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NATIONAL ENERGY CONSUMPTION CHARACTERISTICS AND THEIR ASSOCIATIONS WITH MANUFACTURED EXPORT PERFORMANCE ACROSS GLOBAL EXPORTING ECONOMIES

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Abstract:

This analysis examines whether national energy characteristics correspond to manufactured export specialization, distinguishing international rankings from changes within exporting economies. An annual World Bank panel contains 1,852 observations from 140 economies between 2010 and 2023. Pearson and Spearman correlations, economy mean centering, and economy block bootstrap intervals assess linear correspondence, relative ordering, and uncertainty. Alternative and nuclear energy share and energy use per capita exhibit positive rank correlations with manufactures export share of 0.230 and 0.258, respectively, with both confidence intervals above zero. Corresponding linear correlations remain close to zero, while correlations within economies are small and imprecisely estimated. A balanced sample of 116 economies preserves this contrast and shows changing energy characteristics alongside limited net movement in export composition. The contribution is an empirical distinction between comparative position and domestic adjustment, qualifying interpretations that translate international associations into industrial development pathways. The findings support evaluating energy outcomes and manufacturing specialization separately when assessing industrial strategies, rather than treating favorable national rankings as evidence of subsequent export upgrading.

Key Words: Energy Consumption; Alternative And Nuclear Energy; Manufactured Exports; Panel Data; Bootstrap Inference.

1. Introduction:

Energy transitions create a consequential question for exporting economies: do differences in national energy characteristics correspond to changes in manufacturing representation within international trade? Governments evaluating energy and industrial strategies need to distinguish these relationships because an economy's position relative to other exporters does not necessarily indicate how its own export structure will evolve. Greater energy consumption may accompany industrial capacity, while a larger alternative and nuclear energy share may accompany a different production structure. Neither characteristic, however, establishes that manufacturing will gain a larger share of merchandise exports. This analysis examines that distinction through international comparisons and variation within economies. Comparative advantage provides a theoretical basis for linking productive conditions to export specialization. Costinot, Donaldson, and Komunjer in 2012 show how differences in relative productivity shape trade patterns. Energy conditions can enter this relationship through production requirements and operating constraints, but their implications depend on what is measured. Allcott, Collard-Wexler, and O'Connell in 2016 demonstrate that electricity shortages constrain manufacturing activity in India. Sato and Dechezleprêtre in 2015 find that industrial energy price differences affect international trade, although their estimated effects are small and more pronounced in activities with greater energy requirements. These findings establish the relevance of specific energy conditions without demonstrating that aggregate consumption levels or national energy shares provide equivalent explanations of export specialization.

Research connecting energy consumption more directly to export structure provides a closer comparison. Rehman, Islam, and Raza in 2023 examine renewable and nonrenewable energy consumption alongside export sophistication and diversification in OECD economies. Their panel analysis reports positive relationships between disaggregated energy consumption and both export outcomes. Lee and Ho in 2022 examine the reverse analytical direction across 121 countries, investigating how export diversification relates to energy intensity, renewable energy, and waste energy. Their findings associate diversification with higher energy intensity and lower renewable energy consumption. Together, these papers show that energy characteristics and export structure are interconnected, while differences in outcomes and analytical direction complicate a single interpretation of that relationship. The present analysis distinguishes manufacturing representation from diversification and sophistication. Manufactures export share measures the proportion of merchandise exports classified as manufactured goods. It does not measure the number of exported products, their technological content, or total manufactured export earnings. A change in this share can arise from changes in manufacturing exports, changes elsewhere in the merchandise basket, or both. This distinction matters because firms can alter their product portfolios without producing an equivalent change in aggregate manufacturing representation. Bernard, Redding, and Schott in 2010 document substantial product switching among manufacturing firms, demonstrating that industrial adjustment includes changes within surviving producers. An aggregate export share therefore captures a particular dimension of specialization rather than a comprehensive measure of industrial performance.

Two observed energy indicators define the empirical comparison. Alternative and nuclear energy share represents national energy composition, while energy use per capita represents national consumption scale. The first is not interchangeable with renewable energy consumption because it includes nuclear energy. The second does not directly measure industrial energy requirements, supply reliability, or energy efficiency. These distinctions permit competing expectations. Greater consumption may accompany manufacturing activity, but it also reflects consumption outside manufacturing. Similarly, alternative and nuclear energy may support industrial production, yet its national share does not reveal the cost or continuity of energy available to exporters. The analysis consequently examines observed associations without assigning either indicator a predetermined causal

interpretation. The unresolved issue is therefore narrower than whether energy matters for economic activity. The reviewed evidence does not establish whether positive international ordering in national energy characteristics corresponds to a comparable linear relationship in manufactured export shares, particularly when examining changes within the same economies. Studies of energy prices, electricity shortages, export diversification, and export sophistication address related but different relationships. This analysis extends that evidence by examining whether the apparent relationship depends on the distinction between rankings and original measurement levels, and between pooled observations and variation within economies. Its contribution concerns empirical interpretation rather than identification of a new causal mechanism.

The analysis uses an unbalanced annual panel of 1,852 observations from 140 exporting economies between 2010 and 2023. World Bank indicators provide the two retained energy measures and manufactures export share, with positive merchandise exports defining eligible export activity. Pearson correlations describe linear correspondence, while Spearman correlations assess relative ordering. Correlations calculated from deviations around economy means distinguish variation within economies from pooled comparisons. Economy block bootstrap intervals preserve annual records within resampled economies. A balanced sample of 116 economies provides an additional comparison with constant membership throughout the observation period. The findings reveal positive pooled rank associations alongside weak linear relationships. Spearman correlations with manufactures export share are 0.230 for alternative and nuclear energy share and 0.258 for energy use per capita. The corresponding pooled Pearson correlations remain close to zero, as do correlations within economies. The balanced sample preserves this distinction. It also shows increasing alternative and nuclear energy share and decreasing energy consumption per person alongside an imprecisely estimated net change in manufacturing representation. These results qualify interpretations that translate international rankings directly into expected domestic export trajectories. They do not establish that energy conditions are economically irrelevant or that changing them cannot affect manufacturing.

This study aims to determine how national energy composition and consumption scale relate to manufactured export composition across exporting economies and over time. The central research question asks whether higher positions in the international energy distribution correspond to stronger manufacturing representation and whether that correspondence also appears within economies. The specific objectives are to assess each retained energy indicator's association with manufactures export share, distinguish rank ordering from linear correspondence, and examine whether the principal patterns persist under constant economy membership. The resulting evidence informs a specific policy distinction: progress in national energy characteristics and progress in manufactured export composition require separate measurement. Its international relevance lies in clarifying the interpretation of comparisons across exporting economies while retaining the limits imposed by observational data and sample coverage.

2. Theory, Conceptual Framework and Research Question Development:

This analysis examines how national energy consumption characteristics relate to the share of manufactures in merchandise exports. Comparative advantage provides the theoretical foundation: differences in productive capabilities and input requirements shape export specialization. Costinot, Donaldson, and Komunjer in 2012 establish a framework connecting relative productivity to international trade patterns. Energy enters this relationship as a production input whose availability and composition may influence the activities an economy can sustain competitively. The present framework examines observed associations between energy characteristics and export composition rather than treating energy consumption as an independently identified cause of export performance. The framework distinguishes three observed energy indicators: fossil fuel consumption share, alternative and nuclear energy share, and energy use per capita. These indicators capture energy composition and consumption scale. They enter the analysis separately rather than forming a composite index. The outcome manufactures exports as a percentage of merchandise exports. A larger share indicates greater manufacturing representation in the export basket, but does not necessarily indicate higher export earnings. Because the denominator includes other merchandise exports, the manufacturing share can change even when manufactured export values remain constant.

Fossil fuel consumption share measures the proportion of national energy consumption supplied by coal, oil, petroleum, and natural gas. Its relationship with manufactured export share admits competing explanations. Fossil energy can support industrial production where established technologies depend on these fuels. However, economies specializing in fuel exports may exhibit substantial fossil energy consumption alongside a smaller manufacturing share of merchandise exports. Consequently, a high fossil fuel share does not imply a uniform direction of association with manufactured export performance. Sato and Dechezleprêtre in 2015 find that industrial energy price differences affect international trade, although their estimated effects are small and stronger in sectors with greater energy requirements. Their findings support attention to energy conditions while cautioning against treating them as the dominant explanation for trade patterns. Energy prices and fuel consumption shares measure different characteristics, so that evidence does not establish a directional prediction for the indicator examined here.

RQ1: How does manufactures export share vary with fossil fuel energy consumption share across exporting economies and over time?

Alternative and nuclear energy share captures the contribution of energy sources including hydropower, nuclear, geothermal, and solar energy. A larger share may accompany an energy system capable of supporting manufacturing with less dependence on fossil fuels. However, energy composition alone does not establish production costs, supply continuity, or industrial competitiveness. Economies with similar alternative energy shares can therefore exhibit different export structures. Dechezleprêtre and Sato in 2017 show that competitiveness responses to environmental regulation depend on the outcome and sector examined, with adverse effects generally concentrated in particular activities. Dechezleprêtre, Nachtigall, and Venmans in 2023 also demonstrate that emissions reductions under the European Union emissions trading system need not coincide with deteriorating economic performance. These findings challenge a necessary tradeoff between environmental improvement and productive activity. They do not establish that a larger national alternative and nuclear energy share increases manufactured export share, making an open research question appropriate.

RQ2: How does manufactures export share vary with alternative and nuclear energy share across exporting economies and over time?

Energy use per capita measures national primary energy consumption relative to population. Greater consumption may accompany the machinery, processing capacity, and supporting infrastructure associated with industrial production. At the same time, national consumption includes household, transport, and other activities outside manufacturing. Higher energy use per person therefore cannot be interpreted directly as greater manufacturing productivity or energy efficiency. Allcott, Collard-Wexler, and O'Connell in 2016 show that electricity shortages constrain manufacturing activity in India, providing evidence that energy conditions matter for industrial production. However, their measure of supply shortages differs from national energy consumption per capita. The present analysis consequently examines whether consumption scale accompanies manufacturing specialization without assuming that additional consumption necessarily improves export performance.

RQ3: How does manufactures export share vary with energy use per capita across exporting economies and over time?

The conceptual framework links each observed energy indicator to the same observed export composition outcome. These links represent associations to be examined, not established causal pathways. The research questions can be resolved using the available annual observations through descriptive comparisons and association analysis. Their formulation permits positive, negative, negligible, or inconclusive relationships without imposing a common direction across energy dimensions.

3. Data:

This section establishes data provenance, documents sample selection, and defines the observed measures used to examine energy consumption characteristics and manufactured export composition. The analysis retains only indicators that pass the implemented quality checks and reports descriptive evidence for the resulting common sample.

3.1 Data Sources, Population, and Sample Construction

The observations originate from the World Bank World Development Indicators database, supplied through a consolidated workbook containing source records, indicator definitions, extraction links, and coverage information. The energy indicators identify the International Energy Agency as their underlying provider. Manufactures export share draws on United Nations Comtrade, the World Integrated Trade Solution, and World Bank estimates. Merchandise export values identify the World Trade Organization as their provider. World Bank 2013 documents the database architecture and indicator framework, but the supplied observations represent an API extract rather than the historical printed edition. The retained series are EG.USE.COMM.CL.ZS for alternative and nuclear energy share, EG.USE.PCAP.KG.OE for energy use per capita, TX.VAL.MANF.ZS.UN for manufactures export share, and TX.VAL.MRCH.CD.WT for merchandise exports. Access uses the public World Bank API through api.worldbank.org/v2. The workbook records the retrieval and source update timestamps separately from observation years. Its indicator documentation identifies a Creative Commons Attribution 4.0 licence, subject to the underlying providers' applicable conditions.

The unit of analysis is an exporting economy observed annually from 2010 through 2023. The data form a panel linking national energy characteristics to manufacturing representation in merchandise exports. Energy consumption and exports describe activity during each calendar year. The percentages express annual composition, while energy use per capita expresses annual primary energy consumption relative to population. None of these measures represents an asset stock or an end of year balance. The target population comprises exporting economies worldwide. The accessible frame contains 206 separately reported economies with positive merchandise exports in at least one observation year. It includes countries and separately reported territories, while excluding regional and income aggregates. Selection follows data availability rather than probability sampling. The geographical breadth supports international comparison, but the accessible frame does not establish complete coverage of the target population. The distinction between national energy systems and merchandise trade follows the statistical boundaries described by United Nations Statistics Division 2011 and 2018. International Energy Agency 2023 provides the broader energy system context, while World Trade Organization 2023 distinguishes merchandise trade from commercial services and documents product group coverage. These publications inform interpretation of the supplied indicators rather than supplying additional observations.

Table 1: Sample construction

Stage	Economies Remaining	Annual Observations Remaining	Implemented Rule
Eligible frame within the observation period	206	2,884	Fourteen annual records per economy
Records with both retained energy indicators	149	2,084	Remove 800 records missing alternative and nuclear energy share or energy use per capita
Records with the export outcome	140	1,852	Remove another 232 records missing manufactures export share
Positive merchandise export requirement	140	1,852	All remaining records have observed positive merchandise exports
Final descriptive sample	140	1,852	Unique economy and year combinations with all retained measures available

The final sample retains 64.22 percent of the accessible observations. It is unbalanced: 116 economies contribute all fourteen years, while the remaining 24 contribute between one and thirteen years. Annual sample size ranges from 128 to 136 economies. Reconstructing the sample from the source panel avoids imposing additional losses caused by missing values in the excluded fossil fuel indicator.

3.2 Data Integration, Cleaning, and Quality Assurance:

The supplied panel aligns observations through the World Bank economy identifier and calendar year. The audit confirmed 2,884 unique identifier and year combinations within the selected period, with no duplicate keys. Indicator columns were matched within the same year. No frequency conversion, fiscal calendar adjustment, currency conversion, or inflation

adjustment was required for the retained analytical measures. Merchandise exports remain in current United States dollars because they serve only to identify positive export activity. The quality audit identified a material problem in the supplied fossil fuel consumption series. It reports zero for the United States, China, and Germany throughout 2016 through 2023 and contains six negative percentages in 2015. These records do not support interpreting the series as a comparable measure of fossil fuel consumption share. The analysis therefore excludes the indicator entirely. This decision was made during data inspection, before calculating the reported descriptive statistics. For the retained indicators, checks covered numeric coding, unique observation keys, nonnegative energy consumption, and percentage values between zero and 100. All retained observations passed these checks. Valid extreme observations were preserved. No trimming, winsorization, interpolation, or replacement of missing observations with zero was applied. These checks establish internal consistency with the stated measurement units; they do not independently verify the underlying national statistics.

Table 2: Missing observations in the accessible frame

Indicator	Available Observations	Missing Observations	Economies With at Least One Missing Observation
Alternative and nuclear energy share	2,084	800	58
Energy use per capita	2,084	800	58
Manufactures export share	2,360	524	67
Merchandise exports	2,844	40	8

Missingness overlaps across indicators, so the column totals do not represent separate exclusions. The two retained energy indicators share the same availability pattern. Their annual missing counts range from 57 to 58. Missing manufactures export observations range from 31 to 44 annually, while missing merchandise export observations range from one to eight. At least one retained field is unavailable in 90 economies. The common sample preserves observed values without estimating missing observations. However, complete records need not represent incomplete records. Hughes and colleagues in 2019 show that the suitability of complete case analysis depends on the missingness mechanism, while Little and Rubin in 2019 explain why observed missingness patterns alone cannot establish an ignorable selection process. Accordingly, the descriptive statistics characterize the retained observations rather than an unbiased estimate of all exporting economies. Baraldi and Enders in 2010 distinguish missing observations from substantively meaningful values. White, Royston, and Wood in 2011 and van Buuren in 2018 further show that imputation requires an explicit model and supporting assumptions. The analysis preserves the source missingness pattern because no such model was implemented. The records represent revised historical observations rather than information demonstrably available at each original observation date.

3.3 Variable Measurement, Construction, and Validation:

The retained framework distinguishes national energy composition, national energy consumption scale, and manufactured export composition. Each construct is represented by a directly reported indicator. No latent variable, composite index, moderator, interaction, or calculated control is constructed.

Table 3: 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
Alternative and nuclear energy share	Energy composition indicator	Reported contribution of alternative and nuclear sources to total energy use	World Bank WDI, underlying IEA data	Percent; annual	Original level; higher values indicate a larger alternative and nuclear contribution	Exclude incomplete records from the common sample	National coverage; does not measure manufacturing energy use, supply reliability, or policy stringency
Energy use per capita	Energy consumption scale indicator	Reported primary energy use relative to population	World Bank WDI, underlying IEA data	Kilograms of oil equivalent per person; annual	Original level; higher values indicate greater energy consumption per person	Exclude incomplete records from the common sample	Includes activities outside manufacturing; does not measure energy efficiency
Manufactures export share	Outcome indicator	Manufactures as a share of merchandise exports; SITC Revision 3 sections 5 through 8, excluding division 68	World Bank WDI, underlying Comtrade and WITS data	Percent; annual	Original level; higher values indicate greater manufacturing representation in merchandise exports	Exclude incomplete records from the common sample	Measures export composition rather than export value, profitability, or supplier survival
Merchandise exports	Eligibility indicator	Reported annual merchandise exports	World Bank WDI, underlying WTO data	Current United States dollars; annual	Require an observed positive value	Exclude unavailable or nonpositive records	Used for eligibility, not as an additional outcome or explanatory variable

The export outcome measures specialization within the merchandise basket. This interpretation is consistent with the distinction between relative specialization and absolute trade performance developed by Costinot, Donaldson, and Komunjer in 2012. A larger manufacturing share can reflect changes in manufactured exports, other merchandise exports, or both. Consequently, percentage point differences in this outcome cannot be interpreted as percentage growth in export earnings. The energy measures also require distinct interpretations. Sato and Dechezleprêtre in 2015 examine industrial energy prices, while Allcott, Collard-Wexler, and O'Connell in 2016 examine electricity shortages. Neither characteristic is measured by national energy consumption per capita. Similarly, the evidence examined by Dechezleprêtre and Sato in 2017 and Dechezleprêtre, Nachtigall, and Venmans in 2023 concerns environmental policy and economic performance. Alternative and nuclear energy share is therefore interpreted as an observed energy characteristic, without assigning it the meaning of regulatory stringency or policy effectiveness.

Table 4: Descriptive statistics for the common sample

Indicator	Valid Observations	Mean	Standard Deviation	Median	Minimum	Maximum
Alternative and nuclear energy share, percent	1,852	10.54	14.60	5.00	0.00	100.00
Energy use per capita, kilograms of oil equivalent	1,852	2,472.70	2,919.58	1,505.86	112.88	21,456.36
Manufactures export share, percent	1,852	43.76	29.68	43.34	0.0029	96.22

Statistics are calculated from unrounded source values. Standard deviations use the sample definition. Each observation receives equal weight, so the summaries describe the distribution of observed economy and year records rather than a population weighted global energy or export aggregate.

3.4 Analytical Framework, Identification, and Reproducibility:

The implemented analysis is descriptive. It establishes the distribution and coverage of the retained energy indicators and manufactured export share. Its quantities of interest are observed means, standard deviations, medians, ranges, and annual coverage counts. These summaries do not identify the effect of changing an economy's energy composition or consumption level. The distinction between the substantive question and the quantity identified by the data follows Hernán 2018. National production structure can influence both energy consumption and export composition, while the outcome's merchandise export denominator can change independently of manufacturing activity. The available descriptive calculations do not separate these relationships. Accordingly, their interpretation remains bounded by observed distributions and the common sample. The audit preserves the distinction between original observations and analytical decisions. The period restriction, missingness exclusions, indicator removal, and sample counts are stated explicitly. These decisions were established during the audit rather than through a documented preregistration. This disclosure follows the reporting principle emphasized by Munafò and colleagues in 2017: analytical transparency requires distinguishing decisions made during inspection from decisions fixed in advance.

The source workbook retains the original panel, indicator identifiers, definitions, extraction routes, and provenance fields. Tables 1 through 4 document the additional sample restriction, quality decision, operational definitions, and recalculated summaries. Preserving these links supports the computational traceability emphasized by Peng 2011 and Sandve and colleagues in 2013. The reported counts and statistics can be reconstructed by selecting the stated years, retaining the four required fields, applying the positive export condition, and calculating summaries over the resulting 1,852 records. No public repository identifier or archived software environment accompanies the supplied workbook. Reproduction therefore depends on preserving this particular source extract rather than assuming that a later database download will return identical values. This distinction reflects the reproducibility problem documented by Stodden, Seiler, and Ma in 2018. Across the retained variables, annual timing, original measurement units, common sample membership, and unchanged source precision provide a consistent basis for descriptive comparison.

4. Methods:

4.1 Research Design and Analytical Targets:

This analysis uses a descriptive associational panel design to examine whether national energy characteristics correspond to manufacturing representation in merchandise exports. The unit of analysis is an exporting economy observed annually from 2010 through 2023. The analytical targets are the direction and magnitude of linear and rank associations, their variation within economies, and changes in average characteristics under constant sample membership. The design distinguishes three sources of information. Pooled comparisons combine differences across economies and years. Comparisons between economy averages summarize differences in observed period means. Comparisons within economies examine whether departures from an economy's average energy characteristics correspond to departures from its average manufactured export share. These comparisons answer different questions and are interpreted separately. The analysis estimates unadjusted associations rather than treatment effects. National production structure, income, resource endowments, and other characteristics may influence both energy consumption and export composition. Export activity may also influence energy requirements. Removing economy means does not resolve these competing explanations or remove common annual shocks. Consequently, the estimates describe observed correspondence without identifying causal direction.

4.2 Association Measures and Temporal Comparisons:

The outcome manufactures exports as a percentage of merchandise exports. The two explanatory indicators are alternative and nuclear energy share and energy use per capita. Their definitions and units follow the variable dictionary in Table 3. Both indicators are matched to the outcome in the same calendar year. For each energy indicator, the pooled Pearson correlation is calculated as:

$$r_P = \frac{\sum_{i,t}(x_{it} - \bar{x})\,(y_{it} - \bar{y})}{\sqrt{\sum_{i,t}(x_{it} - \bar{x})^2 \sum_{i,t}(y_{it} - \bar{y})^2}}. \qquad (1)$$

Here, r_P denotes the Pearson correlation; iidentifies an economy; tidentifies an observed year; $x_{it}$is the relevant energy indicator; $y_{it}$is manufactures export share; and $\bar{x}$and $\bar{y}$are means over the retained observations. The summations include available records in the common analytical sample. Spearman correlations apply Equation 1 to pooled ranks rather than original values. Tied observations receive average ranks. Pearson correlations summarize linear correspondence on the original measurement scales, whereas Spearman correlations summarize monotonic ordering. Comparing them assesses whether interpretation depends on original magnitudes or relative positions, following the distinction explained by Schober, Boer, and Schwarte in 2018. Variation within economies is isolated through mean centering:

$$\tilde{x}_{it} = x_{it} - \bar{x}_i,\ \tilde{y}_{it} = y_{it} - \bar{y}_i. \qquad (2)$$

Here, $\tilde{x}_{it}$ and $\tilde{y}_{it}$ are deviations from economy specific observed period means, while $\bar{x}_i$and $\bar{y}_i$denote those means. Equation 1 is then applied to the centered observations. This calculation removes differences in economy averages but does not

constitute an adjusted regression or control for annual common influences. Between economy correlations apply Equation 1 to the paired economy means, giving each economy one observation. Pooled and within economy calculations instead retain every eligible annual record, so economies with longer coverage contribute more observations. Temporal comparisons use the balanced sample. For each retained indicator and the outcome, the average endpoint change is:

$$\bar{\Delta z} = \frac{1}{G_B}\sum_{i=1}^{G_B}\left(z_{i,2023} - z_{i,2010}\right). \qquad (3)$$

Here, $\bar{\Delta z}$ is the average change; zrepresents the measure being summarized; and $G_B$is the number of economies observed in every year. Equation 3 gives each economy equal weight. Changes in percentage measures are expressed in percentage points, while changes in consumption per person retain kilograms of oil equivalent.

4.3 Sample Alignment and Analytical Implementation:

The principal calculations use the 1,852 observations from 140 economies documented in Table 1. All association measures use the same records, preventing differences between Pearson and Spearman estimates from arising through variable specific sample selection. The balanced comparison contains 116 economies and 1,624 observations, with complete annual coverage throughout the observation period. The analytical sequence begins with the source panel. Records are restricted to the observation period, matched through economy identifiers and calendar year, and screened for availability of both retained energy indicators, the export outcome, and positive merchandise exports. The fossil fuel indicator is excluded following the documented quality audit. Sample reconstruction does not require observations for that excluded indicator. The procedure preserves original numeric precision. Percentage indicators must lie between zero and 100, and energy consumption per person must be nonnegative. Valid extreme observations remain unchanged. Missing observations are neither imputed nor interpolated, and no logarithmic transformation, trimming, or winsorization is applied.

Descriptive statistics comprise valid counts, arithmetic means, sample standard deviations, medians, minima, and maxima. Correlations are calculated after these checks, followed by economy mean centering, comparisons between economy averages, and reconstruction of the balanced sample. Selected annual averages and endpoint changes are then calculated using constant economy membership. Complete record selection makes the estimand conditional on observed coverage. It does not establish that excluded records resemble retained records. Hughes and colleagues in 2019 emphasize that the consequences of complete case analysis depend on the missingness process. Accordingly, sample size and geographical breadth are not treated as evidence of population representativeness. Calculations use Python version 3.12.14, NumPy version 2.3.5, and SciPy version 1.17.0. NumPy supplies correlations, descriptive calculations, random number generation, and quantiles. SciPy supplies ranks through rankdata with its average tie convention.

4.4 Uncertainty, Sensitivity, and Reproducibility:

Uncertainty is assessed using an economy block bootstrap. Each replication draws 140 economies with replacement and retains all annual observations belonging to each selected economy. An economy selected more than once contributes its complete record block once per selection. This preserves the observed dependence and coverage pattern within each sampled economy. Each bootstrap replication recalculates pooled Pearson correlations, correlations within economies, and correlations between economy averages. Economy means are reconstructed from the resampled blocks. Spearman correlations are calculated in a separate bootstrap pass using the same economy selection sequence, with pooled ranks recalculated in every replication. The procedure uses 1,999 replications and NumPy default_rng with seed 4217 for association intervals. Reported 95 percent percentile intervals use the 2.5th and 97.5th percentiles of the bootstrap distribution, calculated with linear quantile interpolation. This approach recognizes the clustered structure emphasized by Cameron and Miller in 2015, while requiring independence across resampled economies. It does not fully address dependence generated by common international shocks or correct selection into the observed sample.

For endpoint changes, the bootstrap draws 116 economies with replacement from the balanced sample. Each draw preserves the paired first and last observations used in Equation 3. The procedure recalculates the average change over 1,999 replications using seed 1893 and constructs percentile intervals using the same quantile convention. Sensitivity analysis addresses two specific threats. Comparing Pearson and Spearman estimates examines dependence on measurement scale and relative ordering while holding observations constant. Repeating the association calculations in the balanced sample assesses whether the principal pattern persists with complete coverage and constant economy membership. Balanced sample comparisons change sample composition and therefore do not establish that missingness is harmless. Interpretation considers direction, magnitude, and interval width rather than treating exclusion of zero as sufficient evidence of practical importance. An interval containing zero is not interpreted as proof of no relationship. The analysis also distinguishes uncertainty around an observed association from identification of its underlying explanation. The source workbook preserves observations, definitions, and extraction routes, while Tables 1 and 3 document sample construction and measurement. Equations 1 through 3 and the software settings specify the additional calculations. These details support computational traceability without claiming a new estimator or identification strategy.

5. Findings:

This analysis examines whether national energy composition and consumption scale correspond to manufacturing representation in merchandise exports. The findings distinguish pooled associations from changes within economies and assess sensitivity to measurement scale and sample coverage. The evidence supports an assessment of observed relationships without attributing export outcomes to causal energy effects. The analytical sample contains 1,852 annual observations from 140 exporting economies between 2010 and 2023. Alternative and nuclear energy share averages 10.54 percent, compared with a median of 5.00 percent. Energy use per capita averages 2,472.70 kilograms of oil equivalent, exceeding its median of 1,505.86. Both distributions therefore place more weight on observations with relatively high consumption or energy shares. Manufactures export share averages 43.76 percent, with a median of 43.34 percent and a standard deviation of 29.68 percentage points. This dispersion establishes substantial variation in export composition across the observed economies and years. The outcome measures

manufacturing representation within merchandise exports rather than absolute export capacity. Its interpretation therefore concerns export specialization, consistent with the distinction between relative productive advantages and trade patterns developed by Costinot, Donaldson, and Komunjer in 2012. Differences in this outcome cannot independently establish changes in manufactured export earnings.

Table 5: Associations between energy characteristics and manufactures export share

Energy Indicator	Pooled Pearson Correlation	95 Percent Interval	Pooled Spearman Correlation	95 Percent Interval	Pearson Correlation Within Economies	95 Percent Interval
Alternative and nuclear energy share	0.052	−0.105 to 0.252	0.230	0.077 to 0.374	−0.037	−0.109 to 0.041
Energy use per capita	−0.017	−0.168 to 0.182	0.258	0.092 to 0.419	−0.042	−0.172 to 0.079

Table 5 reveals a distinction between linear association and relative ordering. Alternative and nuclear energy share has a pooled Pearson correlation of 0.052 with manufactures export share. Its interval includes both negative and positive values, providing limited precision about the direction of the linear relationship. The Spearman correlation is 0.230, with an interval entirely above zero. Economies and years ranked higher in alternative and nuclear energy share consequently tend to rank higher in manufacturing representation, although differences in their original percentage values do not exhibit a comparably clear linear relationship. Energy use per capita displays the same distinction. Its pooled Pearson correlation is −0.017, while its Spearman correlation is 0.258. The positive rank association indicates that higher consumption rankings tend to accompany higher manufactured export rankings. However, the near zero Pearson estimate does not support a proportional relationship between additional energy consumption and export composition. As Schober, Boer, and Schwarte explain in 2018, Pearson and Spearman coefficients summarize different features of an association. Their divergence here makes the choice of measurement scale consequential for interpretation.

The relationships weaken when the analysis isolates variation within economies. The corresponding Pearson correlations are −0.037 for alternative and nuclear energy share and −0.042 for energy use per capita. Both intervals cross zero. These estimates indicate little linear correspondence between deviations in an economy's energy characteristics and deviations in its manufactured export share. They do not establish that every economically relevant relationship is absent. Instead, they show that the positive pooled rank associations do not translate into a clearly estimated linear pattern within economies. Correlations between economy averages reinforce this distinction. The Pearson correlations are 0.064 for alternative and nuclear energy share and −0.010 for energy use per capita. Their respective intervals extend from −0.092 to 0.266 and from −0.161 to 0.187. Thus, neither comparison of average levels nor comparison of deviations within economies provides precise evidence of a uniform linear association.

The bootstrap calculations preserve repeated observations within each economy rather than treating every annual record as independent. This addresses the dependence concern emphasized by Cameron and Miller in 2015. The intervals nevertheless remain conditional on the observed sample and the assumption that economies provide independent resampling units. They do not correct for selection into the dataset or fully account for dependence generated by shared international shocks. The balanced sample provides a separate assessment of temporal patterns without changes in economy membership. It contains 116 economies and 1,624 observations, with every economy represented in all fourteen years. Table 6 reports equally weighted economy averages for selected years and the average change between the first and last observation years.

Table 6: Energy characteristics and manufactured export composition in the balanced sample

Indicator	2010	2015	2020	2023	Average Change from 2010 to 2023	95 Percent Interval for Change
Alternative and nuclear energy share, percent	10.83	10.86	11.88	12.75	1.92 percentage points	0.88 to 2.85
Energy use per capita, kilograms of oil equivalent	2,679.54	2,556.20	2,445.44	2,442.45	−237.10	−369.36 to −107.40
Manufactures export share, percent	45.55	47.49	47.34	46.23	0.67 percentage points	−1.48 to 2.88

Alternative and nuclear energy share increased by an average of 1.92 percentage points in the balanced sample, while energy consumption per person decreased by 237.10 kilograms of oil equivalent. Manufactured export share changed by only 0.67 percentage points, with an interval spanning a decrease and an increase. These trajectories demonstrate that a shift in national energy composition and a reduction in consumption per person can coexist with comparatively limited net movement in manufacturing representation within exports. This pattern does not contradict evidence that energy constraints affect industrial activity. Allcott, Collard-Wexler, and O'Connell in 2016 examine electricity shortages and manufacturing performance, whereas the present indicators describe national consumption scale and energy composition. The observed decline in consumption per person cannot therefore be interpreted as evidence of worsening electricity availability or declining manufacturing productivity.

Restricting the association analysis to the balanced sample leaves the principal distinction intact. Pooled Pearson correlations remain close to zero at 0.029 for alternative and nuclear energy share and −0.021 for energy use per capita. Spearman correlations remain positive at 0.196 and 0.290, respectively. Correlations within economies remain small and negative at −0.028 and −0.052. The qualitative contrast between positive rank ordering and weak linear correspondence therefore persists when economy membership remains constant. The evidence also cautions against treating national energy characteristics as a sufficient explanation of international manufacturing specialization. Sato and Dechezleprêtre in 2015 find that industrial energy price differences explain a limited share of trade variation. Although their explanatory measure differs from those examined here, their findings reinforce the need to distinguish an energy related association from a comprehensive account of export performance. The research questions receive a differentiated answer. Higher rankings in alternative and nuclear energy share and energy

consumption per person accompany higher rankings in manufactured export share. However, original level comparisons and changes within economies provide no precise evidence of a common linear relationship. The balanced sample confirms that energy characteristics can change without a corresponding directional shift in manufactured export composition. These conclusions describe the observed panel and remain subject to its coverage and dependence limitations.

6. Discussion:

Energy characteristics distinguish export rankings more clearly than they explain changes in export composition. Table 5 shows positive rank associations alongside weak linear relationships, including correlations within economies whose intervals encompass zero. The contribution of this analysis lies in separating these empirical patterns: an economy's relative position in the energy distribution does not provide equivalent evidence about how its export structure changes over time. This distinction qualifies interpretations that translate international comparisons into expected domestic trajectories. Bernard, Redding, and Schott in 2010 demonstrate that manufacturing adjustment involves firms adding and dropping products. The present evidence complements that perspective by showing that national energy indicators do not closely track aggregate manufacturing representation in exports. It therefore sharpens the distinction between international ordering and industrial adjustment rather than establishing a uniform energy driven relationship. The divergence between pooled rankings and variation within economies also changes how transmission mechanisms should be interpreted. Table 5 provides evidence of association, but its small correlations within economies do not identify a pathway through which energy composition changes manufactured export share. Calel and Dechezleprêtre in 2016 identify technological responses to environmental policy using firm level innovation evidence. That mechanism cannot be inferred from national energy shares alone. Similarly, De Loecker in 2013 examines productivity changes associated with exporting, illustrating that productive capabilities may respond to international market participation. These studies make the direction of interpretation consequential: energy characteristics may accompany productive structures without independently explaining their evolution. The contribution here is to establish the empirical boundary between an observed national association and evidence identifying the process that generates it.

Table 6 further separates energy composition, consumption scale, and export specialization. In the balanced sample, alternative and nuclear energy share increased while energy consumption per person declined, yet the net change in manufactured export share remained imprecisely estimated. These trajectories show that changing energy characteristics need not coincide with a common directional movement in manufacturing representation. They also prevent interpreting lower consumption as demonstrated efficiency improvement. Fowlie, Greenstone, and Wolfram in 2018 distinguish measured energy savings from the broader economic returns to efficiency investment, reinforcing the need to evaluate each outcome directly. The present analysis extends this measurement distinction to international export comparisons: energy composition, consumption, and manufacturing specialization describe separate dimensions of economic change. Their joint observation does not establish that one dimension dominates or transmits changes to another. The persistence of the principal pattern in the balanced sample reduces concern that changing economy membership alone explains the findings. However, Table 5 also shows why international comparisons require attention to the scale and outcome being measured. Lee, Miguel, and Wolfram in 2020 find limited economic responses to household grid connections in rural Kenya, while Aklin and colleagues in 2017 distinguish improvements in basic energy access from broader socioeconomic gains in India. These experiments examine different interventions and outcomes from the present national panel, so they provide interpretive boundaries rather than direct corroboration. Together, they challenge the assumption that improved energy conditions automatically generate the same economic response across settings. The global contribution of this analysis is to show that positive international rank ordering can coexist with weak temporal correspondence, making national rankings an insufficient basis for predicting manufacturing adjustment.

The practical implication is that energy policy and manufacturing performance require separate assessment. Table 6 does not justify treating a larger alternative and nuclear energy share as evidence of export upgrading, while Table 5 does not support using greater energy consumption per person as a proportional predictor of manufacturing representation. Decision makers should therefore evaluate energy outcomes alongside manufactured export values and composition, distinguishing changes in manufacturing activity from changes elsewhere in the merchandise basket. The theoretical implication is equally specific: international differences in energy characteristics provide a descriptive context for specialization, but their temporal relationships require independent evidence. By preserving the distinction between rankings, levels, and changes within economies, this analysis redirects interpretation toward the relationship actually measured and away from policy conclusions that pooled associations alone cannot sustain.

7. Conclusion and Implications:

International rankings can mislead industrial strategy when differences across economies are interpreted as pathways for change within them. This analysis shows that positive international ordering can coexist with weak linear correspondence and limited alignment over time. Its core contribution is an empirical distinction between comparative position and domestic adjustment, qualifying interpretations that treat favorable national conditions as sufficient evidence of manufacturing advancement. The findings refine the application of comparative advantage reasoning by showing why observed specialization and changes in specialization require separate assessment. They establish an interpretive boundary rather than a causal transmission mechanism. For managers, this distinction supports evaluating investment decisions against operational requirements and market opportunities rather than national rankings alone. For policymakers, it supports assessing progress in industrial development separately from progress in the energy system, with explicit attention to what each performance measure captures. Resource allocation should therefore rely on evidence connecting interventions to intended outcomes rather than assuming that improvements across different domains necessarily reinforce one another. Operationally, separate monitoring of physical consumption, production activity, and export composition can reduce misleading performance assessments. The broader social value lies in strengthening the evidential basis for decisions affecting productive investment and public resources, without promising benefits that the analysis has not measured.

The observational panel creates opportunities for more targeted identification. National aggregates provide a comparative perspective, while linked establishment records could reveal how supply conditions and production decisions interact. Product

level export values could distinguish changes in manufacturing activity from changes elsewhere in the export basket. Designs exploiting identifiable policy or infrastructure changes could test causal pathways, while sectoral comparisons could assess differences in production requirements. Historical data vintages and alternative missingness assumptions would strengthen assessments of temporal comparability and selection. These extensions could determine which relationships generalize across institutional settings and which depend on specific productive structures.

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