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Industry Activities

Production and Trade of Knowledge- and Technology-Intensive Industries

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Executive Summary

Key takeaways:

- Knowledge- and technology-intensive (KTI) industries produced $11.1 trillion globally in value added in 2022, a 5.6% increase from 2021 in current U.S. dollars compared with a 15.8% post-pandemic rebound from 2020 to 2021 in current U.S. dollars.
- KTI industries account for about a 10th of U.S. gross domestic product (GDP). Most KTI industry output is in the manufacturing sector, and the U.S. economy is relatively more services oriented.
- The United States, China, the European Union (EU-27), Japan, and South Korea accounted for about 80% of global KTI value added in 2022. In that year, China and the United States were the top two producers of KTI output ($3.0 trillion and $2.9 trillion, respectively), each representing over a quarter of global KTI value added, followed by the EU-27, with a 17.0% share ($1.9 trillion).
- The United States had the largest 2022 global shares of value added in two KTI manufacturing industries—air and spacecraft (57%) and medical and dental instruments (37%)—and was on par with China in pharmaceuticals and in weapons and ammunition manufacturing. China had the largest shares in the other six KTI manufacturing industries: computer, electronic, and optical products (including semiconductors); electrical equipment; railroad, military vehicles, and other transport equipment not elsewhere classified (nec); machinery and equipment nec; motor vehicles, trailers, and semi-trailers; and chemicals and chemical products (excluding pharmaceuticals).
- In 2022, the top six semiconductor-producing locations accounted for 89% of global semiconductor value added, and five of the top six were in East Asia. China alone accounted for almost a third (31.6%), followed by Taiwan (19.2%), the United States (18.1%), South Korea (11.8%), Singapore (4.5%), and Japan (3.9%).
- Globally, KTI manufacturing industries exported $11.4 trillion in 2022 in current U.S. dollars, up 6.6% from 2021, following a decline of 5.1% in 2020 and a post-pandemic increase of 20.2% in 2021. China has been the leading KTI manufacturing exporter country since 2008.
- In 2021, the United States exported $193 billion in KTI-related services, with $91 billion in imports, for a trade surplus of $102 billion in these services.
- Global supply chains mean that exports from a given country often include value from domestic production and from imported inputs. For the United States, the share of domestic content in its gross exports across all industries is much larger than the share of foreign content, fluctuating between 84% and 90% since 2007.

Supply chains for production of goods and services and for technology development that were built over the last decades have been impacted by recent macroeconomic, geopolitical, and pandemic-related headwinds. KTI industries—or research and development (R&D)-intensive industries, defined in more detail below—are an important source for R&D and other intangibles and are a contributor to economic competitiveness and public policy goals across countries. Multinational enterprises (MNEs) and other firms in these industries participate in trade, investment, and other global value chain activities supporting national economic growth and innovation outcomes.

This report focuses on trends in output and international trade by KTI industries, including new analysis of global semiconductor production and the composition of U.S. KTI-related services. Output is measured as *value added*, defined as the value of goods and services minus the cost of intermediate inputs. Together, KTI output and trade patterns provide context for R&D and innovation trends across economic sectors covered in other *Science and Engineering Indicators 2024* reports.

Introduction

U.S. knowledge- and technology-intensive (KTI) or research and development (R&D)-intensive industries compete in a changing environment for international production, R&D, and technology development, impacted by recent macroeconomic, geopolitical, and pandemic-related headwinds (Baldwin and Freeman 2022; Cerdeiro et al. 2021; Goldberg and Reed 2023; OECD 2023a). The latter have affected capital costs, input prices, and the organization of supplier networks, including those for critical minerals and materials, energy, technology, and labor (CRS 2022a; GAO 2022; IMF 2023a; Page 2023). In turn, the economic vitality of KTI industries is an important source for R&D investment, competitiveness, and contributions to public policy goals across countries—from national security, sustainable energy, and communications and other physical infrastructure to environmental protection and health (OECD 2023b).

This report examines production patterns of R&D-intensive industries measured as *value-added output*: the value of goods and services produced by an industry (gross output) minus the cost of intermediate inputs (energy, materials, and purchased services)—henceforth, value added. The resulting measure captures primarily the contribution of labor and capital and avoids double counting when aggregating value of production within and across countries. The report also uses several measures of international trade, as described shortly.

KTI industries are defined as those with high and medium-high R&D intensities based on an international comparable taxonomy developed by the Organisation for Economic Co-operation and Development (OECD 2016) using the International Standard Industrial Classification of All Economic Activities (ISIC). (See **Technical Appendix** and Table SAKTI-1.) These industries comprise 10 in manufacturing—pharmaceuticals; chemicals and chemical products (excluding pharmaceuticals); computer, electronic, and optical products (including semiconductors); electrical equipment; motor vehicles, trailers, and semi-trailers; air and spacecraft and related machinery; weapons and ammunition; railroad, military vehicles, and other transport equipment; other machinery and equipment; and medical and dental instruments[1]—and 3 in services—information technology (IT) and other information services; software publishing; and scientific R&D services. (See the **Glossary** section for definitions.)

This report focuses on two main areas of KTI activity: production patterns and international trade, including new analyses of global semiconductor production and of composition of U.S. KTI-related services. The first section covers trends in U.S. and global KTI production. Statistics on U.S. value added by detailed industry are from the Bureau of Economic Analysis (BEA), whereas international data were obtained from S&P Global's IHS Markit Comparative Industry Service, classified according to ISIC Revision 4.

The second section analyzes cross-border transactions from three perspectives: goods trade, services trade, and trade in value added (TiVA) focused on domestic versus foreign content of U.S. exports. Sources for trade statistics include BEA, S&P Global, and a joint BEA–National Science Foundation (NSF) project on TiVA.

Other *Science and Engineering Indicators 2024* reports cover topics related to KTI industries, especially the forthcoming *Indicators 2024* report "[2024] Research and Development: U.S. Trends and International Comparisons" (covering U.S. and global R&D); the *Indicators 2024* report "[2024] Invention, Knowledge Transfer, and Innovation" (innovation, patenting, and venture capital investment); and the forthcoming *Indicators 2024* report "[2024] The STEM Labor Force" (scientists, engineers, and skilled technical workers).[2]

Production Patterns of Knowledge- and Technology-Intensive Industries

U.S. Industries

KTI industries have accounted for about a 10th of U.S. gross domestic product (GDP) since 2002 (11% in 2022, or $2.9 trillion of $25.7 trillion in current U.S. dollars, based on S&P Global detailed value-added industry data and BEA GDP statistics) (BEA 2023c; **Table KTI-1**; Table SKTI-1; Table SAKTI-2). This relatively modest share reflects that the U.S. economy is relatively less manufacturing intensive and that most KTI industries are in the manufacturing sector given its higher R&D intensity (Wolfe 2022).[3] Indeed, in 2022, manufacturing industries overall accounted for 11.2% of U.S. GDP, compared with 55.6% for total private services.[4]

Table KTI-1

U.S. KTI industries, by value added and share of GDP: 2018–22

(Billions of dollars and percent)

Industry	ISIC, Rev.4, industry code	2018	2019	2020	2021	2022
Billions of dollars						
GDP		20,656.5	21,521.4	21,323.0	23,594.0	25,744.1
All manufacturing		2,373.3	2,408.5	2,279.3	2,541.1	2,894.3
Total private services		11,483.5	12,074.5	11,997.7	13,357.1	14,320.2
All KTI industries		2,181.4	2,287.0	2,337.6	2,583.9	2,886.5
KTI manufacturing		1,295.2	1,335.0	1,299.7	1,401.5	1,594.5
Chemicals and chemical products	20	211.1	213.1	201.6	221.9	258.4
Pharmaceuticals, medicinal chemical, and botanical products	21	165.6	184.0	198.9	217.7	233.7
Weapons and ammunition	252	5.9	6.7	8.1	8.2	8.8
Computer, electronic, and optical products	26	308.0	312.7	320.3	338.2	380.0
Electrical equipment	27	65.1	64.6	61.4	67.7	73.6
Machinery and equipment nec	28	174.0	180.5	171.7	186.4	225.8
Motor vehicles, trailers, and semi-trailers	29	157.8	158.2	143.9	158.7	171.6
Air and spacecraft and related machinery	303	134.9	140.9	124.2	129.3	156.7
Railroad, military vehicles, and transport equipment nec	30X	11.9	12.5	10.7	11.6	13.4
Medical and dental instruments and supplies	325	60.9	61.7	58.9	61.8	72.5
KTI services		886.2	952.0	1,038.0	1,182.4	1,292.0
Software publishing	582	201.6	225.5	267.9	314.3	339.3
IT and other information services	62–63	556.3	587.3	613.6	695.1	772.8
Scientific R&D services	72	128.4	139.2	156.4	172.9	179.9
Analytical ratios (%)						
All KTI/GDP		10.6	10.6	11.0	11.0	11.2
KTI manufacturing/GDP		6.3	6.2	6.1	5.9	6.2
KTI services/GDP		4.3	4.4	4.9	5.0	5.0
GDP structure (selected sectors) (%)						
Manufacturing/GDP		11.5	11.2	10.7	10.8	11.2
Total private services/GDP		55.6	56.1	56.3	56.6	55.6
KTI structure						
KTI manufacturing/all KTI		59.4	58.4	55.6	54.2	55.2
KTI services/all KTI		40.6	41.6	44.4	45.8	44.8
Intrasector shares						
KTI manufacturing/manufacturing		54.6	55.4	57.0	55.2	55.1
KTI services/total private services		7.7	7.9	8.7	8.9	9.0

GDP = gross domestic product; ISIC, Rev.4 = International Standard Industrial Classification, Revision 4; IT = information technology; KTI = knowledge and technology intensive; nec = not elsewhere classified.

Note(s):
Value added is the value of goods and services (gross output) minus the cost of intermediate inputs (energy, materials, and purchased services). Value added is a measure of an industry's contribution to overall GDP. KTI industries include high R&D intensive and medium-high R&D intensive industries based on a classification by the Organisation for Economic Co-operation and Development. The data have been crosswalked to the ISIC, Rev.4, classification. See the Technical Appendix for the crosswalking and Table SAKTI-1. Total private services corresponds to main services in ISIC, Rev.4.

Source(s):
GDP data are from the Bureau of Economic Analysis, Industry Economic Accounts, accessed November 2023 (available at https://www.bea.gov/itable/national-gdp-and-personal-income); value-added data are from S&P Global IHS Markit, Comparative Industry Service special tabulations, October 2023.

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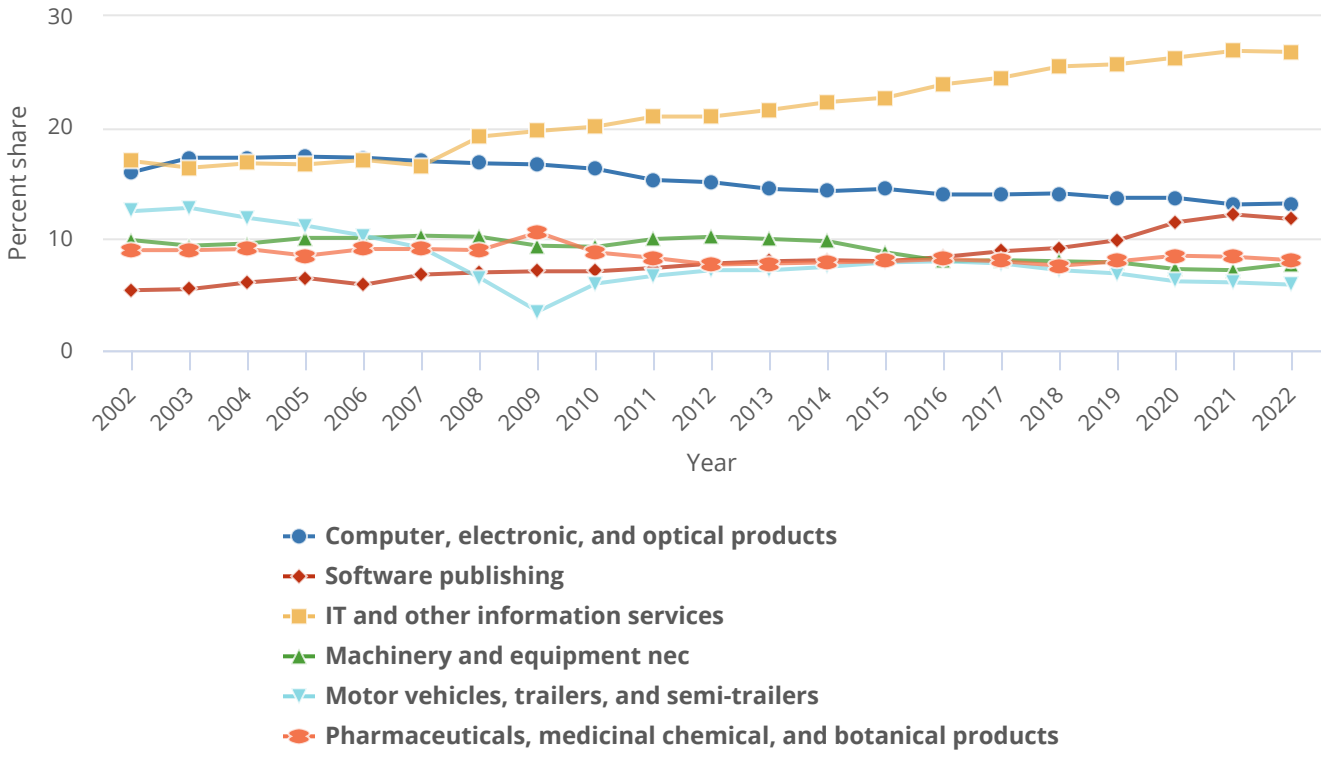
For most of the data since 2002, KTI manufacturing accounted for a larger share of U.S. GDP (6%–7%), compared with KTI services (3%–5%). Despite these relatively constant shares relative to GDP, two changes are notable for value added within U.S. KTI industries. KTI services industries' share in total U.S. KTI value added increased from about a third to 45% from 2002 to 2022, with the KTI manufacturing share declining from over two-thirds in 2002 to 55% in 2022 (Table SKTI-1). In particular, IT and other information services has been the largest U.S. KTI industry by nominal value added since 2008 (**Figure KTI-1**). Because of small but steady increases (with a declining share through 2021 and flat in 2022), the share of software publishing now almost matches the computer, electronic, and optical products manufacturing share of KTI value added. The output trend in these three IT-related industries is consistent with increased U.S. private fixed investment in physical IT (computers, peripheral, and communication equipment) and in intangibles or intellectual property products (IPPs), such as software, since the early 2000s.[5]

Figure KTI-1

Industry share of U.S. total KTI value added, by selected industries: 2002–22



IT = information technology; KTI = knowledge and technology intensive; nec = not elsewhere classified.

Note(s):
Value added is the value of goods and services (gross output) minus the cost of intermediate inputs (energy, materials, and purchased services). *Industry value added* is a measure of an industry's contribution to overall gross domestic product. KTI industries include high R&D intensive and medium-high R&D intensive industries based on a classification by the Organisation for Economic Co-operation and Development. The data have been crosswalked to the International Standard Industrial Classification, Revision 4. See Table SAKTI-2.

Source(s):
S&P Global IHS Markit, Comparative Industry Service special tabulations, October 2023.

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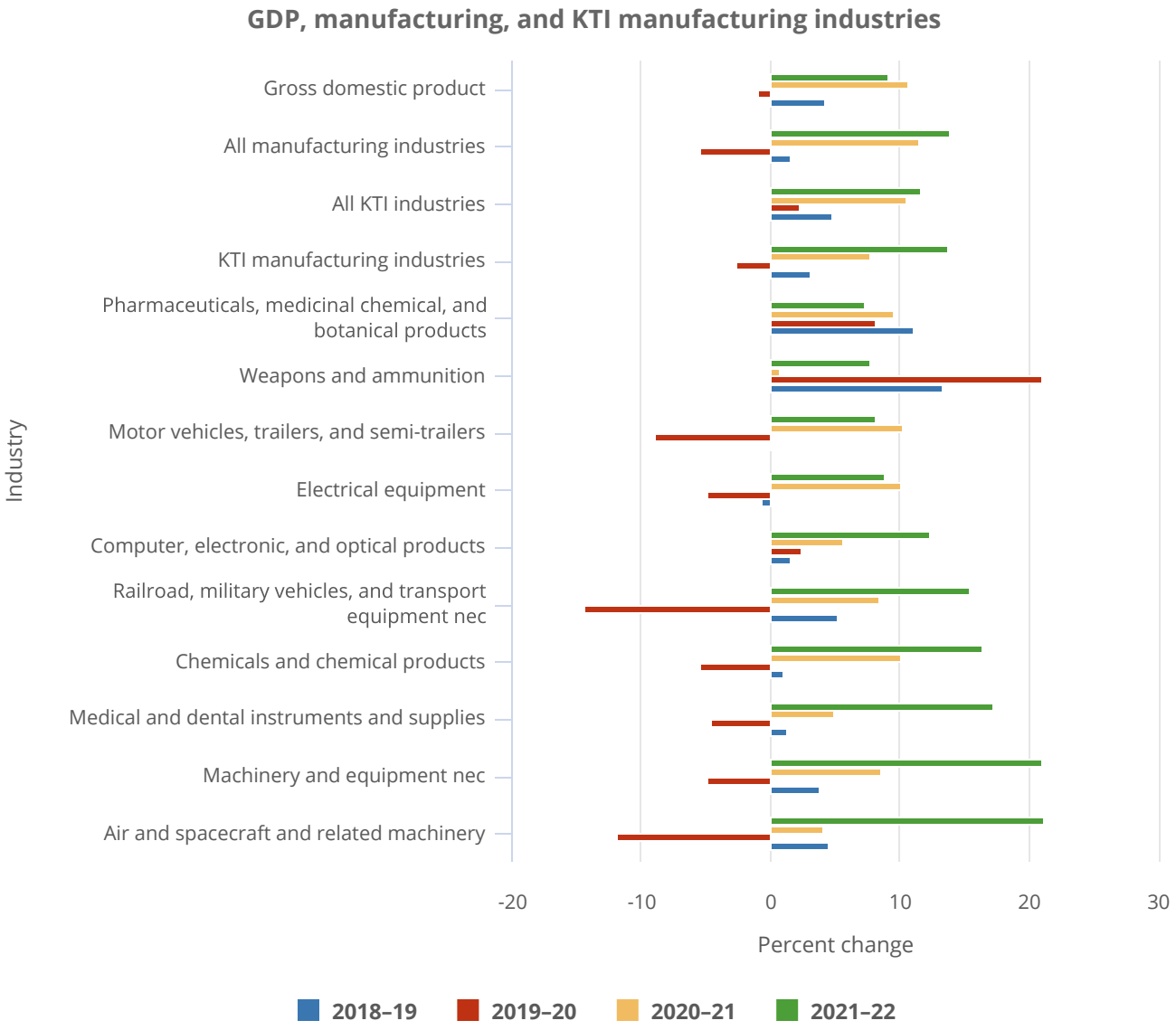
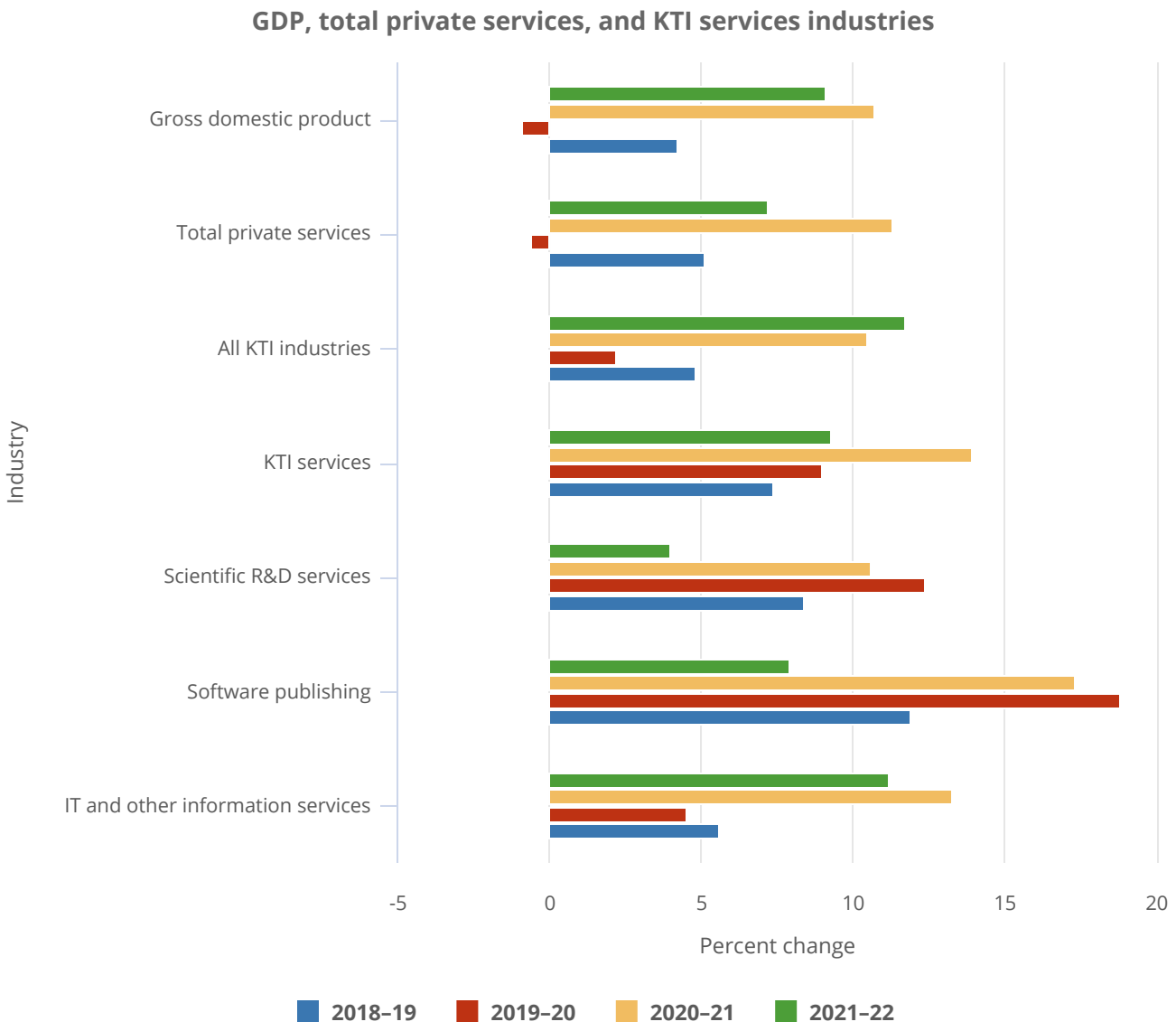
More recently, KTI services production was impacted differently from KTI manufacturing in the last economic downturn, likely reflecting the level and timing of the effects of the pandemic on goods versus services in the overall U.S. economy (Chetty, Friedman, and Stepner 2023). **Figure KTI-2** shows annual percentage changes since 2018 in separate panels for KTI manufacturing and KTI services. Except for weapons and ammunition; pharmaceuticals; and computer, electronic, and optical products—each of which had an annual increase in 2020—value added by U.S. KTI manufacturing industries declined by larger percentages compared with the overall percentage decline in GDP in the 2020 recession. These industries rebounded in 2021, with further increases in 2022. In contrast, all three KTI services industries—software publishing, IT and other information services, and scientific R&D services—posted annual increases since 2018 in current U.S. dollars. Within U.S. KTI manufacturing, value added of air and spacecraft manufacturing and of machinery and equipment manufacturing had annual increases in 2022 over 20% in current U.S. dollars, followed by medical and dental instruments and supplies; chemicals and chemical products (excluding pharmaceuticals); and railroad, military vehicles, and transport equipment nec, each with increases over 15%. U.S. KTI industries are highly geographically concentrated. (See the sidebar **Geography of Domestic KTI Production**.)

Figure KTI-2

Annual percent changes in U.S. value added, by KTI industry: 2018–22





GDP = gross domestic product; IT = information technology; KTI = knowledge and technology intensive; nec = not elsewhere classified.

Note(s):
Value added is the value of goods and services (gross output) minus the cost of intermediate inputs (energy, materials, and purchased services). *Industry value added* is a measure of an industry's contribution to overall GDP. KTI industries include high R&D intensive and medium-high R&D intensive industries based on a classification by the Organisation for Economic Co-operation and Development. The data have been crosswalked to the International Standard Industrial Classification, Revision 4. See Table SAKTI-2. Industry groups are at the top of the figure, and specific industries are sorted from smallest to largest based on annual percent change in 2021–22.

Source(s):
GDP data are from the Bureau of Economic Analysis, Industry Economic Accounts, accessed November 2023 (available at https://www.bea.gov/itable/national-gdp-and-personal-income); value-added data are from S&P Global IHS Markit, Comparative Industry Service special tabulations, October 2023.

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SIDEBAR

Geography of Domestic KTI Production

Similar to other science, technology, and innovation indicators, production by U.S. knowledge- and technology-intensive (KTI) industries is concentrated in a few states. The top five states accounted for about half of U.S. KTI value added in 2021 (latest available year at this level of detail): California alone accounted for 25%, followed by Texas (8%), Washington (6%), New York (5%), and Massachusetts (5%) (see **Table KTI-A**). These top state rankings for the aggregate of all KTI industries have changed little in recent years. This table also shows that, in some states, including California, Washington, New York, and Massachusetts, the KTI value-added share was higher for KTI services than for KTI manufacturing. Nationally, KTI value added accounted for 11.4% of U.S. gross domestic product (GDP) in 2021. As a share of states' GDP, KTI value added was at or above the national figure for several states, topped by Washington (25%), California (20%), Massachusetts (19%), Indiana (17%), and Michigan (14%) (**Figure KTI-A**).

Table KTI-A

GDP, by state share and value-added output of KTI industries: 2021

(GDP, KTI value added, state share of KTI value added)

State	GDP	Value added			State share of all KTI value added		
		KTI manufacturing	KTI services	All KTI	KTI manufacturing	KTI services	All KTI
United States	23,315,081	1,379,813	1,282,761	2,662,574	51.82	48.18	100.00
California	3,373,241	295,151	380,720	675,871	11.09	14.30	25.38
Texas	2,051,769	131,129	73,249	204,377	4.92	2.75	7.68
Washington	677,490	39,566	131,379	170,945	1.49	4.93	6.42
New York	1,901,297	38,424	86,027	124,451	1.44	3.23	4.67
Massachusetts	641,332	39,402	83,989	123,391	1.48	3.15	4.63
Illinois	945,674	61,385	32,536	93,920	2.31	1.22	3.53
North Carolina	662,121	51,793	30,828	82,621	1.95	1.16	3.10
Michigan	572,206	63,520	18,178	81,698	2.39	0.68	3.07
Pennsylvania	844,497	48,403	31,576	79,979	1.82	1.19	3.00
Ohio	756,617	57,427	17,912	75,340	2.16	0.67	2.83
Florida	1,255,558	33,477	41,129	74,606	1.26	1.54	2.80
New Jersey	682,946	38,885	34,293	73,178	1.46	1.29	2.75
Indiana	412,975	61,717	6,625	68,342	2.32	0.25	2.57
Virginia	604,958	11,747	45,974	57,720	0.44	1.73	2.17
Georgia	691,627	26,041	30,716	56,757	0.98	1.15	2.13
Colorado	436,360	14,457	31,468	45,924	0.54	1.18	1.72
Maryland	443,930	17,130	28,562	45,692	0.64	1.07	1.72
Wisconsin	368,611	27,371	13,274	40,645	1.03	0.50	1.53
Minnesota	412,459	25,935	13,392	39,327	0.97	0.50	1.48
Arizona	420,027	25,087	14,208	39,295	0.94	0.53	1.48
Tennessee	427,126	27,378	9,300	36,678	1.03	0.35	1.38
Missouri	358,572	20,079	13,366	33,445	0.75	0.50	1.26
Connecticut	298,395	24,068	9,026	33,094	0.90	0.34	1.24
Oregon	272,191	19,776	12,731	32,507	0.74	0.48	1.22
South Carolina	269,803	20,859	5,420	26,279	0.78	0.20	0.99
Utah	225,340	10,540	14,448	24,989	0.40	0.54	0.94
Alabama	254,110	17,069	5,882	22,952	0.64	0.22	0.86
Iowa	216,860	18,750	3,397	22,146	0.70	0.13	0.83

Table KTI-A

GDP, by state share and value-added output of KTI industries: 2021

(GDP, KTI value added, state share of KTI value added)

State	GDP	Value added			State share of all KTI value added		
		KTI manufacturing	KTI services	All KTI	KTI manufacturing	KTI services	All KTI
Kentucky	237,182	18,310	3,264	21,574	0.69	0.12	0.81
Louisiana	258,571	19,149	2,324	21,473	0.72	0.09	0.81
Kansas	191,381	14,066	4,214	18,280	0.53	0.16	0.69
New Hampshire	99,673	5,790	5,353	11,143	0.22	0.20	0.42
Nebraska	146,285	7,363	3,624	10,987	0.28	0.14	0.41
District of Columbia	153,671	171	10,003	10,174	0.01	0.38	0.38
Oklahoma	215,336	7,594	2,500	10,094	0.29	0.09	0.38
Nevada	194,487	3,418	5,372	8,790	0.13	0.20	0.33
New Mexico	109,583	1,871	6,666	8,537	0.07	0.25	0.32
Arkansas	148,676	5,694	2,356	8,051	0.21	0.09	0.30
Mississippi	127,308	6,025	1,086	7,111	0.23	0.04	0.27
Idaho	96,283	3,498	3,518	7,016	0.13	0.13	0.26
West Virginia	85,434	4,493	982	5,476	0.17	0.04	0.21
Delaware	81,160	3,231	2,040	5,272	0.12	0.08	0.20
Maine	77,963	2,606	1,597	4,202	0.10	0.06	0.16
Rhode Island	66,571	2,219	1,888	4,107	0.08	0.07	0.15
North Dakota	63,560	2,183	1,227	3,410	0.08	0.05	0.13
Vermont	37,104	1,686	1,239	2,925	0.06	0.05	0.11
South Dakota	61,685	2,182	661	2,843	0.08	0.02	0.11
Montana	58,700	623	1,217	1,840	0.02	0.05	0.07
Hawaii	91,096	186	1,396	1,582	0.01	0.05	0.06
Wyoming	41,510	823	322	1,145	0.03	0.01	0.04
Alaska	57,349	67	307	374	*	0.01	0.01

* = amount < 0.01.

GDP = gross domestic product; KTI = knowledge and technology intensive.

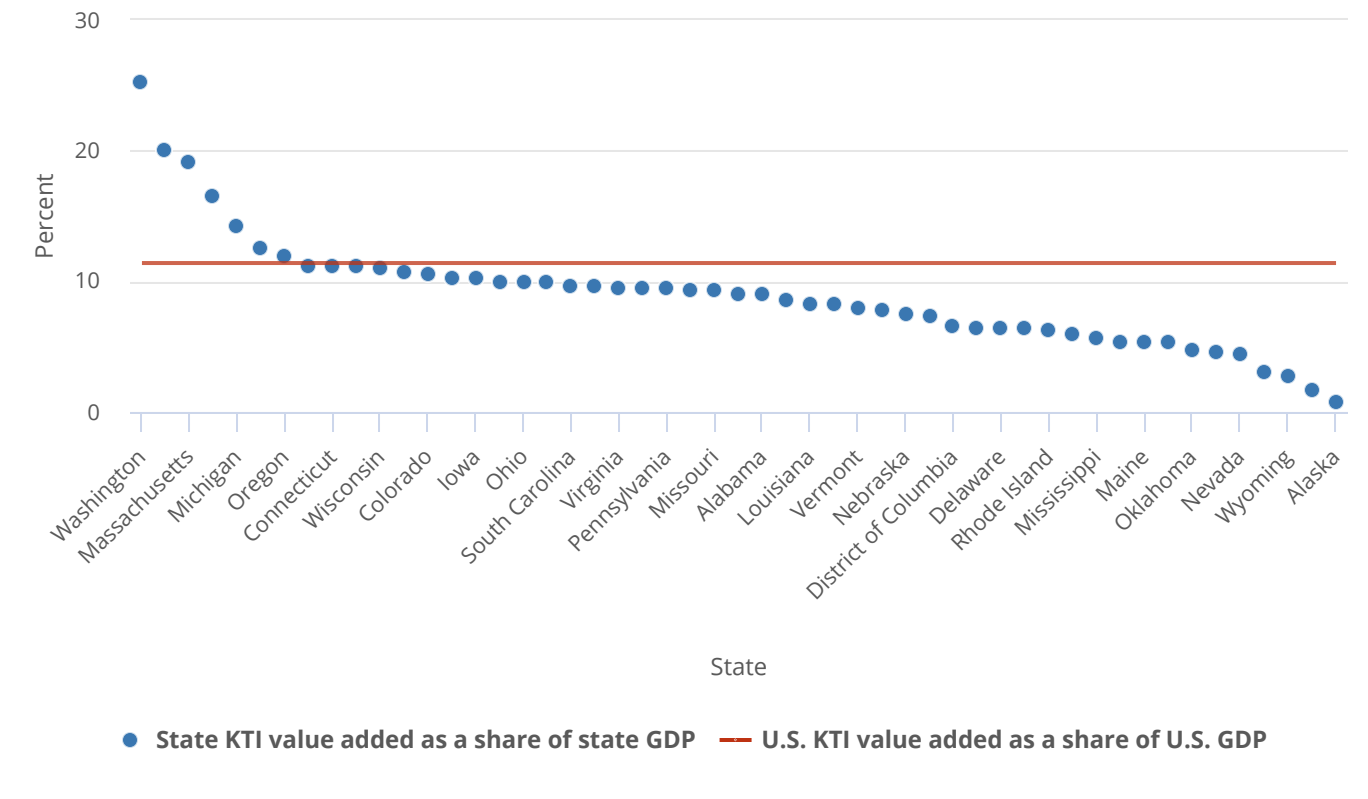
Note(s):
Value added is the value of goods and services (gross output) minus the cost of intermediate inputs (energy, materials, and purchased services). Value added is a measure of an industry's contribution to overall GDP. KTI industries include high R&D intensive and medium-high R&D intensive industries based on a classification by the Organisation for Economic Co-operation and Development. High R&D intensive industries include air and spacecraft and related machinery; pharmaceuticals; computer, electronic, and optical products; scientific R&D; and software publishing. Medium-high R&D intensive industries include motor vehicles, trailers, and semi-trailers; medical and dental instruments; machinery and equipment not elsewhere classified (nec); chemicals and chemical products; electrical equipment; railroad, military vehicles, and transport nec; and information technology and other information services. The underlying industry data are based on the International Standard Industrial Classification, Revision 4. GDP is in millions of current dollars (not adjusted for inflation). Industry detail is based on the 2012 North American Industry Classification System. Calculations are performed on unrounded data.

Source(s):
Bureau of Economic Analysis (BEA), Gross Domestic Product by State (https://www.bea.gov/data/gdp/gdp-state), and BEA special tabulations, accessed July 2023.

Science and Engineering Indicators

Figure KTI-A

KTI value added as a share of U.S. and state GDP: 2021



GDP = gross domestic product; KTI = knowledge and technology intensive.

Note(s):
Value added is the value of goods and services (gross output) minus the cost of intermediate inputs (energy, materials, and purchased services). Value added is a measure of an industry's contribution to overall GDP. KTI industries include high R&D intensive and medium-high R&D intensive industries based on a classification by the Organisation for Economic Co-operation and Development. High R&D intensive industries include air and spacecraft and related machinery; pharmaceuticals; computer, electronic, and optical products; scientific R&D; and software publishing. Medium-high R&D intensive industries include motor vehicles, trailers, and semi-trailers; medical and dental instruments; machinery and equipment not elsewhere classified (nec); chemicals and chemical products; electrical equipment; railroad, military vehicles, and transport nec; and information technology and other information services. The underlying industry data are based on the International Standard Industrial Classification, Revision 4. GDP is in millions of current dollars (not adjusted for inflation). Industry detail is based on the 2012 North American Industry Classification System. Calculations are performed on unrounded data.

Source(s):
Bureau of Economic Analysis (BEA), Gross Domestic Product by State (https://www.bea.gov/data/gdp/gdp-state), and BEA special tabulations, accessed July 2023.

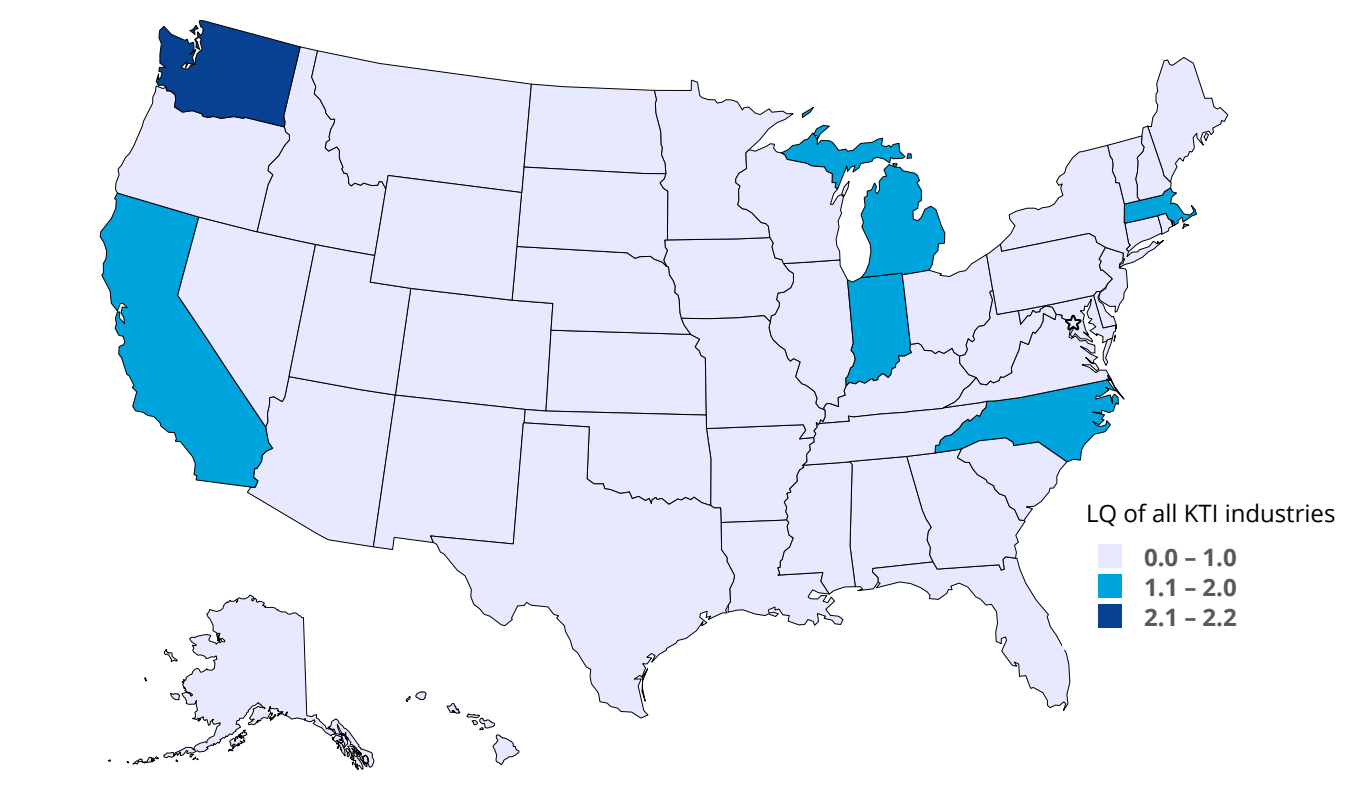
Science and Engineering Indicators

Another way to examine concentration or geographic specialization for a given industry is the location quotient (LQ). This ratio indicator compares the industry's value-added share in state GDP with the corresponding industry share in national GDP (Crawley, Beynon, and Munday 2013). An industry LQ ratio above 1.0 for a given state means that the state has a higher concentration of value added in that industry compared with the overall national economy. The last two sidebar figures show the distribution of the LQ ratio across states for the aggregate of all KTI value added (**Figure KTI-B**) and for two industries (**Figure KTI-C**). Washington, California, and Massachusetts had the largest overall KTI value added based on this measure (**Figure KTI-B**). For information technology (IT) and other information services, the largest U.S. KTI industry by value added, California, Washington, and Virginia were the top locations. For California, the state value-added-to-GDP ratio for this industry was more than twice the national average, with an LQ ratio of 2.2 (**Figure KTI-C**, Panel 1). The IT and other information services industry includes companies offering computer

programming services, including systems that integrate computer hardware, software, and communication technologies, and data processing and hosting activities. For the second industry, manufacturing of computer, electronic, and optical products, which includes semiconductors or computer chips, Oregon, California, and Arizona were at the top based on this indicator, followed by several New England states (**Figure KTI-C**, Panel 2). From 2020 to 2022, U.S. and foreign multinational enterprises announced over $200 billion in private investments to expand U.S. semiconductor manufacturing capacity in 16 states, including Arizona, Texas, Idaho, Ohio, and New York (CRS 2023b). For related material on the 2022 U.S. Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Act and a global perspective on the geography of semiconductor production and supply chains, see the discussion later in this report.

Figure KTI-B

Specialization in production for all KTI industries, by state: 2021



KTI = knowledge and technology intensive; LQ = location quotient.

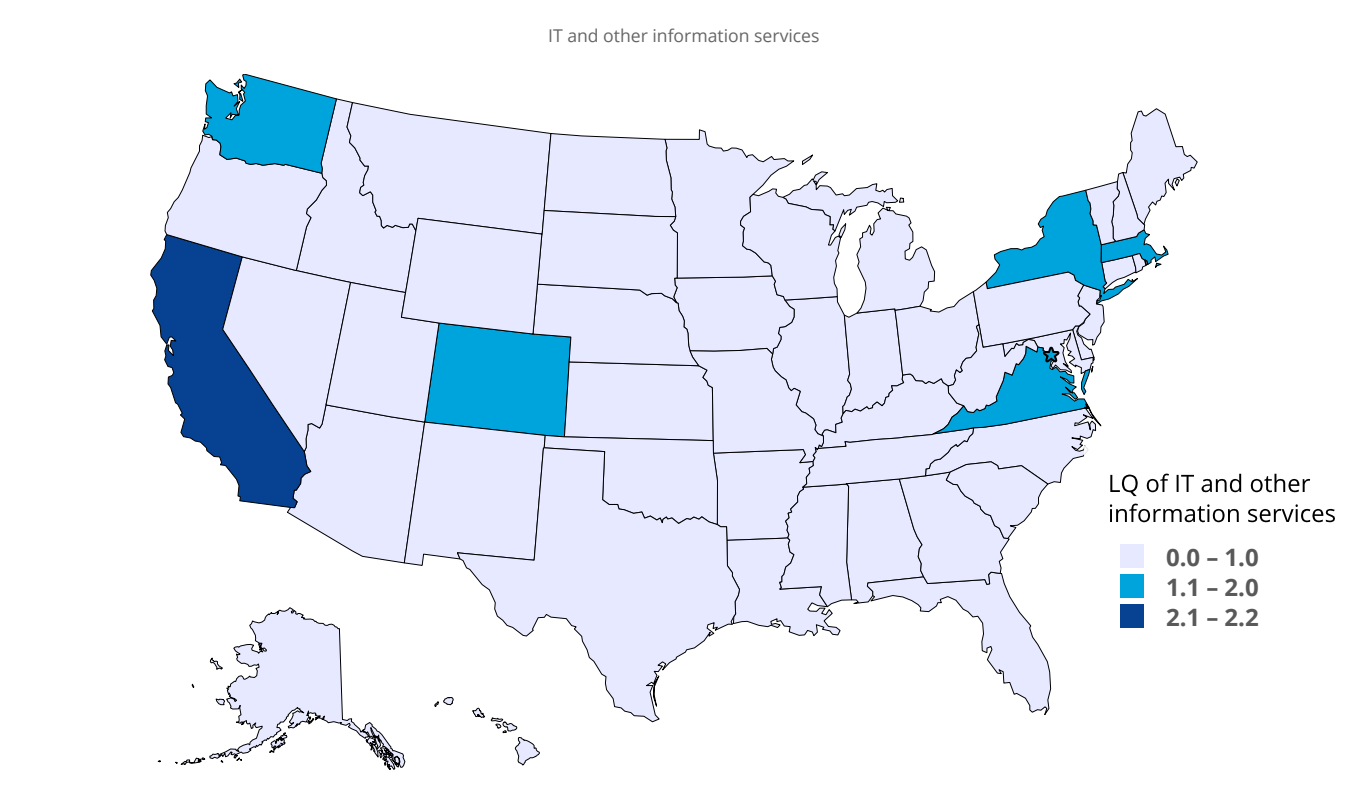
Note(s):
LQ is the ratio of the industry's share of a state's gross domestic product (GDP) to the corresponding industry's share of national GDP. Industry detail is based on the 2012 North American Industry Classification System crosswalked with the International Standard Industrial Classification, Revision 4.

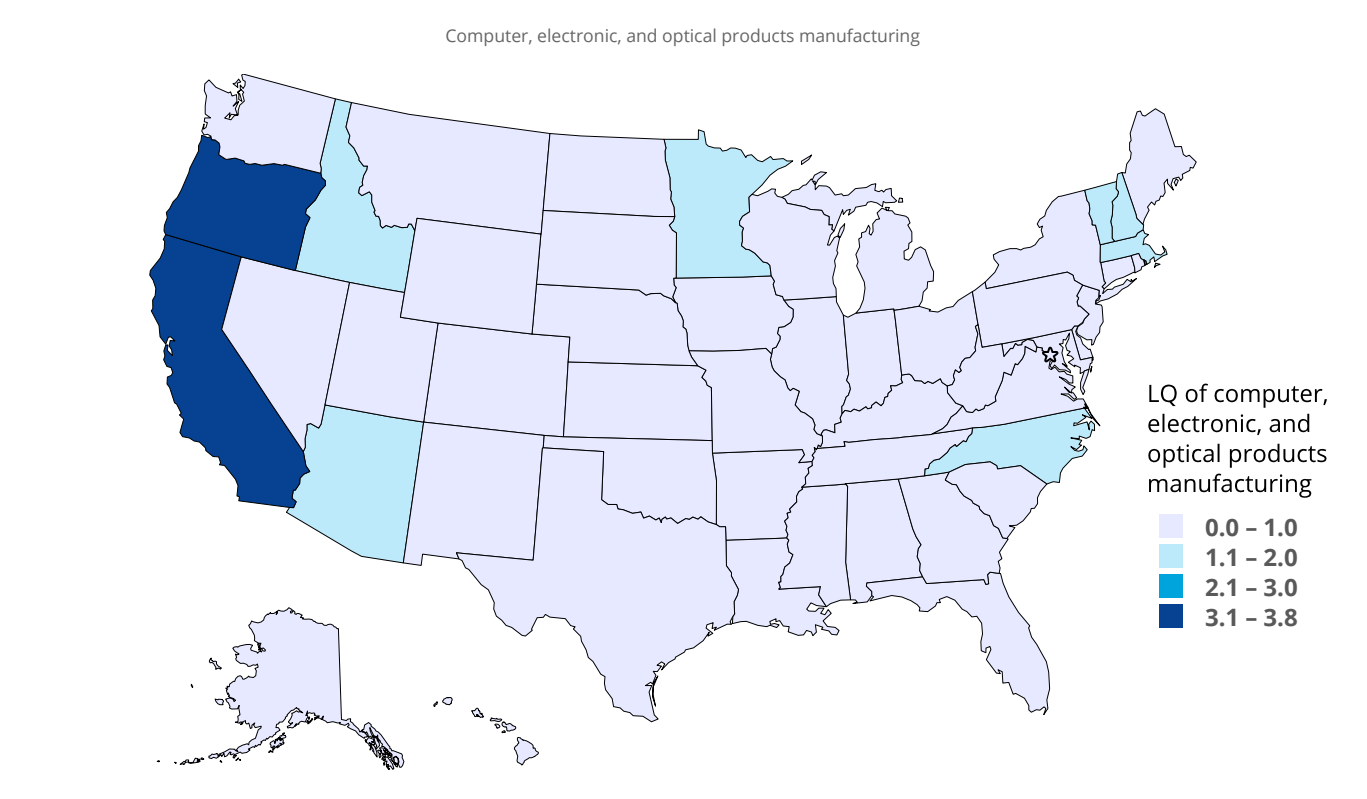
Source(s):
Bureau of Economic Analysis (BEA), Gross Domestic Product by State (https://www.bea.gov/data/gdp/gdp-state), and BEA special tabulations, accessed July 2023.

Science and Engineering Indicators

Figure KTI-C

Specialization in production for two selected industries, by state: 2021





IT = information technology; LQ = location quotient.

Note(s):
LQ is the ratio of the industry's share of a state's gross domestic product (GDP) to the corresponding industry's share of national GDP. Industry detail is based on the 2012 North American Industry Classification System crosswalked with the International Standard Industrial Classification, Revision 4.

Source(s):
Bureau of Economic Analysis (BEA), Gross Domestic Product by State (https://www.bea.gov/data/gdp/gdp-state), and BEA special tabulations, accessed July 2023.

Science and Engineering Indicators

Industries in the Global Economy

This section examines global statistics on KTI industries, starting with value added. Subsequent sections explore the participation of these industries in goods and services trade.

KTI industries produced $11.1 trillion globally in value added in 2022, a 5.6% increase in current U.S. dollars compared with a 15.8% post-pandemic rebound in 2021 following little change in 2019 and 2020, based on current U.S. dollar S&P Global data (Table SKTI-2). By comparison, global GDP increased 3.8% in 2022 following a pandemic-related drop in 2020 and a 13.5% increase in 2021 in current U.S. dollars based on International Monetary Fund statistics (IMF 2023b). Since 2018, KTI value added accounted for between 10% and 11% of global GDP, with 3% from KTI services industries and between 7% and 8% from KTI manufacturing industries (**Table KTI-2**). Overall, services represent a larger share of global GDP compared with manufacturing; within KTI industries globally, however, services value added has a smaller share compared with manufacturing.

Table KTI-2

Global KTI industries, by value added and share of global GDP: 2018–22

(Billions of dollars, percent change, share of global GDP)

Industry	ISIC, Rev.4, industry code	Billions of dollars					Percent change				Share of global GDP				
		2018	2019	2020	2021	2022	2019	2020	2021	2022	2018	2019	2020	2021	2022
GDP		86,219	87,466	85,221	96,764	100,396	1.4	-2.6	13.5	3.8	100.0	100.0	100.0	100.0	100.0
All manufacturing		13,926	13,809	13,457	15,882	17,039	-0.8	-2.5	18.0	7.3	16.2	15.8	15.8	16.4	17.0
Total private services		37,954	38,725	37,791	42,485	44,298	2.0	-2.4	12.4	4.3	44.0	44.3	44.3	43.9	44.1
All KTI industries		9,085	9,094	9,055	10,487	11,079	0.1	-0.4	15.8	5.6	10.5	10.4	10.6	10.8	11.0
KTI manufacturing		6,498	6,389	6,311	7,346	7,821	-1.7	-1.2	16.4	6.5	7.5	7.3	7.4	7.6	7.8
Chemicals and chemical products	20	1,072	1,040	1,018	1,173	1,406	-3.0	-2.2	15.2	19.9	1.2	1.2	1.2	1.2	1.4
Pharmaceuticals, medicinal chemical, and botanical products	21	663	683	736	868	874	2.9	7.8	17.9	0.7	0.8	0.8	0.9	0.9	0.9
Weapons and ammunition	252	39	40	41	47	54	3.9	1.8	14.2	15.1	*	*	*	*	0.1
Computer, electronic, and optical products	26	1,285	1,250	1,281	1,478	1,539	-2.8	2.6	15.4	4.1	1.5	1.4	1.5	1.5	1.5
Electrical equipment	27	661	658	669	794	837	-0.5	1.6	18.6	5.5	0.8	0.8	0.8	0.8	0.8
Machinery and equipment nec	28	1,169	1,145	1,145	1,355	1,427	-2.1	0.0	18.3	5.3	1.4	1.3	1.3	1.4	1.4
Motor vehicles, trailers, and semi-trailers	29	1,074	1,029	922	1,071	1,074	-4.2	-10.4	16.2	0.3	1.2	1.2	1.1	1.1	1.1
Air and spacecraft and related machinery	303	247	257	226	246	277	3.7	-12.0	9.1	12.3	0.3	0.3	0.3	0.3	0.3
Railroad, military vehicles, and transport equipment nec	30X	112	114	103	124	137	1.9	-9.5	20.6	10.4	0.1	0.1	0.1	0.1	0.1
Medical and dental instruments and supplies	325	175	173	170	190	196	-0.7	-2.1	11.7	3.4	0.2	0.2	0.2	0.2	0.2
KTI services		2,588	2,705	2,744	3,141	3,258	4.5	1.5	14.4	3.7	3.0	3.1	3.2	3.2	3.2
Software publishing	582	301	333	382	443	463	10.8	14.6	16.0	4.5	0.3	0.4	0.4	0.5	0.5
IT and other information services	62–63	1,569	1,632	1,654	1,884	1,971	4.0	1.3	13.9	4.6	1.8	1.9	1.9	1.9	2.0
Scientific R&D services	72	718	740	708	814	824	3.0	-4.2	14.9	1.3	0.8	0.8	0.8	0.8	0.8

* = amount < 0.05.

GDP = gross domestic product; ISIC, Rev.4 = International Standard Industrial Classification, Revision 4; IT = information technology; KTI = knowledge and technology intensive; nec = not elsewhere classified.

Note(s):
Value added is the value of goods and services (gross output) minus the cost of intermediate inputs (energy, materials, and purchased services). KTI industries include high R&D intensive and medium-high R&D intensive industries based on a classification by the Organisation for Economic Co-operation and Development. Total private services corresponds to main services in ISIC, Rev.4.

Source(s):
Value added data are from S&P Global IHS Markit, Comparative Industry Service special tabulations, October 2023; GDP data are from International Monetary Fund World Economic Outlook, accessed November 2023 (available at https://www.imf.org/en/Publications/WEO/weo-database/2023/October), and Bureau of Economic Analysis, Industry Economic Accounts, accessed November 2023 (available at https://www.bea.gov/itable/national-gdp-and-personal-income).

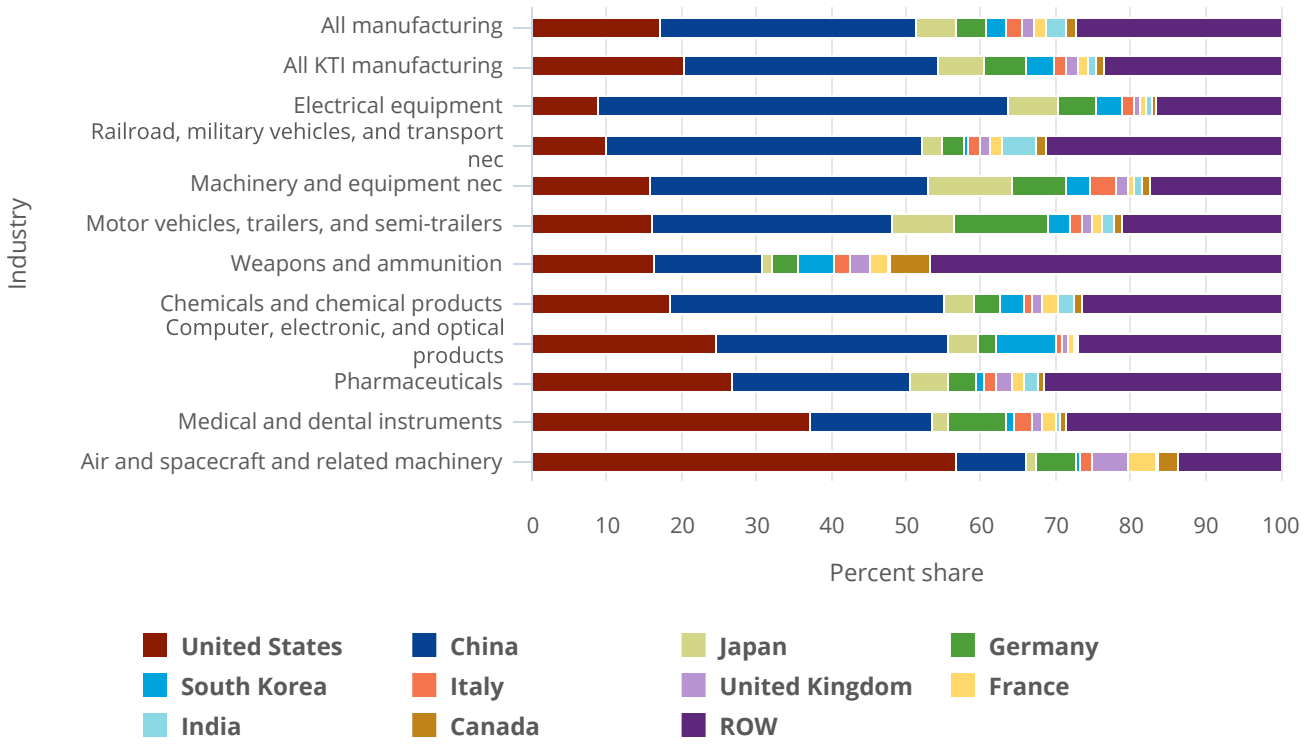
Science and Engineering Indicators

The United States, China, the European Union (EU-27), Japan, and South Korea accounted for about 80% of global KTI value added in 2022 based on S&P Global data in current U.S. dollars (Table SKTI-2). In that year, China and the United States were the top two producers of KTI output ($3.0 trillion and $2.9 trillion, respectively), each representing over a quarter of global KTI value added, followed by the EU-27, with a 17.0% share ($1.9 trillion). (The EU-27 share includes Germany, with 5.2%, or 31% of the EU-27 share.) Another 9% of KTI value added originated from Japan (5.4%) and South Korea (3.6%).

The aforementioned global shares vary across broad KTI sectors (**Figure KTI-3** and **Figure KTI-4**). For manufacturing KTI output, China and the United States accounted for 34% and 20% of the global total, respectively. For services KTI output, these nations' respective shares were almost reversed (12% for China and 40% for the United States), which is consistent with the larger share of total manufacturing in China's GDP and of services in U.S. GDP. Another illustrative measure is KTI value-added intensity, which is the ratio of KTI value added relative to GDP. South Korea had the highest KTI value-added intensity since 2002 (**Figure KTI-5**). In 2022, this ratio was 24% for South Korea, followed by 17% for China. The U.S. KTI value-added intensity has been between 10% and 11% since 2002, similar to the range of global KTI value-added intensity —both at 11% in 2022. The intensity levels for Japan and Germany have been in the middle teens since 2002 (**Figure KTI-5**).

Figure KTI-3

Country share of global KTI manufacturing value added, by KTI industry: 2022



KTI = knowledge and technology intensive; nec = not elsewhere classified; ROW = rest of world.

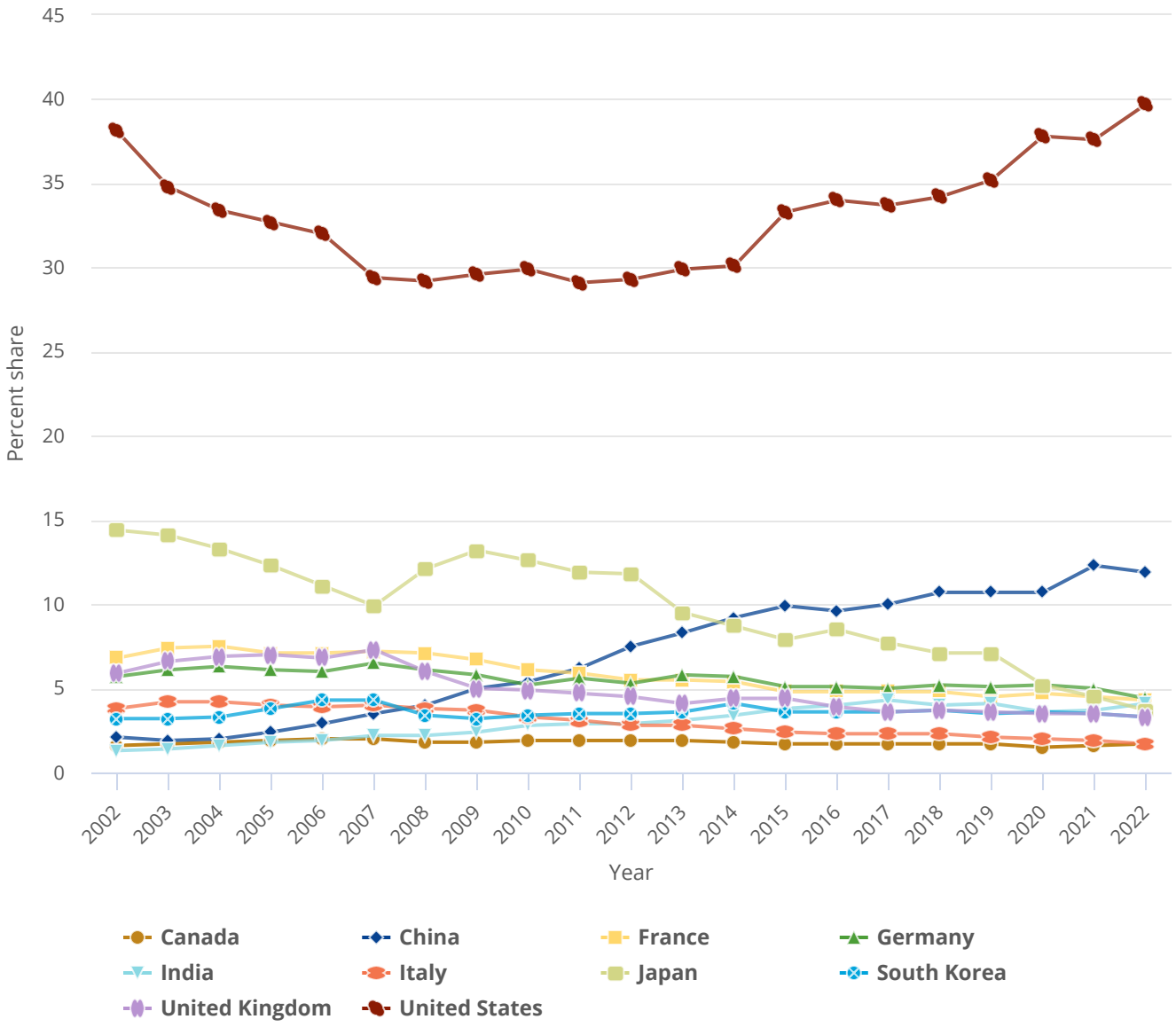
Note(s):
Value added is the value of goods and services (gross output) minus the cost of intermediate inputs (energy, materials, and purchased services). KTI industries include high R&D intensive and medium-high R&D intensive industries based on a classification by the Organisation for Economic Co-operation and Development. Industry groups are at the top of the figure, and specific industries are sorted from smallest to largest based on the U.S. share. The United States is the first country listed, and the other countries are ordered from largest to smallest based on the share of all KTI manufacturing.

Source(s):
S&P Global IHS Markit, Comparative Industry Service special tabulations, October 2023.

Science and Engineering Indicators

Figure KTI-4

Country share of global KTI services value added for selected economies: 2002–22



KTI = knowledge and technology intensive.

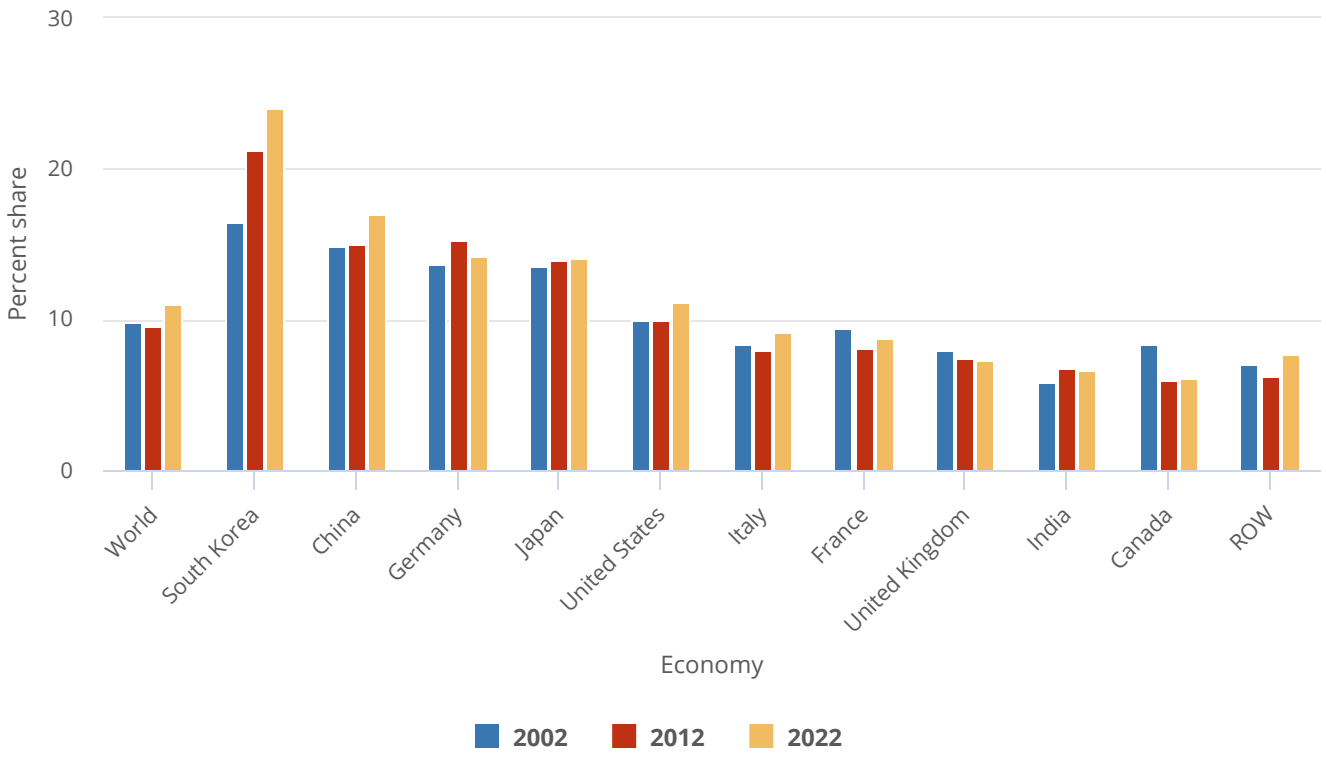
Note(s):
Value added is the value of goods and services (gross output) minus the cost of intermediate inputs (energy, materials, and purchased services). KTI industries include high R&D intensive and medium-high R&D intensive industries based on a classification by the Organisation for Economic Co-operation and Development. KTI services industries include information technology and other information services, software publishing, and scientific R&D.

Source(s):
S&P Global IHS Markit, Comparative Industry Service special tabulations, October 2023.

Science and Engineering Indicators

Figure KTI-5

KTI value added as a share of domestic GDP for selected economies: 2002, 2012, and 2022



GDP = gross domestic product; KTI = knowledge and technology intensive; ROW = rest of world.

Note(s):
Value added is the value of goods and services (gross output) minus the cost of intermediate inputs (energy, materials, and purchased services). KTI industries include high R&D intensive and medium-high R&D intensive industries based on a classification by the Organisation for Economic Co-operation and Development. High R&D intensive industries include air and spacecraft and related machinery; pharmaceuticals; computer, electronic, and optical products; scientific R&D; and software publishing. Medium-high R&D intensive industries include weapons and ammunition; motor vehicles, trailers, and semi-trailers; medical and dental instruments; machinery and equipment not elsewhere classified (nec); chemicals and chemical products; electrical equipment; railroad, military vehicles, and transport nec; and information technology and other information services.

Source(s):
Value-added data are from S&P Global IHS Markit, Comparative Industry Service special tabulations, October 2023; GDP data are from International Monetary Fund World Economic Outlook, accessed November 2023 (available at https://www.imf.org/en/Publications/WEO/weo-database/2023/October), and Bureau of Economic Analysis, Industry Economic Accounts, accessed November 2023 (available at https://www.bea.gov/itable/national-gdp-and-personal-income).

Science and Engineering Indicators

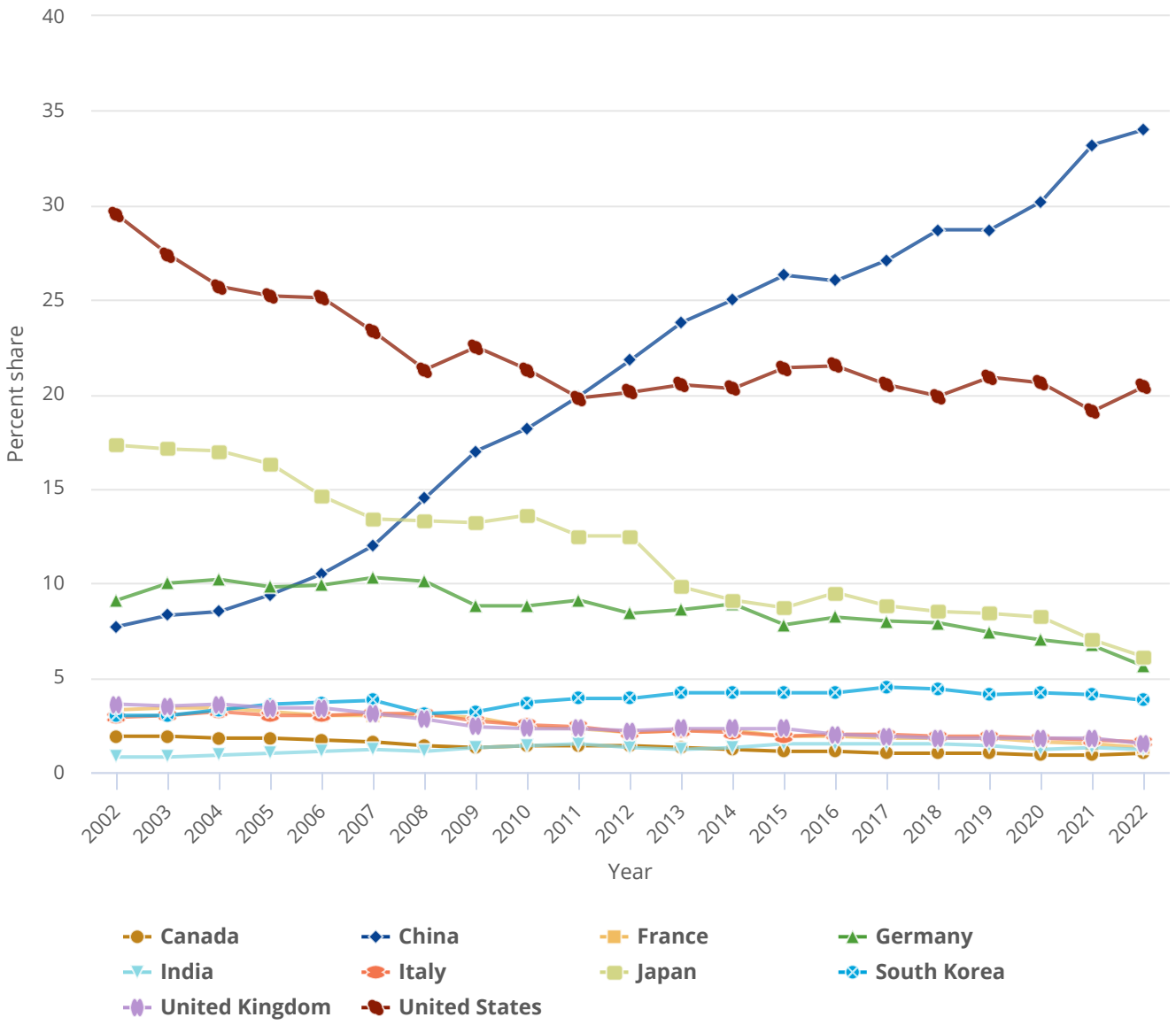
Sectoral and Industry Distributions

KTI manufacturing accounted for 71% of global KTI value added in 2022 compared with the 17% share of overall manufacturing in value added across all industries, given the higher R&D intensity of manufacturing (see the forthcoming *Indicators 2024* report "[2024] Research and Development: U.S. Trends and International Comparisons"). **Figure KTI-6** shows trends in global KTI manufacturing value added of the largest producers. Beginning in 2012 and continuing through 2022, China has maintained its stature as the world's largest KTI manufacturer despite the recent geopolitical and pandemic-related disruptions. The long-term increase in China's KTI manufacturing share was accompanied by the decline in the KTI manufacturing shares of the United States, Japan, and Germany, which mimics trends in total

manufacturing. China's manufacturing KTI value added accounted for about a third of global manufacturing KTI value added in 2022, compared with 22% in 2012 and 8% in 2002 (**Figure KTI-6**). In contrast, the United States accounted for around 20% of global manufacturing KTI value added since 2011, down from 25% in 2006 and from about 30% in 2002. The shares for Japan and Germany also declined over this period.[6]

Figure KTI-6

Country share of global KTI manufacturing value added for selected economies: 2002–22



KTI = knowledge and technology intensive.

Note(s):
Value added is the value of goods and services (gross output) minus the cost of intermediate inputs (energy, materials, and purchased services). KTI industries include high R&D intensive and medium-high R&D intensive industries based on a classification by the Organisation for Economic Co-operation and Development. KTI manufacturing industries include chemicals and chemical products; pharmaceuticals; weapons and ammunition; computer, electronic, and optical products; electrical equipment; machinery and equipment not elsewhere classified (nec); motor vehicles, trailers, and semi-trailers; air and spacecraft and related machinery; railroad, military vehicles, and transport nec; and medical and dental instruments.

Source(s):
S&P Global IHS Markit, Comparative Industry Service special tabulations, October 2023.

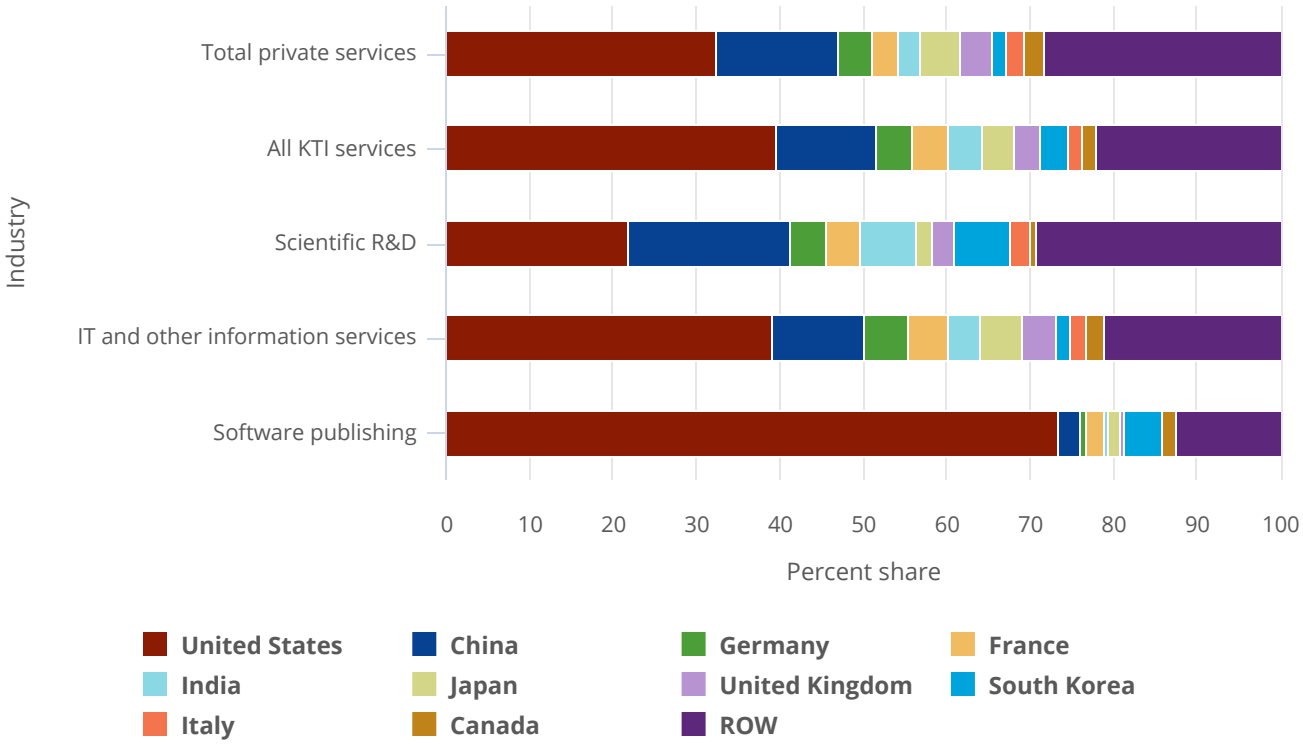
In terms of specific industries, the United States had the largest 2022 global shares of value added in two KTI manufacturing industries—air and spacecraft (57%) and medical and dental instruments (37%)—and was on par with China in pharmaceuticals and in weapons and ammunition manufacturing (**Figure KTI-3**). China had the largest shares in the other six KTI manufacturing industries: electrical equipment (55%); railroad, military vehicles, and other transport equipment nec (42%); machinery and equipment nec (37%); motor vehicles, trailers, and semi-trailers (32%); chemicals and chemical products (excluding pharmaceuticals) (37%); and computer, electronic, and optical products (including semiconductors) (31%). The only other countries with double-digit global shares in individual KTI manufacturing industries in 2022 were Germany, which accounted for 13% of global value added in motor vehicles, trailers, and semi-trailers, and Japan, which had an 11% share in machinery and equipment.

The United States continues to lead global value added by KTI services industries, reaching a peak of 40% in 2022 (**Figure KTI-4**). That year, China had the second-largest global share in KTI services value added (12%), which had increased gradually from the low single digits in the early 2000s to 9% or more since 2014. On the other hand, Japan's share of global KTI services value added declined from 14% in 2002 to below 5% since 2020. Over this period, the shares of Germany and France in global KTI services value added declined from the high single digits to the low single digits, whereas India's shares increased, though from a smaller base and gradually, to 4% in 2022.

In terms of individual industries, the United States produced about three-fourths of global value added from the software publishing industry in 2022, followed by South Korea (4%) and France (2%) (**Figure KTI-7**). For IT and other information services, the share was 39% for the United States, followed by China (11%) and Germany, Japan, and France (each with about a 5% share). Last, the United States and China had similar shares in global scientific R&D services value added, 22% and 19% respectively, followed by India and South Korea, each with about a 7% share.

Figure KTI-7

Country share of global KTI services value added, by KTI industry: 2022



IT = information technology; KTI = knowledge and technology intensive; ROW = rest of world.

Note(s):
Value added is the value of goods and services (gross output) minus the cost of intermediate inputs (energy, materials, and purchased services). KTI industries include high R&D intensive and medium-high R&D intensive industries based on a classification by the Organisation for Economic Co-operation and Development. KTI services comprise scientific R&D, IT and other information services, and software publishing. Industry groups are at the top of the figure, and specific industries are sorted from smallest to largest based on the U.S. share. The United States is the first country listed, and the other countries are ordered from largest to smallest based on the share of all KTI services.

Source(s):
S&P Global IHS Markit, Comparative Industry Service special tabulations, October 2023.

Science and Engineering Indicators

Global Semiconductor Production

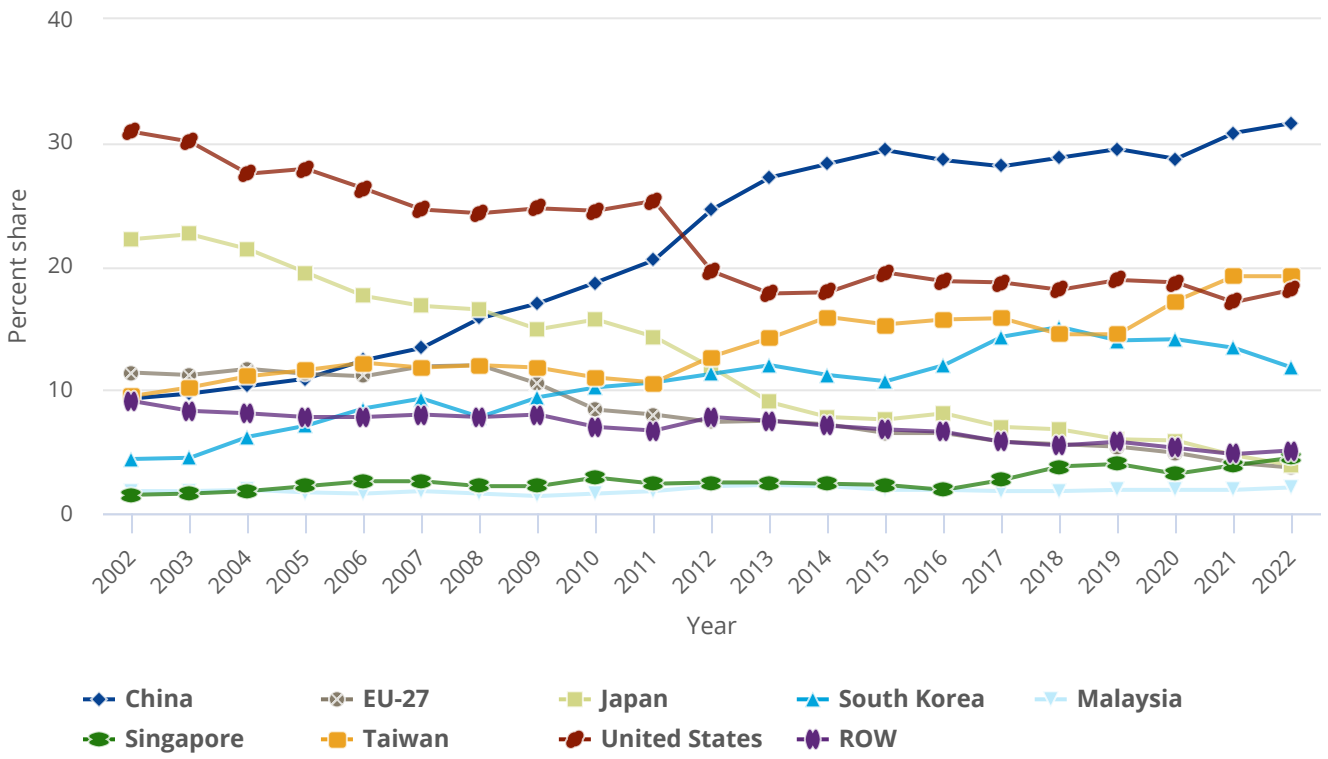
Semiconductors (also called *microchips* or *computer chips*) are key components of critical and emerging technologies and products such as artificial intelligence, quantum computing, autonomous or electric vehicles (EVs), and 5G communications (CRS 2020, 2023b), underpinning economic and national security (CRS 2023c; DOD/DSB 2022; EU 2023; NSTC 2022; VerWey 2019). The 2021 Creating Helpful Incentives to Produce Semiconductors (CHIPS) for America program (Title XCIX of Public Law 116-283, Fiscal Year 2021 National Defense Authorization Act) and the subsequent CHIPS and Science Act of 2022 (Public Law 117-167) aim to increase domestic semiconductor manufacturing capacity. The CHIPS and Science Act appropriated $52.7 billion to revitalize the U.S. semiconductor industry through support of U.S. semiconductor fabrication and technology development along the supply chain, including initiatives supporting R&D, workforce development, and national defense across several agencies and international partners (CRS 2023c; Zimmermann 2022).[7]

Semiconductor production occurs along global value chains (GVCs) comprising R&D, engineering, and design; fabrication; and assembly, testing, and packing (ATP) stages (CRS 2023b). Modular production and cost advantages in Asia facilitated the separation of design and production starting in the late 1970s and early 1980s, with the emergence of chips foundries in Taiwan and other Southeast Asian locations performing contract manufacturing for design-only or fabless companies (Kuan and West 2023). This dynamic was accompanied by foreign direct investment in the region by semiconductor integrated device manufacturers and other firms in the semiconductor supply chain (CRS 2020; Yoffie 1993). Thus, although the United States has led semiconductor R&D and innovation (see the forthcoming *Indicators 2024* report "[2024] Research and Development: U.S. Trends and International Comparisons" and the *Indicators 2024* report "[2024] Invention, Knowledge Transfer, and Innovation"), semiconductor fabrication and ATP manufacturing services have been highly concentrated in Asia for decades, impacting trade and investment patterns in IT. In particular, China, Taiwan, and South Korea have substantially increased their global shares in production and trade of semiconductors and related electronic products over the last 20 years (Branstetter and Li 2023; CRS 2020; Torsekar and VerWey 2019).

Semiconductor production is highly concentrated, with the top four producing locations accounting for 81% and the top eight for 95% of global semiconductor value added in 2022. Further, six of the top eight were in East Asia. China alone accounted for almost a third (32%), followed by Taiwan (19%), the United States (18%), South Korea (12%), Singapore (4%), and Japan (4%) (**Figure KTI-8**). The EU-27 and Malaysia were next, with global shares between 2% and 4%.

Figure KTI-8

Global share of value added for semiconductor manufacturing for selected economies: 2002–22



EU-27 = European Union; ROW = rest of world.

Note(s):
Value added is the value of goods and services (gross output) minus the cost of intermediate inputs (energy, materials, and purchased services). Semiconductor manufacturing refers to industry "Manufacture of electronic components and boards" (International Standard Industrial Classification, Revision 4, 261), which includes the manufacture of semiconductors and other components for electronic applications.

Source(s):
S&P Global IHS Markit, Comparative Industry Service special tabulations, October 2023.

Science and Engineering Indicators

Global Trade in Knowledge- and Technology-Intensive Output

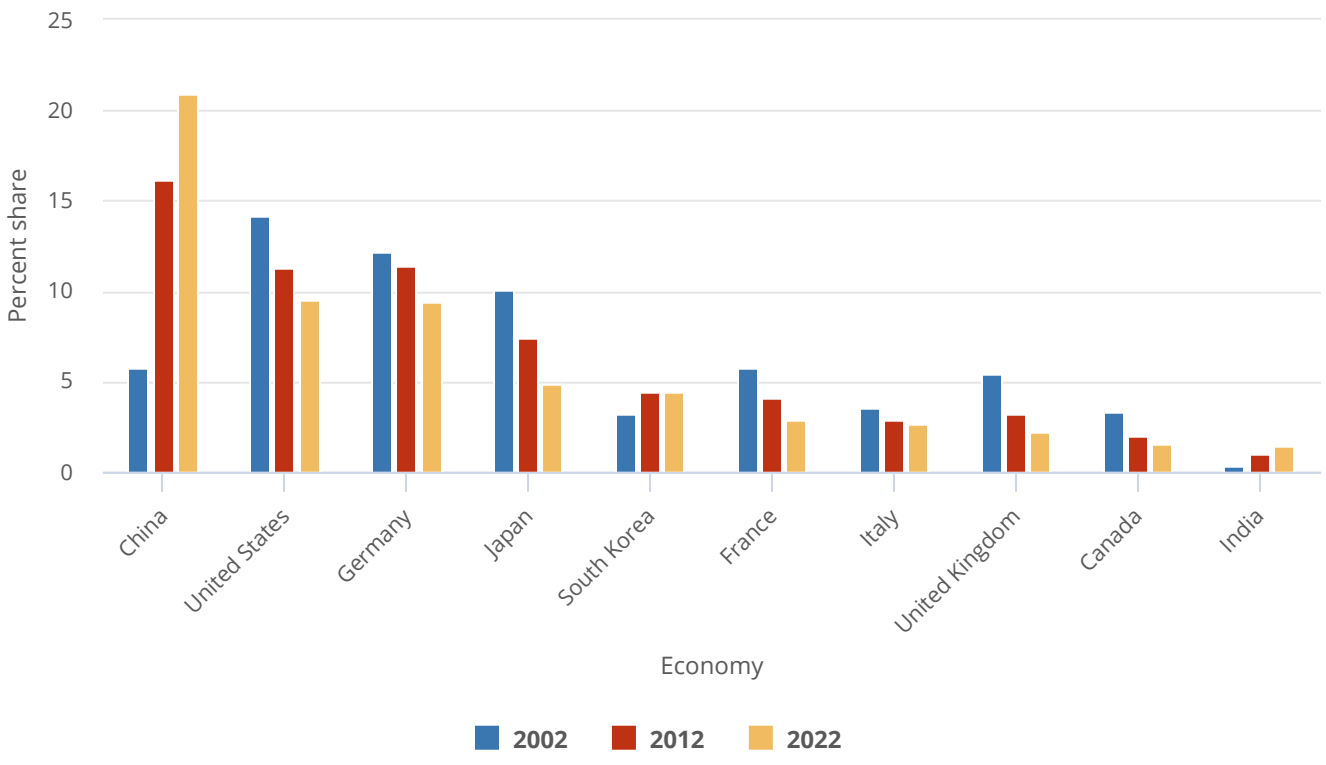
International trade has long been recognized as a key channel of knowledge and technology spillovers (Coe and Helpman 1995; Criscuolo, Haskel, and Slaughter 2010) as well as a factor in a country's competitiveness and productivity growth (Aghion and Howitt 2009; Baily, Bosworth, and Doshi 2020). Further, the trade patterns in KTI industries examined next reflect some of the output patterns examined in the previous section. Together, KTI output and trade patterns reflect and impact innovation activities in the business sector (Ambos et al. 2021; Autor et al. 2020; Ito et al. 2023; Jaax and Miroudot 2021).

Gross Flows of Trade in KTI Goods Output

Globally, KTI manufacturing industries exported $11.4 trillion in 2022 in current U.S. dollars, up 6.5% from 2021, following a decline of 5.1% in 2020 and a post-pandemic increase of 20.3% in 2021, according to S&P Global data (Table SKTI-3). China has been the leading KTI manufacturing exporter country since 2008 based on current U.S. dollars, with a share of 20.9% in 2022 (**Figure KTI-9**). In 2022, China's KTI manufacturing goods exports reached $2.4 trillion in current U.S. dollars, followed by those of the United States and Germany (both with $1.1 trillion) (**Figure KTI-10**). KTI goods exports from the United States and China grew by 10% and 9%, respectively, in 2022, furthering post-pandemic increases of 16% and 29%, respectively, in 2021 (Table SKTI-3). China was the only country among the top five KTI goods exporters that posted increases in KTI goods exports (3%) and overall manufacturing exports (1%) in 2020 (Table SKTI-3).

Figure KTI-9

Country share of global KTI manufacturing exports for selected economies: 2002, 2012, and 2022



KTI = knowledge and technology intensive.

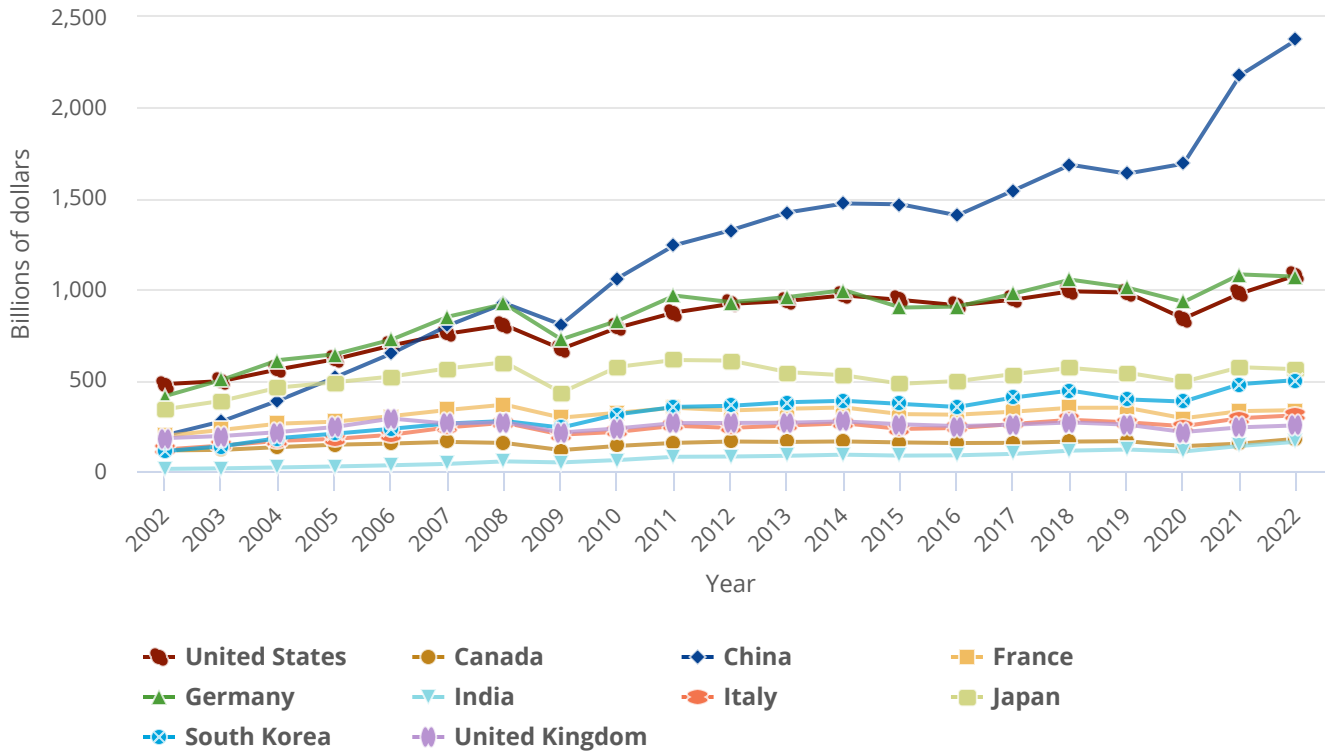
Note(s):
KTI manufacturing exports include exports from the following industries: chemicals and chemical products; pharmaceuticals; computer, electronic, and optical products; electrical equipment; machinery and equipment not elsewhere classified (nec); motor vehicles, trailers, and semi-trailers; air and spacecraft and related machinery; weapons and ammunition; and other transport equipment (the latter comprises railway locomotives and rolling stock manufacturing and transport equipment nec and military equipment manufacturing).

Source(s):
S&P Global IHS Markit, Comparative Industry Service special tabulations, October 2023.

Science and Engineering Indicators

Figure KTI-10

Gross exports of KTI manufacturing industries for selected economies: 2002–22



KTI = knowledge and technology intensive.

Note(s):
Data include trade for the following KTI industries: chemicals and chemical products; pharmaceuticals; computer, electronic, and optical products; electrical equipment; machinery and equipment not elsewhere classified (nec); motor vehicles, trailers, and semi-trailers; air and spacecraft and related machinery; weapons and ammunition; and other transport equipment (the latter comprises railway locomotives and rolling stock manufacturing and transport equipment nec and military equipment manufacturing).

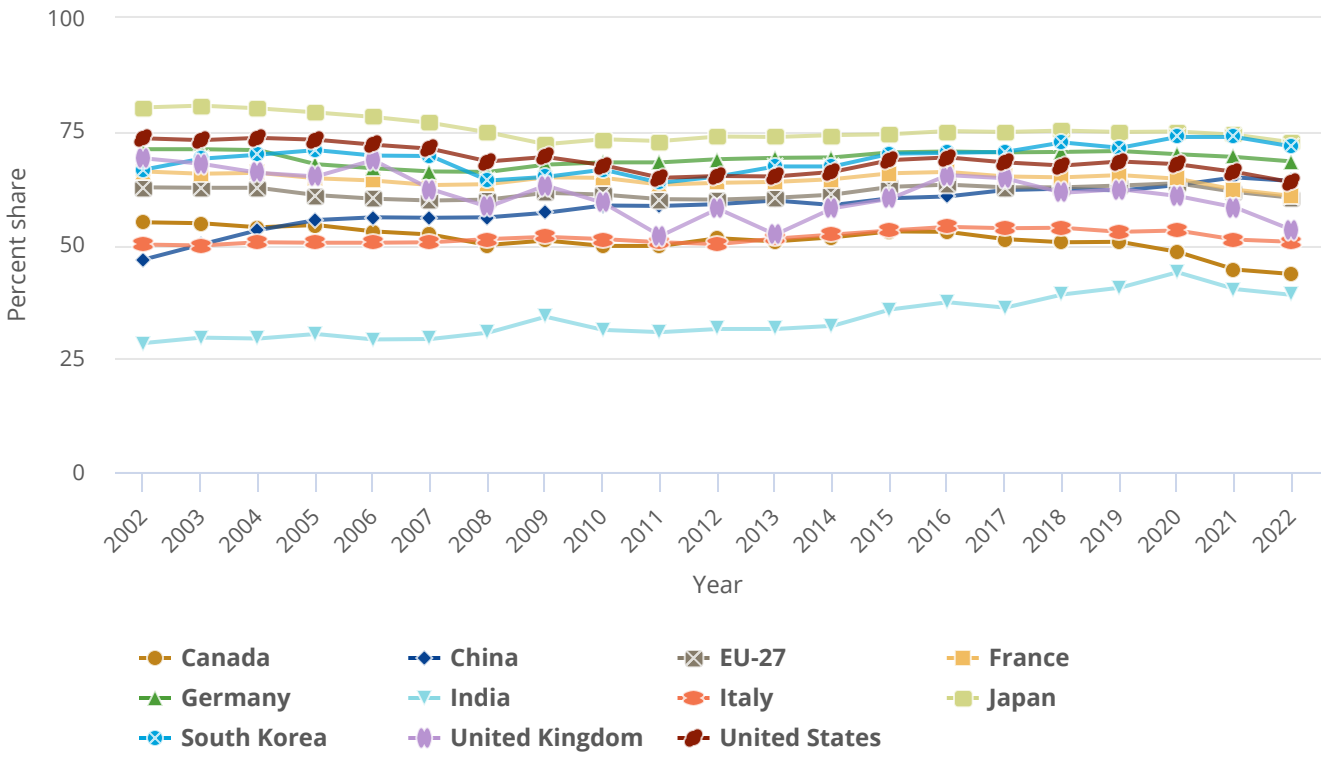
Source(s):
S&P Global IHS Markit, Comparative Industry Service special tabulations, October 2023.

Science and Engineering Indicators

As a share of global manufacturing exports, global KTI manufacturing exports have fluctuated narrowly around 60% since 2002 (Table SKTI-3). At the country level, China's share of KTI goods exports to total manufacturing exports increased notably (from 47% to 64%) from 2002 to 2022, with smaller gradual increases for India (from 28% to 39%) and South Korea (from 67% to 72%) over the same period. The share for most other major countries declined, including for the United States (from 74% to 64%), Japan (from 80% to 73%), and Germany (from 71% to 68%) (**Figure KTI-11**).

Figure KTI-11

KTI manufacturing exports as a share of all manufacturing exports for selected economies: 2002–22



EU-27 = European Union; KTI = knowledge and technology intensive.

Note(s):
KTI manufacturing exports include exports from the following industries: chemicals and chemical products; pharmaceuticals; computer, electronic, and optical products; electrical equipment; machinery and equipment not elsewhere classified (nec); motor vehicles, trailers, and semi-trailers; air and spacecraft and related machinery; weapons and ammunition; and other transport equipment (the latter comprises railway locomotives and rolling stock manufacturing and transport equipment nec and military equipment manufacturing).

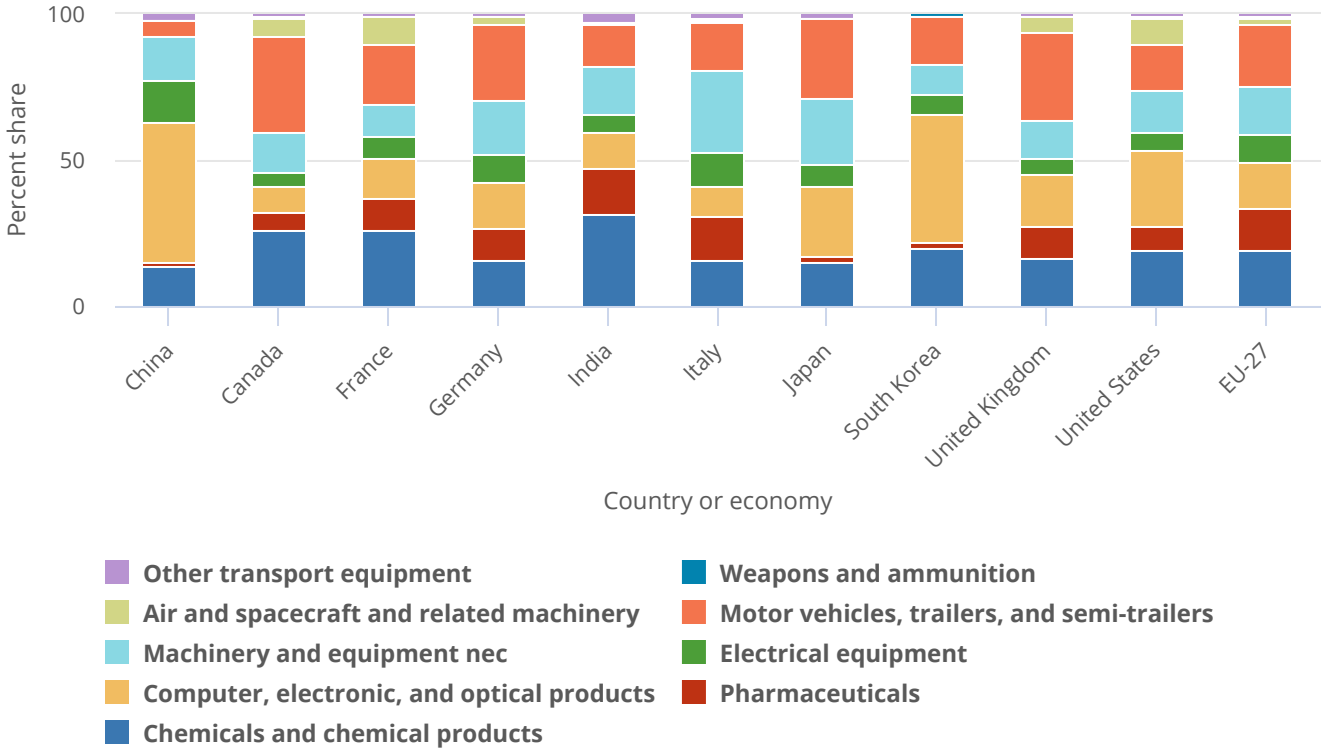
Source(s):
S&P Global IHS Markit, Comparative Industry Service special tabulations, October 2023.

Science and Engineering Indicators

The distribution of exports by type of goods or industry has long been an indicator of specialization of national economies (WTO 2013). Computer, electronic, and optical products industry exports (which include semiconductors) accounted for 49% of China's KTI goods exports and for 44% of South Korea's in 2022, based on current U.S. dollar data (**Figure KTI-12**). This was followed by the United States, with a share of 26%, and Japan, with 24%. The largest shares of KTI goods exports by the motor vehicles, trailers, and semi-trailers manufacturing industry were for Canada (33%), the United Kingdom (30%), Japan (27%), Germany (26%), South Korea (16%), and the United States (15%). Export data for motor vehicles, trailers, and semi-trailers manufacturing include but do not separate out EVs.

Figure KTI-12

Industry composition of country KTI manufacturing exports for selected economies: 2022



EU-27 = European Union; KTI = knowledge and technology intensive; nec = not elsewhere classified.

Note(s):
KTI manufacturing exports include exports from the following industries: chemicals and chemical products; pharmaceuticals; computer, electronic, and optical products; electrical equipment; machinery and equipment nec; motor vehicles, trailers, and semi-trailers; air and spacecraft and related machinery; weapons and ammunition; and other transport equipment (the latter comprises railway locomotives and rolling stock manufacturing and transport equipment nec and military equipment manufacturing).

Source(s):
S&P Global IHS Markit, Comparative Industry Service special tabulations, October 2023.

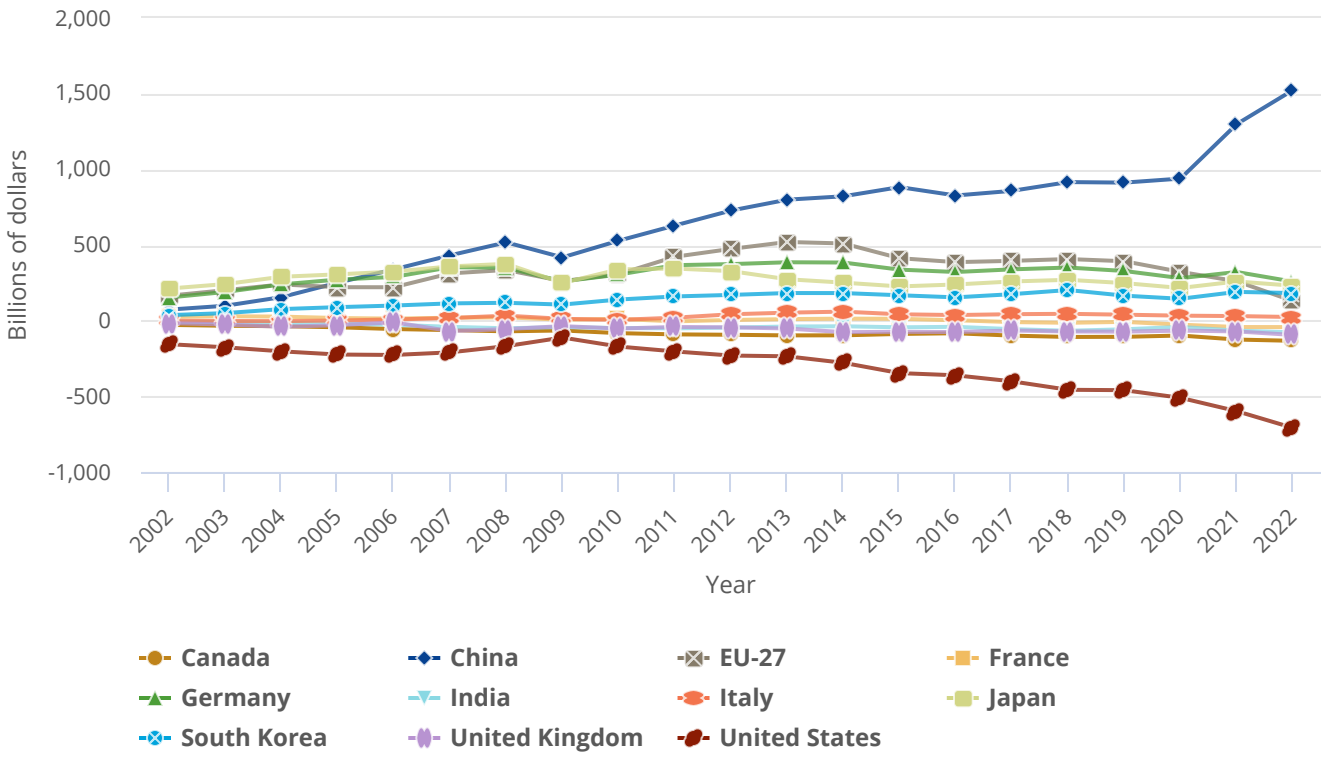
Science and Engineering Indicators

Among the countries included in **Figure KTI-12**, exports by the pharmaceutical manufacturing industry accounted for the largest shares of KTI goods exports in India (16%); Italy (15%); and the United Kingdom, France, and Germany (each with 11%). In addition, chemicals and chemical products manufacturing (excluding pharmaceuticals) accounted for the largest KTI export shares in India (31%), Canada (26%), France (26%), South Korea (20%), and the United States (20%). Exports by the air and spacecraft manufacturing industry had the largest shares in the United States and France (both with 10%).

The United States had a KTI goods trade deficit of $708 billion in 2022 in current U.S. dollars (**Figure KTI-13**) based on S&P Global data. Across all goods, the U.S. trade deficit was $1.2 trillion in 2022, based on BEA and Census Bureau trade statistics (BEA 2023b, Table 2.1). In contrast, China had increasing trade surpluses in KTI goods, tripling from less than $500 million in 2009 to $1.5 trillion in 2022 in current U.S. dollars, based on S&P Global data. China's overall manufacturing trade surplus experienced a similar pattern of growth based on the same source (Table SKTI-3).

Figure KTI-13

KTI manufacturing trade balance for selected economies: 2002–22



EU-27 = European Union; KTI = knowledge and technology intensive.

Note(s):
Data include trade for the following KTI industries: chemicals and chemical products; pharmaceuticals; computer, electronic, and optical products; electrical equipment; machinery and equipment not elsewhere classified (nec); motor vehicles, trailers, and semi-trailers; air and spacecraft and related machinery; weapons and ammunition; and other transport equipment (the latter comprises railway locomotives and rolling stock manufacturing and transport equipment nec and military equipment manufacturing).

Source(s):
S&P Global IHS Markit, Comparative Industry Service special tabulations, October 2023.

Science and Engineering Indicators

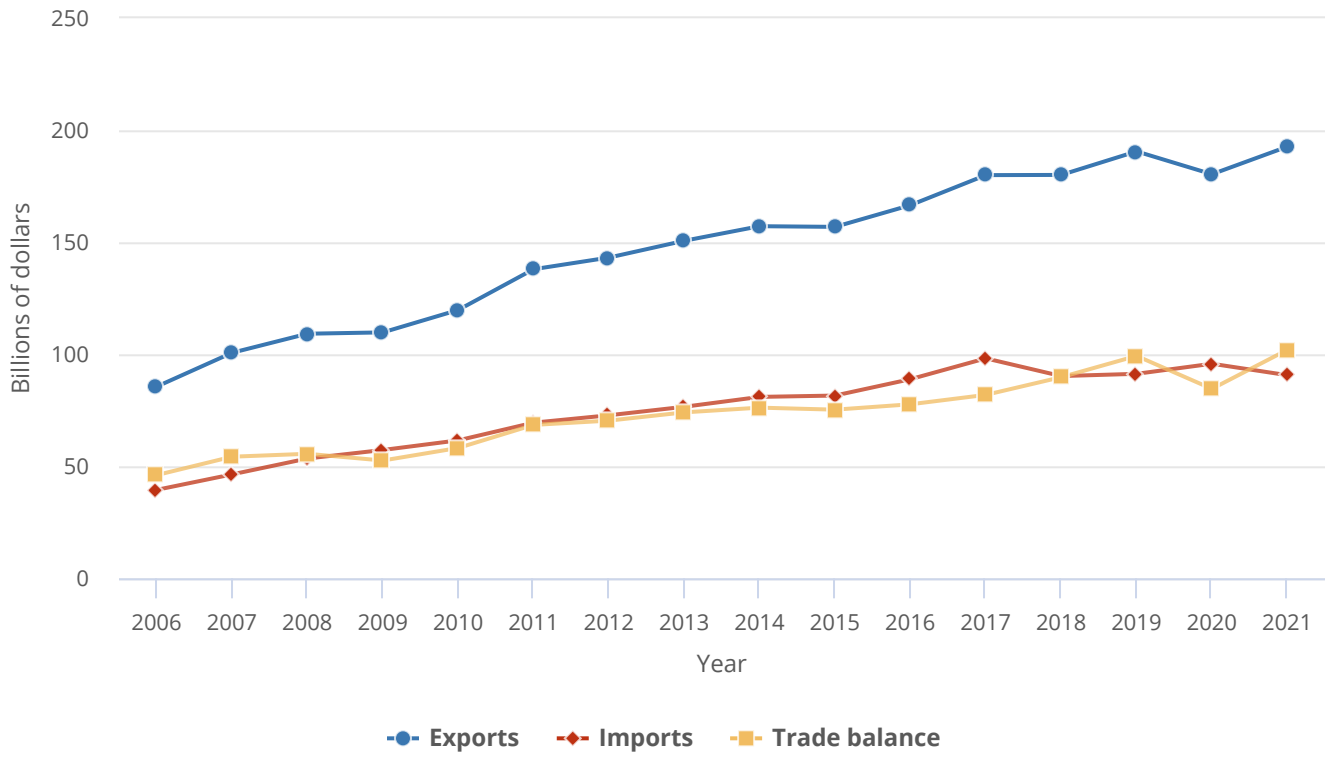
U.S. KTI-Related Services Trade

U.S. international trade in services statistics are published regularly by BEA by type of services rather than by industries.[8] KTI-related services include three major categories: (1) R&D services, engineering services, and scientific and other technical services; (2) computer software, cloud computing, and database services; and (3) IPP charges for the use of computer software and for R&D outcomes (patents, industrial processes, and trade secrets). Trade in these services, sometimes referred to as *trade in intangibles*, occurs across geographies but often within multinational enterprises (MNEs) (in part for intellectual property [IP] protection purposes) (Kano, Tsang, and Yeung 2020; Lanz and Miroudot 2011; Mudambi 2008; Rao and Vinod 2019), especially for R&D services trade (Moris 2018).[9]

Figure KTI-14 shows aggregate trade in U.S. KTI-related services. Exports and the positive trade balance (surplus) of these services appeared to resume their upward trends in 2021 (in current U.S. dollars) after their 2020 declines. In 2021, there were $193 billion in U.S. exports of KTI-related services, versus $91 billion in imports, for a trade surplus of $102 billion in these services, based on BEA statistics. The largest contributors to U.S. KTI-related services exports in 2021 were licenses for the use of outcomes of R&D ($56 billion in exports) and R&D services ($47 billion in exports), for a combined 54% of U.S. exports in these services. The next-largest exports were for IP license charges to reproduce or distribute computer software and for computer software services, including customization (**Figure KTI-15**).

Figure KTI-14

Exports, imports, and trade balance of KTI services for the United States: 2006–21



KTI = knowledge and technology intensive.

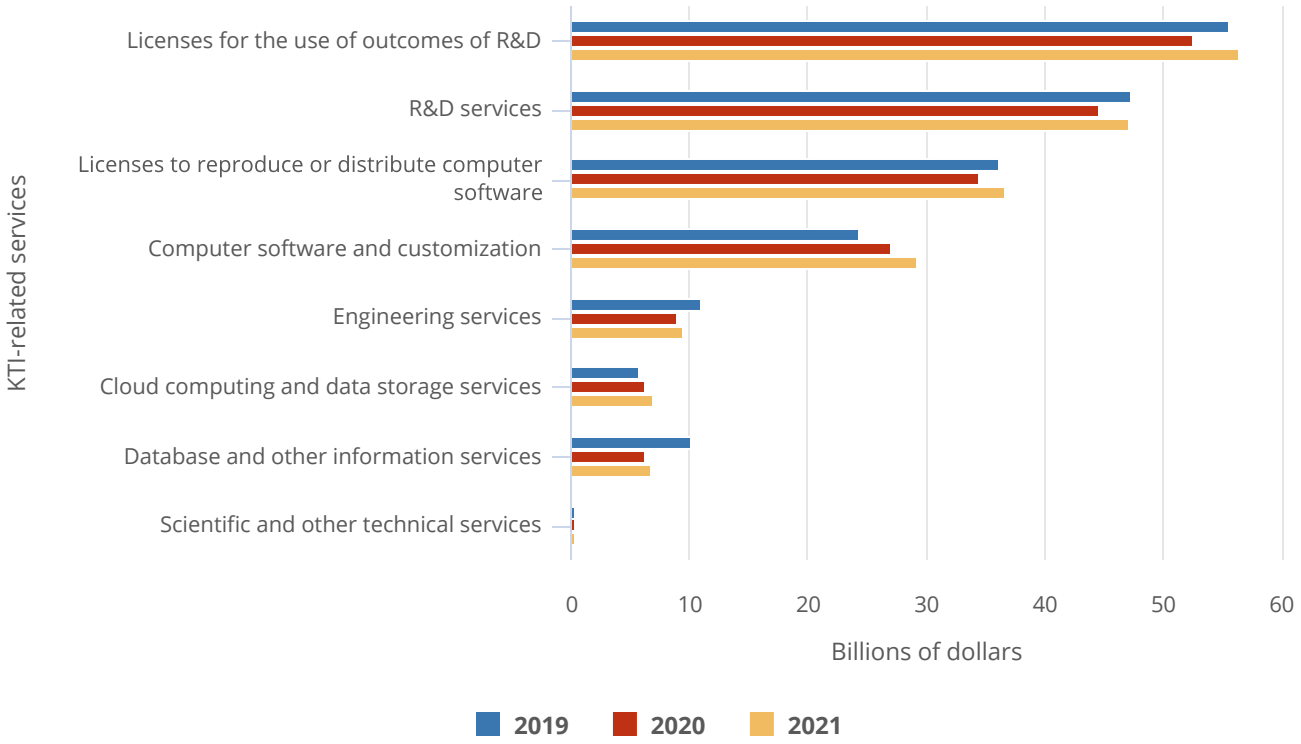
Note(s):
These data are not reported by industry but by type of service. This figure reports data on U.S. trade in services for the following KTI-related services: cloud computing and data storage services; database and other information services; computer software, including end-user licenses and customization; R&D services and licenses for reproduction or distribution of computer software and use of R&D outcomes; engineering services; and scientific and other technical services.

Source(s):
Bureau of Economic Analysis, Table 2.1. U.S. Trade in Services, by Type of Service, accessed 21 June 2023.

Science and Engineering Indicators

Figure KTI-15

Exports of KTI-related services for the United States, by type of service: 2019–21



KTI = knowledge and technology intensive.

Note(s):
These data are not reported by industry but by type of service.

Source(s):
Bureau of Economic Analysis, Table 2.1. U.S. Trade in Services, by Type of Service, accessed 21 June 2023.

Science and Engineering Indicators

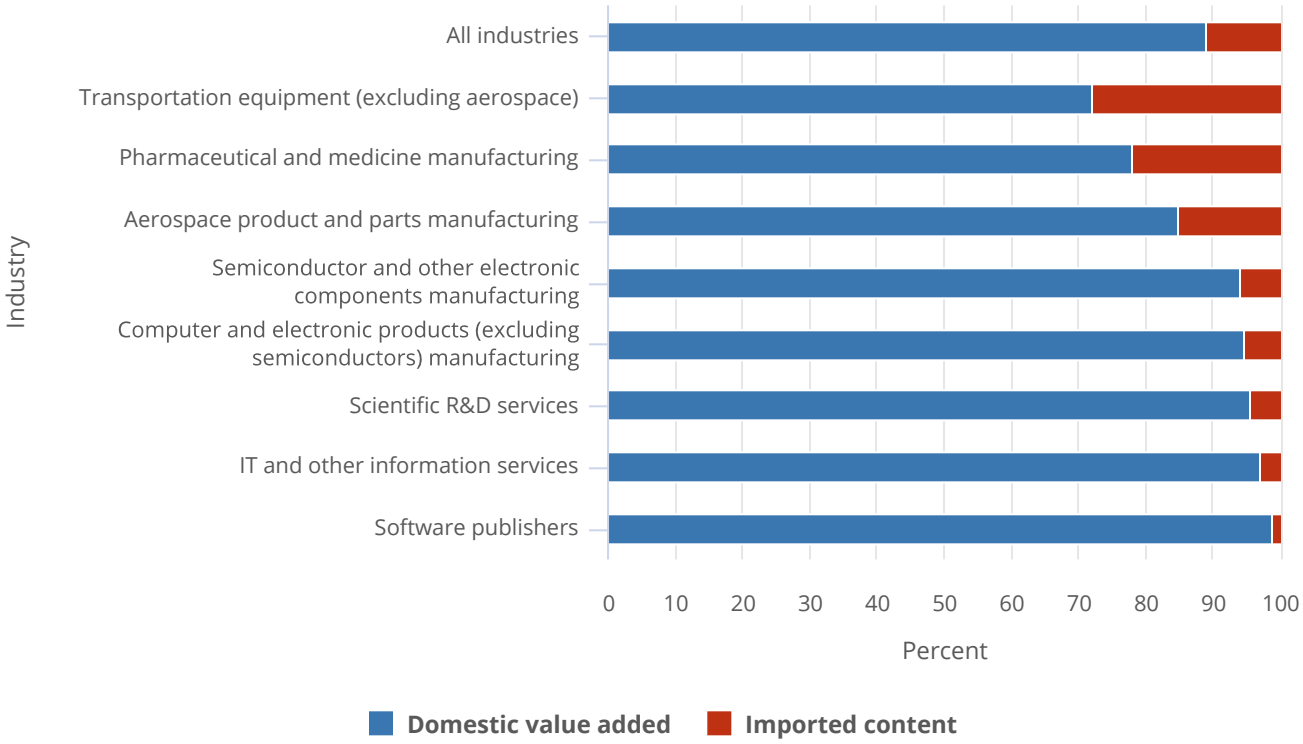
U.S. Trade in Value Added in KTI Output

The separation or fragmentation of production stages along supply chains, from R&D and design to production and marketing across locations, has been a distinctive feature of global value chains (GVCs) for decades (Baldwin and Freeman 2021). From the perspective of international trade statistics, these activities result in manufactured intermediate inputs crossing borders multiple times, creating issues of double counting in traditional or gross trade statistics (Johnson and Noguera 2012; Timmer et al. 2014). One way to analyze the role of supply chains in trade is with TiVA data that disaggregate gross exports into domestic versus imported content (Koopman, Wang, and Wei 2014; Timmer et al. 2014). This section presents TiVA statistics from a single-country perspective, with the United States as a reference (exporting) country.[10] Statistics in this section are based on the North American Industry Classification System (NAICS). (See Table SAKTI-2. For related OECD TiVA indicators for the United States and other countries up to 2018, see OECD [2021] and sources therein.)

The interconnectedness of today's global supply chains results in exports from a given country including value from domestic and imported inputs. Across all industries, the share of domestic content in U.S. gross exports is much larger than that of foreign content, fluctuating between 84% and 90% since 2007 (Table SKTI-4). This is consistent with the smaller role of trade overall in the U.S. economy compared with that in smaller advanced economies. **Figure KTI-16** shows the distribution of domestic content versus imported content of U.S. gross exports for all industries and selected KTI industries. KTI services industries had the largest domestic content share. Among KTI manufacturing industries shown in the figure, transportation equipment (excluding aerospace) had the largest imported content share.

Figure KTI-16

Domestic value added and imported content of U.S. gross exports: 2021



IT = information technology.

Note(s):
These statistics are preliminary and are subject to revision. The industry data are based on the North American Industry Classification System.

Source(s):
Bureau of Economic Analysis, Trade in Value Added Data, available at https://www.bea.gov/data/special-topics/global-value-chains, accessed 8 April 2023.

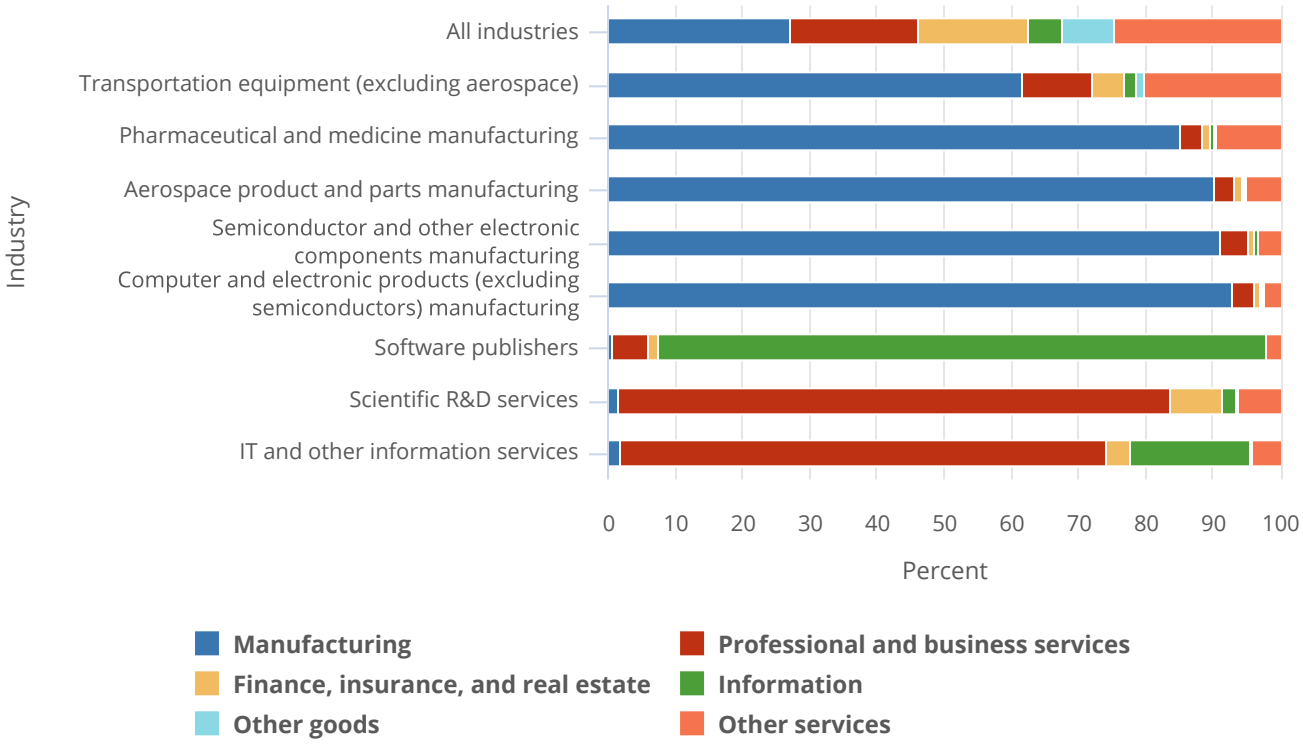
Science and Engineering Indicators

Figure KTI-17 shows the different industries that contributed to domestic value added in U.S. exports in 2021. Across all industries (KTI and non-KTI), domestically located manufacturing companies (regardless of domestic or foreign ownership) produced 27% of domestic value added of U.S. exports for that year. Thus, services and other nonmanufacturing industries produced almost three-fourths of the domestic value added in U.S. gross exports.[11]

However, the relative contribution of manufacturing and services to domestic value added in U.S. gross exports varies for specific exporting KTI industries. Notably, in 2021, nonmanufacturing industries contributed more domestic value added to the exports of the transportation equipment industry (excluding aerospace) compared with exports of other industries in **Figure KTI-17**.

Figure KTI-17

Domestic value-added content of gross exports, by exporting industry and source sector: 2021



IT = information technology.

Note(s):
These statistics are preliminary and are subject to revision. The industry data are based on the North American Industry Classification System.

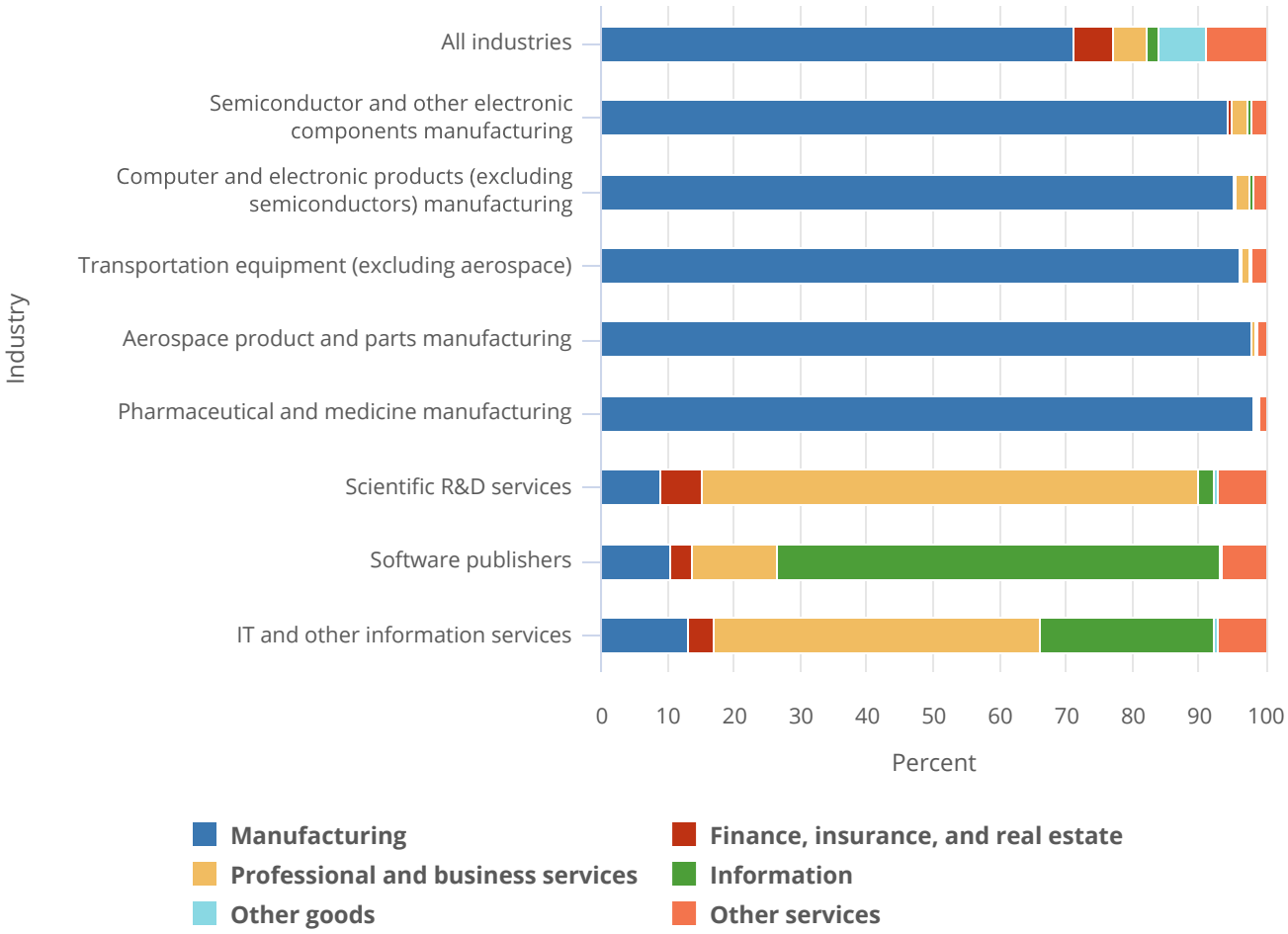
Source(s):
Bureau of Economic Analysis, Trade in Value Added Data, available at https://www.bea.gov/data/special-topics/global-value-chains, accessed 8 April 2023.

Science and Engineering Indicators

Figure KTI-18 shows the contribution of different industries to the foreign value-added content in U.S. exports in 2021. Similar to the case for domestic content, manufacturing imported content contributed the largest share for exports by KTI manufacturing industries. At the same time, for some U.S. exports such as those from pharmaceutical manufacturing, the value-added contribution of manufacturing was higher for the imported content (98%) than for the domestic content (85%) (**Figure KTI-17** and **Figure KTI-18**).

Figure KTI-18

Imported content in U.S. gross exports, by exporting industry and source sector: 2021



IT = information technology.

Note(s):
These statistics are preliminary and are subject to revision. The industry data are based on the North American Industry Classification System.

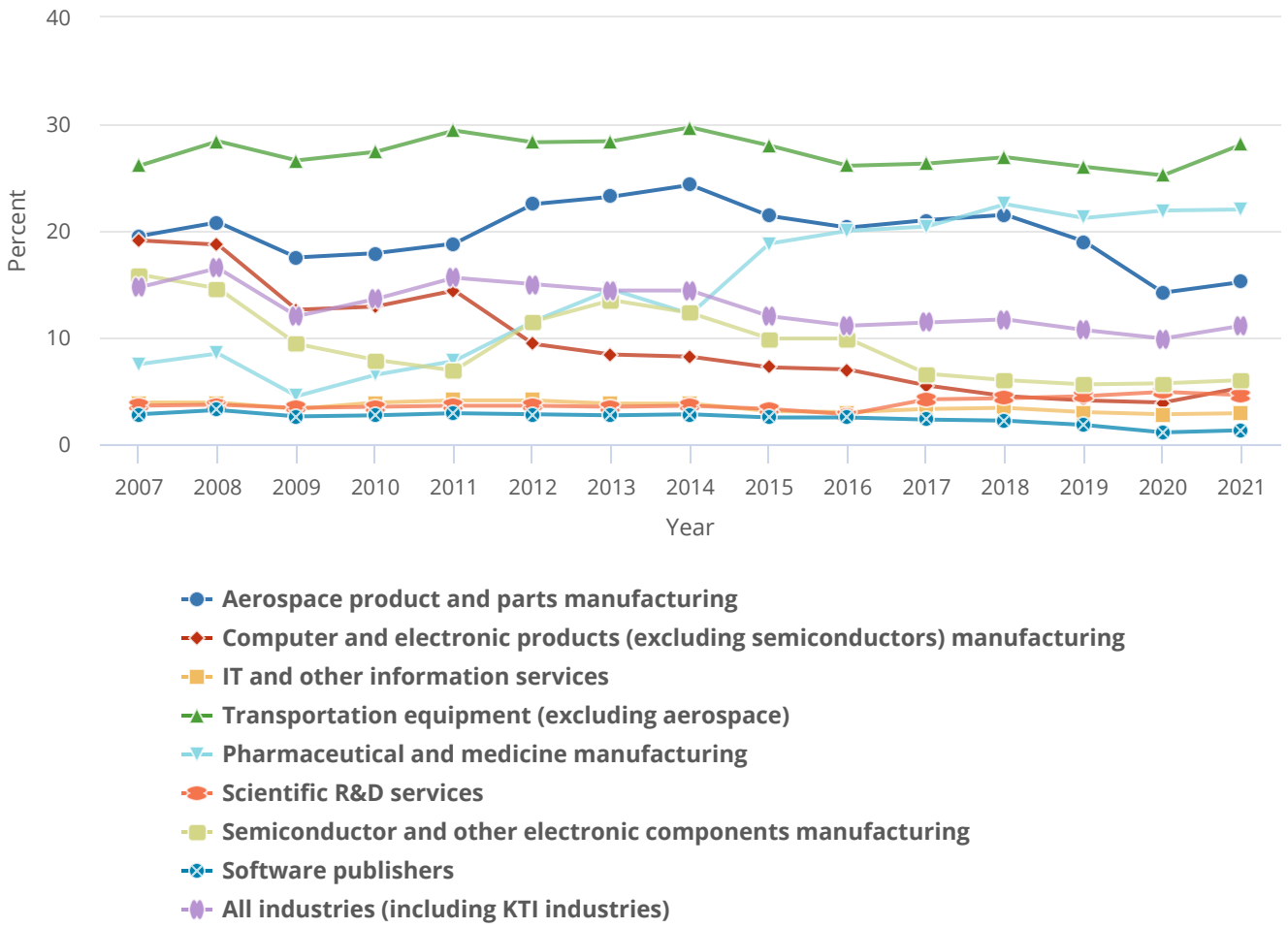
Source(s):
Bureau of Economic Analysis, Trade in Value Added Data, available at https://www.bea.gov/data/special-topics/global-value-chains, accessed 8 April 2023.

Science and Engineering Indicators

Figure KTI-19 examines trends in the imported content of U.S. exports within selected KTI industries. Across all industries (KTI and non-KTI), imported content declined from 17% in 2008 at the beginning of the financial crisis to 12% in 2015 to around 10% since 2019.

Figure KTI-19

Imported content share in U.S. gross exports, by exporting industry: 2007–21



IT = information technology; KTI = knowledge and technology intensive.

Note(s):
These statistics are preliminary and are subject to revision. The industry data are based on the North American Industry Classification System. KTI industries include high R&D intensive and medium-high R&D intensive industries based on a classification by the Organisation for Economic Co-operation and Development.

Source(s):
Bureau of Economic Analysis, Trade in Value Added Data, available at https://www.bea.gov/data/special-topics/global-value-chains, accessed 8 April 2023.

Science and Engineering Indicators

The figure also shows that the share of imported content of U.S. exports has been the largest for transportation equipment (excluding aerospace) manufacturing, at 25% or more since 2007. The imported content share of pharmaceutical and medicine manufacturing exports increased from the single digits in the late 2000s to 20% in 2016, plateauing around 22% since then for the second-highest share of imported content among U.S. KTI industries. For exports by the aerospace product and parts manufacturing industry, this share fluctuated around 20% from 2007 to 2019, declining to about 15% since 2019. The imported content shares of U.S. exports by the computer and electronic products manufacturing and semiconductor manufacturing industries have been in the single digits since 2012 and 2017, respectively.

Conclusion

KTI industries, the 10 manufacturing and 3 services R&D-intensive industries featured in this report, are important contributors to GDP and trade across countries and regions. Value added of U.S. KTI industries accounted for a modest share of U.S. GDP. This reflects that most KTI industry output is in the manufacturing sector, which represents a smaller share of the U.S. economy compared with services. At the same time, however, the growth of value added of U.S. KTI services relative to U.S. KTI manufacturing has been a notable trend over the last two decades. More recently, U.S. KTI services industries experienced growth even through the pandemic-related downturn, whereas U.S. KTI manufacturing industries experienced a steep decline in 2020 but a robust recovery in 2021 and 2022.

Consistent with other economic indicators, value added by KTI industries is highly concentrated globally. The United States, China, the EU-27, Japan, and South Korea accounted for about 80% of worldwide KTI value added in 2022. In that year, China and the United States were the top two producers of KTI output, each representing over a quarter of global KTI value added.

Some differences in the relative shares in KTI output across countries reflect the broader structure of their economies in terms of manufacturing versus services. Other trends appear to be tied to industry-specific developments, with fragmented supply chains and modular production networks reflecting, in part, cumulative competitive advantages in R&D and manufacturing across regions. Most notably, five of the top six semiconductor-producing locations were in East Asia in 2022, consistent with decades-long trends. Global KTI manufacturing exports rebounded in 2021 and 2022 following a pandemic-related decline in 2020.

Glossary

Definitions

Air and spacecraft and related machinery, manufacture of: Includes the manufacture of airplanes for the transport of goods or passengers, defense forces, or other purposes; helicopters; gliders and hang gliders; dirigibles and hot air balloons; parts and accessories of the aircraft of this class; ground-flying trainers; spacecraft and launch vehicles, satellites, planetary probes, orbital stations, and shuttles; intercontinental ballistic missiles; overhaul and conversion of aircraft or aircraft engines; and aircraft seats.

Chemicals and chemical products, manufacture of: This industry includes the transformation of organic and inorganic raw materials by a chemical process and the formation of products.

Computer, electronic, and optical products, manufacture of: Includes the manufacture of computers, computer peripherals, communications equipment, and similar electronic products, as well as components such as electronic components and boards. The latter include resistors, microprocessors, and semiconductors. Also includes consumer electronics; measuring, testing, navigating, and control equipment; irradiation, electromedical, and electrotherapeutic equipment; optical instruments and equipment; and magnetic and optical media.

Electrical equipment, manufacture of: This industry includes the manufacture of products that generate, distribute, and use electrical power, as well as electrical lighting, signaling equipment, and electric household appliances.

European Union (EU-27): The EU comprises 27 member nations: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden. The United Kingdom withdrew from the EU on 1 February 2020. Unless otherwise noted, data on the EU include all 27 member countries.

Global value chain (GVC): A chain of activities to produce goods and services that may extend across firms or countries. These activities include design, production, marketing and sales, logistics, and maintenance.

Gross domestic product (GDP): The market value of all final goods and services produced within a country in a given period.

Information technology (IT) and other information services: This industry is the composite of International Standard Industrial Classification of All Economic Activities (ISIC) sectors 62 (computer programming, consultancy, and related activities) and 63 (information service activities). ISIC 62 includes providing expertise in information technologies: writing, modifying, testing, and supporting software; planning and designing computer systems that integrate computer hardware, software, and communication technologies; and on-site management and operation of clients' computer systems or data processing facilities. ISIC 63 includes Web search portals and data processing and hosting activities.

Intangibles or intellectual property products (IPPs): IPPs are the result of R&D or innovation leading to knowledge that the developers can market or use to their own benefit in production because use of the knowledge is restricted by means of legal or other protection. They include R&D; mineral exploration and evaluation; computer software and databases; and entertainment, literary and artistic originals, and other IPPs.

Knowledge- and technology-intensive (KTI) industries: Industries classified by the Organisation for Economic Co-operation and Development (OECD) as high R&D intensive and medium-high R&D intensive industries. OECD defines industry R&D intensity as the ratio of an industry's business R&D expenditures to its value added.

Machinery and equipment not elsewhere classified (nec), manufacture of: This industry includes the manufacture of machinery and equipment that act independently on materials either mechanically or thermally or perform operations on materials (such as handling, spraying, weighing, or packing). Includes the manufacture of fixed and mobile or handheld devices, regardless of whether they are designed for industrial, building, and civil engineering; agricultural; or home use. Also included is the manufacture of special equipment for passenger or freight transport within demarcated premises.

Medical and dental instruments and supplies, manufacture of: Includes manufacture of laboratory apparatus, surgical and medical instruments, surgical appliances and supplies, dental equipment and supplies, orthodontic goods, and dentures and orthodontic appliances.

Motor vehicles, trailers, and semi-trailers, manufacture of: This industry includes the manufacture of motor vehicles for transporting passengers or freight. Also included is the manufacture of parts and accessories and of trailers and semi-trailers.

Pharmaceuticals (manufacture of basic pharmaceutical products and pharmaceutical preparations): This industry includes the manufacture of basic pharmaceutical products, pharmaceutical preparations, and medicinal chemical and botanical products.

Railroad, military vehicles, and transport not elsewhere classified (nec), manufacture of: This manufacturing industry is the composite of International Standard Industrial Classification of All Economic Activities (ISIC) 302 (railway locomotives and rolling stock), ISIC 304 (military fighting vehicles), and ISIC 309 (transport equipment nec).

Scientific research and development (R&D) services: This industry includes the activities of three types of R&D: (1) basic research, (2) applied research, and (3) experimental development.

Semiconductors: This industry refers to the manufacture of electronic components and boards (International Standard Industrial Classification of All Economic Activities 261), which includes semiconductors and other components for electronic applications.

Software publishing: This industry includes publishing of ready-made (noncustomized) software: operating systems, business and other applications, and computer games for all platforms.

Total private services: Aggregate of the following International Standard Industrial Classification of All Economic Activities (ISIC) industries (ISIC Revision 4): wholesale and retail trade and repair of motor vehicles and motorcycles; transportation and storage; accommodation and food service activities; information and communication; financial and insurance activities; real estate activities; professional, scientific, technical activities; and administrative and support service activities. This aggregate corresponds to Business Sector Services (ISIC aggregate “D45T82”) in economic and R&D data from the Organisation for Economic Co-operation and Development (OECD).

Value added: Value added is a net measure of output; it is the difference between the value of goods and services (gross output) and the cost of intermediate inputs that were used in production, including energy, materials, and services. Industry value added is a measure of an industry’s contribution to overall GDP.

Weapons and ammunition, manufacture of: This industry includes the manufacture of heavy weapons (such as artillery, mobile guns, and rocket launchers), small arms (revolvers, shotguns, light machine guns), ammunition, and explosive devices, as well as hunting and sporting firearms. Excludes the manufacture of space vehicles and tanks or other fighting vehicles (included in other industries).

Key to Acronyms and Abbreviations

ATP: assembly, testing, and packing

BEA: Bureau of Economic Analysis

CHIPS: Creating Helpful Incentives to Produce Semiconductors

EU-27: European Union

EV: electric vehicle

GDP: gross domestic product

GVC: global value chain

IMF: International Monetary Fund

IP: intellectual property

IPP: intellectual property product

ISIC: International Standard Industrial Classification of All Economic Activities

IT: information technology

KTI: knowledge and technology intensive

LQ: location quotient

MNE: multinational enterprise

NAICS: North American Industry Classification System

NCSES: National Center for Science and Engineering Statistics

nec: not elsewhere classified

NSF: National Science Foundation

OECD: Organisation for Economic Co-operation and Development

R&D: research and development

TiVA: trade in value added

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Notes

1 R&D-intensive manufacturing industries may engage in design, processes, or materials analyzed in the literature under several headings, including advanced manufacturing and intelligent manufacturing. Examples include additive or nano-based manufacturing and biotechnology and biomanufacturing. For additional information, see Brocal, Sebastián, and González (2019), IDA (2012), and PCAST (2020).

2 For business employment and labor costs in U.S. R&D-intensive industries, see Moris (2019) and Moris and Shackelford (2023).

3 See Thomas (2022) for comprehensive economic statistics on U.S. manufacturing.

4 See the Glossary section for the definition of total private services used in this report.

5 U.S. software investment was on par with the aggregate of computer and peripheral equipment and communications equipment at about $166 billion for both in 2004. Since then, software investment outgrew its tangible IT investment counterpart so that in 2021, the former is about twice the latter in current U.S. dollar terms ($512.4 billion vs. $262.8 billion); see BEA (2022).

6 For a comparison of long-term trends in manufacturing output and productivity in the United States, Japan, and Germany, see Baily, Bosworth, and Doshi (2020).

7 For information on related export controls and foreign investment regulations, see CRS (2022b, 2023a, 2023c).

8 See Bruner and Grimm (2019) for an analysis of BEA services trade by industry. For long-term trends in international services trade and automation, see Baldwin (2022).

9 See also Fu and Ghauri (2021) on intangibles and global trade imbalance.

10 Given the single-country perspective, additional domestic value added could be embedded in imported content; thus, data on domestic value-added content may be considered a lower bound on the level of domestic value added embedded in U.S. gross exports. Data are from a joint statistical project of BEA and the National Center for Science and Engineering Statistics within NSF; see BEA (2023a).

11 For analysis of services and GVCs across OECD countries, see Miroudot and Cadestin (2017).

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