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U.S. Integrated Circuit Exports and Global Value Chain Positioning: Strategic Implications for International Business and Supply Chain Management

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Abstract

The United States remains a dominant exporter of integrated circuits (ICs), a cornerstone of global technological advancement and industrial competitiveness. However, the evolving geopolitical and policy landscape has reshaped export flows, partner concentration, and the structure of value creation within the global semiconductor ecosystem. This study examines the dynamics of U.S. IC exports from 2015 to 2024, evaluating shifts in competitiveness and market diversification using a framework built on Revealed Comparative Advantage (RCA) and Herfindahl-Hirschman Index (HHI). Using annual UN Comtrade data for HS codes 8542 (ICs), the analysis identifies a post-2022 realignment driven by trade tensions and industrial policy interventions such as the CHIPS and Science Act. Results reveal a decline in exports to East Asia—especially the Chinese mainland and Hong Kong SAR—accompanied by increased flows to Mexico, Singapore, and the European Union. These findings suggest a regionalized restructuring of U.S. semiconductor exports toward allied economies. From a business management perspective, this shift reflects a growing emphasis on resilience, policy alignment, and strategic adaptation within global supply networks.

Keywords

Integrated Circuits, Export Competitiveness, Revealed Comparative Advantage, International Business, Supply Chain Management, Trade Policy

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1. Introduction

Semiconductors are essential inputs for nearly all advanced technologies, from artificial intelligence to defense systems. Integrated circuits (ICs) form the foundation of these systems, linking design capabilities, fabrication capacity, and international trade networks. As a global leader in semiconductor design and innovation, the United States serves as a major exporter of ICs (VerWey, 2019). However, the sector has undergone significant structural change amid intensified geopolitical frictions, export restrictions, and efforts to rebuild domestic capacity (Hamdani & Belfencha, 2024; Reuters, 2024; NAI, 2016). The imposition of tariffs and export controls since 2018, coupled with the enactment of the CHIPS and Science Act (U.S. Congress, 2022), has redefined both the geography and strategy of U.S. IC exports (Wiseman et al., 2025). This study examines how these developments have altered U.S. export competitiveness and market orientation across major trade partners.

The research contributes to the literature by quantifying changes in export concentration and competitiveness, focusing on the implications of trade realignment for business strategy and supply chain management. It employs standard trade indicators to identify key shifts in the global position of the United States within semiconductor value chains. The guiding question is: How have U.S. IC export structures evolved in response to policy interventions and geopolitical pressures, and what are the resulting implications for global business operations? (**Figure 1**).

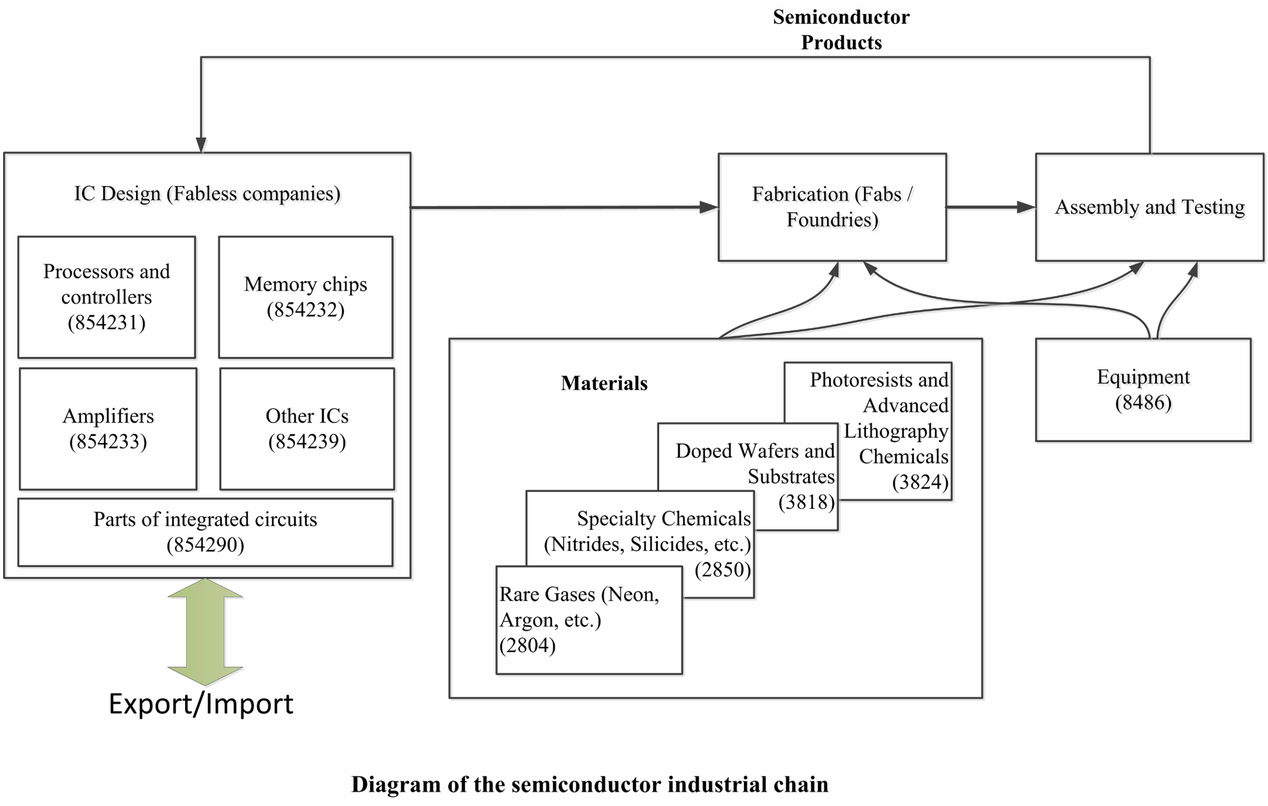

Figure 1. Structure of the semiconductor industrial value chain.

2. Literature Review

The semiconductor industry has been widely studied as a cornerstone of modern global value chains due to its technological complexity, geographic fragmentation, and strategic economic importance. Previous research emphasizes that semiconductor production is highly segmented, with design and intellectual property concentrated in the United States, fabrication dominated by East Asia, and assembly, testing, and packaging distributed across emerging economies (OECD, 2025). This international division of labor has created deep interdependencies between economies but has also exposed structural vulnerabilities, as revealed during the U.S.-China trade tensions and COVID-19 supply-chain disruptions. Studies by the OECD (2025) highlight that the semiconductor ecosystem's spatial concentration amplifies risks, while U.S. government and industry reports underscore the need for diversification and regional resilience through policies such as the CHIPS and Science Act.

Quantitative analyses of trade competitiveness often employ the Herfindahl-Hirschman Index (HHI) and the Revealed Comparative Advantage (RCA) as key indicators (Funke & Wende, 2022). The HHI provides a measure of export concentration, allowing researchers to evaluate the degree of market diversification and geographic dependence (Belbali et al., 2024). Meanwhile, RCA captures the relative specialization of a country's exports in a particular product compared to the global average, providing insight into structural competitiveness within international markets (Lin & Bethmann, 2023). These metrics have been widely applied to manufacturing sectors such as machinery, automotive components, and electronics, yet only limited studies have disaggregated the semiconductor trade into its HS 6-digit subcategories to examine the evolution of competitiveness across product segments over time.

Most existing research tends to treat semiconductors as a single aggregated export category, thereby overlooking differences between logic ICs, memory ICs, amplifiers, and component parts—each with distinct technological trajectories and market linkages. Furthermore, traditional statistical analyses often provide static snapshots, failing to capture how export structures evolve through time or respond to policy and geopolitical shifts. Few studies integrate quantitative concentration measures (HHI, RCA) with visual or network-based analyses such as Sankey flow diagrams, which effectively trace shifts in export relationships and regional flows (Bliemel & Wixted, 2022; Hummels et al., 2001).

To address these limitations, this study introduces a combined temporal-quantitative-visual framework that integrates HHI, RCA, and Sankey flow visualization for U.S. integrated-circuit exports between 2015 and 2024. This approach enables a multidimensional understanding of trade dynamics, revealing how export concentration, competitiveness, and regional distribution interact in response to global value-chain realignments, supply-chain shocks, and U.S. industrial policy.

3. Methodology

3.1. Data Source and Coverage

The study utilizes annual data from the United Nations Comtrade (UN Comtrade) database covering U.S. exports between 2015 and 2024, specifically for products classified under Harmonized System (HS) code 8542—Integrated Circuits (ICs) and its five six-digit subcategories (854231, 854232, 854233, 854239, and 854290). UN Comtrade is chosen as the primary data source because it is the most comprehensive and internationally standardized database for global trade statistics. It aggregates official customs data reported by individual countries, ensuring consistency, comparability, and coverage across both product categories and partner economies. This makes it highly suitable for quantitative trade analysis involving technology-intensive sectors such as semiconductors, where the granularity of HS codes and partner-level export data is critical for tracing global value chains.

The temporal coverage of 2015-2024 is designed to capture major structural shifts in the international semiconductor trade environment during the past decade. This period includes several economically and geopolitically significant phases:

- 2018-2020 U.S.-China Trade War, which introduced export controls, tariffs, and supply-chain decoupling trends affecting semiconductor trade flows.
- 2020-2022 COVID-19 Pandemic, which disrupted global manufacturing, logistics, and semiconductor supply chains, creating severe shortages that reshaped sourcing strategies and trade dependencies.
- 2022-2024 Post-pandemic Recovery and the CHIPS and Science Act, which represent U.S. policy interventions aimed at reshoring semiconductor production, incentivizing domestic fabrication, and reducing dependence on East Asian suppliers.

This temporal coverage captures the pre-shock baseline and the disruption period phase of U.S. semiconductor exports. The 2024 data are drawn from UN Comtrade's provisional release (accessed September 2025); while minor revisions may occur, their inclusion enables timely assessment of post-CHIPS Act trade patterns.

In the UN Comtrade system, Taiwan region is classified under the aggregated category "Other Asia, nes (S19)". Consequently, all references to S19 in this study include Taiwan region's export and import flows, along with a few smaller Asian economies grouped under the same designation.

The selection of HS 8542 and its detailed six-digit subcategories enable a focused examination of trade patterns across different types of integrated circuits, reflecting the technological and functional diversity within the semiconductor industry:

- HS 854231—Processors and controllers, including CPUs and microcontrollers, which are central to computing and electronic devices.
- HS 854232—Memory chips, critical for data storage and performance in computers and mobile devices.
- HS 854233—Amplifiers, essential for analog and communication signal pro-

cessing.

- HS 854239—Other integrated circuits not elsewhere classified, covering logic, mixed-signal, and system-on-chip components used across varied industrial and consumer applications.
- HS 854290—Parts of integrated circuits, representing intermediate components and supporting materials within the semiconductor value chain.

This detailed classification provides the foundation for analyzing U.S. export concentration and competitiveness across differentiated IC categories, offering deeper insight into structural shifts within the semiconductor trade ecosystem (Table 1).

Table 1. HS codes and their importance in the global semiconductor supply chain.

HS Code	Description	Trend Summary (2015-2024)	Interpretation
854231	Processors and controllers, electronic integrated circuits	Moderate concentration (0.18 - 0.25) with a mid-period rise	Reflects export dependence on East Asian partners; post-2020 stabilization coincides with diversification efforts consistent with reshoring and regional realignment policies.
854232	Memories (e.g., DRAM, flash)	Gradual increase from ~0.15 to >0.20	Indicates increasing partner concentration, likely tied to dominance of few East Asian memory producers (Samsung, SK Hynix).
854233	Amplifiers	Sharp spike around 2018-2019 (>0.3), then drop post-2020	Suggests short-term export concentration spike during trade war; normalization post-2020 as markets rebalanced.
854239	Other integrated circuits (non-processors)	Stable, around 0.12 - 0.15	Implies sustained diversification—supported by broader global client base and less geographic specialization.
854290	Parts of integrated circuits	Moderate variation (0.12 - 0.22)	Sensitive to supply chain reallocation; 2020 peak reflects pandemic-era disruptions, followed by stabilization.

Together, these subcategories represent the core of the U.S. semiconductor export portfolio, spanning both high-end logic and memory devices as well as supporting components. Their inclusion allows the study to analyze differentiated export dynamics, assess technological composition shifts, and observe how trade and policy shocks differently impacted various IC segments.

3.2. Analytical Framework

Export values are expressed in current USD and deflated to 2020 constant prices using the U.S. Consumer Price Index (CPI). The CPI is used as a general deflator to adjust for inflation and ensure comparability of export values over time (Feenstra & Taylor, 2017; Hummels et al., 2001). Although a Producer Price Index (PPI) or Export Price Index (EPI) would provide greater industry precision, these indices are reported under NAICS or SITC classifications and are not directly compatible with HS-coded trade data used in this study.

Three indicators are used to measure competitiveness and concentration:

To assess export structure and competitiveness:

(1) Export Partner Share

$$s_{ij}(t)=\frac{X_{ij}(t)}{\sum_k X_{ik}(t)} \tag{1}$$

where $X_{ij}(t)$ is exports from the U.S. (*i*) to partner *j* in year *t*.

(2) Herfindahl-Hirschman Index (HHI) for concentration

$$\text{HHI}(t)=\sum_j \left(s_{ij}(t)\right)^2 \tag{2}$$

A higher HHI indicates greater partner concentration and reduced diversification. To complement the Herfindahl-Hirschman Index (HHI), this study incorporates the Revealed Comparative Advantage (RCA) index to evaluate the relative export competitiveness of each semiconductor category. While the HHI captures the degree of export concentration and market dependence by measuring how trade flows are distributed across partner countries, the RCA provides insight into the structural strength of U.S. exports within the global semiconductor market. Specifically, the RCA compares the share of a given product in a country's total exports to its share in total world exports, thereby identifying whether the United States holds a comparative advantage in that product. An RCA value greater than one indicates specialization and competitive strength, whereas a value below one reflects relative weakness. Together, the HHI and RCA enable a multidimensional analysis of U.S. semiconductor trade—assessing both the concentration risk and the underlying competitiveness of each export category.

(3) Revealed Comparative Advantage

Revealed Comparative Advantage (RCA) following Balassa (1965), is a widely used indicator to evaluate a country's relative export competitiveness in a specific product or industry compared with the global average. It provides an empirical measure of trade specialization by examining the share of a product in a nation's exports relative to the share of that product in world trade. The RCA is expressed as:

$$\text{RCA}_{\text{US}}(t)=\frac{X_{\text{US,IC}}(t)/X_{\text{US,total}}(t)}{X_{\text{world,IC}}(t)/X_{\text{world,total}}(t)} \tag{3}$$

where:

$X_{\text{US,IC}}(t)$ = U.S. exports of integrated circuits in year *t*;

$X_{\text{US,total}}(t)$ = total U.S. exports of all goods in year *t*;

$X_{\text{world,IC}}(t)$ = total world exports of integrated circuits in year *t*;

$X_{\text{world,total}}(t)$ = total world exports of all goods in year *t*;

An RCA value greater than 1 (RCA > 1) indicates that the United States possesses a comparative export advantage in integrated circuits—meaning the share of ICs in total U.S. exports exceeds their share in total world exports. Conversely, an RCA value less than 1 (RCA < 1) implies that the U.S. exhibits below-average competitiveness in this sector relative to global patterns.

The RCA framework is particularly useful because it is unit-free and comparable across time and countries, allowing analysts to track competitiveness trends even in rapidly evolving industries such as semiconductors. Unlike nominal trade balance or growth measures, RCA isolates structural specialization, capturing whether a country's export composition aligns with its technological or factor-based advantages. In this study, RCA is used to quantify how U.S. competitiveness in integrated circuit exports has evolved from 2015 to 2024 in relation to global semiconductor trade.

This analysis complements the HHI by addressing a different dimension of trade structure: whereas HHI measures geographic concentration (diversification of export destinations), RCA measures product-level competitiveness (relative strength in a specific category). The combined interpretation of RCA and HHI thus provides a comprehensive assessment of both where and how strongly the United States participates in global semiconductor trade networks.

4. Results and Discussion

4.1. Export Trends

Table 2 presents the evolution of U.S. integrated circuit (IC) exports by HS subcategory and by the top seven destination countries between 2015 and 2024, measured in billions of U.S. dollars. The data reveal both the rapid growth and structural transformation of the U.S. semiconductor export profile over the decade. In 2015, total exports were concentrated primarily in HS 854231 (processors and controllers) and HS 854232 (memories), which together accounted for more than half of total IC export value. These categories remained dominant throughout the period, reflecting the United States' technological leadership in high-performance logic and memory components.

However, the geographic composition of exports changed significantly over time. Early in the period, East Asia—especially the Chinese mainland, Hong Kong SAR, Taiwan region, and South Korea—represented the largest collective share of U.S. IC exports, consistent with the region's central role in downstream assembly and electronics manufacturing. Export flows to these destinations increased steadily through 2021, supported by global demand for computing and consumer electronics. Beginning in 2022, however, the data show a visible realignment: exports to the Chinese mainland and Hong Kong SAR declined amid tightened U.S. export controls and broader geopolitical tensions, while shipments to Mexico, Singapore, and European markets grew sharply.

Mexico's share more than doubled, reflecting near-shoring and assembly relocation under the USMCA framework. Singapore expanded as a logistics and re-export hub, handling high-value ICs destined for Southeast Asia and India. Meanwhile, the European Union—particularly Germany and the Netherlands—became an increasingly important destination, driven by automotive electrification and AI-related demand.

Overall, Table 2 underscores that U.S. IC exports have diversified regionally while remaining technologically concentrated in high-end IC categories. The decade's trend suggests a gradual transition from a China-centric export structure toward a multi-regional configuration, balancing East Asian demand with growing North American and European integration. This evolution provides the empirical foundation for the subsequent analysis of regional composition (Section 4.2), export concentration (HHI, Section 4.3), and competitiveness (RCA, Section 4.4).

Table 2. U.S. integrated circuit exports by HS category and top 7 export destinations, 2015-2024 (Billion USD).

HS_Category	Country/Region	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
854231	CHN	3.474	3.847	3.106	3.929	6.537	8.207	9.720	6.600	2.512	5.763
	MEX	2.771	3.310	3.618	3.912	6.633	8.266	8.305	9.354	9.167	9.340
	KOR	2.750	2.094	2.513	2.572	2.524	2.454	2.141	1.445	1.746	1.823
	MYS	2.563	2.394	2.450	1.781	1.326	1.375	2.109	2.355	2.519	5.897
	CAN	1.090	0.931	0.944	1.127	0.851	0.691	0.611	0.621	0.579	0.473
	S19	0.843	1.557	1.133	1.129	1.055	1.419	1.750	1.946	1.829	1.058
	HKG	0.553	0.711	0.592	0.570	0.559	0.517	0.749	0.694	0.534	0.606
854232	S19	1.251	1.047	1.078	1.031	0.729	0.640	0.635	0.460	0.477	0.436
	SGP	0.662	0.439	0.611	0.595	0.536	0.592	0.424	0.367	0.343	0.232
	CHN	0.594	0.371	0.474	0.353	0.108	0.072	0.094	0.148	0.041	0.034
	MEX	0.500	0.493	0.504	0.559	0.415	0.641	0.504	0.421	0.381	0.620
	THA	0.259	0.160	0.151	0.159	0.014	0.012	0.023	0.039	0.030	0.039
854233	MYS	0.252	0.396	0.263	0.232	0.153	0.109	0.128	0.185	0.065	0.079
	KOR	0.223	0.125	0.107	0.055	0.039	0.017	0.015	0.023	0.015	0.011
	MEX	0.172	0.177	0.199	0.238	0.129	0.126	0.136	0.195	0.153	0.206
	HKG	0.153	0.239	1.432	1.143	0.951	0.746	0.568	0.457	0.461	0.263
	CHN	0.150	0.131	0.427	0.453	0.363	0.390	0.435	0.397	0.391	0.366
	MYS	0.086	0.091	0.084	0.114	0.076	0.118	0.110	0.122	0.089	0.090
	S19	0.071	0.052	0.061	0.078	0.093	0.139	0.195	0.264	0.099	0.107
854239	KOR	0.066	0.101	0.145	0.158	0.142	0.061	0.043	0.048	0.039	0.032
	PHL	0.049	0.046	0.068	0.082	0.078	0.074	0.083	0.052	0.074	0.074
	MEX	1.828	2.106	1.936	2.108	1.710	1.637	2.330	2.668	2.242	1.272
	MYS	1.219	1.182	1.140	1.016	1.027	1.046	1.320	1.398	1.325	1.245
	PHL	0.854	0.875	0.858	0.819	0.747	0.643	0.722	0.778	0.821	0.717
	HKG	0.781	0.730	2.112	1.754	1.661	2.050	2.448	1.645	1.519	1.668
	CHN	0.737	0.777	1.210	1.301	1.098	1.452	1.936	2.172	2.127	2.501
854290	S19	0.594	0.657	0.707	0.788	0.859	1.001	1.746	2.544	2.177	2.862
	CAN	0.421	0.503	0.521	0.499	0.522	0.367	0.477	0.606	0.473	0.297
	PHL	0.356	0.374	0.395	0.430	0.472	0.201	0.080	0.079	0.059	0.045
	HKG	0.113	0.085	0.034	0.030	0.031	0.030	0.077	0.060	0.052	0.115
	SGP	0.081	0.116	0.128	0.077	0.154	0.068	0.090	0.092	0.074	0.077
	MEX	0.077	0.077	0.064	0.049	0.036	0.016	0.013	0.037	0.026	0.114
	CHN	0.051	0.053	0.070	0.061	0.043	0.040	0.079	0.100	0.063	0.053

Source: UN Comtrade.

4.2. Regional Composition

The regional distribution of U.S. integrated-circuit (IC) exports shows a clear shift from heavy East Asian dependence toward more balanced global integration between 2015 and 2024. In 2015, East Asia collectively accounted for roughly 48 percent of total U.S. IC exports—led by the Chinese mainland (18 percent), South Korea (12 percent), Taiwan region (included within the UN Comtrade category "Other Asia, nes (S19)," estimated at around 10%), and Hong Kong SAR (7 percent)—reflecting the region's dominant role in global semiconductor assembly and electronics manufacturing.

By 2024, East Asia's combined share had fallen to about 43 percent, signaling meaningful diversification of export destinations. Three regions in particular absorbed much of this reallocation:

Mexico's share increased from 20 percent to 26 percent, driven by assembly, testing, and packaging (ATP) relocation and near-shoring strategies under the United States-Mexico-Canada Agreement (USMCA) framework. Singapore's share declined slightly from about 5 percent to 2 percent, though it remains an important logistics and re-export hub for high-value ICs bound for Southeast Asia and India. Exports to the European Union, particularly Germany and the Netherlands, rose from roughly 4 percent to 7 percent, reflecting growing semiconductor demand in automotive, renewable-energy and AI-related sectors.

Figure 2 visualizes these dynamics through a Sankey flow diagram of U.S. IC exports to the top 17 countries and regions from 2015 to 2024. The figure vividly depicts the two-phase transformation of U.S. semiconductor trade patterns. During the first phase (2015-2021), export flows to the Chinese mainland, Hong Kong SAR, South Korea, and Taiwan region—the latter recorded within the UN Comtrade aggregate category "*Other Asia*, *nes* (S19)"—widen steadily, illustrating the consolidation of East Asia's role as the principal downstream manufacturing base. In the second phase, beginning around 2022, the flows to the Chinese mainland and Hong Kong SAR begin to narrow, coinciding with the introduction of U.S. export controls on advanced semiconductors and a broader policy shift toward supply-chain realignment. At the same time, flows to Mexico, Vietnam, and several Southeast Asian economies broaden, indicating a transition toward friend-shoring and regional diversification. As Yellen (2022) noted, friend-shoring involves deepening relationships and diversifying supply chains with trusted partners to strengthen economic resilience.

By 2023-2024, the Sankey structure shows Mexico emerging as a consistently thick and continuous destination band—evidence of stable growth and closer North American integration—while flows to Singapore and the EU expand in parallel, reflecting their complementary logistical and technological roles. The visual evidence reinforces the quantitative findings: the United States has reduced geographic concentration and expanded strategic export linkages beyond East Asia.

This geographic transition illustrates a structural re-orientation of U.S. semiconductor exports. While East Asia remains a critical downstream manufacturing base, the post-2020 period has brought accelerating regional diversification, aligning with policies aimed at supply-chain resilience, friend-shoring, and strategic decoupling. The results complement the declining HHI and RCA patterns discussed later, indicating that the U.S. export network is evolving from concentrated efficiency toward strategically distributed stability.

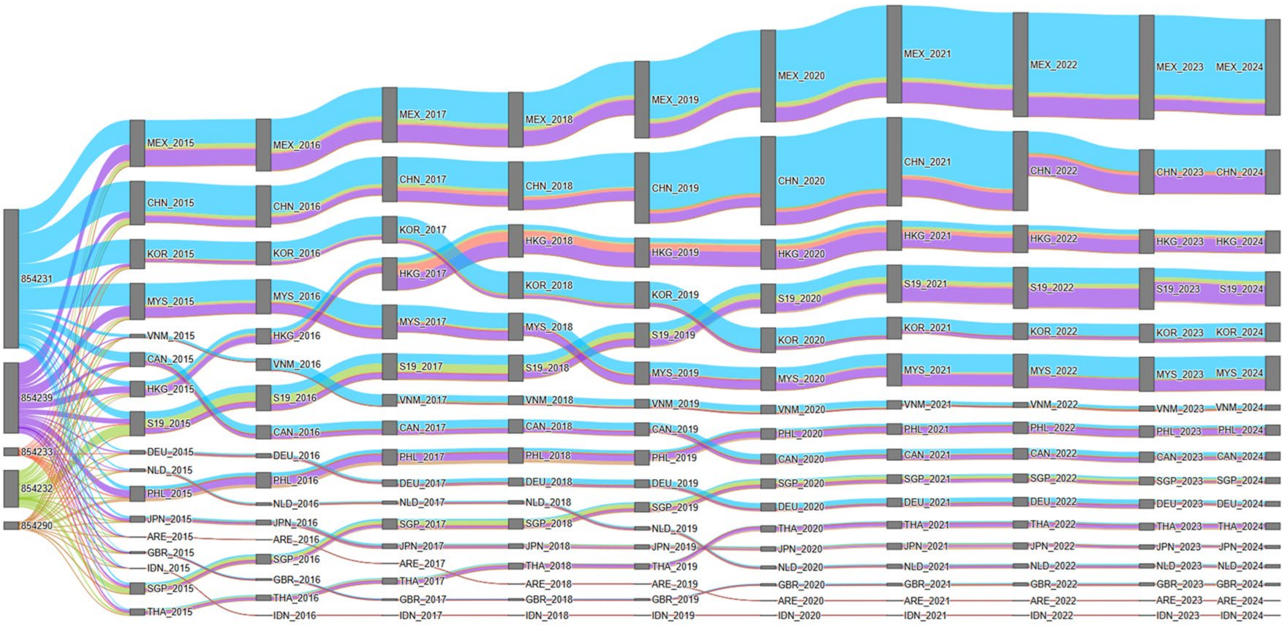

Figure 2. U.S. integrated circuit exports to top 17 countries/regions, 2015-2024 (Sankey Visualization).

4.3. Concentration Analysis (HHI)

Figure 3 illustrates the evolution of the Herfindahl-Hirschman Index (HHI) for U.S. integrated-circuit (IC) exports across five major HS subcategories—854231 (processors and controllers), 854232 (memories), 854233 (amplifiers), 854239 (other ICs), and 854290 (parts)—from 2015 to 2024. The HHI measures the degree of geographic concentration in export destinations, with values closer to 1 indicating higher concentration and values near 0 reflecting diversification. Across all categories, HHI values remained within the 0.11 - 0.24 range, signifying moderate concentration and partial diversification throughout the period.

The data show distinct temporal phases in export concentration. Between 2015 and 2017, all categories exhibited relatively low and stable HHI values, indicating a broad and balanced export distribution across key partner countries. However, within this period, HS 854233 (amplifiers) displayed a notable temporary peak in both HHI and RCA in 2017, reflecting the United States' short-term dominance in high-frequency radio-frequency (RF) amplifier exports during the early phase of 5G infrastructure deployment. U.S. firms such as Qorvo, Skyworks, and Broadcom supplied advanced GaAs/GaN amplifier modules to a concentrated group of East Asian manufacturing hubs—chiefly the Chinese mainland, South Korea, and Taiwan region—resulting in heightened export concentration (HHI) and a surge in relative competitiveness (RCA). This pattern underscores the technological advantage of U.S. compound-semiconductor producers before Asian firms expanded in-house RF integration.

During 2018 to 2020, concentration rose sharply for several categories—most notably HS 854233 (amplifiers), which peaked at 0.30 in 2017, and HS 854231 (processors), which climbed from 0.14 in 2015 to 0.22 in 2020. This surge corresponds to the U.S.-China trade war and COVID-19 supply-chain disruptions, both of which temporarily limited market diversification and redirected exports toward a narrower set of destinations. In contrast, HS 854239 (other ICs) maintained consistently low HHI values (≈0.12), highlighting resilience and stable global demand across a wider customer base. After 2021, the HHI values for most categories declined or stabilized, signaling renewed diversification. The CHIPS and Science Act (U.S. Congress, 2022), coupled with broader supply-chain adjustments and "friend-shoring" initiatives, contributed to this rebalancing by promoting export growth to Mexico, Singapore, and EU markets. By 2024, concentration levels for amplifiers and memory ICs had fallen markedly (≈0.13 - 0.20), suggesting improved geographic spread.

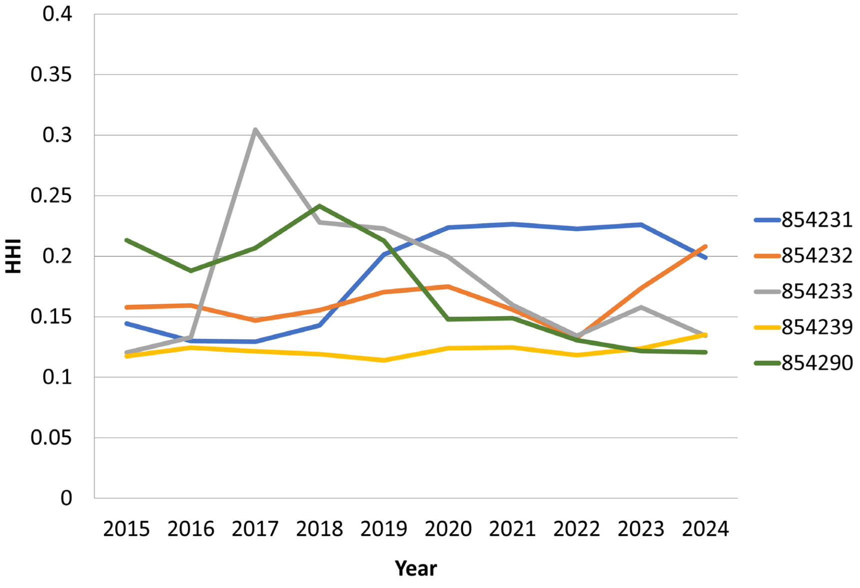

Figure 3. Herfindahl-Hirschman Index (HHI) for U.S. integrated-circuit exports by HS Category, 2015-2024. Source: Author's calculations based on data from UN Comtrade.

Figure 3 visually reinforces these trends: processor and amplifier lines show pronounced mid-period peaks followed by gradual convergence toward more moderate levels, while the curves for other ICs and parts remain comparatively flat. The visual pattern depicts a temporary contraction followed by structural diversification, consistent with the regional realignment observed in the Sankey plot (Section 4.2).

Overall, the HHI analysis indicates that U.S. semiconductor exports became less geographically concentrated after 2021, reducing exposure to external shocks and partner-specific dependencies. While some product categories remain moderately concentrated due to technological specialization, the post-2022 trend demonstrates that policy-induced realignment and market diversification have enhanced export resilience (Varadarajan et al., 2024). This quantitative outcome aligns with the broader narrative of the U.S. transition from efficiency-driven globalization toward strategically distributed supply-chain stability.

4.4. Competitiveness Analysis (RCA)

The Revealed Comparative Advantage (RCA) index measures the relative export competitiveness of the United States in integrated circuits (ICs) compared with the world average. Following Balassa (1965), the RCA is defined as the ratio between the share of ICs in total U.S. exports and the share of ICs in total world exports. Values greater than 1 indicate a comparative advantage, while values below 1 suggest relatively lower export specialization.

Figure 4 illustrates the evolution of RCA for U.S. integrated-circuit exports from 2015 to 2024. The solid curve represents the total RCA across all IC subcategories (HS 8542), while the shaded band indicates the range between the minimum and maximum RCA values among the five major HS codes—854231 (processors and controllers), 854232 (memories), 854233 (amplifiers), 854239 (other ICs), and 854290 (parts).

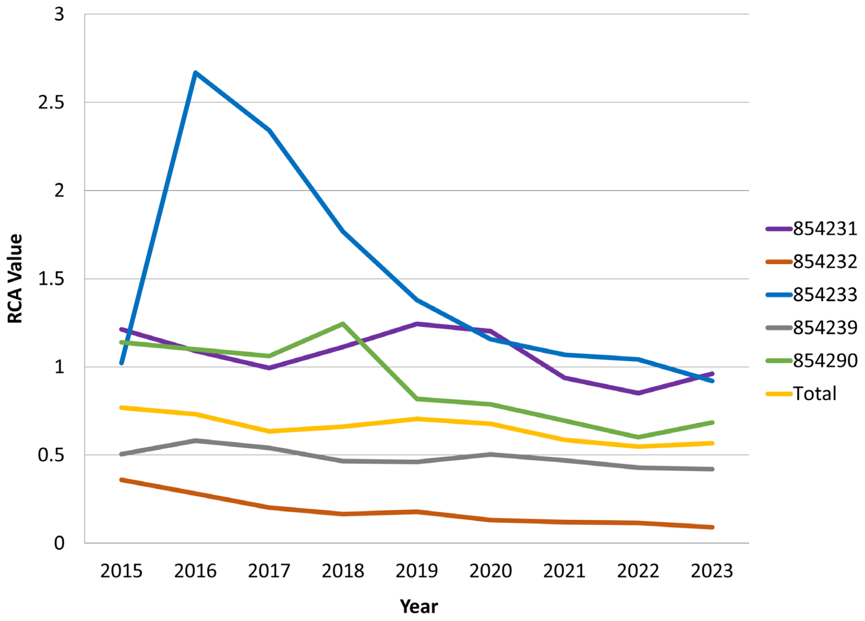

Figure 4. Revealed Comparative Advantage (RCA) of U.S. Integrated-Circuit Exports, 2015-2024. The orange line represents total RCA (HS 8542), and the shaded band indicates the range across five HS sub-categories (854231-854290). Source: Author's calculations based on data from UN Comtrade and ITC Trade Map.

The overall RCA trend reveals a gradual decline in U.S. export competitiveness over the decade. Between 2015 and 2017, total RCA values averaged around 0.75

- 0.80, reflecting moderate specialization within global semiconductor exports. During this period, the competitiveness spread among IC subcategories was relatively narrow, indicating that U.S. export performance was balanced across logic, memory, and supporting components. Notably, HS 854233 (amplifiers) showed a short-term RCA peak in 2017, driven by strong global demand for high-frequency RF amplifier modules during early 5G infrastructure expansion, temporarily boosting U.S. export competitiveness in that segment. However, beginning in 2018, RCA values began to fall steadily—dropping below 0.65 by 2020 and reaching a low near 0.55 in 2023—signaling erosion in U.S. relative export strength. This downward movement corresponds to major structural shocks in the semiconductor industry: the U.S.-China trade conflict, which limited access to key Asian markets, and COVID-19-era supply-chain disruptions, which constrained both production and distribution capacity. The shaded RCA range in **Figure 4** widens slightly during 2018-2020, suggesting greater divergence in competitiveness across product segments. In particular, processor and amplifier categories experienced sharper declines than memory or other ICs, consistent with temporary trade restrictions and shifts in global demand composition.

After 2021, the RCA band begins to narrow again, and the total RCA line shows modest recovery, reflecting early supply-chain realignment and the effects of policy interventions such as the CHIPS and Science Act (U.S. Congress, 2022), which supported domestic fabrication and R&D investment. By 2024, total RCA stabilizes at roughly 0.6, indicating that the United States retains moderate but declining comparative advantage in integrated-circuit exports. The reduced spread between the minimum and maximum RCA values across HS categories implies a converging competitiveness structure, where product-level differences are diminishing as firms adapt to trends consistent with regionalization and evolving trade policies.

Overall, the RCA dynamics highlight a structural transformation of U.S. semiconductor trade: the nation remains a technological leader and policy driver, but its export competitiveness has weakened relative to rapidly expanding East Asian producers. Combined with the HHI results, these findings demonstrate a shift from efficiency-based global specialization toward a model emphasizing innovation leadership, strategic autonomy, and regional supply-chain resilience.

4.5. Policy Implications

The results of this study carry significant policy implications for the United States' semiconductor strategy and global economic governance. The combined HHI-RCA analysis demonstrates that the U.S. export network is shifting from a model of concentrated efficiency—driven by cost optimization and dependence on East Asian manufacturing—to one of strategic diversification, emphasizing resilience, innovation capacity, and geopolitical alignment (Nandi, 2025).

The observed post-2021 reduction in export concentration and regional diversification underscores the effectiveness of recent U.S. industrial policies, notably the CHIPS and Science Act (U.S. Congress, 2022), in reshaping the semiconductor trade landscape. By incentivizing domestic fabrication and regional collaboration, these measures have mitigated supply-chain vulnerabilities exposed during the U.S.-China trade conflict and the COVID-19 pandemic. Policymakers should continue to strengthen such frameworks through sustained R&D investment, public-private partnerships, and workforce development, ensuring that domestic capacity complements, rather than replaces, global cooperation (Khan et al., 2021).

While this study focuses on export dynamics, it is equally important to recognize the upstream dependencies that influence the United States' broader position in the semiconductor value chain. The U.S. remains reliant on imports of advanced lithography and etching equipment (HS 8486) from Japan and the Netherlands, as well as critical materials such as photoresists and high-purity process gases from South Korea and Taiwan region. These dependencies underscore the structural interdependence of the global semiconductor ecosystem—where export diversification and domestic capacity expansion must be balanced with secure access to foreign technologies and materials. Strengthening this upstream resilience through collaborative R&D and allied sourcing agreements complements the CHIPS Act's emphasis on domestic manufacturing and innovation.

The declining RCA values highlight a relative loss of export competitiveness despite increased policy intervention. This suggests that long-term competitiveness cannot rely solely on subsidies or protectionist measures. Instead, it depends on reinforcing the United States' technological frontier—through sustained innovation in design automation, advanced lithography, and AI-enabled chip architectures. Policy efforts should therefore prioritize knowledge-intensive comparative advantage, integrating educational, industrial, and research ecosystems to sustain global leadership in high-value segments of the IC supply chain.

The diversification toward Mexico, Singapore, and the European Union indicates the rise of regionalized semiconductor alliances. Future trade and industrial policy should focus on formalizing friend-shoring partnerships through joint R&D initiatives, reciprocal investment incentives, and cross-border standards for data security and intellectual-property protection. Strengthening these alliances can enhance mutual resilience while maintaining efficient production networks.

The U.S. government must integrate export policy with corporate governance and ESG considerations. Transparent reporting on supply-chain restructuring, sustainable sourcing, and compliance with export controls can build investor confidence and align semiconductor governance with broader sustainability goals.

In summary, the findings suggest that U.S. semiconductor policy must evolve from short-term resilience management toward a long-term competitiveness framework—anchored in innovation, regional collaboration, and institutional trust. Such an approach will ensure that the United States remains not only a major semiconductor producer but also a central orchestrator of the next generation of global technology supply chains.

4.6. Limitation

While this study provides an integrated analysis of U.S. semiconductor export concentration and competitiveness, several limitations should be acknowledged.

First, the analysis relies primarily on aggregated trade data from UN Comtrade and ITC Trade Map at the HS 6-digit level. Although this level of granularity captures product-category differentiation, it does not fully reflect firm-level or technology-node differences (e.g., advanced vs. legacy chips). Future research could combine trade statistics with industry-specific production data or firm disclosures to capture the technological intensity and value-added structure of exports.

Second, the RCA and HHI indicators used here are static ratio measures that describe observed trade patterns but do not directly capture causal mechanisms such as changes in cost structures, R&D investment, or policy-related shifts in capacity. Extending the framework with econometric or network-based models could identify how policy events (e.g., tariffs, export controls, CHIPS Act incentives) quantitatively affect competitiveness and concentration over time.

Third, the study focuses on export performance, while import dependencies—particularly for semiconductor manufacturing equipment and materials—are not included in the main model. A balanced view of import-export interdependence would provide a more comprehensive assessment of national resilience (VerWey, 2019).

The time series analyzed (2015-2024) captures only the initial phase of post-CHIPS Act restructuring. The long-term impacts of domestic fabrication incentives, friend-shoring partnerships, and AI-driven demand shifts will require continued monitoring as more data become available. Looking ahead, AI-related demand is expected to reshape trade patterns in the integrated-circuit sector—particularly for high-performance processors (HS 854231) and memory devices (HS 854232)—as the expansion of data centers and cloud computing sustains global demand for advanced chips. These trends align with the broader transition toward technology-intensive exports and resilience-oriented supply-chain realignment.

Despite these limitations, the combined HHI-RCA-Sankey framework establishes a replicable foundation for future studies on semiconductor trade structure, providing both quantitative rigor and strategic insight into the evolving global value chain.

5. Conclusion

This study examined the evolution, concentration, and competitiveness of U.S. integrated-circuit (IC) exports from 2015 to 2024 using a combined analytical framework that integrates Herfindahl-Hirschman Index (HHI), Revealed Comparative Advantage (RCA), and Sankey flow visualization. The results reveal a clear structural transition in U.S. semiconductor trade patterns—from heavy East Asian dependence toward broader regional diversification and strategic realignment.

The HHI analysis demonstrated that export concentration peaked during the

2018-2020 trade-war and pandemic period, followed by a steady decline after 2021 as near-shoring and friend-shoring policies took effect. The RCA results indicated a gradual erosion of export competitiveness, reflecting both intensified East Asian competition and the U.S. strategic shift from export volume to technological and policy leadership. The Sankey visualization confirmed these patterns, showing the narrowing of flows to the Chinese mainland and Hong Kong SAR and the expansion of exports to Mexico, Singapore, and the European Union.

Collectively, these findings suggest that the U.S. semiconductor industry is undergoing a strategic reconfiguration—shifting from a model of efficiency-based globalization to one centered on resilience, innovation, and alliance-based regionalization. Although the nation's comparative export advantage has weakened, its long-term strength lies in innovation capacity, policy coordination, and institutional trust rather than sheer export share.

Looking ahead, sustained competitiveness will depend on how effectively the United States can balance technological leadership, international collaboration, and supply-chain autonomy in an increasingly fragmented global economy. Continued integration of data-driven analysis with industrial policy evaluation will be essential for guiding the next phase of semiconductor globalization—where resilience, security, and innovation define strategic advantage.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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