive associations and exploratory sensitivity checks

Comparison	Annual Observations or Transitions	Herfindahl Hirschman Index	Largest Exporter Share	Four Largest Exporters' Share
Pearson correlation with import unit value	15 years	0.253	0.247	0.221
Spearman rank correlation with import unit value	15 years	Negative 0.068	Negative 0.071	Negative 0.050
Pearson correlation excluding 2010	14 years	Negative 0.004	Negative 0.111	Negative 0.007
Pearson correlation between annual changes	14 transitions	Negative 0.119	Negative 0.347	Negative 0.010
Pearson correlation using imports without estimated weights	15 years	0.018	0.008	Negative 0.093

The full sample Pearson correlations are positive but small, ranging from 0.221 to 0.253. Rank correlations are slightly negative for every indicator, showing that the positive linear associations do not correspond to a consistently increasing ordering of concentration and unit values. Removing 2010 reduces the Pearson correlations to approximately zero for the Herfindahl Hirschman index and the combined leading exporter share, while the largest exporter correlation becomes negative. The positive full sample associations therefore depend materially on the initial observation. Annual change comparisons reinforce the absence of consistent positive alignment. Correlations between consecutive changes range from negative 0.010 for the combined leading exporter share to negative 0.347 for the largest exporter share. These results describe short term movements and do not establish a negative structural relationship. They show that the positive correlations in annual levels do not persist when attention shifts to changes between adjacent observations.

Weight estimation also affects the descriptive results. Recalculating unit values after excluding records flagged as carrying estimated weights leaves between 73 and 99 importing economies annually. Correlations with concentration then become 0.018, 0.008 and negative 0.093. This restriction changes both measurement exposure and reporter composition, so it cannot isolate estimation error. It demonstrates that the positive associations do not persist under this alternative inclusion rule. The three concentration measures themselves overlap strongly. Their pairwise Pearson correlations range from 0.921 to 0.982. Their agreement therefore establishes consistency across related summaries of the export distribution rather than three independent empirical confirmations. Across all comparisons, the principal finding remains increasing geographic concentration accompanied by an unstable descriptive relationship with import unit values.

The measurement boundary is substantive. Hallak and Schott, 2011, show that observed trade unit values combine price and quality components, while Manova and Zhang, 2012, document price variation across exporters and destinations. These findings support interpreting the antibiotic outcome as aggregate expenditure per kilogram rather than a comparable transaction price. The present records also do not distinguish the markup mechanism examined by De Loecker, Eeckhout and Unger, 2020, from the productive reallocation mechanism examined by Autor and colleagues, 2020. Neither mechanism follows directly from the observed concentration increase. The three research questions yield a common descriptive answer. Antibiotic exports became more geographically concentrated, particularly around the leading exporting economy, while import unit values showed no stable positive alignment with that concentration. The direction and magnitude of the associations changed across rank comparisons,

endpoint exclusion, annual changes and weight screening. The evidence establishes structural concentration within observed trade, without establishing a concentration driven increase in antibiotic import prices.

6. Discussion:

Antibiotic exports became more geographically concentrated without a stable accompanying increase in import unit values. Tables 4 and 5 establish this distinction: positive correlations in annual levels weaken or reverse under rank comparisons, exclusion of the initial year and comparisons of annual changes. The contribution lies in showing that a persistent structural shift in the export distribution can coexist with an unstable expenditure relationship. Equations 2 to 4 measure geographic concentration, whereas Equation 5 measures expenditure per kilogram across eligible imports. These distinct objects should not be interpreted as a direct concentration and price mechanism. Antràs, 2020, emphasizes that international production relationships require attention to the organization of transactions across borders. The antibiotic evidence adds a sector specific boundary: increasingly concentrated export origins do not, by themselves, establish rising procurement costs for comparable products.

The instability of the associations changes how the apparent relationship should be interpreted. In Table 5, removing the initial observation largely eliminates the positive linear association, while annual changes provide no consistent positive alignment. Consequently, the aggregate pattern cannot distinguish competitive pressure, productive advantage or changes in the traded product basket. Khandelwal, 2010, demonstrates that export prices alone do not identify product quality, reinforcing the need to distinguish observed expenditure from the characteristics of what is purchased. Equation 5 retains precisely this compositional dependence because its numerator and denominator aggregate antibiotic chemicals by value and weight. The empirical contribution is therefore a clearer measurement boundary: the observed relationship depends on temporal comparison and aggregation, rather than revealing a demonstrated transmission channel from concentration to prices.

The comparison between concentration indicators reveals a more specific structural development than a general increase in exporter dominance. Table 4 shows that the largest exporter share increased more than the combined share of the four leading exporters. Read through Equations 3 and 4, this difference identifies stronger leadership within an increasingly concentrated leading group, accompanied by a smaller combined share for the next three ranked economies. The result separates dominance by the leading export origin from collective concentration among major origins. It does not establish dominance by a firm or a common pricing strategy. Kugler and Verhoogen, 2012, find that relationships between producer size and prices involve input and output quality choices in Colombian manufacturing. Their evidence highlights why the present geographic redistribution cannot be translated directly into a supplier pricing effect. The contribution is to distinguish where export value accumulates from how individual producers set prices.

Weight coverage materially conditions the economic interpretation of customs aggregates. Table 5 shows that excluding records with estimated weights changes the concentration correlations toward zero or negative values. Because this restriction also changes the participating economies, the comparison identifies sensitivity to record inclusion rather than the magnitude of estimation error. Table 2 and Equation 5 make the underlying issue explicit: an expenditure ratio depends on which records supply both usable value and weight. This finding changes the evidential role of coverage information from supplementary documentation to a condition for interpreting aggregate comparisons. Baldwin and Freeman, 2022, distinguish supply chain exposure from the broader consequences of disruption and adjustment. Applied here, geographic concentration, weight coverage and expenditure outcomes require separate reporting; none provides a sufficient substitute for the others.

The international relevance concerns how global sourcing evidence informs procurement and trade monitoring. Bonadio and colleagues, 2021, examine disruption transmission through a model spanning countries and sectors, demonstrating the importance of production linkages for interpreting international exposure. The present findings address a different empirical object: worldwide antibiotic export shares and aggregate import expenditure per kilogram. Table 5 shows why a concentrated global export structure cannot establish that every importing economy faces the same expenditure pattern. Decision makers should therefore report concentration alongside weight coverage and unit values, and examine whether apparent alignment survives the comparisons implemented here before using it to justify procurement changes. The theoretical refinement is a separation between geographic dependence and observed expenditure outcomes. Tables 4 and 5, interpreted through Equations 2 to 5, establish that concentration can rise persistently while its descriptive association with import unit values remains sensitive to timing and measurement.

7. Conclusion and Implications:

Greater dependence on a few exporting economies does not automatically translate into higher antibiotic purchasing costs. This analysis reveals that broad geographic consolidation, stronger leadership and the collective prominence of major exporters evolved without a stable corresponding expenditure pattern. Their descriptive relationships changed with temporal comparisons and record inclusion, establishing a distinction between structural dependence and observed expenditure. The contribution is an empirical qualification of interpretations that infer pricing consequences directly from geographic concentration. Theoretically, the findings sharpen the boundary between the distribution of trade and competitive conduct: geographic dominance alone cannot identify supplier behavior or establish a causal pricing pathway. For procurement managers, the evidence supports interpreting sourcing patterns alongside expenditure composition and weight coverage before changing purchasing strategies. International monitoring agencies should report these dimensions together and disclose whether apparent relationships persist across alternative comparisons. Operationally, retaining source flags, tracking denominator coverage and documenting changes in reporting participation can improve the transparency of procurement intelligence. Policy responses should distinguish concerns about concentrated sourcing from evidence of increasing costs, allowing each concern to receive appropriate investigation. The social relevance lies in informing decisions about essential antibiotic supply through evidence that separates observed structural change from claims about affordability and access.

The fifteen annual observations provide a basis for extending the analysis to more detailed trade relationships. Product specific records could distinguish changes in chemical composition from movements in comparable prices, while bilateral data could reveal differences across importing economies. Linking customs records to manufacturers and procurement transactions would permit investigation of competitive conduct and purchasing conditions. Consistent reporter samples and independently

measured weights could assess the sensitivity associated with coverage changes. Designs incorporating identifiable supply events could examine causal transmission, extending the descriptive contribution toward explanations that can be evaluated across different institutional and market settings.

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