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RESEARCH ARTICLE

Navigating Complexities in Sino-US trade relations: An in-depth analysis of RCA, TCI, and ESI in SITC commodities

Zeeshan Iqbal[1*], Shahzad Ahmad[2], Imad Ahmad[2]

[1] *School of International Trade and Economics, University of International Business and Economics, Beijing, China*

[2] *Department of Customs Administration, School of Government, University of International Business and Economics, Beijing, China*

*** Corresponding author:** Zeeshan Iqbal, zeeshani356@gmail.com; zeeshani356@uibe.edu.cn

ABSTRACT

This paper presents a thorough examination of Sino–U.S. trade dynamics from 2008 to 2022, utilizing the Standard International Trade Classification (SITC) for commodity categorization. It employs essential trade indices, including the Revealed Comparative Advantage (RCA), the Trade Complementarity Index (TCI), and the Export Similarity Index (ESI), to assess trade competitiveness and complementarity. The RCA findings reveal China's persistent comparative advantage in sectors such as machinery and transport equipment (C7), with values predominantly exceeding 1. At the same time, the United States demonstrates significant advantages in chemicals (C5) and crude materials (C2), also with RCA values above 1. TCI analysis shows China's stability in C0 but declining complementarity in C2, whereas the US demonstrates increasing complementarity in C2, C5, C7, and C8. ESI results reveal high structural similarity in C7 and partial alignment in C8, suggesting potential for bilateral cooperation. The study recommends that both countries strategically leverage their respective strengths and pursue collaboration in areas with high complementarity to optimize trade outcomes in a shifting global economic landscape.

Keywords: SITC; RCA; TCI; ESI; Sino-U.S.; trade

1. Introduction

In recent years, scholarly interest in the competitive and complementary dimensions of international trade has intensified, particularly in the context of China’s trade relations with major global economies. International trade continues to play a pivotal role in national development, serving as a cornerstone of economic growth and a key driver of global integration. This study focuses on trade between China and the United States, two of the world’s largest trading economies, whose bilateral trade relationship has become increasingly complex, marked by both deep interdependence and periodic disputes.

To analyze trade flows between these two nations, this study adopts the Standard International Trade Classification (SITC), a framework developed by the United Nations Statistics Division to provide a harmonized method for categorizing traded goods. The SITC system, currently in its fourth revision (Rev. 4),

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facilitates consistent and comparable international trade statistics by classifying goods based on their economic characteristics and end-use. It is widely used by governments, international organizations, and researchers to examine the composition of trade and identify global trade trends. Given the evolving landscape of global trade, particularly from 2008 to 2022, a period marked by important economic events and policy shifts, this study conducts a detailed empirical analysis of China-US trade patterns using three robust trade indices: the Revealed Comparative Advantage (RCA), the Trade Complementarity Index (TCI), and the Export Similarity Index (ESI). The RCA, introduced by [1], assesses a country's relative export performance in specific commodities, indicating areas of comparative strength or weakness. The TCI, proposed by [2], evaluates how well the export profile of one country aligns with the import demands of another, offering insight into the potential for mutually beneficial trade. The ESI, developed by [3], measures the degree of similarity in export structures between countries, capturing the extent of competition or convergence in trade portfolios.

This research aims to identify the competitive advantages and complementarities in SITC-classified goods between China and the US, with the objective of uncovering structural patterns and trade dynamics that have emerged over the past 15 years. Given that China has become the largest overseas market for many American exports, and the US remains one of the most important markets for Chinese goods, this trade relationship holds significant economic and geopolitical implications. In 2022 alone, total trade in goods and services between the two countries reached approximately $758.4 billion, with the US experiencing a trade deficit of $367.4 billion (China General Administration of Customs, 2023). Amid growing economic interdependence, trade frictions have also intensified, highlighting the need for deeper empirical insights into the structure and evolution of this critical bilateral relationship. By examining the competitive and complementary aspects of trade through the lens of RCA, TCI, and ESI, this study contributes to a more nuanced understanding of China-US trade. It provides evidence-based implications for policymakers and trade strategists.

2. Literature review

2.1. Comparative advantages and competitiveness of trade

The notion of comparative advantage was first presented by David Ricardo in 1817 cite by [4,5] also Michael Porter also proposed the theory of international competitiveness in 1990 in his book The Competitiveness of Nations. [17] examined the competitiveness of trade between China and Vietnam based on "the Belt and Road" project using the RCA and ESI. The effect of agricultural trade support on the competitiveness of agricultural products in the Turkish market was examined by [6]. In his research,[7] also discovered that a nation's competitiveness is correlated with both the sustainability of its agricultural industry and its ability to export agricultural goods. Six of China's representative agricultural products were evaluated for international competitiveness using two evaluation indices: the trade competitiveness (TCI) index and the RCA index. The researcher also looked at how the competitiveness of these products changed between 1994 and 2013. The Belt and Road Trade competitive advantage networks' structure and determinants are examined by [8]. The comparative advantages and complementarity of agricultural trade between China and the United States utilizing sixteen primary agricultural goods since 1997 were empirically analyzed by [9] using the RCA, CMS, TCD, SI, and TCI models. According to one of their findings, the agricultural products that China and the US export represent the features of each nation's resources. The RCA and TCI indices were used to analyze [18] study, which asserts that although the agricultural trade between China and Souteast asian countries exhibits both competitiveness and complementarity, complementarity is more critical.[10] noted that Ricardo's (1817) Principles of Political Economy and Taxation gave a generalization of Smith's

views on the concept of comparative advantage, which remains a fundamental theory for why countries trade with one another. His two-country, two-good example demonstrates that countries can engage in mutual advantage trade, even if one has a clear advantage in producing both items. The theory not only argues that trade might be beneficial, but it also anticipates production specialization patterns and trade direction. Specifically, countries will specialize their production in the good with the lowest opportunity cost of production (relative to the other country), and this will be the good exported to the other country in exchange for the product with a relatively higher opportunity cost to produce. The Ricardian theory of comparative advantage has been extended beyond the two-good setting to a multiproduct setting [11] and even to multiproduct, multicounty general equilibrium circumstances e.g., [12,13].

2.2. Literature for Sino-US trade complementarity

According to [14] conducted a descriptive evaluation of the complementarity and competitiveness within China-US trade. [15] proposed that the primary cause of the swift expansion of trade between China and the United States, along with the rapid increase of the American trade deficit with China, is greater complementarity than competitiveness in Sino-U.S. trade ties. [16] examined the trade structures of two-nations using the HS classification, suggesting significant potential for Sino-U.S. agricultural trade. They advocated for policy adjustments to enhance reciprocity and mutual benefit, thereby facilitating an increase in agricultural trade between the two countries. [9] examined the complementarity of Sino-U.S. agricultural commerce based on the SITC categorization. [19] indicated that the trade complementarity between China and the United States is robust and increasingly intensifying. Within the WTO framework of free trade, significant potential for enhanced complementarity exists. [14] conducted an examination of Sino-U.S. trade complementarity based on SITC classifications, asserting that China and the United States exhibit significant trade complementarity and that both nations should maintain their current trade policies.

2.3. Summary of previous studies and this study's contribution

Previous research on international trade dynamics between China and its key partners, particularly the United States, has extensively employed trade indices such as the Revealed Comparative Advantage (RCA), Trade Complementarity Index (TCI), and, to a lesser extent, the Export Similarity Index (ESI). Studies such as [9,19] focused on evaluating comparative advantage and trade complementarity, primarily within agricultural or broadly aggregated merchandise categories.[17] extended this analysis to China–Vietnam trade under the Belt and Road framework, while others like [6,7] explored competitiveness within sector-specific contexts, particularly in agriculture. These studies collectively affirm that China maintains competitive advantages in labor-intensive goods, while the US holds strengths in high-tech and resource-based exports.

However, these earlier works are limited in several key aspects. First, many focus on outdated datasets, mostly pre-2010, and do not account for post-WTO accession shifts or the implications of more recent trade disruptions. Second, while some studies apply individual indices like RCA or TCI, very few use all three indices (RCA, TCI, ESI) together in an integrated framework, which limits their ability to capture the full complexity of bilateral trade relationships. Third, most of the analyses are conducted using general commodity categories or HS classifications, lacking the sectoral granularity offered by the SITC system, especially its fourth revision. Finally, minimal attention has been given to longitudinal dynamics across more than a decade, making it challenging to assess structural changes in comparative advantage and complementarity.

This study addresses these gaps by offering a comprehensive, longitudinal analysis of Sino-U.S. trade from 2008 to 2022 using SITC Rev. 4 data and a triangulated application of RCA, TCI, and ESI. By focusing on ten SITC commodity groups, it uncovers evolving trends in comparative advantage, complementarity, and

export similarity. Unlike prior studies, it captures both convergence and divergence in trade structures, identifies key sectors with sustained or emerging trade strengths, and provides a detailed empirical basis for policy recommendations. It integrated and updated approach contributes a novel and policy-relevant perspective to the literature on China-US trade relations, particularly in the context of ongoing global economic realignments and trade tensions.

Table 1. Sino-US trade comparison in total sitc traded commodities.

Years	CH Exports to the US	CH Imports from the US	China Trade surplus	US Exports to China	US Imports from China	US Trade deficit
2008	252.84	81.86	170.98	71.46	356.3	-284.84
2009	221.3	77.76	143.54	69.58	309.53	-239.95
2010	283.78	102.73	181.05	91.91	382.96	-291.05
2011	325.01	123.12	201.89	104.12	417.34	-313.22
2012	352.44	133.77	218.67	110.52	444.39	-333.87
2013	369.06	153.39	215.67	121.72	459.11	-337.39
2014	397.1	160.06	237.04	123.68	486.3	-362.62
2015	409.98	148.69	261.29	116.07	504.03	-387.96
2016	385.68	135.12	250.56	115.59	481.31	-365.72
2017	430.33	154.44	275.89	129.8	525.76	-395.96
2018	479.28	156.02	323.26	120.15	563.2	-443.05
2019	419.32	123.79	295.53	106.63	472.46	-365.83
2020	452.49	136.34	316.15	124.65	457.16	-332.51
2021	577.13	180.97	396.16	151.07	541.53	-390.46
2022	582.76	178.96	403.80	153.84	575.69	-421.85

Author own calculations, form UNCOMTRAD data in US million Dollars.

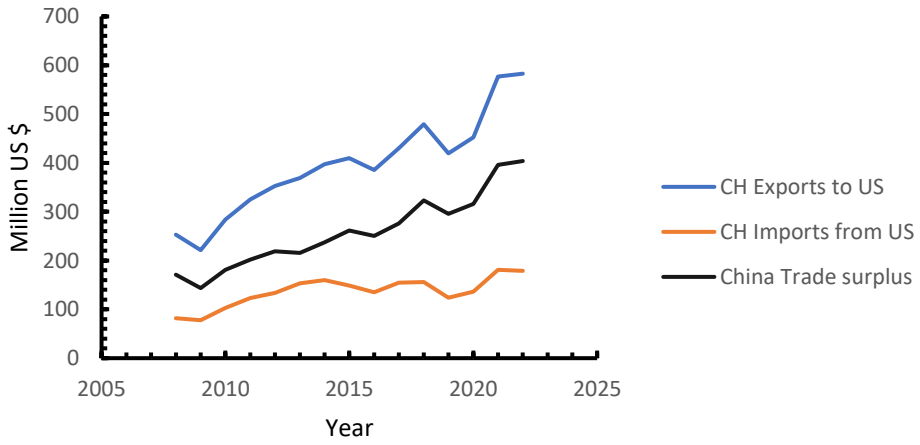

Figure 1. China trade overview with the US

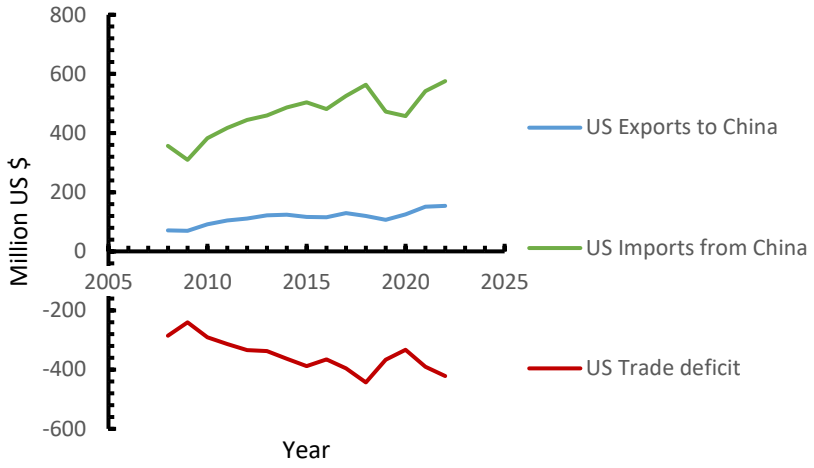

Figure 2. US trade overview with China

The **Table 1** shows the trade patterns between China and the United States from 2008 to 2022, emphasizing SITC commodities. In past years, China's exports to the United States have frequently exceeded its imports, leading to an expanding trade surplus for China. In 2008, the surplus was reaching $170.98 million, increasing to $403.80 million in 2022. On the other hand, the US persistently encountered a trade deficit, which varied over the years. The deficit reached a maximum of -$443.05 million in 2018 and, after that, decreased to -$421.85 million in 2022. Both countries notably experienced an increase in total trade volume, with China's exports to the US and US exports to China growing throughout the years. This data indicates a complex and dynamic economic interaction between the two nations, shaped by factors including market demand, economic policy, and global economic situations.

3. Methodology and data

In this paper, we use various methods such as the RCA Index (RCA), Trade Complementarity Index (TCI), and ESI (SI). So far, the Data has been collected from the period 2008 to 2022; we have analyzed these indicators to understand how China and the US compare in terms of trade in SITC commodities. We aim to identify trends and changes in their comparative advantages and complementarity after the Great Recession.

Table 2. List of SITC commodities.

0 – Food and live animals
1 – Beverages and tobacco
2 – Crude materials, inedible (except fuels)
3 – Mineral fuels, lubricants, and related materials
4 – Animal and vegetable oils, fats, and waxes
5 – Chemicals and related products
6 – Manufactured goods (classified by material)
7 – Machinery and transport equipment
8 – Miscellaneous manufactured articles
9 – Commodities not classified elsewhere

SITC- Rev-4 UNcomtrade

3.1. RCA index

The RCA Index was introduced by [1]. It represents the ratio of the export share of a particular commodity relative to the overall exports of that commodity from a specific country, compared to the export share of the same commodity relative to the total global exports of commodities. If the ratio > 1, it indicates that the specific commodity of that country reveals a comparative advantage, and vice versa. The model can be characterized as:

$$\boldsymbol{RCA} = (\boldsymbol{X^k_{i\,j}} \;/\; \boldsymbol{X^t_{ij}}) \;/\; (\boldsymbol{X^k_{i\,w}} \;/\; \boldsymbol{X^t_{i\,w}}) \tag{1}$$

When using RCA, Ei, and Et represent the export value of a commodity from country *I* and the whole export value of country I, respectively. On the other hand, Wi and Wt represent the export values of a commodity from the world and the total export value of the world during the same period.

3.2. Trade complementarity index (TCI)

The Trade Complementary Index was first proposed by Kojima Kiyoshi and perfected by Peter Drysdale in 1967. The model can be described as:

$$\boldsymbol{C^k_{ij} = RCA^k_{xi} \times RCA^k_{mj}} \tag{2}$$

where C^k_{ij} Is the complementarity index between country *i* and country *j* for commodity *k*, RCA^k_{xi} indicates the comparative advantage of country *i* in commodity *k* by way of exports, and RCA^k_{mj} It is used to show the comparative disadvantage of country *j* in commodity *k* by way of imports, the equations of which are given below:

$$\boldsymbol{RCA^k_{xi} = \left(\frac{X^k_i}{X_i}\right) / \left(\frac{X^k_w}{X_w}\right)} \tag{3}$$

$$\boldsymbol{RCA^k_{mj} = \left(\frac{M^k_j}{M_j}\right) / \left(\frac{X^k_w}{X_w}\right)} \tag{4}$$

where M^k_j Is the import value of commodity *k* in nation *j*, and *Mj* is the overall import value of country *j*; X^k_i and X^k_w The export values of commodity *k* of country *i* and the world's total, respectively; *Xi* and *Xw* are the total export values of country *i* and the world. The Balassa-proposed index, RCA^k_{xi}, actually measures a country's comparative advantage in product *k;* the higher the value, the more so. However, the more product *k* that country *j* imports, the higher its comparative disadvantage in that commodity is, as indicated by the larger value of RCA^k_{mj}. A country's product C^k_{ij} It can be used to quantify the degree of trade complementarity between two countries where country *i* has a comparative advantage in commodity *k* and country *J* has a comparative disadvantage. The two nations have trade complementarity in commodities *k* if C^k_{ij}> 1. The higher the value, the higher the levels of complementarity. C^k_{ij}<1 indicates low complementarity; the lower the value, the lower the complementarity degrees. 10 SITC commodities goods from China and the US were chosen for this study; all information was taken from official sources, including the U.N. Comtrade statistical databases.

3.3. ESI (SI)

The ESI (SI), first put forward by [3], is used to measure the degree of similarity of exports between two countries or regions in the third or world market. The model can be depicted as:

$$\boldsymbol{SI(ab,n) = \left[\sum min\left(\frac{X^k_{an}}{X_{an}}, \frac{X^k_{bn}}{X_{bn}}\right)\right] \times 100} \tag{5}$$

where *SI*(*ab, n*) is the similarity index of the country *a* and the country's exports in market *n* or the world market, $X_{an}^{k}/\ X_{an}$ Is the share of the commodity *k* of country *A*'s export in market *n* as against the country *a*'s total export value in market *n*, whereas X_{bn}^{k}/X_{bn} Is the share of the commodity *k* of the country's export in market *n* as against the country's total export value in market *n*. This index varies from 0 to 100. If the exports of both countries in the third country or the world market (i.e., in market *n*) are entirely the same, this index is 100; if totally different, it is 0. When the index continues to rise during a specific period, it indicates that Country A and Country B are getting more and more competitive with each other in the third market (i.e., in market n). When the index keeps going down, however, it shows that the trade between Country A and Country B is getting more and more specialized, i.e., more and more complementary.

Where *SI (ab, n)* denotes the similarity index of the exports of a country *a* and country *b* in market *n* or world market. $X_{an}^{k}/\ X_{an}$ represents the proportion of commodity *k* in country *A*'s exports within market *n* relative to the total export value of the country and in that market, while X_{bn}^{k}/X_{bn} Indicates the proportion of commodity *k* in the country's exports within market *n* relative to the total export value of country *b* in that market. This index ranges from 0 to 100. If the exports of both countries in a third country or the global market (i.e., in market *n*) are identical, this index is 100; if entirely dissimilar, it is 0. When the index consistently increases over a designated timeframe, it signifies that country *A* and country B are becoming increasingly competitive with one another in the third market (i.e., in market *N*). When the index continues to decline, it indicates that the trade between country *A* and country *B* is becoming increasingly specialized or more complementary.

4. Results and discussion

Table 3. The RCA of China's SITC-products (2008–2022).

Year	C0	C1	C2	C3	C4	C5	C6	C7	C8	C9
2008	0.333	0.018	0.165	0.069	0.037	0.357	1.041	1.330	2.789	0.015
2009	0.328	0.018	0.132	0.029	0.046	0.308	0.997	1.493	2.857	0.016
2010	0.360	0.014	0.120	0.026	0.045	0.365	1.022	1.584	3.131	0.013
2011	0.337	0.016	0.122	0.022	0.042	0.395	1.004	1.589	3.017	0.012
2012	0.349	0.020	0.144	0.026	0.047	0.410	1.110	1.708	3.162	0.001
2013	0.327	0.022	0.139	0.025	0.064	0.411	1.155	1.727	3.212	0.001
2014	0.321	0.021	0.158	0.026	0.059	0.440	1.228	1.824	3.228	0.001
2015	0.351	0.024	0.171	0.032	0.061	0.470	1.474	1.888	3.780	0.000
2016	0.350	0.030	0.161	0.052	0.052	0.442	1.343	1.836	3.637	0.027
2017	0.337	0.029	0.133	0.043	0.051	0.485	1.337	1.925	3.613	0.070
2018	0.346	0.035	0.139	0.034	0.057	0.518	1.377	2.009	3.697	0.066
2019	0.263	0.028	0.111	0.025	0.058	0.427	1.226	1.759	3.349	0.204
2020	0.256	0.013	0.092	0.013	0.053	0.482	1.679	1.972	3.630	0.325
2021	0.255	0.015	0.089	0.012	0.044	0.501	1.432	2.019	4.209	0.474
2022	0.257	0.017	0.103	0.013	0.059	0.591	1.394	1.963	3.968	0.569

The author's calculations data has been collected from UNCOMTRADE.

The **Table 3** shows the RCA(RCA) of China with the United States from 2008 to 2022 for commodities classified under the SITC. The RCA index is a measure of a country's relative advantage or disadvantage in exporting a particular class of goods based on the trade flow compared to the global average. An RCA value greater than 1 indicates that the country has a comparative advantage in exporting that class of goods. In the table, each column (labeled 0 to 9) represents a different class of commodities. The exact commodities are not listed but would correspond to the detailed categories of the SITC. The rows represent different years. For each year, the RCA values for each commodity class are given.

China's comparative advantage (values greater than 1) is consistent across several commodity classes over the years. For example, columns 6, 7, and 8 consistently show values above 1, indicating a strong comparative advantage in these classes. There seems to be a general trend of RCA values decreasing in some commodity classes over time (e.g., column 5 shows a decrease from 2008 to 2022), which could suggest a diminishing comparative advantage in these areas. On the other hand, some classes show an increase in RCA values (e.g., column 9), which could indicate an emerging or strengthening comparative advantage. The data could be used to analyze the impact of economic policies, global market changes, trade agreements, or shifts in production capabilities and technologies.

Column 0: The RCA values in this category show a decreasing trend from 2008 to 2022, starting with 0.333 and ending with 0.257, indicating a decline in comparative advantage over time. Column 1: This column has very low RCA values throughout, all below 0.1, which suggests that China does not have a significant comparative advantage in these commodities. The trend is relatively stable with slight fluctuations. Column 2: The RCA values here show a slight decrease over time, with minor ups and downs. The comparative advantage in this category seems to be diminishing gradually. Column 3: The values are consistently low, with a slight decreasing trend, indicating a stable but low comparative advantage in this commodity class. Column 4: The RCA values in this category are pretty low and exhibit a decreasing trend over the years, implying a weakening comparative advantage. Column 5: Starting with an RCA value of 0.357 in 2008, there is a general decreasing trend through 2022, suggesting a significant reduction in comparative advantage. Column 6: The RCA values start strong at 1.041 and remain above one throughout the period, indicating a consistent comparative advantage. However, there's a slight overall decline, suggesting that while China maintains a comparative advantage, it may be reduced slightly. Column 7: Like column 6, the values here are consistently above 1, with a peak in 2015. There's a slight decreasing trend, but the numbers suggest a strong and sustained comparative advantage. Column 8: This column shows values that are consistently above 1, with a peak in 2015 as well. Despite some fluctuations, the comparative advantage is strong, although there's a slight decline towards 2022. Column 9: The RCA values here start at 0.015 in 2008 and increase sharply to 0.569 by 2022. It indicates a growing comparative advantage, with the most significant increase happening after 2019.

Table 4. The RCA of USA's SITC-products (2008–2022).

Year	C0	C1	C2	C3	C4	C5	C6	C7	C8	C9
2008	0.595	0.255	8.145	0.046	0.665	1.204	0.507	1.108	0.604	0.201
2009	0.669	0.318	10.496	0.077	0.297	1.441	0.554	0.985	0.676	1.900
2010	0.777	0.364	9.311	0.144	1.194	1.599	0.536	1.107	0.789	2.166
2011	0.970	0.291	8.466	0.145	0.361	1.528	0.473	1.045	0.758	1.847
2012	1.250	0.315	9.851	0.171	0.689	1.430	0.519	1.008	0.825	1.895
2013	1.550	0.405	8.974	0.188	0.378	1.423	0.530	1.170	0.855	2.426

Year	C0	C1	C2	C3	C4	C5	C6	C7	C8	C9
2014	1.280	0.465	9.047	0.128	0.364	1.412	0.558	1.252	0.826	3.119
2015	1.485	0.451	8.662	0.264	0.106	1.555	0.498	1.257	0.921	3.643
2016	1.057	0.427	9.799	0.370	0.337	1.571	0.530	1.237	0.967	3.329
2017	0.987	0.374	8.233	1.033	0.107	1.625	0.511	1.220	0.973	3.372
2018	0.766	0.321	4.158	0.820	0.058	1.547	0.517	1.091	1.033	3.387
2019	0.799	0.120	4.372	0.379	0.060	1.587	0.484	1.111	1.027	2.184
2020	1.597	0.090	6.541	1.468	0.137	1.703	0.675	1.252	1.048	1.123
2021	2.355	0.318	4.912	1.302	0.074	1.670	0.565	1.191	0.991	1.164
2022	2.287	0.307	6.370	0.845	0.048	1.925	0.515	0.990	0.958	1.310

Table 4. (*Continued*)

The author's calculations data has been collected from UNCOMTRADE.

Table 4 shows RCA of the United States with China from 2008 to 2022 for commodities classified under the SITC (SITC). C0, the RCA values start at 0.595 in 2008 and show an overall increasing trend, peaking in 2021 at 2.355 before a slight decrease in 2022. It indicates a growing comparative advantage in this commodity class over the period. C1 shows fluctuating RCA values with no clear trend. The values are relatively low, suggesting that the US does not have a strong comparative advantage in these commodities. In C2, The RCA values are high, starting at 8.145 in 2008 and reaching a peak in 2012. There is a decrease in later years, but the values remain relatively high, indicating a strong comparative advantage. In C3, the RCA values are very low and decrease over the period, suggesting a weak comparative advantage for the US in these commodities. C4 Starting with a moderate RCA value in 2008, there is an overall decreasing trend with some fluctuations, indicating a declining comparative advantage in this commodity class. C5 consistently above 1 indicates a sustained and strengthening comparative advantage in exporting these commodities. In C6, The RCA values start above 1, indicating a comparative advantage, which appears to remain stable with slight fluctuations over time. C7 also starts with values above 1, showing some fluctuation but generally indicating a maintained comparative advantage, with a slight trend towards a decrease by 2022. C8 Beginning at 1.108 in 2008, the RCA values fluctuate over the years but generally indicate a stable comparative advantage in this class of commodities. C9, the RCA values start at 0.201 and show significant variability over the years. There was a notable increase in 2010 and 2015, but the trend does not show a clear direction, suggesting an unstable comparative advantage in these commodities. The US shows a strong comparative advantage in certain commodity classes (especially column 2), while others exhibit slightly fluctuating trends. Some classes show an increasing comparative advantage over time (column 0), while others indicate a decreasing or unstable comparative advantage (columns 3, 4, and 9). Changes could influence these variations in domestic production, trade policies, global market trends, and competitive dynamics.

4.1. Comparison between two countries RCA

The USA demonstrates a stronger and growing comparative advantage in commodity classes 2 and 5, while China exhibits a stronger and growing advantage in classes 6, 7, and 9. Both countries are relatively competitive in class 8. To enhance trade, the USA could capitalize on its strength in classes 2 and 5, while China could leverage its advantages in classes 6, 7, and 9. Collaborative strategies in class 8 could mutually benefit both countries. Further analysis should consider specific commodities and economic factors for a comprehensive trade strategy.

Table 5. China-US trade TCI (Exports).

Year	C0	C1	C2	C3	C4	C5	C6	C7	C8	C9
2008	0.164	0.005	1.080	0.002	0.016	0.360	0.508	1.452	1.988	0.061
2009	0.172	0.006	1.258	0.001	0.010	0.378	0.545	1.451	2.252	0.561
2010	0.210	0.006	0.962	0.001	0.035	0.460	0.500	1.694	2.735	0.704
2011	0.242	0.004	0.836	0.001	0.007	0.471	0.408	1.575	2.377	0.526
2012	0.329	0.007	1.149	0.001	0.016	0.459	0.504	1.610	2.645	0.444
2013	0.373	0.008	1.009	0.001	0.009	0.459	0.532	1.876	2.736	0.489
2014	0.295	0.010	1.109	0.001	0.009	0.488	0.592	2.079	2.618	0.727
2015	0.359	0.010	1.277	0.003	0.003	0.581	0.605	2.237	3.227	1.113
2016	0.252	0.012	1.412	0.007	0.009	0.564	0.637	2.100	3.256	0.994
2017	0.232	0.011	1.029	0.015	0.003	0.619	0.585	2.110	3.207	1.310
2018	0.186	0.011	0.546	0.010	0.002	0.633	0.602	1.870	3.335	1.403
2019	0.135	0.003	0.451	0.002	0.002	0.515	0.499	1.578	2.934	1.076
2020	0.264	0.001	0.484	0.004	0.003	0.604	0.865	1.823	2.821	0.600
2021	0.361	0.004	0.313	0.003	0.001	0.613	0.563	1.704	2.874	0.493
2022	0.394	0.005	0.514	0.002	0.001	1.037	0.511	1.434	2.708	0.482

The author's calculations data has been collected from UNCOMTRADE.

Table 5 shows trade complementarity index of the two countries' 10 major SITC Category products during the period of 2008–2022 from two aspects: China exports to the world market and the US exports to the world market correspondingly. The results we have got from the analysis for the SITC Commodities of China and the United States Trade complementarity. From the point of view of China exporting to the world, the following category products have high complementarity indexes (TCI>1): Column 0 (0.164 to 0.394): The TCI values consistently rise, suggesting an increasing complementarity in China's exports to the world over the years, reaching a peak in 2022 at 0.394. Column 1 (0.005 to 0.012): These low TCI values indicate minimal complementarity in China's exports to the world in this commodity class, with slight fluctuations. Column 2 (1.080 to 0.514): Initially, high TCI values decreased over the years, indicating a diminishing complementarity in China's exports in this class, reaching 0.514 in 2022. Column 3 (0.002 to 0.007): Extremely low TCI values suggest very little complementarity in China's exports to the world in this class, with minimal fluctuations. Column 4 (0.002 to 0.003): Very low and stable TCI values signify low complementarity in China's exports to the world in this commodity class. Column 5 (0.360 to 1.037): TCI values show a fluctuating pattern, peaking in 2020 at 1.037, indicating variable complementarity in China's exports to the world in this class. Column 6 (0.408 to 0.865): TCI values fluctuate with a peak in 2020 at 0.865, suggesting varying levels of complementarity in China's exports in this class. Column 7 (1.452 to 2.237): TCI values consistently rise, indicating a growing complementarity in China's exports to the world in this class, reaching 2.237 in 2015. Column 8 (1.988 to 3.335): TCI values increase, suggesting a strengthening complementarity in China's exports in this class, reaching 3.335 in 2018. Column 9 (0.061 to 1.403): TCI values fluctuate with a peak in 2018 at 1.403, indicating variable complementarity in China's exports to the world in this class.

China's exports to the world show increasing complementarity in columns 0, 5, 7, and 8, while columns 1, 3, 4, and 9 exhibit low and variable complementarity. Columns 2 and 6 experience diminishing

complementarity over the years. Policymakers and businesses must consider these patterns for strategic trade decisions.

Table 6. US-China trade TCI (Exports).

Year	C0	C1	C2	C3	C4	C5	C6	C7	C8	C9
2008	0.374	0.057	45.514	0.002	0.371	1.782	0.275	1.334	0.471	0.003
2009	0.445	0.081	78.108	0.006	0.052	2.277	0.340	1.365	0.600	0.017
2010	0.624	0.118	64.879	0.019	0.854	2.947	0.331	1.573	0.743	0.581
2011	0.987	0.076	57.984	0.019	0.208	2.686	0.276	1.403	0.735	2.197
2012	1.680	0.088	78.510	0.027	0.457	2.466	0.320	1.422	0.945	2.212
2013	2.227	0.150	66.423	0.031	0.114	2.422	0.334	2.242	1.014	3.017
2014	1.792	0.207	69.772	0.019	0.165	2.435	0.359	2.513	0.982	4.317
2015	2.346	0.201	65.698	0.070	0.011	2.823	0.314	2.514	1.147	5.010
2016	1.346	0.167	76.559	0.108	0.104	2.855	0.334	2.203	1.194	2.166
2017	1.162	0.143	58.715	0.695	0.025	3.001	0.311	2.153	1.181	5.048
2018	0.727	0.126	19.043	0.624	0.007	2.866	0.314	1.914	1.341	3.679
2019	0.664	0.022	14.352	0.123	0.009	2.699	0.280	1.646	1.278	0.359
2020	2.393	0.017	29.444	1.700	0.031	3.218	0.390	1.837	1.314	0.166
2021	5.648	0.122	23.269	2.005	0.012	3.030	0.267	1.679	1.192	0.162
2022	5.078	0.055	35.722	0.734	0.006	3.508	0.238	1.224	1.078	0.132

The author's calculations data has been collected from UNCOMTRADE.

Table 6 shows trade complementarity index of the two countries' 10 major SITC Category products during the period of 2008–2022 from two aspects: China exports to the world market and the US exports to the world market correspondingly. The results we have got from the analysis for the SITC Commodities of China and the United States Trade complementarity. From the point of view of the US exports to the world, the following category products have high complementarity indexes (TCI>1): Column 0 (0.374 to 5.078): TCI values show a substantial increase over the years, peaking in 2022 at 5.078. Indicates a significant rise in complementarity in US exports to the world, with a notable surge in recent years. Column 1 (0.022 to 0.207): TCI values remain relatively low. Suggests modest complementarity in this commodity class, with slight fluctuations. Column 2 (14.352 to 78.510): Initially low, TCI values sharply increase and then stabilize at a high level. Indicates a significant and sustained complementarity in US exports to the world in this class, with a peak in 2013. Columns 3 and 4 (0.002 to 1.700): Low to moderate TCI values suggest variable complementarity in these commodity classes. A peak in 2020 indicates a notable increase in complementarity in column 4. Column 5 (1.782 to 3.508): TCI values show an increasing trend, reaching a peak in 2022 at 3.508. Reflects a growing complementarity in US exports to the world in this category. Column 6 (0.238 to 0.390): TCI values exhibit fluctuations but remain relatively low. Suggests varying complementarity in this commodity class, with a slight increase in 2020. Columns 7 and 8 (1.224 to 2.514): TCI values consistently rise, indicating a growing complementarity in US exports to the world. Peaks in 2015 for column 7 and 2018 for column 8 highlight increased complementarity. Column 9 (0.003 to 0.359): Low and variable TCI values suggest modest and fluctuating complementarity in this commodity class.

The overall trend indicates a substantial increase in complementarity in US exports to the world, with notable peaks in columns 2, 5, 7, and 8. Commodity classes with high and stable TCI values (e.g., column 2) signify sustained and significant complementarity, while others show variable patterns.

4.2. Comparison of both countries TCI indexes

The Trade Complementarity Index (TCI) analysis for Sino-U.S. trade reveals noteworthy trends. China shows a growing complementarity in exports, with strengths in stable columns like 0, though challenges exist in diminishing trends (e.g., column 2). In contrast, the US exhibits dynamic growth, particularly in columns 2, 5, 7, and 8, showcasing sustained advantages. Both countries face variable complementarity in specific columns, suggesting evolving dynamics. For China, strategic focus on particular commodity classes and addressing challenges is vital. The US can leverage its strengths in dynamic columns, emphasizing continued growth in advantageous areas. This TCI analysis provides actionable insights for policymakers and businesses, emphasizing adaptability in trade strategies over time.

Table 7. ESI of China and the US with world.

Year	C0	C1	C2	C3	C4	C5	C6	C7	C8	C9
2008	8.891	0.527	6.680	8.108	0.382	19.327	27.954	89.884	33.798	4.449
2009	7.785	0.499	5.328	5.634	0.269	16.621	20.194	69.476	30.171	9.305
2010	32.753	17.832	60.776	9.142	6.450	15.372	11.076	34.750	10.412	10.041
2011	8.498	29.386	8.862	73.055	32.459	19.489	13.022	38.804	11.233	11.866
2012	75.131	8.442	47.922	30.420	3.963	16.952	13.085	41.121	11.713	13.303
2013	12.127	0.738	7.682	13.803	0.298	24.457	36.437	113.631	52.586	14.004
2014	12.776	0.762	7.799	14.364	0.273	25.729	39.662	117.268	55.803	13.886
2015	11.874	0.831	6.605	9.949	0.259	24.953	38.041	114.557	53.218	14.154
2016	11.942	0.851	6.499	9.103	0.257	23.722	34.825	107.687	49.010	14.340
2017	12.371	0.852	6.979	13.164	0.287	25.798	36.445	116.091	50.542	14.589
2018	12.949	0.890	7.220	18.056	0.289	28.834	39.569	125.852	52.574	15.670
2019	12.638	0.823	6.908	18.629	0.292	28.593	39.092	124.514	53.588	16.102
2020	12.643	0.674	7.137	14.119	0.347	28.187	39.535	123.879	51.859	12.617
2021	14.906	0.719	9.004	21.348	0.462	39.279	49.156	154.107	65.633	15.265
2022	15.664	0.781	10.195	33.607	0.544	45.530	54.207	161.074	69.627	18.584

The author's calculations data has been collected from UNCOMTRADE.

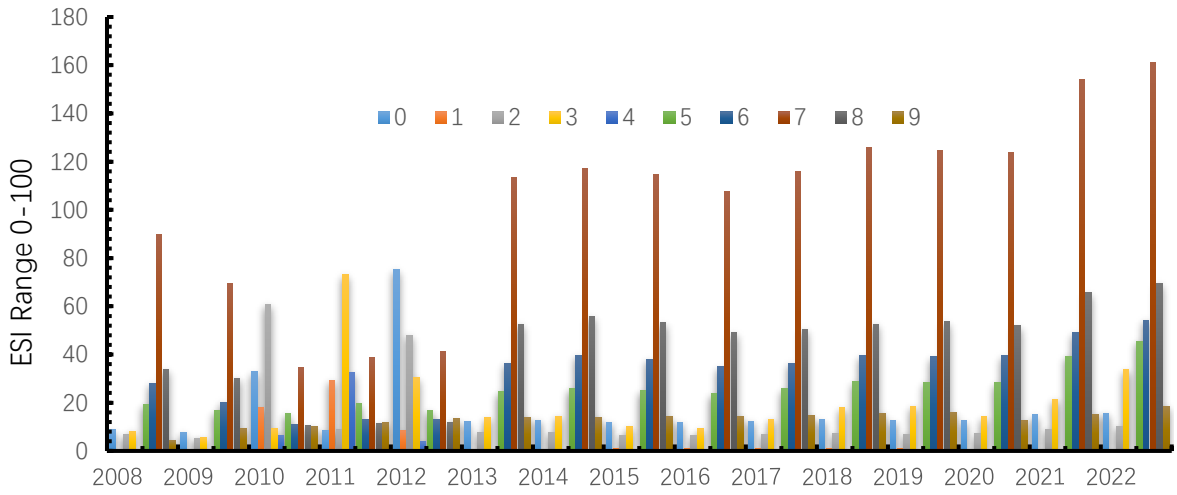

Figure 3. Exports similarity graph.

Table 7 shows the Export Similarity Index (ESI) measures the extent to which two countries' export structures align in the global market, with values ranging from 0 (no similarity) to 100 (identical structures). The analysis reveals varying degrees of similarity across SITC categories between China and the United States from 2008 to 2022. Notably, C7 (machinery and transport equipment) consistently recorded high ESI values, beginning with 89.88 in 2008, indicating strong and persistent convergence in this sector. Similarly, C3 (mineral fuels) showed high similarity, peaking at 73.06 in 2011. C2 (crude materials) exhibited a volatile pattern, with a peak of 60.78 in 2011, followed by fluctuations. C5 (chemicals) demonstrated a clear upward trend, culminating in 45.53 in 2022, suggesting growing alignment in this sector. In contrast, categories such as C4 (animal and vegetable oils) and C9 (miscellaneous) experienced overall low but fluctuating similarity, while C8 (miscellaneous manufactured articles) peaked at an unusually high 125.85 in 2018, reflecting a temporary convergence. These findings suggest that strategic cooperation should focus on sectors with sustained high similarity, particularly C7 and C3, while emerging convergence in C5 presents new opportunities. Conversely, sectors with unstable or declining similarity (e.g., C2 and C4) warrant cautious engagement, supported by continuous monitoring and adaptive trade policies. Such an approach can enhance bilateral trade synergies and support the development of a resilient and mutually beneficial trade relationship.

5. Discussion

The existing literature on trade competitiveness and complementarity has widely employed indices such as the Revealed Comparative Advantage (RCA), Trade Complementarity Index (TCI), and Export Similarity Index (ESI) to explore bilateral trade dynamics, particularly in agricultural and broad manufacturing sectors. For instance, [9] utilized RCA and TCI to examine the comparative and complementary advantages in Sino-U.S. agricultural trade, highlighting the alignment of export structures with resource endowments. Similarly, [17] analyzed China–Vietnam trade using RCA and ESI under the Belt and Road Initiative, emphasizing the growing competitiveness in selected commodities. [9] earlier contended that Sino-U.S. trade is predominantly complementary, particularly in merchandise trade, due to structural differences in economic development stages. However, these studies are either limited in temporal scope, mainly focusing on pre-2010 trends, or constrained by their sectoral or geographic scope. Notably, most prior analyses have not simultaneously employed all three indices (RCA, TCI, ESI), nor have they offered a detailed SITC-based analysis that allows for nuanced cross-commodity and cross-period comparisons.

This study fills these critical gaps by providing a comprehensive analysis of China-US trade relations from 2008 to 2022 across ten SITC commodity categories using all three indices. It extends previous findings by not only identifying China's sustained comparative advantages in machinery and transport equipment (SITC 7), manufactured goods (SITC 6), and miscellaneous manufactured articles (SITC 8) but also by confirming the United States' strengths in chemicals (SITC 5) and crude materials (SITC 2), as evidenced by consistent RCA values above 1. The TCI results further reveal strong and rising trade complementarity in categories where both countries hold asymmetric strengths. At the same time, ESI values in SITC 7 and 8 indicate growing structural export similarity, suggesting emerging competition in key sectors. These findings point to a nuanced relationship between simultaneous rivalry and cooperation, which was previously underexplored in the literature. By triangulating RCA, TCI, and ESI within a single framework and anchoring the analysis on the SITC Rev.4 classification, this study provides a more granular and internationally comparable perspective on bilateral trade. It also captures structural changes in competitiveness following China's WTO accession and the global financial crisis—areas neglected mainly in earlier research. Thus, this study not only extends the empirical coverage but also offers practical insights for trade policy optimization between the world's two largest economies.

6. Conclusion and recommendations

This study provides a comprehensive assessment of Sino-U.S. trade relations through the application of Revealed Comparative Advantage (RCA), Trade Complementarity Index (TCI), and Export Similarity Index (ESI) across ten SITC commodity categories from 2008 to 2022. The RCA results underscore distinct comparative advantages: the United States maintains a consistent edge in crude materials (SITC 2) and chemicals (SITC 5), while China shows persistent strength in manufactured goods (SITC 6), machinery and transport equipment (SITC 7), and an emerging advantage in commodities not elsewhere classified (SITC 9). These findings are reinforced by the TCI analysis, which reveals that China's trade complementarity is strengthening in categories such as SITC 7 and 8. In contrast, the United States displays notable complementarity in SITC 2 and 5. The ESI findings indicate high export similarity in machinery (SITC 7) and mineral fuels (SITC 3), pointing to overlapping export structures and potential competition but also mutual areas of alignment that can foster cooperation.

Together, these results suggest that China and the US are positioned both competitively and complementarily within global trade networks. A strategic trade policy should thus capitalize on respective comparative advantages, China in SITC 6, 7, and 9, the US in SITC 2 and 5, while simultaneously leveraging high-similarity sectors (e.g., SITC 3 and 7) to develop collaborative frameworks. Such an approach would allow both economies to mitigate trade tensions, optimize trade portfolios, and build a more stable and mutually beneficial relationship amid an increasingly complex global market environment.

7. Recommendations

Based on the empirical findings, a series of policy recommendations are proposed to enhance the trade relationship between China and the United States. First, both countries should adopt a strategic commodity focus by prioritizing trade in sectors where they demonstrate sustained comparative advantages, as indicated by RCA values consistently above one. For China, this includes SITC categories 6, 7, and 9, while for the United States, SITC categories 2 and 5 are extreme. Targeted investment and supportive industrial policies in these areas could significantly boost export efficiency. Second, bilateral trade initiatives should emphasize sectors with high trade complementarity, such as SITC 7 and 8 for China and SITC 2 and 5 for the US, where structural asymmetries present opportunities for mutually beneficial exchange. In addition,

diversification strategies are necessary to mitigate risks associated with volatility in RCA and TCI values, helping both nations reduce overreliance on vulnerable sectors. To remain adaptive to changing global conditions, it is essential to institutionalize continuous monitoring mechanisms that assess trade performance using RCA, TCI, and ESI metrics.

Furthermore, collaboration in technology-intensive sectors, particularly those showing increasing export similarity, should be encouraged through joint ventures, research and development partnerships, and knowledge-sharing platforms. To maintain a stable and cooperative trade environment, the establishment of institutional dialogue channels and robust dispute resolution frameworks is also crucial. Lastly, trade policies must integrate sustainable development goals (SDGs), promoting ethical sourcing, environmental stewardship, and inclusive trade practices in alignment with global standards. Collectively, these strategies can enable China and the United States to navigate complex global trade dynamics more effectively, capitalize on mutual strengths, and foster a resilient and balanced bilateral trade relationship.

8. Limitations and future research direction

This study, while offering comprehensive insights into Sino-U.S. trade dynamics using RCA, TCI, and ESI across SITC commodity classifications, is limited by its exclusive focus on merchandise trade and its reliance on secondary data from UN COMTRADE, which may not fully capture informal trade flows or recent disruptions such as COVID-19-related supply chain shocks. Additionally, the analysis does not incorporate services trade or qualitative policy factors that influence bilateral trade relations. Future research should expand to include services and digital trade, assess the impact of geopolitical tensions and non-tariff measures, and explore firm-level data better to understand microeconomic drivers of comparative advantage and export similarity. Incorporating machine learning techniques for trade pattern prediction and scenario analysis could further enrich the policy relevance of future studies.

Conflict of interest

The authors declare no conflict of interest.

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Appendix

SITC Section 0: Food and Live Animals

- Division 00: Live animals.
- Division 01: Meat and meat preparations.
- Division 02: Dairy products and birds' eggs.
- Division 03: Fish, crustaceans, mollusks, and preparations thereof.
- Division 04: Cereals and cereal preparations.
- Division 05: Vegetables and fruits.
- Division 06: Sugars, sugar preparations, and honey.
- Division 07: Coffee, tea, cocoa, spices, and manufacturers thereof.
- Division 08: Feeding stuff for animals (excluding unmilled cereals).
- Division 09: Miscellaneous edible products and preparations.

SITC Section 1: Beverages and Tobacco

- Division 11: Beverages.
- Division 12: Tobacco and tobacco manufacturers.

SITC Section 2: Crude Materials, Inedible, Except Fuels

- Division 21: Hides, skins, and fur skins, raw.
- Division 22: Oil seeds and oleaginous fruits.
- Division 23: Crude rubber (including synthetic and reclaimed).
- Division 24: Cork and wood.
- Division 25: Pulp and waste paper.
- Division 26: Textile fibers and their wastes.
- Division 27: Crude fertilizers and crude minerals (excluding coal, petroleum, and precious stones).
- Division 28: Metalliferous ores and metal scrap.
- Division 29: Crude animal and vegetable materials, n.e.s.

SITC Section 3: Mineral Fuels, Lubricants, and Related Materials

- Division 32: Coal, coke, and briquettes.
- Division 33: Petroleum, petroleum products, and related materials.
- Division 34: Gas, natural, and manufactured.
- Division 35: Electric current.

SITC Section 4: Animal and Vegetable Oils and Fats

- Division 41: Animal oils and fats.
- Division 42: Fixed vegetable fats and oils, crude, refined, or fractionated.

SITC Section 5: Chemicals and Related Products

- Division 51: Organic chemicals.
- Division 52: Inorganic chemicals.
- Division 53: Dyeing, tanning, and coloring materials.
- Division 54: Medicinal and pharmaceutical products.
- Division 55: Essential oils and resinoids and perfume materials; toilet, polishing, and cleansing preparations.
- Division 56: Fertilizers manufactured.
- Division 57: Plastics in primary forms.
- Division 58: Plastics in non-primary forms.
- Division 59: Chemical materials and products, n.e.s.

SITC Section 6: Manufactured Goods Classified Chiefly by Material

- Division 61: Leather, leather manufacturers, n.e.s., and dressed fur skins.
- Division 62: Rubber manufactures, n.e.s.
- Division 63: Cork and wood manufactures (excluding furniture).
- Division 64: Paper, paperboard, and articles of paper pulp, paper, or paperboard.
- Division 65: Textile yarn, fabrics, made-up articles, n.e.s., and related products.
- Division 66: Non-metallic mineral manufacturers, n.e.s.
- Division 67: Iron and steel.
- Division 68: Non-ferrous metals.
- Division 69: Manufactures of metals, n.e.s.

SITC Section 7: Machinery and Transport Equipment

- Division 71: Power-generating machinery and equipment.
- Division 72: Machinery specialized for particular industries.
- Division 73: Metalworking machinery.
- Division 74: General industrial machinery and equipment, n.e.s. and machine parts, n.e.s.
- Division 75: Office machines and automatic data processing machines.
- Division 76: Telecommunications and sound recording and reproducing apparatus and equipment.
- Division 77: Electrical machinery, apparatus, and appliances, n.e.s., and electrical parts thereof.
- Division 78: Road vehicles (including air cushion vehicles).
- Division 79: Other transport equipment.

SITC Section 8: Miscellaneous Manufactured Articles

- Division 81: Prefabricated buildings; sanitary, plumbing, heating, and lighting fixtures and fittings, n.e.s.
- Division 82: Furniture and parts thereof: bedding, mattresses, mattress supports, cushions, and similar stuffed furnishings.
- Division 83: Travel goods, handbags, and similar containers.
- Division 84: Articles of apparel and clothing accessories.
- Division 85: Footwear.
- Division 86: Instruments and apparatus for measuring or checking, n.e.s.
- Division 87: Professional, scientific, and controlling instruments and apparatus, n.e.s.
- Division 88: Photographic apparatus, equipment and supplies, and optical goods, n.e.s., watches and clocks.
- Division 89: Miscellaneous manufactured articles, n.e.s.

SITC Section 9: Commodities and Transactions not Classified Elsewhere

- Division 91: Postal packages not classified according to kind.
- Division 93: Special transactions and commodities not classified according to kind.
- Division 96: Coin (other than gold coin), not being legal tender.

Division 97: Gold, non-monetary (excluding gold ores and concentrates).