How governments can measure competitiveness in the new world order

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EY Parthenon

Building a better working world

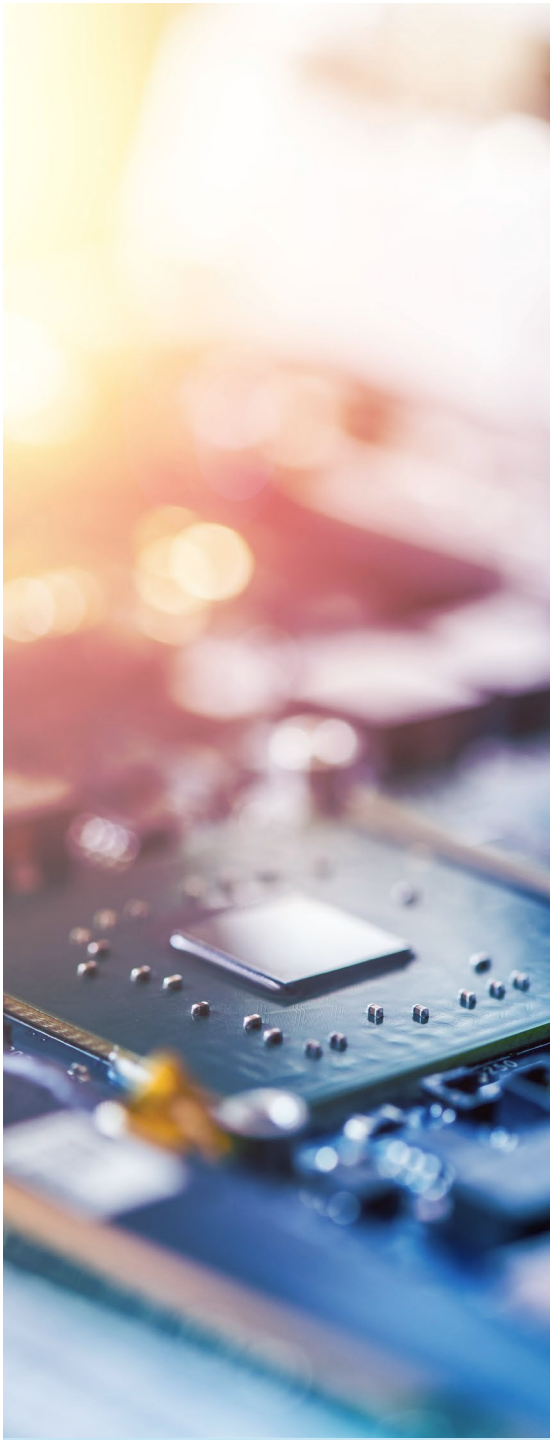
How governments can measure competitiveness in the new world order

As geopolitical uncertainty redefines global economic policy, and distinct country alliances reorient trade, governments need to more accurately prioritize investment in industries and innovation to strengthen the economy at home and competitiveness on the world stage.

Four plausible scenarios over the next five years emerge from an analysis of geopolitical relations and countries' economic policy stances: self-reliance would result from decaying alliances and weak economic growth; Cold War II, in contrast, would result from a hardening of alliances and ideological competition; friends-first trade blocs would allow trade and capital to flow relatively freely among allies; and globalization lite would unfold with a relatively liberalized and globalized operating environment with lower geopolitical tensions, according to the EY Geostrategic Business Group.

Amid this uncertainty, CEOs rank a further increase in geopolitical tensions among the greatest risks to business growth, according to the EY 2022 CEO Outlook Survey published in October 2022. What is clear is the need for greater rigor on where governments and businesses invest limited capital. For US policymakers and their global counterparts, many of the available frameworks for measuring competitiveness limit analysis. The metrics these frameworks employ to benchmark countries' competitive standings often do not apply to specific industries with technical and complex value chains, such as semiconductors.

Boosting the labor market and export capacity can strengthen US gross domestic product and economic resilience. Autonomy in critical supply chains also decreases dependence on other countries for critical materials and products. Such efforts can significantly strengthen national security, especially during times of crisis. As seen during the pandemic, a strong reliance on foreign materials or produced goods results in serious US vulnerabilities. With greater competitiveness that fosters innovation as industry leaders push boundaries on existing technologies, leaders can reshape the tide of global trade.



The EY-Parthenon team has developed and refined a system of metrics that may help countries and their leaders better understand their competitiveness in the current economy. This three-pronged framework for analysis can help the US and other nations measure where additional investment and support are needed. To measure global competitiveness in one industry, the EY-Parthenon framework defines and measures an industry's value chain competitiveness in three categories:

1. Global market leadership
2. Business leadership
3. Innovation leadership (in one or more industries)

Leadership pillar	Guiding principle	Key question	Metrics
Global market leadership	Market share	Is the country of interest leading in the global market compared to other countries?	Global market size, market share by country (e.g., commercial research reports)
	Government support	Do the country of interest's companies in the industry receive more government export support compared to foreign companies?	Export and trade-related financing (e.g., export credit agency transactions data and public EXIM (Export-Import Bank of the United States) bank data
Business leadership	Export strength	Is the country of interest leading in exports in the industry compared to other countries?	Total export volume, export share, export growth, export market share, export market penetration
	Financial strength	Do the country of interest's companies in the industry perform better compared to foreign companies?	Aggregated company financial data, including revenue, net income, return on invested capital (e.g., CapIQ financial data)
	Industry leadership	How do the country of interest's companies' industry leaders compare to foreign companies?	Leading companies' share of industry revenue (e.g., percentage of total industry revenue)
Innovation leadership	Innovation strength	Is the country of interest more innovative compared to other countries?	Patent/invention strength indexes
	Research and development	Is the country of interest leading in research and development compared to other countries?	Total R&D expenditure, industry standards share

Each of these three categories contains metrics — including global market size, research and development (R&D) expenditures, and export volume — that guide assessment of an industry's value chain. Each metric applies to one stage of an industry's value chain, and value chains are assessed for each country individually. Once information is gathered, the framework calculates comparative leadership scores for each segment of the value chain in each country. The framework estimates the current strength of the value chain stage and potential future strength of the value chain stage (Table 1) for each country being considered. For example, in studying the semiconductor industry, the score for materials in the US value chain will be different than materials in China's value chain.

Table 1

Global comparative leadership scoring

Estimated current strength of value chain stage	Low	Medium	High
High			
Medium			
Low			

Potential future strength of value chain stage

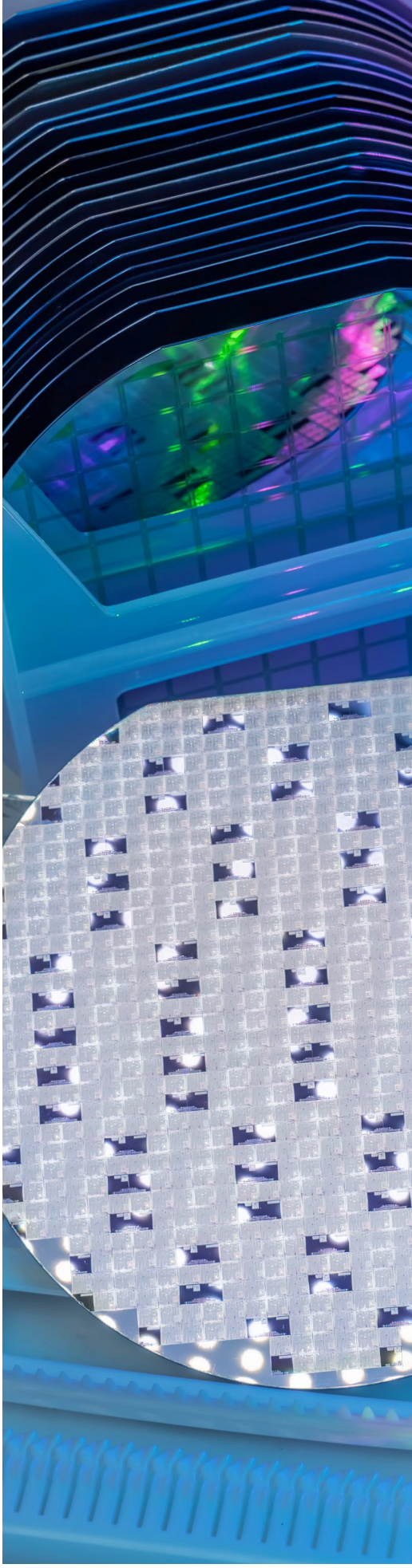
After each value chain segment receives a score, it is possible to assess an entire industry's competitiveness by synthesizing all individual scores (e.g., semiconductor competitiveness in the United States vs. China's semiconductor value chain).

Not every industry analysis can include every metric, depending on data availability. In some cases, proxy data, synthetic benchmarks or qualitative insights may substitute certain defined metrics. In all cases, qualitative analysis by industry experts must be used to synthesize various metrics on a replicable, repeatable basis.

Can US semiconductors gain a competitive edge?

The three-part framework can be applied to the semiconductor industry. Its value chain helps illustrate the advantage of studying competitiveness in a specific industry with a technical and complex value chain.

Several federal agencies list semiconductor manufacturing as a priority for US government support, particularly as a method to decrease US dependence on China. Bipartisan support for the CHIPS and Science Act of 2022,[1] which provides more than $52b and tax credits to increase US semiconductor industry independence, illustrates that Washington leaders recognize the need to invest in opportunities for American workers and industries, across value chains, from research and development to manufacturing and distribution.



[1] "FACT SHEET: CHIPS and Science Act Will Lower Costs, Create Jobs, Strengthen Supply Chains, and Counter China," whitehouse.gov, August 9, 2022.

The roughly $527b global market for semiconductors, which enable virtually every electronic device, is made up of five value chain components: R&D and design; equipment manufacturing; materials; fabrication; and assembly, testing and packaging (ATP). Semiconductors are the fourth-largest US export category and directly support roughly 250,000 US jobs, largely due to US leadership in semiconductor R&D and design.

The semiconductor value chain is highly globalized and relies on over 300 inputs that cross borders dozens of times. However, 75% of global semiconductor manufacturing capacity is in Asia.[2] Only about 10% of semiconductor capacity is in the United States, where the 10-year cost of a new semiconductor fabrication plant can be 30% higher than in Taiwan or South Korea and 50% more costly than construction in mainland China.[3]

Table 2

Semiconductor industry value chain*

Stage	R&D and design	Manufacturing equipment	Materials	Fab	ATP	End use**
Product categories	**R&D and design** ▸ Designers use electronic design automation (EDA) and IP cores to design new chips ▸ Occurs either in-house at integrated device manufacturer (IDM) or in a design-only "fabless" firm	**Fabrication equipment** ▸ Production of lithography, deposition and other equipment used in chip production **ATP equipment** ▸ Production of dicing, bonding other equipment used in ATP stage	**Raw materials** ▸ Sand ▸ Rare earth metals **Fab materials** ▸ Silicon wafers ▸ Photomasks, photoresists ▸ Chemicals **Packaging materials** ▸ Lead frames ▸ Bond wires	**Chip fabrication (fab)** ▸ Complex process involving deposition, photolithography, etching and other steps to create patterns in wafer according to design ▸ Occurs within IDM or outsourced to pure-play foundry	**Assembly, testing, and packaging** ▸ Cutting a finished wafer into chips ▸ Mounting chips on frames with wires ▸ Enclosing chips in protective casing ▸ Occurs within IDMs or outsourced semiconductor assembly and test (OSAT) firms	**Computer** ▸ PCs, servers **Communications** ▸ Radios **Consumer** ▸ Phones, tablets **Auto/industrial** ▸ Cars, trucks ▸ Machinery
Example global suppliers	▸ Broadcom ▸ Intel ▸ Mediatek ▸ Samsung ▸ Qualcomm	▸ KLA ▸ Lam Research ▸ Samsung	▸ Global Foundries ▸ Intel ▸ Samsung ▸ Shin-Etsu ▸ SK siltron	▸ Global Foundries ▸ Intel ▸ Samsung ▸ SK hynix ▸ TSMC ▸ UMC	▸ Amkor Technology ▸ ASE Group ▸ Intel ▸ Samsung ▸ SK hynix ▸ TSMC	▸ HP ▸ Intel ▸ Lenovo ▸ Qualcomm ▸ Samsung

* Forbes: Intel, Nvidia, et al. and American Semiconductor Hegemony
** End uses are not considered in this paper's value chain analysis.

[2] "FACT SHEET: CHIPS and Science Act Will Lower Costs, Create Jobs, Strengthen Supply Chains, and Counter China," whitehouse.gov, August 9, 2022.

[3] "2021 State of the U.S. Semiconductor Industry," semiconductors.org, September 24, 2021.

Global market leadership

The first layer of the EY-Parthenon competitiveness framework is global market leadership. It aims to identify a country's economic position within a global industry, with areas of strength and weakness compared to another country or region. The category considers metrics regarding market share and level of government support.

Market share metrics evaluate if the country of interest is leading in the global market of a particular industry compared to other countries. These metrics can be assessed by industry or by value chain stage and include global market size, global market growth, market share by country, market share over time by country and market concentration:

- Global market size in an industry or value chain stage is calculated by the sum of revenue of public companies operating within the market. It demonstrates an industry's importance to the global economy and/or the estimated number and size of public companies.
- Global market growth is calculated as the per-year percent growth in revenue of public companies operating within the market, which indicates where the market of interest is growing the quickest and the potential impact on jobs growth.
- Market share by country is the percent of global industry market size captured by country calculated as the sum of revenue of public companies within each country. Like market growth, it indicates a country's relative importance to the global market.
- Market share over time by country indicates the change in each country's market share calculated as the per-year percent growth in revenue of public companies operating within the market. It demonstrates which country has more growth, the contributing factors to growth, and the implications of growth or decline.
- Concentration of a market is also important to represent relative size distributions of firms for each country in the context of the global market. Policymakers can calculate it using the Herfindahl-Hirschman Index, which takes the sum of the squares of each firm competing in the global market for each country.

The second area of global market leadership, **government support**, evaluates if companies in the industry receive more government support compared to foreign companies in the industry. The metrics are intended to be evaluated respectively for all companies of interest:

- Government support includes export and trade-related financing. This metric encompasses the value and number of transactions by export credit agencies supporting exports within an industry or value chain segment, demonstrating which industries and value chain segments receive targeted government support through export credit products.
- Government subsidies and tax credits similarly indicate the breadth and types of government subsidies that may support industries. To assess this metric, policymakers can examine types and the estimated value of subsidies and/or tax credits that apply to research, development or production within an industry or value chain segment.
- Government regulatory standards may support strong markets by assuring the quality and safety of products and services. Conversely, they may constrain markets. In either scenario, qualitative analysis can reveal industry-specific government standards and regulations that support or limit market competitiveness.

Market share and government support metrics can be applied to the semiconductor industry value chain for the United States and mainland China, respectively. As seen in the third column in the table below, after gathering select metrics, the US semiconductor market has global market leadership in the R&D and design, fabrication and ATP segments of the semiconductor value chain as compared to mainland China's capabilities.

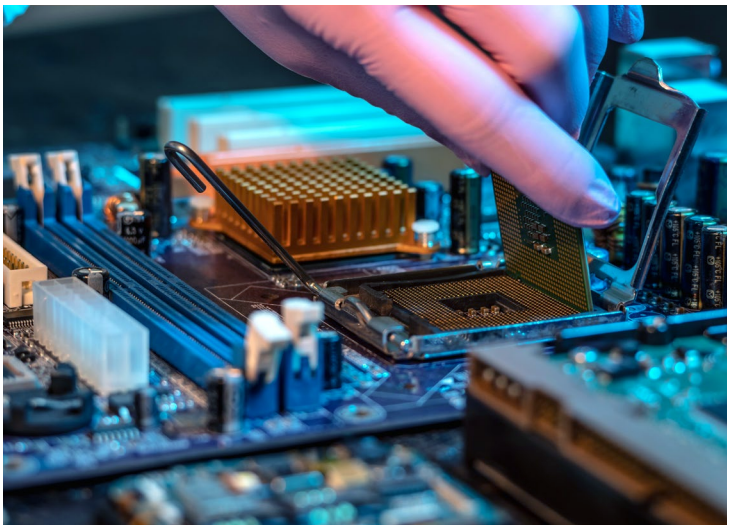


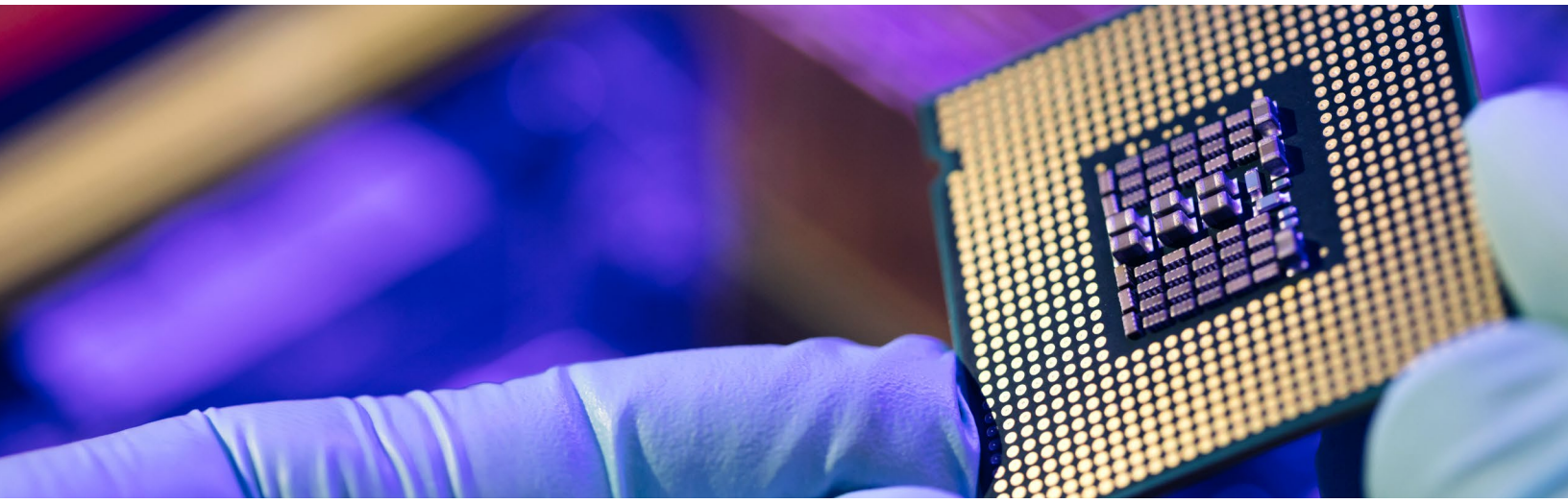
Table 3

Select global market leadership metrics

● High … ○ Low	US score	Select global market leadership metrics
R&D and design		**Government support (US)** ▸ **Sources of US competitive advantage:** Research and design are the US's largest competitive advantage due to presence of world-leading fabless firms like Qualcomm, Broadcom, AMD, Nvidia and Apple and IDMs like Intel and Micron that collectively dominate chip design.[2] ▸ **High legislative priority:** The Facilitating American-Built Semiconductors Act (FABS Act) includes tax credits for design and manufacturing in the US.[3] ▸ **Industry leaders** (e.g., Intel, Micron) believe continuing research is critical to US competitiveness.[3] **Government support (China Mainland)** ▸ **Fundamental weakness:** China not competitive but is actively deploying resources to advance. ▸ 2016 export ban against ZTE due to violation of Iran sanctions spurred Chinese recognition of dependence on foreign firms. The Semiconductor Industry Association (SIA) (SIA) and Oxford Economics estimate that China accounts for less than 3% of value added in electronic design automation software and core IP.[1] ▸ **Core focus of Made in China 2025**, which mentions design and IP development for semiconductors as the first areas of investment.[4, 5]
Equipment		**Government support (US)** ▸ **Not a specific focus of legislative efforts** as the US already has a dominant position together with allied countries: Japan, Netherlands, Germany.[2] **Government support (China Mainland)** ▸ **Core focus of Made in China 2025**, which specifically highlights manufacturing equipment.[4, 5] ▸ **Focus of private investment due to weakness:** China is a laggard in the equipment space, particularly in lithography equipment. Semiconductor manufacturing equipment (SME) is a key choke point in the Chinese semiconductor supply chain, and Chinese companies are actively pursuing this space, particularly scanners and steppers.[2] ▸ **China does produce ATP equipment**, which is the lowest-value segment of SME.[2]
Materials		**Government support (US)** ▸ **Low priority:** Despite little raw material production in the country, the US is already competitive in many intermediate fab materials like photomasks and photoresists. Japan dominates ATP material production and is an allied country.[2] ▸ **Not a key focus of pending legislation**, but materials producers do support FABS and CHIPS Acts. **Government support (China Mainland)** ▸ **China produces raw materials and dominates rare earth processing**, as many rare earth metals are mined there. China dominates mining of low-grade gallium, beryllium, tungsten and magnesium.[6] ▸ **China is weak in wafer manufacturing:** China is not a significant player in 300 mm diameter wafers, which make up 99.7% of fab capacity, making the country reliant on imports.[2] ▸ **China is weak in other fab materials:** Japan, US, Taiwan and Korea dominate fab material production, including photomasks, photoresists and chemicals.[2] ▸ **China produces some ATP materials**, although Japan dominates this type of material.[2]

● High … ○ Low	US score	Select global market leadership metrics
Fab		**Government support (US)** ▸ **Fundamental legislative priority:** Key focus of the CHIPS ($52b of incentives) and FABS Acts.[7] ▸ **White House priority:** Biden administration highlighted fabs in January 2021 Supply Chain Fact Sheet, January 2022 Semiconductor Manufacturing Fact Sheet and January 2022 remarks on semiconductor supply.[8] **Government support (China Mainland)** ▸ **High priority to develop more advanced fab capabilities:** Most Chinese capacity is in older, less efficient 14-nanometer scale chips instead of cutting-edge 5-nanometer scale chips.[2] ▸ **Core focus of Made in China 2025**, which mentions the imperative to increase domestic capabilities.[5] ▸ **National Integrated Circuit Development Investment Fund** established in 2014 with $21b in funding. Renewed in 2019 with over $35b of new funding.[9] ▸ **High priority for last 16 years:** One of 16 megaprojects outlined in the 2006 National Medium and Long-Term Plan for the Development of Science and Technology.[10]
ATP		**Government support (US)** ▸ **National weakness:** ATP is a labor-intensive process that few companies choose to do in the US. ▸ **Fundamental priority:** Bringing back some of these jobs to the US is a key focus of the CHIPS and FABS Acts in Congress and subject of repeated press releases by the White House.[3] ▸ **Manufacturing leadership subject of March 2022 hearing** in the Senate highlighted US's continuously declining leadership in both the fab and ATP spaces.[3] **Government support (China Mainland)** ▸ **China is already a major ATP player and wants to solidify its lead**:[2] Success in this value chain segment depends on low labor costs, which is one of China's key advantages. Chinese firms' market share increased to about 40% in 2020 due to acquisitions.[11] Some firms are relocating to SE Asia. ▸ **Core focus of Made in China 2025** policy, which specifically highlights the need to develop independence in advanced testing and encapsulation technology.[9]

1 SIA Chipping In Report – May 2021
2 CSET Semiconductor Supply Chain Brief
3 March 23, 2022, Hearing in Senate Committee on Commerce, Science, and Transportation
4 US Chamber of Commerce: Made in China 2025
5 State Council's Made in China 2025
6 USGS, Mineral Commodities Summaries 2020
7 Congress.gov CHIPS Act and FABS Act
8 White House.Gov
9 SIA: China's Semiconductor Industry
10 PRC State Council: 2006-2020 National Medium- and Long-Term Program for Science and Tech Development
11 Brookings: State of China's Semiconductor Industry



Business leadership

Business leadership in the EY-Parthenon competitiveness framework addresses the financial strength of companies within an industry to identify the relative financial leadership of companies in the country of interest compared to companies in other countries used in the comparison. There are two subcategories within the business leadership category: export strength and financial strength.

Export strength evaluates the extent to which a country of interest is leading in exports in an industry compared to other countries. These metrics can be assessed by industry or by value chain stage and include export volume, export contribution, export growth, export market share and foreign market penetration:

- Export volume, which reflects the total dollar amount of exports by country, and it should be evaluated by value chain stage and industry. Accordingly, the measurements can demonstrate relative export strength among value chain stages and provide comparison of export-oriented value chain stages to market size.
- Export contribution is the contribution of industry exports to a country's total exports. The contribution level establishes the relative importance of exports to a country's economy.
- Indications of the direction and pace of a country's exports and contributing factors for growth also are important pieces of information. Export growth, the annual percentage growth rate of export value at market prices, can provide insight into the direction and pace of exports.
- Export market share uses countries' percent shares of total exports of a product to a particular country or region. It indicates countries and regions where exporters may grow share or compete with other countries.
- Similarly, foreign market penetration identifies value chain stages where a country is diversified across the global market. Foreign market penetration is the number of countries to which each country exports a particular product divided by the number of countries that import the product.

Financial strength, the second group of metrics in business leadership, provides insights on average financial performance of the public companies operating in the value chain of interest. Financial strength includes multiple metrics that rely on measurements from a specific year, preferably the most recent fiscal year. The financial strength category includes average revenue, revenue growth, net income, return on invested capital, employment potential and management scoring. Most of these metrics are assessed as averages of multiple public and private companies' prior-year data. However, company data availability may be limited. In that case, qualitative data may supplement financial strength analysis:

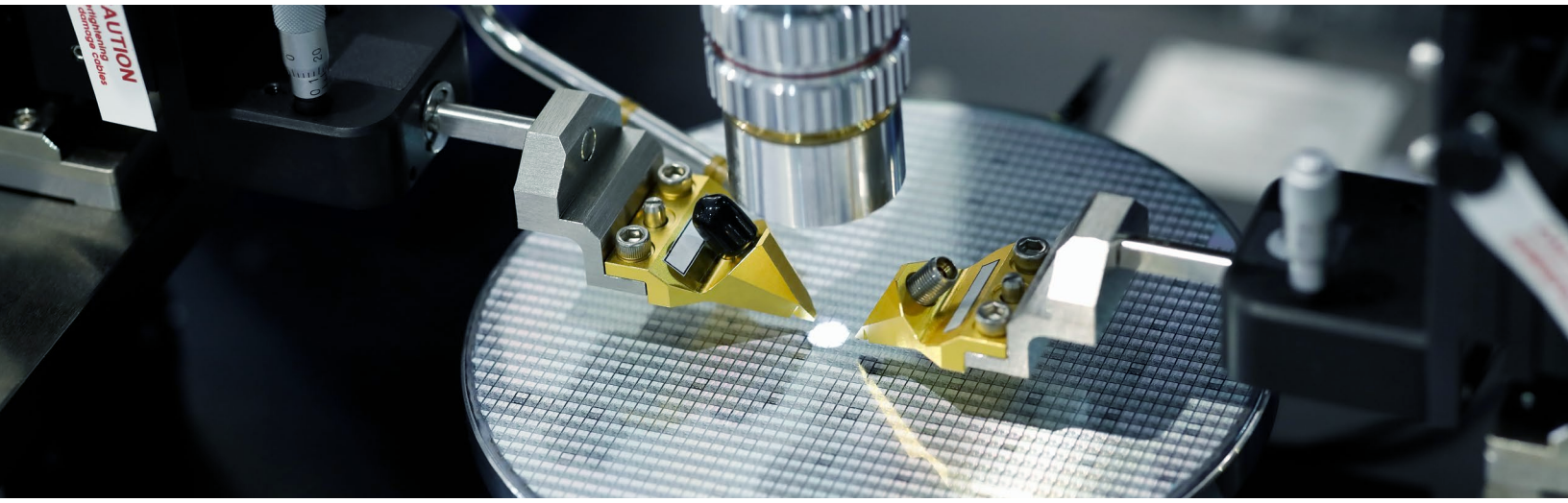
- Average revenue is the sum of revenue of public companies divided by the number of public companies in the industry.
- Average revenue growth is the annual percentage growth rate in public company revenue of the country of interest and other countries calculated using the compound annual growth rate (CAGR).
- Average net income is public companies' net income divided by the number of public companies within the industry.
- Average return on invested capital is the sum of return on invested capital for public companies divided by the number of public companies within the industry.
- Average return on assets is the sum of returns on assets for public companies divided by the number of public companies within the industry.
- Employment potential examines an industry or value chain segment at large. It demonstrates in-country economic impact of an industry's growth or leadership by documenting total employment in the industry in the current year or projected employment in a future year.
- The World Management Survey, a data set of company-level management practices, can be used within each country to empirically benchmark management strength across organizations and countries.

By applying export strength and financial strength metrics to the semiconductor value chain, business leadership in each segment of the semiconductor industry can be clearly understood. In the third column in the following table, sample metrics provide detail for the business leadership scores that indicate the United States is a business leader in semiconductor ATP but is not a strong leader in the other value chain stages.

Table 4

Select business leadership metrics

● High ... ○ Low	US score	Select business leadership metrics
R&D and design	◔	**Export strength** ▸ **No physical products produced in this stage:** Designers use IP cores and electronic design automation (EDA) software to design chips. Those designs are digital files sent to partner firms that specialize in fab (called foundries) for physical production, most often overseas.[1] ▸ **US dominates R&D and design, Asia dominates fab:** US firms dominate R&D and design and concentrate efforts in the US but conduct fabrication in mainland China, Taiwan and Korea.[2] **Financial strength** ▸ **Second-largest group of semiconductor jobs in the US:** The SIA and Oxford Economics estimate that about 33% of the US semiconductor workforce was in fabless design firms.[3]
Equipment	◑	**Export strength** ▸ **US exported $18b in 2021:** UN Comtrade database shows $18b in exports in 2021 for HS code 8486.20, which encompasses semiconductor manufacturing equipment.[4] ▸ **Upward trend** of 39% year-over-year (YoY) increase in exports from 2020 to 2021.[4] **Financial strength** ▸ **Third-largest source of semiconductor-related jobs are in the US**, although these jobs are at SME firms that sell to semiconductor fabs, including foundries like TSMC and IDMs like Intel.[2]
Materials	◑	**Export strength** ▸ **US has few raw materials:** US does not export significant volume of raw input materials as they are not found in the US. China dominates primary production of many raw materials.[5] ▸ **US is a major producer of most fab materials**, including photomasks and photoresists.[6] ▸ **US has small share of wafer production:** Japanese, Taiwanese, German and Korean firms dominate wafer production with 96% cumulative share and have limited production capacity in the US.[7] ▸ **US produces some ATP materials**, such as lead frames and bond wires, but Japan dominates.[6] **Financial strength** ▸ **Indirect impact on up to 133k US jobs:** Semiconductor Industry Association estimated that up to 133k US jobs in natural resources and mining are indirectly impacted by the semiconductor industry as many critical materials go into semiconductor manufacturing.[3]



● High ... ○ Low	US score	Select business leadership metrics
Fab	◑	**Export strength** ▸ **US exported $7.5b in 2021:** UN Comtrade database shows $7.5b in exports in 2021 for HS code 8541, which encompasses general semiconductors.[4] ▸ **Upward trend** of 20% YoY increase in exports from 2020 to 2021.[4] ~12% of fab manufacturing in US and ~75% in Asia.[2] ▸ **Potential for exports to increase even more** with more domestic investment in fabs due to pending legislation (CHIPS and FABS Acts).[8] **Financial strength** ▸ **US employment increasing with new fab development:** SIA estimates federal incentives would create 89k jobs between now and 20263. Intel's new fab in Ohio will bring 3k jobs.[6] TSMC's new fab in Arizona will bring 1.6k jobs.[7] Samsung's new fab in Texas will bring 2k jobs.[9] ▸ **US fabs are 30–50% more expensive than abroad**, largely due to lack of US government incentives as compared to other countries' incentives.[10]
ATP	◕	**Export strength** ▸ **US exported $44.2b in 2021:** UN Comtrade database shows $7.5b in exports in 2021 for HS code 8542, which encompasses finished integrated circuits that have gone through the ATP process.[4] ▸ **Potential for exports to increase** with more domestic investment in ATP facilities due to pending legislation (CHIPS and FABS Acts).[8] **Financial strength** ▸ Firms headquartered in the US have about a 28% market share globally, although most of it physically takes place in **SE Asian countries with lower labor costs**.[7]

1 Brown et al., "Chips and Change," 67.
2 Semiconductor Industry Association: State of the Semiconductor Industry 2021
3 SIA Chipping In Report – May 2021
4 UN Comtrade database
5 USGS, Mineral Commodities Summaries 2020
6 VLSI Research
7 CSET: The Chipmakers
8 Congress.gov CHIPS Act and FABS Act
9 Samsung
10 March 23, 2022, Hearing in Senate Committee on Commerce, Science, and Transportation

Innovation leadership

The third category of the EY-Parthenon competitiveness framework, innovation leadership, assesses a country's position as an innovation leader in an industry or value chain stage. The two pillars of the category are innovation strength and R&D.

Innovation strength evaluates if companies in the industry outperform foreign companies in terms of innovation. Metrics in this category rely heavily on patent data:

- When assessed qualitatively between countries and for multiple value chain outputs, the time series of patent filings and patent families can indicate global innovation trends in a particular technology.
- Patent owner portfolio aggregates and time series of patent owner trends demonstrate comparative leadership by active patent filers in a particular technology landscape.
- Aggregate patent citations, which are the number of citations to non-patent literature and science articles, are used to measure the quality of patents at the country level.
- Country-level estimates of total intellectual property (IP) portfolio, time series trends of country-level estimates, and country technology adoption and IP concentration measures present geographic distribution of innovation in a particular technology landscape.
- Country inventor aggregate estimates and the time series of country inventor estimates leverage an estimated inventor labor force to demonstrate comparative leadership.
- Aggregate new incorporations and spinouts, or the number of documented new corporations established in the country in the past year, are metrics to demonstrate comparative leadership that focus on entrepreneurship and commercialization.

R&D metrics include total public R&D expenditures, estimated private R&D expenditures, estimated academic R&D expenditures and average R&D expenditures. Each of these metrics helps determine if the country of interest is leading in research and development in an industry as compared to other countries:

- The sum of R&D expenditures of public companies within an industry or value chain stage, or a total public R&D expenditure metric, provides analysis of the R&D intensity in public companies and insight into product sophistication and export competitiveness.
- An important part of value chains is R&D in private companies, including venture capital and equity funding. Calculating estimated private R&D expenditures, which are the sum of R&D expenditures of private companies within an industry or value chain stage, is helpful for comparative analysis, although data completeness is unlikely due to information privacy barriers.
- Similarly, academic R&D expenditures may be difficult to gather or incomplete due to information barriers. Still, the sum of R&D expenditures of companies within an industry or value chain stage would provide analysis of R&D intensity in academic institutions, which frequently drive innovation.
- Finally, average R&D expenditures, the sum of total R&D expenditures by public companies divided by the total number of public companies, measures the dispersion of R&D expenditures among public companies and provides insights on potential outliers (e.g., industry-leading public companies contributing to total R&D expenditures).

Innovation strength and R&D metrics have been applied to the five stages of the semiconductor value chain, some of which are shown in the final column of the table below. Compared to mainland China, the United States is a leader in all value chain segments except for materials.

Table 5

Select innovation leadership metrics

● High ... ○ Low	US score	Select innovation leadership metrics
R&D and design	●	Innovation strength ▸ **Chip design determines the future of all electronic technology:** This design stage of the value chain is fundamental to the future development of all goods that use electricity. ▸ **Foundation technology as custom chip design can unlock 1,000x increases in efficiency and speed** and drive downstream tech innovation over the span of a few years.[1]
Equipment	◕	Innovation strength ▸ **Advances in equipment enable innovation in design and fab:** Photolithography equipment in particular requires extreme precision to draw new designs onto wafers. Innovation in this space takes many years to impact downstream industries that use semiconductors. ▸ **Improvements in this space are a fundamental limit to industry innovation:** Leading chipmakers like Intel, Samsung and TSMC recognize that without more advanced equipment they cannot continue to innovate, motivating them to invest in ASML, the leading Dutch lithography company.[2]
Materials	◔	Innovation strength ▸ **Not seen as a key area of innovation in the short term**, although researchers are exploring new materials like high-power gallium nitride, graphene and pyrite to replace and/or complement current silicon-based semiconductors that could radically improve speed.[3]
Fab	●	Innovation strength ▸ **Fab innovation enables downstream tech innovation:** Ever-decreasing nanometer scale of fab technology enables more power-efficient electronics with greater computing capacity over just a few years.[4] ▸ Currently **all leading-edge capacity** at the sub-10-nm scale **is in Asia**, mostly in Taiwan.[5]
ATP	◕	Innovation strength ▸ **Packaging is increasingly important:** The 2018 McClean Report from IC Insights, an industry analysis leader, highlighted the growing role of packaging in improving performance.[6] ▸ **Lack of innovation in packaging is slowing down overall performance gains:** The rate of density improvement in logic and memory chips is increasing much more quickly than packaging interconnections.[2]

1 CSET: The Chipmakers
2 Barron's, Nature Electronics, and CSET Semiconductor Supply Chain Brief
3 International Roadmap for Devices and Systems: Semiconductor Materials
4 Congress.gov CHIPS Act and FABS Act
5 CSET Semiconductor Supply Chain Brief
6 2018 McClean Report, pg. 466
7 A Density Metric for Semiconductor Technology

Table 6

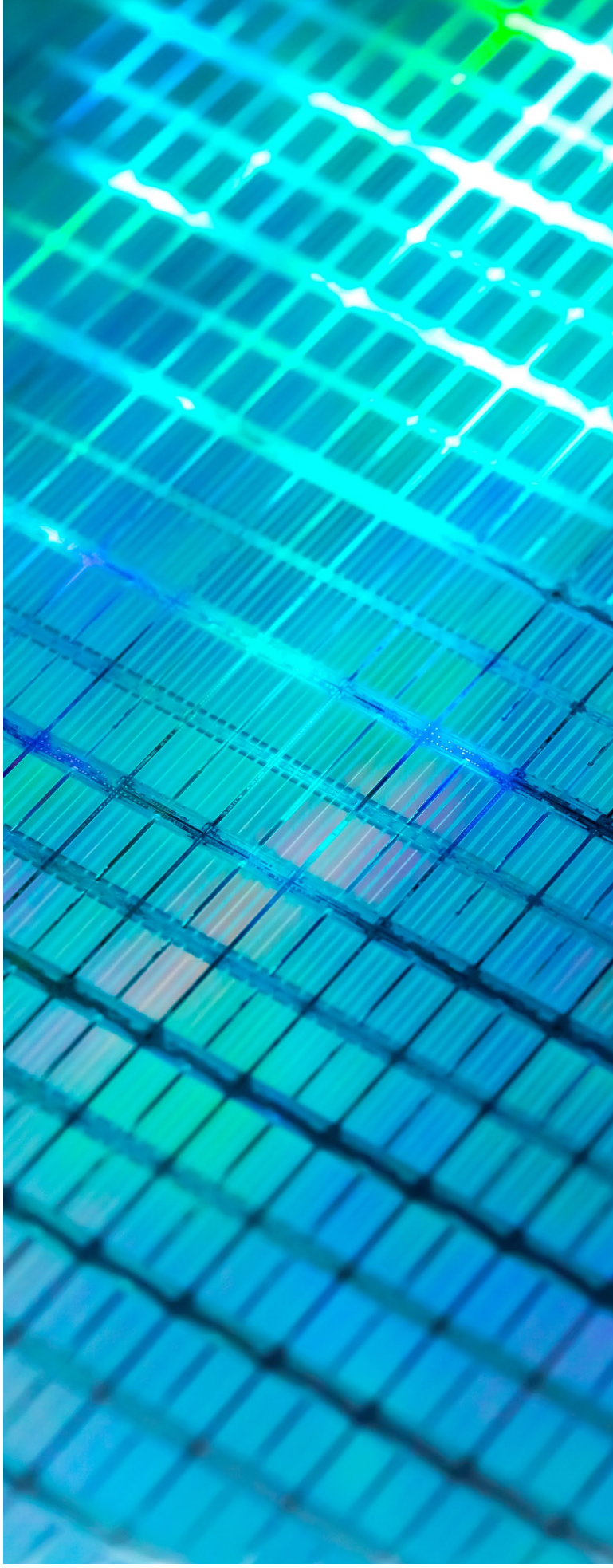
Semiconductor value chain comparative leadership scoring

● High ... ○ Low	Global market leadership	Business leadership	Innovation leadership	Rank
ATP	●	◕	◕	1
Fab	◕	◑	●	2
R&D and design	◕	◔	●	3
Equipment	◔	◑	◕	4
Materials	◑	◑	◔	5

Summary

The comparative leadership methodology assesses a value chain by global market leadership, business leadership and innovation leadership, with scores based on current strength and the potential for future strength in these three areas. When the methodology is applied to the semiconductor industry, chip fabrication scores the highest, indicating that it is a competitive area for the United States when compared to China. Policymaking bodies may consider focusing their agendas on US businesses that work in a value chain stage that is currently competitive (e.g., chip fabrication) or uncompetitive (e.g., semiconductor materials), depending on the policy outcomes desired.

This framework can apply to any value chain — not only to the semiconductor industry — thus providing a thorough context for discussing "global competitiveness" in any industry of interest. For the sake of national defense, economic strength and innovation, assessments of US competitiveness need to be at the forefront of national conversations. If policymakers can identify comparative advantages in specific industries and value chain segments, they can identify initiatives to support areas that will most impact the United States' ability to compete in and contribute to the global economy.



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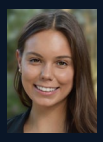

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