How Stringent Export Controls on Emerging Technologies Would Harm the U.S. Economy

BY STEPHEN EZELL AND CALEB FOOTE | MAY 2019

U.S. firms could lose $14.1 to $56.3 billion in export sales over five years, with missed export opportunities threatening 18,000 to 74,000 jobs.

The U.S. Commerce Department's Bureau of Industry and Security (BIS) is developing rulemaking regarding extending export controls to an enlarged set of emerging and foundational technologies (EFTs)—new or foundational technologies that in some narrow cases are essential to national security and are not currently covered by existing export control rules. However, defining an overly restrictive set of EFTs for export controls could significantly impede the competitiveness of U.S. advanced-technology industries and constrain their output, exports, and employment growth. This report outlines these risks and models the potential direct effects of export controls on a specific subset of EFTs—emerging technologies that have been identified by BIS as possible candidates for export controls—at three levels of potential export reductions (5, 10, and 20 percent, depending on how restrictive the export controls actually applied to emerging technologies end up being). It finds that U.S. firms could lose $14.1 to $56.3 billion in export sales over five years, with missed export opportunities threatening from 18,000 to 74,000 jobs.

INTRODUCTION

The Export Control Reform Act (ECRA), signed into law on August 18, 2018, requires BIS to impose export controls on EFTs that are "essential to the national security of the United States," and not already subject to such controls.[1] Export controls regulate the

shipment or transfer of controlled technologies, information, or services outside of the United States, ranging from requiring an application process to monitoring of production or an outright ban. At a minimum, BIS must institute licensing requirements for these technologies to nations in Country Group D:5—the designation for countries facing a comprehensive arms embargo—and consider a complete ban on their export to those 21 nations.[2] Group D:5 countries disproportionately do not engage in significant trade with the United States. The lone exception is China, which received more than 90 percent of U.S. exports among the countries in this group in 2018.[3] Congress has explicitly voiced concern over China, stating that export controls are needed "to protect U.S. technologies from aggressive attempts by China and other countries to obtain those technologies using both legal and illicit means."[4]

Part of Congress's motivation for taking this step was to address the forced transfer of these technologies to China, particularly through joint ventures. Rather than include it through the reform of the Committee on Foreign Investment in the United States (CFIUS), Congress chose to use the export control regime. As such, firms in the United States may neither sell nor engage in a transfer or joint venture with any of these Group D:5 nations for any technology included by BIS on the export control list. The challenge, however, is that while exporting technology products to a nation such as China usually boosts U.S. competitiveness in advanced industries—something that supports U.S. national security—technology transfer often does not. Designating a technology on the control list thus limits both exports and transfer of that technology. However, limiting exports would reduce output and competitiveness of advanced industry firms in the United States, while also reducing jobs.

In ECRA, Congress did not define what constitutes either emerging or foundational technologies, leading BIS to issue a request for comment (in the form of an advanced notice of proposed rulemaking "ANPRM" published in the *Federal Register* on November 19, 2018) on 14 categories of technology being considered for potential designation as emerging technologies, with an additional list of foundational technologies forthcoming.[5] What will qualify as foundational technologies is unknown at this point, although they may include certain key commodities or technologies that today are lesser controlled and which may not require a license or could go under a license-exception mechanism. The categories BIS is considering for defining as emerging technologies are:[6]

- Biotechnology (e.g., nanobiology, synthetic biology, genomic and genetic engineering, and neurotech);
- Artificial intelligence (AI) and machine learning technology (e.g., neural networks and deep learning, evolution and genetic computation, reinforcement learning, computer vision, expert systems, speech and audio processing, natural language processing, planning, audio and video manipulation technologies, AI cloud technologies, and AI chipsets);
- Position, Navigation, and Timing technology;

- Microprocessor technology (e.g., systems-on-chip) and stacked memory on chip);
- Advanced computing technology (e.g., memory-centric logic);
- Data analytics technology (e.g., visualization, automated analysis algorithms, and context-aware computing);
- Quantum information and sensing technology (e.g., quantum computing, quantum encryption, and quantum sensing);
- Logistics technology (e.g., mobile electric power, modeling and simulation, total asset visibility, and distribution-based logistics systems);
- Additive manufacturing;
- Robotics (e.g., micro-drone and micro-robotic systems, swarming technology, self-assembling robots, molecular robotics, robot compliers, and smart dust);
- Brain-computer interfaces (e.g., neural-controlled interfaces, mind-machine interfaces, direct neural interfaces, and brain-machine interfaces);
- Hypersonics (e.g., flight-control algorithms, propulsion technologies, thermal-protection systems, and specialized materials);
- Advanced materials (e.g., adaptive camouflage, functional textiles, and biomaterials); and
- Advanced surveillance technologies (e.g., faceprint and voiceprint technologies).

While the objective of protecting U.S. national security is laudable and critical, there are several dangers in implementing broad restrictions on the sale of emerging and foundational technologies.

Advanced technologies—including those identified in this report for possible designation as emerging technologies—increasingly shape competitive advantage for nations across the globe. Limiting U.S. exports thereof would make it more difficult for U.S. firms in the race for global innovation advantage. Increased advanced-technology exports help U.S. companies, and thereby the U.S. economy, maintain its competitive position in two ways. First, they enable greater sales and, by extension, reinvestment in research and development (R&D) of next-generation technologies by U.S. companies. Second, they reduce the sales for foreign competitors, including in competitor countries, making it more difficult for them to progress and innovate.[7]

While the objective of protecting U.S. national security is laudable and critical—and export controls on some very specific EFTs could play an important role toward that goal, such as preventing the spread of AI-enabled advanced weapon systems—there are several dangers in implementing broad restrictions on the sale of EFTs. Imposing export controls necessarily harms domestic firms in the short run, reducing their sales and thus their ability to reinvest profits in the R&D that enables them to continue to innovate and to create the high-paying, tech-based jobs associated with cutting-edge technology sectors. Further, imposing export controls on technologies that are globally available from foreign firms does not significantly slow the adoption of those technologies by potential adversaries, but it does redirect revenues from firms in the United States to their foreign competitors, which hampers U.S. competitiveness.

Moreover, it's increasingly uncommon for U.S. firms to be so far ahead of the rest of the world in advanced technologies that these technologies are not available outside the United States. For instance, in a March 2019 report, "Is China Catching Up to the United States in Innovation?" the Information Technology and Innovation Foundation (ITIF) demonstrated that China is far less reliant on copying than it once was, surpassing the United States across many indicators of innovation, including per capita computer science and engineering degrees, and fielding the greatest number of supercomputers rated among the 500 most powerful in the world.[8] From advanced manufacturing to AI, many nations, including China, are positioning themselves to become leaders in emerging technologies.[9]

Overly broad export controls on emerging technologies can also slow product development processes by adding steps, such as the need to secure deemed-export licenses for employees or technology-transfer licenses for partners or subsidiaries. Such extra steps can delay U.S. firms in getting innovative products to market, thus harming their competitiveness. At the same time, export controls can limit the ability of U.S. companies to attract international talent and hire the most-qualified engineers. In the most extreme cases, certain U.S. companies may elect to not develop a technology due to the added burden of export controls.[10] Similarly, U.S. companies could be excluded from value chains involved in the development of next-generation products or services if a foreign enterprise (whether Asia- or Europe-headquartered, for instance) were to harbor concerns that a lack of clarity about export controls would potentially make the U.S. enterprise an unreliable partner.

Even where the United States might still be far enough ahead to keep new technologies away from potential antagonists, overly broad export-control restrictions still raise serious concerns. In many sectors, what constitutes "state of the art" changes too rapidly for export rules to reliably and readily adapt. In these cases, broad rules risk preventing makers of fast-advancing products from adequately competing, putting them in the position of having to petition rule makers and then wait for definitional changes while competitors expand their market share selling products that may have quickly become mainstream.[11]

An illustrative example of the risks involved in imposing broad export controls comes from the satellite industry. In 1998, Congress found that two U.S. satellite firms had illegally transferred sensitive data to China, and tightened export controls in response to require that all commercial satellites and related technologies be licensed.[12] The significant regulatory burden and uncertainty caused by these controls led not only to foreign satellites being preferred, but also to an effort to fully avoid U.S. partnership and controlled materials by organizations including the European Space Agency.[13] A drastic decline in U.S. enterprises' competitiveness followed, with a 2007 Department of Defense study finding that the U.S. market share for commercial communications satellites had fallen by 19 percent, with $2.4 billion in lost sales directly attributable to export controls between 2003 and 2006.[14] Worse still, BIS conducted a survey in 2014 in the process of loosening export controls on commercial satellites, finding that nearly one-third of U.S. firms impacted by satellite controls altered their R&D expenditures to avoid developing controlled technologies.[15] This helps explain why, despite loosened export controls, U.S.

firms have not significantly rebounded, only increasing their market share from 41 percent in the early 2000s to 44 percent in 2016.[16]

Imposing strict export controls across communications satellites broadly, rather than on narrow technologies with specific military applications, both failed to prevent China (and others) from gaining the technology to develop its own satellite industry and left U.S. firms ill-equipped to innovate for the future. Moreover, U.S. industry lost out in joint development projects, as the uncertainty wrought by the excessive export controls made U.S. industry to be considered a potentially unreliable partner. Accordingly, export controls should be narrowly construed and tailored to the specific purpose of limiting the proliferation of technologies that are vital to securing a military or national-security advantage for the United States. When they attempt to stifle the development of foreign industries more broadly, export controls are likely to fail, while simultaneously stripping U.S. firms of the resources to develop future technologies that are more directly vital to national security.

When they attempt to stifle the development of foreign industries more broadly, export controls are likely to fail, while simultaneously stripping U.S. firms of the resources to develop future technologies that are more directly vital to national security.

METHODOLOGY

In order to quantify the potential economic and employment impact to the United States of overly broad export controls, ITIF estimated these effects at both the industry and national and state levels. The evolving definitions and nascent nature of the emerging technologies designation preclude the use of detailed data, such that ITIF used the North American Industry Classification System (NAICS) to identify 12 sectors that rely on or are developing technologies referenced by BIS:

- 3254 (Pharmaceutical and Medicine Manufacturing);
- 3332 (Industrial Machinery Manufacturing);
- 3341 (Computer and Peripheral Equipment Manufacturing);
- 33422 (Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing);
- 3344 (Semiconductor and Other Electronic Component Manufacturing);
- 3345 (Navigational, Measuring, Electromedical, and Control Instruments Manufacturing);
- 3364 (Aerospace Product and Parts Manufacturing);
- 3391 (Medical Equipment and Supplies Manufacturing);
- 5112 (Software Publishers);
- 5182 (Data Processing, Hosting, and Related Services);
- 5415 (Computer Systems Design and Related Services); and
- 54171 (Research and Development in the Physical, Engineering, and Life Sciences).

U.S. exports to Group D:5 countries in 2013 and 2018 were determined for the first eight sectors using the Census Bureau's USA Trade Online tool.[17] However, the Census Bureau lacks data for NAICS 5112, 5182, 5415, and 54171, as it does not provide detailed industry data on service exports. Instead, Bureau of Economic Analysis data on exports of telecommunications, computer, and information services in 2013 and 2017 were used as an estimate of those sectors' exports.[18] These sectors do not precisely target potentially affected technologies, but they do allow for an estimate of how and where the relevant industries engage in global trade.

The most recent data from these sources is used as a baseline to calculate first the overall output and exports, and then the potential 5-, 10-, or 20-percent reduction in exports from the selected sectors to Group D:5 nations that could be caused by export controls. In other words, the methodology examines what the effects would be if 5, 10, or 20 percent of the products in certain categories (e.g., Semiconductor and Other Electronic Component Manufacturing) were deemed as emerging technologies and thus ineligible for export. Growth between 2013 and 2018 in each sector was used as a baseline to forecast each sector's growth over the next five years, providing an estimate for the impact of different implementations of this policy into the future.

In terms of employment impact, the International Trade Administration has estimated that an average of 5,744 jobs are supported by every $1 billion in high-tech exports (including direct and indirect employment effects). ITIF used this estimate to calculate the number of jobs threatened by possible export controls on emerging technologies, again calculated at each of the three reduction levels.[19]

To approximate the distribution of this effect across U.S. states, ITIF utilized both state-level goods-exports data for the NAICS sectors from the Trade Online tool, and high-tech services-exports data from The Trade Partnership, a consultancy, in a manner analogous to how ITIF applied it in prior reports, including "The 2017 State New Economy Index" and "High-Tech Nation: How Technological Innovation Shapes America's 435 Congressional Districts."[20] From this, each state's percentage of total U.S. high-tech exports was calculated and multiplied by the previously calculated national impact of potential export controls. In other words, the report assumes that the impacts of any control on a particular emerging technology effect the firms in that industry equally in each state. Moreover, for analysis at the state level, the report assumes that restrictions would be for particular levels of output for all industries. Clearly, any restrictions would be more targeted, thereby changing the actual state impacts.

RESULTS AND ANALYSIS

Table 1 provides data regarding current U.S. exports to covered countries (China and other Group D:5 nations) in comparison with total U.S. exports to the world in 2013 and 2018. Over this period, total U.S. exports grew by 5.4 percent, from nearly $1.6 trillion to nearly $1.7 trillion, while exports to covered countries fell by $9.6 billion, which was predominantly driven by declines in exports to countries other than China. Exports of

covered high-tech goods grew more quickly from 2013 to 2018 (by 13.4 percent) than total exports—especially to China, where U.S. high-tech exports grew by 41.7 percent. However, U.S. high-tech exports to other covered countries significantly decreased over this period, falling by nearly 70 percent, from $3.9 billion to $1.2 billion. A smaller proportion of information and communications technology (ICT) service exports went to covered nations, yet they exhibited similar trends to covered goods, with dramatic Chinese growth (92.5 percent) and decline elsewhere (80.3 percent) from 2013 to 2017, albeit from very small bases.

Table 1: U.S. exports to countries facing export controls ($ billions)[21]

	All Goods		Covered Goods		ICT Services	
	2013	2018	2013	2018	2013	2017
Worldwide Total	1,578.5	1,664.1	407.9	462.5	34.4	42.2
China	121.7	120.3	32.9	46.6	0.5	1.0
Other Group D:5 Nations	21.2	13.0	3.9	1.2	1.1	0.2

Table 2 estimates the range of direct economic impacts stringent export control restrictions on emerging technologies could cause, calculating the effect of restrictions that reduce exports from the selected high-tech sectors to the covered nations by 5, 10, or 20 percent. If export controls in the identified sectors affected, on average, 5 percent of current exports, firms in the United States would lose $2.4 billion in sales in the first year, thereby threatening more than 14,000 U.S. jobs that are supported by current exports. At 10 percent and 20 percent, these figures grow to $4.9 billion and more than 28,100 jobs, and $9.8 billion and nearly 56,300 jobs, respectively. Further, projecting from the growth in exports between 2013 and 2018, ITIF estimates that additional exports of nearly $1 billion to more than $3 billion would have been foregone after five years of export controls, for a total of $14.1 billion to $56.3 billion in lost revenue over five years, which could otherwise have supported an additional 4,400 to 17,700 jobs.

Table 2: Direct economic losses by magnitude of export controls[22]

	5 Percent	10 Percent	20 Percent
Exports (Billions), Year 1	$2.4	$4.9	$9.8
Jobs, Year 1	14,070	28,140	56,270
Exports (Billions), Year 5	$3.2	$6.4	$12.9
Cumulative Exports (Billions), Years 1–5	$14.1	$28.2	$56.3
Jobs, Year 5	18,500	37,000	73,990

The aerospace sector faces the largest risk, with 38 percent of total exports, potentially losing more than $900 million to $3.7 billion in exports, which support approximately 5,300 to 21,400 jobs.

Table 3 breaks down by industry the year one impacts of the different levels of export controls presented in table 2. Losses to the ICT services sectors represent only 2.4 percent of total losses, with $59 million in lost exports and about 340 jobs threatened if restrictions reduce exports by 5 percent, two-thirds of which come from the computer services sector. In contrast, the aerospace sector faces the largest risk, with 38 percent of total exports, potentially losing more than $900 million to $3.7 billion in exports, which support approximately 5,300 to 21,400 jobs. The next four sectors—semiconductors; navigation, measurement, and control instruments; industrial machinery; and pharmaceuticals—represent a slightly larger share of exports, collectively risking losses of approximately $1.1 billion to $4.5 billion in exports in the first year of the 5 and 20 percent scenarios, supporting 6,500 to 26,100 jobs. Medical equipment, computers, and wireless communications are significantly smaller, accounting for only $324 million of lost exports in the 5 percent scenario—but even those exports currently support nearly 1,900 jobs, with an additional 5,600 jobs threatened if export controls reduced 20 percent of current exports.

Table 3: Direct economic losses by magnitude of export controls and industry after one year[23]

	5 Percent		10 Percent		20 Percent	
	Exports (Millions)	Jobs	Exports (Millions)	Jobs	Exports (Millions)	Jobs
Pharmaceuticals	$206	1,185	$413	2,370	$825	4,739
Industrial Machinery	$224	1,286	$448	2,572	$896	5,144
Computers	$120	688	$240	1,377	$479	2,753
Wireless Communications	$67	386	$134	772	$269	1,544
Semiconductors	$397	2,281	$794	4,561	$1,588	9,122
Navigation, Measurement, and Control Instruments	$310	1,779	$619	3,558	$1,239	7,116
Aerospace	$930	5,339	$1,859	10,679	$3,718	21,358
Medical Equipment	$137	789	$275	1,577	$549	3,154
Telecom Services	$12	68	$24	137	$48	273
Computer Services	$39	221	$77	442	$154	885
Information Services	$8	46	$16	92	$32	184

California, Texas, and Washington would experience the greatest losses by a wide margin, as they together account for 41.7 percent of the United States' high-tech exports.

Tables 4, 5, and 6 break down the estimated impact of export controls on emerging technologies by U.S. state at the 5-, 10-, and 20-percent reduction levels, respectively. California, Texas, and Washington would experience the greatest losses by a wide margin, as they together account for 41.7 percent of the United States' high-tech exports and individually face the potential of losing as much as $1.8 billion and 10,340 jobs, $1.2 billion and 6,990 jobs, and $1.1 billion and 6,150 jobs, respectively, in the first year of export controls. Florida, Massachusetts, New York, Kentucky, Illinois, Georgia, and Indiana round out the 10 states facing the largest impact, each of which would lose over 1,100 more jobs in the 20 percent scenario than in the 5 percent scenario in the first year.

Table 4: State-level impact of 5 percent export restrictions on high-tech exports[24]

	% of U.S. High-tech Exports	Exports, Year 1 (Millions)	Jobs, Year 1	Exports, Year 5 (Millions)	Jobs, Year 5
Alabama	0.6	$14.5	83	$19.0	109
Alaska	0.0	$0.4	2	$0.5	3
Arizona	2.1	$50.3	289	$66.2	380
Arkansas	0.3	$8.0	46	$10.6	61
California	18.4	$450.2	2,586	$591.9	3,400
Colorado	1.1	$26.6	153	$34.9	201
Connecticut	2.0	$49.8	286	$65.5	376
Delaware	0.4	$10.8	62	$14.2	82
District of Columbia	0.2	$4.3	25	$5.7	33
Florida	4.4	$108.6	624	$142.8	820
Georgia	3.0	$72.3	415	$95.1	546
Hawaii	0.0	$0.3	2	$0.4	3
Idaho	0.4	$9.0	52	$11.8	68
Illinois	3.0	$72.4	416	$95.2	547
Indiana	2.6	$64.7	372	$85.1	489
Iowa	0.3	$7.1	41	$9.3	54
Kansas	0.7	$17.5	100	$23.0	132
Kentucky	3.1	$75.6	434	$99.4	571
Louisiana	0.1	$2.1	12	$2.8	16
Maine	0.1	$3.5	20	$4.6	27
Maryland	1.1	$26.8	154	$35.2	202
Massachusetts	4.0	$98.7	567	$129.8	746
Michigan	1.1	$28.1	161	$36.9	212
Minnesota	1.7	$40.4	232	$53.2	305
Mississippi	0.5	$11.1	64	$14.6	84
Missouri	0.6	$15.8	91	$20.7	119
Montana	0.0	$1.1	7	$1.5	9
Nebraska	0.2	$4.7	27	$6.1	35
Nevada	0.5	$11.2	64	$14.7	84

New Hampshire	0.6	$15.2	87	$20.0	115
New Jersey	2.3	$56.7	326	$74.6	429
New Mexico	0.5	$12.2	70	$16.1	92
New York	3.2	$77.9	447	$102.4	588
North Carolina	2.6	$64.5	371	$84.9	487
North Dakota	0.0	$1.0	5	$1.2	7
Ohio	2.2	$53.8	309	$70.8	407
Oklahoma	0.3	$7.7	44	$10.2	58
Oregon	2.6	$62.8	361	$82.6	474
Pennsylvania	2.4	$58.0	333	$76.2	438
Rhode Island	0.1	$2.0	12	$2.7	15
South Carolina	1.8	$43.3	249	$56.9	327
South Dakota	0.0	$0.3	2	$0.4	2
Tennessee	1.8	$44.3	255	$58.3	335
Texas	12.4	$304.3	1,748	$400.1	2,298
Utah	0.8	$19.6	113	$25.8	148
Vermont	0.4	$9.6	55	$12.7	73
Virginia	1.3	$30.9	178	$40.7	234
Washington	10.9	$267.8	1,538	$352.1	2,023
West Virginia	0.1	$1.9	11	$2.5	14
Wisconsin	1.2	$29.2	168	$38.4	221
Wyoming	0.0	$0.1	0	$0.1	1

Table 5: State-level impact of 10 percent export restrictions on high-tech exports[25]

	% of U.S. High-tech Exports	Exports, Year 1 (Millions)	Jobs, Year 1	Exports, Year 5 (Millions)	Jobs, Year 5
Alabama	0.6	$28.9	166	$38.0	218
Alaska	0.0	$0.8	4	$1.0	6
Arizona	2.1	$100.7	578	$132.4	760
Arkansas	0.3	$16.1	92	$21.1	121
California	18.4	$900.4	5,172	$1,183.8	6,800
Colorado	1.1	$53.1	305	$69.8	401
Connecticut	2.0	$99.7	573	$131.1	753
Delaware	0.4	$21.6	124	$28.4	163
District of Columbia	0.2	$8.7	50	$11.4	65
Florida	4.4	$217.2	1,248	$285.6	1,640
Georgia	3.0	$144.6	831	$190.1	1,092
Hawaii	0.0	$0.7	4	$0.9	5
Idaho	0.4	$17.9	103	$23.6	136
Illinois	3.0	$144.8	832	$190.4	1,094
Indiana	2.6	$129.5	744	$170.3	978
Iowa	0.3	$14.2	81	$18.6	107
Kansas	0.7	$34.9	201	$45.9	264
Kentucky	3.1	$151.2	869	$198.9	1,142
Louisiana	0.1	$4.3	25	$5.6	32
Maine	0.1	$7.0	40	$9.2	53
Maryland	1.1	$53.5	308	$70.4	404
Massachusetts	4.0	$197.5	1,134	$259.7	1,492
Michigan	1.1	$56.1	322	$73.8	424
Minnesota	1.7	$80.9	465	$106.3	611
Mississippi	0.5	$22.1	127	$29.1	167
Missouri	0.6	$31.6	181	$41.5	238
Montana	0.0	$2.3	13	$3.0	17
Nebraska	0.2	$9.3	54	$12.3	71
Nevada	0.5	$22.3	128	$29.3	168

New Hampshire	0.6	$30.4	175	$40.0	230
New Jersey	2.3	$113.5	652	$149.2	857
New Mexico	0.5	$24.4	140	$32.1	184
New York	3.2	$155.8	895	$204.8	1,177
North Carolina	2.6	$129.1	741	$169.7	975
North Dakota	0.0	$1.9	11	$2.5	14
Ohio	2.2	$107.7	619	$141.6	813
Oklahoma	0.3	$15.5	89	$20.3	117
Oregon	2.6	$125.6	721	$165.1	949
Pennsylvania	2.4	$115.9	666	$152.4	875
Rhode Island	0.1	$4.1	23	$5.4	31
South Carolina	1.8	$86.6	498	$113.9	654
South Dakota	0.0	$0.6	4	$0.8	5
Tennessee	1.8	$88.7	509	$116.6	670
Texas	12.4	$608.6	3,496	$800.2	4,596
Utah	0.8	$39.2	225	$51.5	296
Vermont	0.4	$19.3	111	$25.3	146
Virginia	1.3	$61.9	355	$81.4	467
Washington	10.9	$535.6	3,077	$704.2	4,045
West Virginia	0.1	$3.8	22	$5.0	29
Wisconsin	1.2	$58.4	336	$76.8	441
Wyoming	0.0	$0.2	1	$0.2	1

Table 6: State-level impact of 20 percent export restrictions on high-tech exports[26]

	% of U.S. High-tech Exports	Exports, Year 1 (Millions)	Jobs, Year 1	Exports, Year 5 (Millions)	Jobs, Year 5
Alabama	0.6	$57.8	332	$76.0	437
Alaska	0.0	$1.5	9	$2.0	12
Arizona	2.1	$201.4	1,157	$264.7	1,521
Arkansas	0.3	$32.2	185	$42.3	243
California	18.4	$1,800.7	10,343	$2,367.6	13,600
Colorado	1.1	$106.2	610	$139.7	802
Connecticut	2.0	$199.4	1,145	$262.1	1,506
Delaware	0.4	$43.3	249	$56.9	327
District of Columbia	0.2	$17.3	99	$22.8	131
Florida	4.4	$434.4	2,495	$571.2	3,281
Georgia	3.0	$289.2	1,661	$380.2	2,184
Hawaii	0.0	$1.4	8	$1.8	10
Idaho	0.4	$35.9	206	$47.2	271
Illinois	3.0	$289.6	1,664	$380.8	2,187
Indiana	2.6	$259.0	1,488	$340.5	1,956
Iowa	0.3	$28.3	163	$37.3	214
Kansas	0.7	$69.8	401	$91.8	527
Kentucky	3.1	$302.5	1,737	$397.7	2,284
Louisiana	0.1	$8.6	49	$11.3	65
Maine	0.1	$14.1	81	$18.5	106
Maryland	1.1	$107.1	615	$140.8	809
Massachusetts	4.0	$395.0	2,269	$519.3	2,983
Michigan	1.1	$112.2	644	$147.5	847
Minnesota	1.7	$161.7	929	$212.7	1,222
Mississippi	0.5	$44.3	254	$58.2	334
Missouri	0.6	$63.1	362	$83.0	477
Montana	0.0	$4.5	26	$6.0	34
Nebraska	0.2	$18.7	107	$24.6	141
Nevada	0.5	$44.6	256	$58.7	337

New Hampshire	0.6	$60.8	349	$80.0	459
New Jersey	2.3	$227.0	1,304	$298.4	1,714
New Mexico	0.5	$48.8	281	$64.2	369
New York	3.2	$311.6	1,790	$409.7	2,353
North Carolina	2.6	$258.2	1,483	$339.4	1,950
North Dakota	0.0	$3.8	22	$5.0	29
Ohio	2.2	$215.4	1,237	$283.2	1,626
Oklahoma	0.3	$30.9	178	$40.6	233
Oregon	2.6	$251.2	1,443	$330.3	1,897
Pennsylvania	2.4	$231.8	1,331	$304.8	1,751
Rhode Island	0.1	$8.2	47	$10.7	62
South Carolina	1.8	$173.2	995	$227.8	1,308
South Dakota	0.0	$1.2	7	$1.6	9
Tennessee	1.8	$177.4	1,019	$233.2	1,340
Texas	12.4	$1,217.2	6,992	$1,600.4	9,193
Utah	0.8	$78.4	450	$103.0	592
Vermont	0.4	$38.6	221	$50.7	291
Virginia	1.3	$123.8	711	$162.7	935
Washington	10.9	$1,071.2	6,153	$1,408.5	8,090
West Virginia	0.1	$7.6	44	$10.0	57
Wisconsin	1.2	$116.8	671	$153.6	882
Wyoming	0.0	$0.3	2	$0.4	2

In summary, the economic and employment impacts of overly stringent export controls on emerging technologies would be significant and provide one more reason why the administration should tread extremely cautiously in identifying emerging or foundational technologies as candidates for export controls. Indeed, while the scope of technologies that may be identified as foundational is currently unknown, the deleterious economic and employment effects identified in this report would only be heightened if a broader set of technologies were made candidates for export controls.[27]

POLICY PRINCIPLES AND RECOMMENDATIONS

Several policy principles and recommendations should guide the administration's development of an export control regime for emerging and foundational technologies.

First, **export controls must be regularly updated to reflect the global state of play in advanced-technology industries, such that controls do not preclude U.S. enterprises' ability to sell high-tech goods and services that are on a technical par with commercially available goods and services from foreign competitors.** For instance, in some cases, overly stringent export control regulations have prevented the sale of noncritical high-performance computing (HPC) systems to customers in certain nations, a policy decision that (as has been the case with regard to China) has had the unintended consequence of further spurring these nations to pursue their own HPC development programs. HPC vendors from a number of countries, from China and Japan to South Korea and Taiwan, have benefitted from their ability to step in and make sales in situations wherein potential sales of U.S.-made HPC systems have been impeded by export control regulations. When Chinese makers of HPC interconnects and high-speed network-interface chips are able to support the development of HPC systems nearing speeds of 100 petaflops, as *Scientific Computing World* has reported, U.S. export controls preventing exports of similar, U.S.-produced components are unlikely to achieve their intended purpose.[28] That's why a thorough understanding of the global state of play with regard to commercially available advanced technology systems will be vital to developing a U.S. regime of export controls for emerging and foundational technologies. As such, the issue of foreign availability is fundamental to whether BIS should establish a control on an identified emerging technology.[29] **Accordingly, emerging technologies that are ultimately deemed to meet the statutory standards for export controls should be designated as such only in cases of exclusive development and availability within the U.S. market—and the controls should be removed if and when that exclusivity no longer exists.[30]**

BIS's scope of controls for emerging products should be limited to those products that provide a specific, identifiable, and qualitative military advantage.

BIS's scope of controls for emerging products should be limited to those products that provide a specific, identifiable, and qualitative military advantage.[31] BIS's November 2018 advanced notice of proposed rulemaking noted that technologies essential to U.S. national security are those that, for example, "have potential conventional weapons, intelligence collection, weapons of mass destruction [WMD], or terrorist applications or could provide the United States with a qualitative military or intelligence advantage."[32] This means it is important to identify the narrow and specific instances wherein technology fields, such as armaments, munitions, and technological utilization in the battlefield space, are still nascent and have a connection back to national security equities. This matters because technologies frequently have multiple applications, the majority of which do not present national security concerns.[33]

Indeed, many of the technologies BIS identified for possible inclusion as emerging technologies (e.g., AI, blockchain, virtual reality) are dual-use in nature and still in relatively early phases of development. These factors pose a challenge for identifying

technologies—some of which may have only limited military use—without compromising their development domestically.[34] AI is a case in point. As an emerging "general purpose technology," it is a technology that will be used broadly in many sectors and applications to cut costs and drive innovation. As such, AI will be used in a massive number of applications, most of which will be commercial. It's difficult to imagine how an export control regime would limit AI exports without significantly reducing overall U.S. exports, competitive advantage, or innovation.

However, that is not to say BIS should do nothing. In some cases, BIS should focus on ensuring existing bans on certain sensitive applications continue to cover new sensitive applications that make use of emerging or foundational technologies. For example, a ban on certain advanced weapons systems should also extend to all AI-enabled advanced weapons systems. However, what it generally should not do is broadly and unilaterally limit or ban the sale of EFTs to other nations. Unilateral controls imposed on entire, broad technology areas such as AI would make it very difficult for U.S. advanced-technology companies to innovate and compete effectively in global markets. As noted, China and other nations are already working on developing these technologies, and for many of them, there are alternative sellers in other nations. In most cases, simply possessing the technology does not significantly advance our adversaries' technical capabilities.

Recognize that existing export control regimes already adequately protect many of the technologies identified. For instance, additive manufacturing (3D printing) depends on the digital print instruction file from which an object is synthesized (i.e., printed) through successive layers of materials. But such digital print instruction files are subject to existing dual-use regulations and International Traffic in Arms Regulations (ITAR) governing the transfer of technical data, which means subjecting additive manufacturing technology to additional export controls is unnecessary and counterproductive.[35] Therefore, as BIS and related agencies identify specific national security risks stemming from the development of AI and other advanced-technology applications, they should first determine whether existing catch-all controls in the ITAR and the Export Administration Regulations that are designed to address military and WMD threats are insufficient.[36] The United States Munitions List Category XI(d), for example, controls all technical data of any sort directly related to any of the military electronics or computers subject to the ITAR.

Export controls should not be placed on established technologies. The list of technologies identified as possible candidates for export controls actually includes several long-established technologies, and controls should not be applied to them retroactively. Examples include additive manufacturing, AI evolution and genetic algorithms, expert systems research, and logistics modeling and optimization technology—which has been used to solve mathematical optimization problems for well over 30 years.[37] Indeed, in most cases, the so-proposed "emerging technologies" have already emerged.

Existing license exceptions should apply to any controls applied to emerging technologies. Existing license exceptions, exclusions, or authorizations should apply to any controls applied to emerging technologies.[38]

Continue to coordinate export controls internationally. Export control regimes are most successful when they are coordinated internationally. ECRA already encourages the use of multilateral control agreements, stating in Section 1752 that "[e]xport controls that are multilateral are most effective" and calling for the "less effective" unilateral controls to have "limited" use.[39] Instead of unilaterally identifying a set of emerging technologies as candidates for export controls, the administration should collaborate with like-minded nations to identify a narrow and specific set of technologies that should be subject to export controls.

Recognize that partnerships are essential. Given the complexity involved in designating emerging (or foundational) technologies, ITIF supports BIS's formation of an Emerging Technology Technical Advisory Committee. A strong partnership between government, industry, and academia will be essential if an export control regime for EFTs is going to be established that produces the intended benefit of protecting U.S. national security and promoting U.S. technical leadership without compromising U.S. economic competitiveness or even unwittingly undermining that same technical leadership.[40]

The export control regime should be established in order to protect U.S. national security interests without placing U.S. competitiveness in emerging technologies at risk.

Focus not just on product exports but also on technology transfer. Rather than restricting exports of most emerging and foundational technologies, BIS should focus on the transfer of EFT-based technical know-how to U.S. adversaries. For instance, the Chinese government has employed the weapon of forced technology transfer to gain technological know-how in a variety of industries, from rail and biopharmaceuticals to cloud computing. This suggests that BIS should focus less on product exports and more on transfers of actual technology know-how (joint ventures, technology licensing, etc.) to organizations (e.g., private companies, state-owned enterprises, and government organizations) from nations that continue to make coerced technology transfer a central component of their economic development strategies.[41]

Finally, as important as it is to examine the efficacy of export controls on emerging technologies, **the United States needs comprehensive strategies to ensure it remains the world's leader in developing advanced technologies in areas like artificial intelligence (AI), quantum computing, and biomedical innovation.** Export controls will mean very little if the United States is not at the forefront of developing the world's most sophisticated technologies. This means the United States needs to increase federal investment in R&D (which recently has fallen to its lowest point as share of GDP since 1995), ensuring a robust STEM talent pipeline, and developing comprehensive strategies to ensure U.S. leadership in particular technology areas.[42] For instance, succeeding in AI requires more than just having leading companies make investments. It requires a healthy ecosystem of AI companies, robust AI inputs, and organizations that are motivated and free to use AI. A national AI strategy is necessary to bolster U.S. competitiveness, strengthen national security, and maximize the societal benefits that the country could derive from AI. To that end, a national strategy should: support key AI organizational inputs, such as data, AI skills, and R&D; accelerate public sector adoption of AI, including for national security; spur AI development and adoption in industry; support digital free trade policies; foster

innovation-friendly regulation; and provide workers with better tools to manage AI-driven workforce transitions.[43]

CONCLUSION

Although the U.S. government is right to act to prevent defense-related technologies from being adopted by potential adversaries, BIS should be cautious in its application of export controls to emerging technologies. Moreover, the export control regime should be established in order to protect U.S. national security interests without placing U.S. competitiveness in emerging technologies at risk. Broad export controls would reduce the revenues domestic firms rely on to invest in the technologies that allow them to stay competitive in the long term while providing employment, thereby threatening jobs across the United States. Instead, restrictions should be constructed to target specific military technologies as narrowly as possible while BIS evaluates the potential of coordinated international action, which is necessary for any export control regime to be effective.

ENDNOTES

1. John S. McCain National Defense Authorization Act for Fiscal Year 2019, Sec. 1758, H.R.5515, 115th Cong. (2018), https://www.congress.gov/bill/115th-congress/house-bill/5515/text#toc-H354D0B2951CE453DA3268434BECD0636.
2. Bureau of Industry and Security, "License Exceptions Supplement No. 1," August 3, 2018, https://www.bis.doc.gov/index.php/documents/regulation-docs/2255-supplement-no-1-to-part-740-country-groups-1/file.
3. U.S. Census Bureau, USA Trade Online (exports, by NAICS and destination), accessed April 29, 2019, https://usatrade.census.gov/data/.
4. Conference Report to Accompany H.R. 5515, 115th Cong. (2018), 2186, https://docs.house.gov/billsthisweek/20180723/CRPT-115hrpt863.pdf.
5. "Review of Controls for Certain Emerging Technologies," *Federal Register* Vol. 83, No. 223, November 19, 2018, https://www.gpo.gov/fdsys/pkg/FR-2018-11-19/pdf/2018-25221.pdf.
6. Bureau of Industry and Security, "Review of Controls for Certain Emerging Technologies," November 19, 2018, https://www.federalregister.gov/documents/2018/11/19/2018-25221/review-of-controls-for-certain-emerging-technologies.
7. Robert D. Atkinson and Stephen J. Ezell, "Comments to the U.S. Commerce Department on Export Controls for Emerging Technologies" (Information Technology and Innovation Foundation, December 2018), 2, https://itif.org/publications/2018/12/13/comments-us-commerce-department-export-controls-emerging-technologies.
8. Robert D. Atkinson and Caleb Foote, "Is China Catching Up to the United States in Innovation?" (Information Technology and Innovation Foundation, March 2019), https://itif.org/publications/2019/04/08/china-catching-united-states-innovation.
9. Stephen J. Ezell et al., "Manufacturing Digitalization: Extent of Adoption and Recommendations for Increasing Penetration in Korea and the U.S." (Information Technology and Innovation Foundation, August 2018), https://itif.org/publications/2018/08/13/manufacturing-digitalization-extent-adoption-and-recommendations-increasing; Robert Atkinson, review of *AI Super-Powers: China, Silicon Valley, and the New World Order*, by Kai-Fu Lee (Boston: Houghton Mifflin Harcourt, 2018), https://www.nyjournalofbooks.com/book-review/ai-superpowers.
10. Jeffrey Rittener, "Intel Comments Re: Review of Certain Emerging Technologies (RIN 0694-AH61)," January 10, 2019, 7.
11. Stephen J. Ezell and Robert D. Atkinson, "The Vital Importance of High-Performance Computing to U.S. Competitiveness" (Information Technology and Innovation Foundation, April 2016), https://itif.org/publications/2016/04/28/vital-importance-highperformance-computing-us-competitiveness.
12. Karri Allen, "Communications Satellites and U.S. Export Controls: Correcting the Balance," *CommLaw Conspectus* 18, (2009), scholarship.law.edu/cgi/viewcontent.cgi?article=1462&context=commlaw.
13. Ibid.
14. Ibid.
15. Bureau of Industry and Security, "U.S. Space Industry "Deep Dive" Assessment: Impact of the U.S. Export Controls on the Space Industrial Base," February 2014, https://www.bis.doc.gov/index.php/documents/technology-evaluation/898-space-export-control-report/file.
16. Ibid.; Satellite Industry Association, "State of the Satellite Industry Report 2017," (June 2017), https://www.sia.org/wp-content/uploads/2017/07/SIA-SSIR-2017.pdf.

17. U.S. Census Bureau, USA Trade Online (state and total exports, by NAICS and destination), accessed April 29, 2019, https://usatrade.census.gov/data/.
18. Bureau of Economic Analysis, "U.S. Trade in Services, by Type of Service and by Country or Affiliation," October 19, 2018, https://www.bea.gov/data/intl-trade-investment/international-trade-goods-and-services.
19. Chris Rasmussen, "Jobs Supported by Exports 2016: An Update," International Trade Administration, August 2, 2017, https://www.trade.gov/mas/ian/build/groups/public/@tg_ian/documents/webcontent/tg_ian_005543.pdf.
20. The Trade Partnership, "CompTIA Tech Trade Snapshot," May 2018, https://tradepartnership.com/reports/comptia-tech-trade-snapshot-imports-and-exports-of-tech-products-and-services-2018/; Robert D. Atkinson and John Wu, "The 2017 State New Economy Index" (Information Technology and Innovation Foundation, November 2017), https://itif.org/publications/2017/11/06/2017-state-new-economy-index; John Wu, Adams Nager, and Joseph Chuzhin, "High-Tech Nation: How Technological Innovation Shapes America's 435 Congressional Districts" (Information Technology and Innovation Foundation, November 2017), https://itif.org/publications/2016/11/28/technation.
21. U.S. Census Bureau, USA Trade Online (exports, by NAICS and destination), accessed April 29, 2019, https://usatrade.census.gov/data/; Bureau of Economic Analysis, "U.S. Trade in Services, by Type of Service and by Country or Affiliation," October 19, 2018, https://www.bea.gov/data/intl-trade-investment/international-trade-goods-and-services.
22. U.S. Census Bureau, USA Trade Online (exports, by NAICS and destination), accessed April 29, 2019, https://usatrade.census.gov/data/; Bureau of Economic Analysis, U.S. Trade in Services, by Type of Service and by Country or Affiliation, October 19, 2018, https://www.bea.gov/data/intl-trade-investment/international-trade-goods-and-services; Rasmussen, "Jobs Supported by Exports 2016: An Update."
23. Ibid.
24. U.S. Census Bureau, USA Trade Online (exports, by NAICS and destination), accessed April 29, 2019, https://usatrade.census.gov/data/; Bureau of Economic Analysis, U.S. Trade in Services, by Type of Service and by Country or Affiliation, October 19, 2018, https://www.bea.gov/data/intl-trade-investment/international-trade-goods-and-services; Chris Rasmussen, "Jobs Supported by Exports 2016: An Update," International Trade Administration, August 2, 2017, https://www.trade.gov/mas/ian/build/groups/public/@tg_ian/documents/webcontent/tg_ian_005543.pdf ; The Trade Partnership, "CompTIA Tech Trade Snapshot", May 2018, https://tradepartnership.com/reports/comptia-tech-trade-snapshot-imports-and-exports-of-tech-products-and-services-2018/.
25. Ibid.
26. Ibid.
27. Conversely, of course, a more-limited set of export controls on emerging technologies would reduce the effects estimated here.
28. "China: Two 100 Petaflop Machines," *Scientific Computing World,* August 25, 2015, https://www.scientific-computing.com/news/china-two-100-petaflop-machines-within-year.
29. Information Technology Industry Council (ITI), "Comment on ANPRM Regarding Review of Controls for Certain Emerging Technologies" (ITI, January 10, 2019), 2, https://www.itic.org/public-policy/ITICommentsECRAEmergingTechnologyANPRM.pdf.
30. Ibid, 3.
31. Ibid, 9.
32. "Review of Controls for Certain Emerging Technologies," *Federal Register*.

33. Rittener, "Intel Comments Re: Review of Certain Emerging Technologies (RIN 0694-AH61)," 3.
34. Atkinson and Ezell, "Comments to the U.S. Commerce Department on Export Controls for Emerging Technologies," 2–3.
35. HP Inc., "Comments Submitted in Response to ANPRM on 'Emerging Technologies,'" January 10, 2019, 2.
36. Google, "Comments Submitted in Response to Advanced Notice of Proposed Rulemaking Regarding Review of Controls for Certain Emerging Technologies," 10, January 10, 2019.
37. ITI, "Comment on ANPRM Regarding Review of Controls for Certain Emerging Technologies," 4.
38. Ibid, 6.
39. John S. McCain, National Defense Authorization Act for Fiscal Year 2019, Sec. 1752, H.R.5515, 115th Cong. (2018), https://www.congress.gov/bill/115th-congress/house-bill/5515/text#toc-H354D0B2951CE453DA3268434BECD0636.
40. Rittener, "Intel Comments Re: Review of Certain Emerging Technologies (RIN 0694-AH61)," 7.
41. Atkinson and Ezell, "Comments to the U.S. Commerce Department on Export Controls for Emerging Technologies," 7.
42. *Reauthorization of the SBA's Innovation Programs: Hearing Before the U.S. Senate Small Business and Entrepreneurship Committee*, (testimony of Stephen J. Ezell, Vice President, Global Innovation Policy, Information Technology and Innovation Foundation), 116th Cong. (2019) https://www.sbc.senate.gov/public/index.cfm/2019/5/reauthorization-of-the-sba-s-innovation-programs.
43. Joshua New, "Why the United States Needs a National Artificial Intelligence Strategy and What It Should Look Like" (Center for Data Innovation, December 2018), https://www.datainnovation.org/2018/12/why-the-united-states-needs-a-national-artificial-intelligence-strategy-and-what-it-should-look-like/.

ACKNOWLEDGMENTS

The authors wish to thank Rob Atkinson for providing guidance on this report. Any errors or omissions are the authors' alone.

ABOUT THE AUTHORS

Stephen J. Ezell is ITIF vice president for Global Innovation Policy and focuses on science, technology, and innovation policy as well as international competitiveness and trade policy issues. He is the coauthor of *Innovating in a Service Driven Economy: Insights Application, and Practice* (Palgrave McMillan, 2015) and *Innovation Economics: The Race for Global Advantage* (Yale 2012).

Caleb Foote is a research assistant at the Information Technology and Innovation Foundation. Prior to joining ITIF, Caleb graduated from Brown University with a concentration in Economics. He previously interned for TechHelp and serves as a trustee of the American Parliamentary Debate Association.

ABOUT ITIF

The Information Technology and Innovation Foundation (ITIF) is a nonprofit, nonpartisan research and educational institute focusing on the intersection of technological innovation and public policy. Recognized as the world's leading science and technology think tank, ITIF's mission is to formulate and promote policy solutions that accelerate innovation and boost productivity to spur growth, opportunity, and progress.

FOR MORE INFORMATION, VISIT US AT WWW.ITIF.ORG.