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Note: Comments on earlier drafts from C. Fred Bergsten, Kimberly Ann Elliott, Ellen Frost, Gary C. Hufbauer, J. Bradford Jensen, Catherine Mann, Marcus Noland, William Reinsch, David Rose, Howard Rosen, Jeffrey Schott, Neena Shenai, Edwin M. Truman, and Mark Webber have greatly improved this brief, though errors that remain are entirely our own responsibility.

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OVERVIEW

In the early 1990s, as the Cold War ended, US export controls that aimed to keep high-tech goods and technologies out of the hands of enemies deterred from $15 billion to $25 billion of such exports, according to Peterson Institute research at the time. Recent US export controls, aimed at a different set of potential security threats, and only modestly streamlined in administrative structure until 2010 reform initiatives, seem to deter US high-tech exports considerably less.

As percentages of seven broad industrial categories of high-tech exports, estimated American export shortfalls from national security controls have fallen from roughly 5 percent in the early 1990s to slightly over 1 percent in the mid-2000s. These estimates are reasonably robust across alternative estimation techniques and also for a data update through 2011.

Reform of American national-security export controls would seem therefore, somewhat surprisingly, to have only modest effects on the level of US high-tech exports. (Such reform would, of course, shift the identities of import customers for American high-tech exports more significantly.)

Our explanation for these modest overall export-suppression effects, even in high-profile importer markets like China’s, is two-fold. American exporters seem to have developed a distinctive competitive ability to shift their sales efforts flexibly among customers and products that are subject to tight, loose, and few controls. (Customers include their own overseas affiliates, and products include inputs traded within global supply chains.) Important importing countries seem to have developed a distinctive ability to shift their sourcing flexibly among alternative suppliers, including a growing set of emerging exporters of high-tech goods.

Though importing countries that are global security threats are still deprived of up to $250 billion worth of high-technology goods annually, according to our estimates, it is European, Japanese, and leading emerging exporters, rather than the United States, which currently seem to suffer the largest export shortfalls, unlike the early 1990s.

INTRODUCTION

American export policies are in makeover mode. As part of an effort to speed recovery and to “rebalance” the macroeconomy, the Obama administration has urged a medium-term, five-year doubling of American exports, the National Export Initiative (NEI). In parallel, and as part of growing concerns over national and global security, it initiated a sweeping redesign of the licensing systems that for years have aimed to deny cutting-edge, “dual use” (military and civilian) goods\(^1\) and technologies to countries and ideological movements that pose threats to global peace and stability. Taken

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1. For dual-use examples, sensors, night-vision equipment, aircraft and aircraft engines, firearms and ammunition, space vehicles, submersible vessels, and oceanographic equipment.
together, these two efforts seek to advance a third important objective, stronger American growth by rekindling historic momentum in innovation and high-technology sectors.

This Policy Brief relates to all three endeavors. It assesses the degree to which the United States under-exports in important high-tech industrial sectors (chemicals, metal products, machinery, equipment, and instruments), and whether estimated export shortfalls are correlated with still-cumbersome American export-control procedures. It is based on a forthcoming Peterson Institute Working Paper (Sundaram and Richardson 2013) that refines a prior generation’s set of Peterson estimates. Those early-1990s estimates implied large American export shortfalls from national-security controls, as large as 5 percent of its high-tech exports.

Importing countries that are considered to be security threats by the United States and its peer/rival suppliers are denied access to as much as $250 billion per year of high-tech exports, according to our estimates, roughly half of their potential normal imports from the 10 exporters on which we focus.

In the current update, our central estimates suggest surprisingly small high-tech export losses in the mid-2000s, just a little more than 1 percent of American export potential, and even less in an update to 2011. Large estimated shortfalls in tightly controlled, high-risk destination markets do indeed appear. But they seem to be largely counterbalanced by superior American export performance in moderate-risk destination markets, which include China, India, and a large group of former Eastern Bloc and “nonaligned” countries. The superior performance there is estimated to come at the expense of traditional American exporter rivals from Europe and Japan, and also at the expense of newly emerging rivals with high-tech export capability, from Brazil, China, India, Israel, and Mexico. These rivals, however, out-perform US exporters in the highest-risk destination markets.

Most of our estimates are statistically robust; that is, their patterns are qualitatively and quantitatively similar across a range of alternative estimation methods and for data updated through 2011.2

Three conclusions stand out. First, the apparent resilience of American high-tech export success is quite surprising in our preferred estimates. Our main explanation for it is the growing flexibility that large, globally agile corporate exporters have developed to respect national-security export restrictions, while at the same time adjusting their investment, supply-chain, and marketing strategies to compensate in a way that avoids overall losses of corporate business. In this they have been aided by modest streamlining of historical US export-control procedures.

Second, and also surprising, is the apparent global success of security-oriented export controls. Importing countries that are considered to be security threats by the United States and its peer/rival suppliers are denied access to as much as $250 billion per year of high-tech exports, according to our estimates, roughly half of their potential normal imports from the 10 exporters on which we focus.

Third—and following from the first two conclusions—European, Japanese, and emerging-economy exporters seem to be the principal sources of global high-tech export denial for security reasons. Our estimates suggest that they are not as resilient or resourceful as their American-exporter rivals and peers. (Important in these conclusions, but implicit, is the fact that every country’s recorded exports include exports by affiliates of “foreign investors.”)

Our statistical procedures for estimating high-tech export shortfalls improve markedly on the statistical craftsmanship that supported the 1993 study. But in both studies, detailed institutional knowledge is required to make sense of the statistical estimates.

AMERICAN EXPORTS AND EXPORT CONTROLS: INSTITUTIONAL BACKDROP AND HISTORY

The National Export Initiative (NEI) and the Restoration of American Growth

The spirit of the NEI is creative. American consumption cannot drive recovery while households are saving more to rebuild devastated balance sheets. American business investment cannot drive recovery until broad-based recovery is visibly on the horizon. And American fiscal stimulus cannot drive recovery in any sustained way given today’s overhang of large and growing national debt.

By contrast, net exports are a very attractive tool to drive recovery, not merely as the default option, but

- because successful export promotion often goes hand in hand with economic dynamism that contributes to strong aggregate productivity growth,3 and

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2. However, as detailed below, in one particular important sector, electrical machinery, we cannot completely rule out volatile estimates. And these include one narrow extreme in which the US export shortfall in that particular important sector is as high as 25 percent.

3. See Lewis and Richardson (2001), Bradford, Grieco, and Hufbauer (2005), and Melitz and Treffer (2012) for selectively spaced surveys. Merely arithmetically, a doubling of US export intensity, say from 10 percent to 20 percent of GDP, as proposed in Bergsten (2011) and christened “from 10 in ’10 to 20 in ’20,” would raise aggregate US productivity growth rates by more than a tenth.
because American exports that satisfy global consumption, investment, and government-procurement demands are widely agreed to be the US contribution to a healthier and more balanced (rebalanced) global recovery.

Moreover, because American exports include manufactures and services that embody exceptional levels of American innovation and dynamism, a successful doubling of exports implicitly boosts those sectors of the American economy that have demonstrable competitive and comparative advantage. Export facilitation privileges those sectors that have especially high levels and growth of productivity relative to other sectors, essentially implementing the most fundamental and least objectionable form of commonsense industrial policy—recognizing and encouraging exporting “winner” sectors, if not necessarily “picking winners” among them.4

To realize these creative export objectives most predictably, the NEI implicitly targets high-technology exports. The most recent Economic Report of the President (2012) devotes almost 20 pages to policy initiatives that support existing exporters and expand their market access, which enhance exporting by new small- and medium-sized firms, and which reset the rules for official export finance that level the playing field with emerging-economy export rivals like China. A generation ago, as emerging and newly industrializing economies were in their infancy, following a putative Japanese development model, similar concerns led to an American export drive that was remarkably successful, and that paralleled the so-called information-and-communication technology (ICT) revolution of the same period (Mann with Kierkegaard 2006).

Peterson Institute research (Hufbauer and Rodriguez 2001, Richardson and Rindal 1995 and 1996) was instrumental in this generational antecedent to today’s NEI and Richardson (1993) was the part of that research devoted to the way that many of our own American policies at the time “shot ourselves in the ‘export foot’.”

Of these “export disincentives” (XDs) in the early ‘90s, the most important quantitatively, far and away, was our national-security export-control regime. The 1993 study (pages 127–130) found that $15 billion to $25 billion of lost high-tech exports could be attributed to export controls for purposes of national security and anti-proliferation, and more than half of that amount to unilateral American controls that were not mirrored by our security partners (who were simultaneously our historical exporter rivals).

The current Policy Brief is an update of that part of the 1993 study. It aims to determine whether export losses of those magnitudes, due to national-security and other export controls, are still characteristic today. Our initial suspicion for this study was that recent apoplectic expert assessments of US export controls, described in the next section, almost surely suggested high quantitative estimates representing foregone exports, much higher than 20 years ago.

In this updated research, however, that suspicion has not been confirmed—though foregone exports are still present, quantitatively. We estimate that lost American high-tech exports attributable to export controls6 are in the neighborhood of $1.7 billion to $6.6 billion per year—negligible to 1.1 percent of measured high-tech exports. Tables 1 and 2 summarize results whose detail is described on the next page. The first and second rows pertain to moderate- and high-threat importers, and the third row adds up estimated export gains and losses from the first two rows. Grey shading differentiates estimated US export shortfalls from estimated above-normal exports.

American Export Controls and National Security: History and Current Assessments

The American export control system has for more than half a century aimed to keep the cream of advanced US technology out of the hands of enemies and threatening entities. Its original Cold War motivation embodied the noblest of American objectives—to safeguard both national security and technological momentum—and to do so multilaterally on behalf of the entire “Western Alliance.”

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6. Economic sanctions, such as those targeting Cuba, Iran, Libya, and Syria, are included in the current study (as they were also in the 1993 study) because of their close relationship to the motives behind today’s national-security controls. More thoroughgoing political sanctions, such as those isolating Burma/Myanmar and North Korea, are not included.

7. In the mid-1990s a new set of inter-governmental conventions was adopted by adherents to the Cold War COCOM arrangements (COCOM stood for Coordinating Committee on Multilateral Export Controls), with the hope of preserving the multilateralism of remaining export controls. These so-called Wassenaar Arrangements agreed multilaterally to pare the list of controlled dual-use items and expand the arrangements’ membership, e.g., to Russia and four Central European countries in 1996. Since that time, the Wassenaar Arrangements have expanded still further, to some 40 countries, which exchange information and hold periodic update meetings. But today this all amounts to little more than mutual notification arrangements. Every adherent informs the others of its own evolving export control procedures and coverage, but national discretion to imitate or not turns Wassenaar, at best, into de facto parallel unilateralism: not really concerted, hardly multilateral.
Today’s American export-control regime has the same broad motivation. But it has changed, of course—changed much too little, say its critics—in its targets, focus, and flexibility.

Its targets are different—proliferators, terrorists, and the institutions and states that tolerate them, instead of a Communist-bloc “second world.” Its focus is slightly amplified—“deemed exports” of technology, embodied in non-national employees, require licensing today; and garden-variety chemicals like fertilizers and “pathogenic organisms” may currently require licensing because of their potential usefulness in biological and chemical weapons (NRC 2009). The regime has become considerably more flexible in the 2000s—there are now a variety of license exceptions, blanket licenses for certain goods to trusted partners, Strategic Trade Authorizations (STAs) for license-free exports to governments of 37 close allies, often NATO partners, Validated End User (VEU) certifications (selective, multiple-transaction licensing since 2007 for authorized foreign recipients of US exports—often multinational corporate affiliates in moderate-threat countries such as China), and coordinated-across-agencies lists of suspicious entities abroad in target countries.

An all-encompassing intra-company transfer (ICT) license was proposed in writing in 2008, but never finalized (IUST, June 20, 2012, 5 and November 16, 2012, 17), and would likely have some role in ongoing reform.

None of this evolution amounts to much in the eyes of jaundiced export-control veterans and critics.

In the eyes of some commentators, the system devolved after the Cold War ended. One long-time export-control veteran (Wallerstein 2009), both analyst and overseer, said that the system became continuously “more arcane and ineffective.” More government agencies became more seriously involved, sometimes contentiously. More dual-use goods and technologies became available from more untraditional exporter sources (the proliferation of what is called “foreign availability”—the capacity for exports by suppliers with less assiduous control regimes).

In 2009 National Research Council (NRC) study Beyond ‘Fortress America’ is the latest in an NRC series of brutally grim assessments of American losses of exports and competitiveness from ill-focused export controls. That report is almost apoplectic in its indictment (no good for national security, no good for national prosperity). Another recent

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Table 1  Estimates 2011: US export overage to medium-threat importers (tier 3); US export shortfalls to high-threat importers (tier 4); and net estimates by sector, 2005 dollars, overage or shortfall

<table>
<thead>
<tr>
<th>Industrial chemicals</th>
<th>Chemical products</th>
<th>Metal products</th>
<th>Non-electric machinery</th>
<th>Electrical machinery</th>
<th>Transport equipment</th>
<th>Scientific equipment</th>
<th>Total</th>
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<td>−3.2</td>
<td>−3.4</td>
</tr>
</tbody>
</table>


Source: Sundaram and Richardson (2013), table 5 and data underlying table SA.

Table 2  Estimates 2004: US export overage to medium-threat importers (tier 3); US export shortfalls to high-threat importers (tier 4); and net estimates by sector, 2005 dollars, overage or shortfall

<table>
<thead>
<tr>
<th>Industrial chemicals</th>
<th>Chemical products</th>
<th>Metal products</th>
<th>Non-electric machinery</th>
<th>Electrical machinery</th>
<th>Transport equipment</th>
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<td>−1.1</td>
<td>−6.6</td>
</tr>
</tbody>
</table>


Source: Sundaram and Richardson (2013), table 5.

8. A deemed-export license is necessary to employ foreign nationals in any project in which they would attain access to technologies and other information relevant to controlled exports. In recent license applications, deemed exports represent only 5 percent—roughly 1000 per year in number out of 20,000. And 700 out of those 1000 come from only four American companies and are reportedly focused on Chinese nationals (IUST, February 26, 2010, 5–7).
assessment (Shenai 2010, 2) called the system “an over 50 year old piecemeal framework which no longer structurally or substantively serves its purpose.” Still another, a Foreign Affairs paper entitled “Losing Control,” has the dismissive subtitle “How U.S. Export Restraints Jeopardize National Security and Harm Competitiveness.”

Of course, export-control policy has always deterred exports—for security and other good reasons! But the underlying questions have always been how good the reasons really were and how serious the quantitative export deterrence was. Recent answers from the critical experts above have been uniformly discouraging. The results summarized below are more encouraging.

There are more than the usual reasons to appreciate the importance of expert critiques. On similar matters in the past they have been proved correct. That was one of the most surprising conclusions from Richardson (1993). In that study there was a striking correspondence between what experts said qualitatively about export disincentives (XDs) and what economic theory and empirical calculations showed about their size. Experts seemed to know which XDs were important and which were not. Even more surprising, experts had the ranking correct, from biggest XD (export controls) to smallest (antitrust, border tax adjustments).9

Such critical expert assessments began to be taken more seriously in late 2009. The US administration initiated a broad-based review of the export control regime. In early 2010, then-Defense Secretary Robert Gates presented the detailed results of the review in a speech remarkable for its wry detail and pithy candor.10

Several factors contribute ... to the wrong technology falling into the wrong hands. One major culprit is an overly broad definition of what should be subject to export classification and control. The real-world effect is to make it more difficult to focus on those items and technologies that truly need to stay in this country. Frederick the Great’s famous maxim that “he who defends everything defends nothing” certainly applies to export control.

This problem goes back a long way, and was evident well before the collapse of the Soviet Union. In 1982, when I became deputy director for intelligence at CIA, my responsibilities included tracking prohibited transfers of U.S. technology. It soon became apparent that the length of the list of controlled technologies outstripped our finite intelligence monitoring capabilities and resources. It had the effect of undercutting our efforts to control the critical items. We were wasting our time and resources tracking technologies you could buy at RadioShack.

Today, the government reviews tens of thousands of license applications for export to EU and NATO countries. In well over 95 percent of these cases, we say “yes” to the export. Additionally, many parts and components of a major piece of equipment—such as a combat vehicle or aircraft—require their own export licenses. It makes little sense to use the same lengthy process to control the export of every latch, wire, and lug nut for a piece of equipment like the F-16, when we have already approved the export of the entire aircraft.

In short, the time for change is long overdue if the application of controls on key items and technologies is to have any meaning. We need a system that dispenses with the 95 percent of “easy” cases and lets us concentrate our resources on the remaining 5 percent. By doing so, we will be better able to monitor and enforce controls on technology transfers with real security implications while helping to speed the provision of equipment to allies and partners who fight alongside us in coalition operations.

A second major obstacle we face is the bureaucratic apparatus that has grown up around export control—a byzantine amalgam of authorities, roles, and missions scattered around different parts of the federal government. In theory, this provides checks and balances—the idea being that security concerns, customarily represented by DoD, would check economic interests represented by the Commerce Department and balance out diplomatic and relationship-building equities represented by State. In reality, this diffusion of authority—where separate export-control lists are maintained by different agencies—results in confusion about jurisdiction and approval, on the part of companies and government officials alike ....

The system has the effect of discouraging exporters from approaching the process as intended. Multi-national companies can move production offshore,

9. But experts didn’t turn out to know everything. Compared to the quantitative, theory-based estimates, experts made one big systematic mistake. They “compressed the dispersion”—they systematically over-weighted the export losses from small estimated XDs, and under-weighted those from large estimated XDs. The qualitative expert assessments were summarized in chapter 5 of the 1993 book. The quantitative estimates made up chapters 4 and 5 of the book.

eroding our defense industrial base, undermining our control regimes in the process, and not to mention losing American jobs. Some European satellite manufacturers even market their products as being not subject to US export controls, thus drawing overseas not only potential customers, but some of the best scientists and engineers as well. At the same time, onerous and complicated restrictions too often fail to prevent weapons and technologies from going places they shouldn’t. They only incentivize more creative circumvention strategies—on the part of foreign companies, as well as countries that do not have our best interests at heart.

Concurrently, we have not updated our system to deal with the U.S. military’s transition to off-the-shelf procurement. More and more, our military is taking advantage of commercially manufactured items, presenting challenges when determining whether or not a given technology is acceptable for export. There are electronic components used in many third-generation cellular devices that are also important components of sophisticated stealth-defeating radar systems. We need to update our export-control system to reflect these realities.

Finally, the current export-control regime impedes the effectiveness of our closest military allies, tests their patience and goodwill, and hinders their ability to cooperate with US forces—this at a time when we count on allies and partners to fight with us in places like Afghanistan and potentially elsewhere. Not too long ago, a British C-17 spent hours disabled on the ground in Australia—not because the needed part wasn’t available, but because US law required the Australians to seek US permission before doing the repair. These are two of our very strongest allies for God’s sake! Similarly, close, long-standing allies and partners like South Korea have bought US aircraft only to encounter difficulties and delays in getting spare parts—something that weakens our bilateral relationships, our credibility, and ultimately American security.

Secretary Gates proceeded to initiate a four-part reform process to design, ideally and ultimately, a single export-control list, a single licensing agency, a single enforcement-coordination agency, and a single information-technology system. Though progress to date has been slow, especially on single-agency consolidation, the proposed reforms have moved ahead. Unifying definitions and electronic record-keeping systems are well-advanced by early 2013, under an Automated Export System (AES). The US administration created two new multi-agency, enforcement-oriented, information-gathering units in early 2012, with roughly 40 staff (IUST, March 9, 2012, 30).

But the integration of lists is only part way through the proposal stage—after more than two years of thoroughgoing inter-agency consideration of revisions to export-control categories and rules, with public and industry input. These revisions aim to transfer large numbers of items from State Department jurisdiction to the Commerce Department’s Commerce Control List (CCL). But all proposed revisions must be reviewed by Congress with 30-day notification, a process that is just beginning, piecemeal and contentiously, in early 2013. So-called pre-notification negotiations between administration officials and expert congressional staff remain awkward and halting. Congressional members, especially in the House of Representatives, are traditionally security vigilant, whereas administration agencies often have public mandates that are partly economic-commercial.11

The over-arching goal is to make controls target-effective, heightening the success of controls in denying access to key goods and technologies to truly high-threat buyers, and simultaneously streamlining the controls process in the large number of other cases. Target-effectiveness would be ultimately enhanced, according to administration plans to date, by a three-tier re-grouping of goods and technologies, with the highest tier being truly critical12 to maintaining US military and intelligence superiority. Streamlining would be ultimately enhanced by consolidation of most export licensing under the jurisdiction of a single agency, still very much a twinkle in reformers’ eyes.

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11. In the 2011–12 House, very similar Republican and Democratic alternative reform bills were in a drafting stage, each aimed at reauthorization of the moribund (since 2001, or by some reckonings since 1990) Export Administration Act. There was little-if any 2011–12 Senate initiative. See IUST, June 10, 2011, 21 and February 3, 2012, 1, 24–25.

12. Some administration officials have described the second tier, informally dubbed the Commerce Munitions List, to be made up of items “ancillary” to US military supremacy. All other items would fall into the residual third tier, and be subject to normal export-control procedures mediated by the Commerce Department’s Bureau of Industry and Security (BIS). The same officials, however, envision significant scaling back of third-tier control requirements, and significant narrowing of the 20-year-old commitments under the Wassenaar Arrangement (described above in note 7) to the first and second tier only (Wassenaar currently covers almost all items subject to US export controls). See IUST, December 9, 2011, 3–6, and November 4, 2011, 1, 23–25.
METHODS FOR ESTIMATING EXPORT NORMS AND SHORTFALLS

Any assessment of under- or over-exports requires a norm against which performance is measured. Shortfalls of measured exports from a well-accepted norm are then arguably an estimate of under-exports. The 1993 study pioneered recourse to a so-called gravity-equation norm for this purpose, building on the research of Bergstrand (1985). That study uncovered revealing patterns in US export shortfalls. They were especially large for high-tech sectors and concentrated on traditional Cold War enemies and security threats, and they were smaller percentages of Japanese and European rival exports.

The current study further builds on the near-universal acceptance of gravity-equation norm-setting in the ensuing 20 years, as well as on the significant methodological improvements in its empirical implementation and interpretation.13

Gravity-equation norming creates best-fit statistical estimates of what a country’s expected exports should be, sector-by-sector and trading-partner-by-trading-partner. They typically correlate a country’s exports with a long and familiar list of determinants, including trading partners’ size and prosperity and “distance” between them geographically, culturally, and institutionally (e.g., Do they both belong to a free trade area? Do they share a language? Are they cross-penetrated by diaspora populations or foreign direct investment from the same source countries?). When enough years of data are available, typical gravity-equation approaches can even control for trends in export supply capability and for atypical “shocks” to key export determinants such as hard-to-measure comparative advantage.

When using this empirical approach to setting an expected export norm, any other hard-to-measure (unmeasured, unmeasurable) export determinants will be reflected in the portion of measured exports that is not “explained by” (correlated with) the traditional gravity-equation determinants. This is the statistician’s measure called residual exports—what is left over to explain in export variation after purging measured export variation statistically of the familiar best-fit influences.

In the 1993 study, two years of unexplained residual exports, for the United States and for four traditional rival exporters, across 65 to 130 trading-partner importers, were the prime suspects for diagnosing the effects of export controls.

They were subjected to a sort of forensic diagnosis, judgmental and careful, but admittedly subjective.

Estimated US gravity-equation export residuals in the early 1990s turned out to be atypically negative, signifying US export shortfalls, as expected,

- in high-tech sectors compared to standard-tech,
- for importing trading partners that were identified as high threats to security compared to other importers, and
- in cases where the United States pursued stronger security-based stringency than its “Western Alliance” rival exporters (so-called unilateral-control cases in the earlier study).

The current study updates such forensic diagnosis, and does so using arguably broader and tighter methods. Eleven years of data across 169 trading partners and nine exporter rivals are used. The forensics are refined by a much less subjective, much more (statistically) definitive approach to the data called “difference-in-difference” analysis, developed in the past 20 years. Its name is perfectly descriptive, because the difference-in-difference technique is able to estimate statistically the size of export differences between American and rival exporters in different sectors across different groups of trading partners (trading partners that differ from each other in their degree of “security threat”) and across different years. Each estimated export shortfall can be assigned a statistical precision that is not possible in the subjective forensic approach of the 1993 study (e.g., being 95 percent confident that an estimated shortfall of 25 is the center of a likely range from 10 to 40).14

A further advantage of the current study’s 11 years of data (1994–2004)15 is the ability to estimate growing “foreign availability” of high-tech exports from newly emerging rival exporters. The US export-control regime has long paid lip service to the futility of export controls for national security in a world where the controlled goods, services, and technologies are available for import from rivals with loose controls, or with none at all. In such a world, export controls deliver zero security benefits.

13. Frankel (1997) was another Peterson Institute early user of gravity-equation approaches to norm-setting, followed by many others. Anderson (2011) is a recent survey (among many such surveys) by one of the pioneers of gravity equations’ multiple uses in explaining trade and in norm-setting, and of their multiple refinements in doing so. Less frequently used approaches to export norm-setting include so-called constant-market-shares analysis, applied, for example, by Del Gatto et al. (2011) and Noland (1998) and RCA (Revealed Comparative Advantage) analysis.

14. The modern methods could admittedly be applied to the old data underlying the 1993 study, and this would make comparisons of the results arguably apples-to-apples comparisons by adding statistical precision to the earlier results. But it would be unlikely to change their qualitative patterns. Unusual residuals that stand out in the subjective forensic approach are replicated in the modern approach by a large coefficient on a zero/one dummy variable attached to a country identity in the data, such as security threat. What the modern approach adds is statistical precision, whether that estimated coefficient is statistically significant.

15. Extended, as described below and in Sundaram and Richardson (2013) to 18 years (1994–2011) in a traded-goods shadow data set for the high-tech industrial-goods data that we use for our principal results.
A closely related advantage of these 11 years is that we are able to control for natural trends in competitive and comparative advantage in every exporter, associated for example with successful emerging-economy production shifts up the quality ladder from simple to more sophisticated goods or into global supply chains. Most of these natural shifts are the consequence of successful outward-oriented development strategies, not of traditional export controls, and need ideally to be purged from measured exports before the remaining differences in exports from their norms are correlated with the presence and strength of national-security controls.

To briefly summarize the estimates discussed in detail below, our current study finds qualitative echoes of the 1993 study, but large quantitative differences from it.

- US export shortfalls are still present in high-tech sectors—and are similarly large compared to estimates in the early 1990s—for importing trading partners that were identified as the highest threats to security.

- But for importers representing a moderate security threat (China, Russia, and many other nonaligned countries, not yet “trusted” destinations in the technical language), no US high-tech shortfalls can be found in the mid-2000s, nor as late as 2011! In fact US exporters over-export to them as a group according to our estimates, recovering 77 percent to 94 percent of their aggregate high-tech shortfalls to the highest-threat importers, depending on the control group of importers (see below).

- Nevertheless, export controls seem to work. High-threat and moderate-threat destinations together under-import up to $250 billion of high-tech goods annually from our world of 10 exporters, according to our estimates, roughly half of their norm. Yet unlike our mid-1990s estimates, almost all the corresponding under-exports are associated with nine US-rival high-tech exporters, both rich rivals and emerging.

### ESTIMATES—HIGH-TECH EXPORT SHORTFALLS FOR THE UNITED STATES AND ITS RIVALS

#### Data and Export Profile

We adopt a very broad, inclusive, and widely embraced measure of high-technology industrial sectors, the same as we used in the 1993 study: chemicals and pharmaceuticals, metal products, machinery, equipment, and instruments.16 With this measure, along with their respective employment, capital formation, research and development spending, etc. Our broad measure matches up very closely to the top-two out of four OECD (2001) groupings (called high-tech and medium-high-tech). Narrower measures are also possible, but often lack the time or country coverage of our broad measure, which is essential for our difference-in-difference gravity approaches. NSB (2012), for example, measures high-tech manufacturing essentially as the OECD high-tech category alone, using direct and indirect (i.e., embodied in intermediate inputs) research-and-development cost shares as their indicator of technological intensity. Narrower trade-based measures, such as the Standard International Trade Classification (SITC) underlie our extended 1994–2011 “shadow” updating of the current study, but correlate poorly with purely domestic measures of interest. The US Census Bureau’s 10-sector Advanced Technology Products (ATP) measure is trade-based and narrower still (see NSB 2012, chapter 6 and appendixes), and the TechAmerica Foundation (2011) conception is narrower still (and focused on our ISIC 383 and 385, electrical equipment and instruments).

16. International Standard Industrial Classification (ISIC) sectors 351–52 and 381–85, corresponding to the broad measure used in Richardson (1993) and to familiar, purely domestic conceptions of technologically intensive sectors, the United States and its nine principal exporter-rivals17—we call them the “focus-10”—exported a little over $3 trillion of high-tech goods in the mid-2000s, roughly half of world-wide chemicals/pharmaceuticals exports and three-fifths of metals/machinery/equipment exports. From the mid-2000s to 2011, world-wide high-tech exports grew larger by 3 to 9 percent per year, depending on sector, financial crisis notwithstanding.18

Machinery and equipment sectors account for around 80 percent of recent focus-10 exporter high-tech exports, subdivided roughly equally between electrical and other machinery and transport equipment (22 to 26 percent each), with scientific equipment and instruments much smaller (6 percent). Chemicals and metals accounted for around 20 percent of focus-10 high-tech exports. For American exporters, scientific equipment and chemicals export shares are 1 to 2 percent higher compared to their nine rivals, with correspondingly 1 to 2 percent lower shares in the other sectors.

Our traditional European exporter-rivals and Japan accounted for a little less than two-thirds of total focus-10 high-tech exports. Emerging exporter-rivals and the United States roughly split the remaining third (16.3 percent for them, 18.3 percent for us).
Comparative Estimates Using Primitive Prior-Study Cross-Section Methods

In order to preview how estimates of American export shortfalls from national-security controls may have changed over the past 20 years or so, we initially used dated methods that were as comparable as possible to those of the earlier study. Primitive cross-sectional gravity equations established norms for what US exports should be; subjective forensic examination of residuals examined their correspondence with export controls.

For the mid-2000s, these old methods uniformly revealed two results, one unsurprising, one surprising.

- Estimated American export shortfalls in high-tech sectors to former Eastern Bloc enemies were unsurprisingly reduced from the early 1990s, in both percentage and constant-dollar measures.\(^{19}\)

- But estimated American export shortfalls in high-tech sectors to China in the early 1990s were surprisingly reversed using the old study’s primitive cross-section methods. $3 billion to $6 billion US shortfalls in the early 1990s became $10-billion-plus over-exports to China in the mid-2000s cross-sections (i.e., more US high-tech exports to China than would be expected compared to other destinations in a given year).\(^{20}\)

19. Estimated mid-2000s high-tech export shortfalls to Russia, for example, were roughly $3 billion per year. Estimates of lost American exports to the whole group of Eastern Bloc enemies were roughly $11 billion $12 billion per year, of which half could be attributed to stricter US unilateral implementation of controls, compared to the traditional rival-exporter group used in the 1993 study (France, Germany, Japan, the United Kingdom). This estimated unilateral loss is quite comparable to the estimated unilateral range in Richardson (1993, 102–103).

20. In a slavishly repeated-template appendix in its annual reports, the BIS (various years) provides broad bird’s-eye data that confirms casual expectations that the incidence of export controls might be less marked after the Cold War ends. The proportion of all US exports (not just high-tech, nor just exports that require a license) that were sold to controlled destinations (roughly our tier 3 and 4 countries described below) hovers stably around 3 percent for most of our 1994–2004 data period. That share begins rising to 4 percent in fiscal year 2003 and to 5 percent in fiscal year 2004, and then continues to rise, surprisingly, nearly tripling in share to 8.4 percent in fiscal year 2011. This surge raises a number of questions. For example, does the across-the-board trade growth of China alone explain this surge? Does distinctly rapid US security-threat destinations, and are partially offset by rivals’ over-exports. But in modestly threatening destinations—many times larger markets than the highest threat group—large rivals’ shortfalls are partially offset by US over-exports. Supplier substitution (arbitrage) across importer markets is one way of accounting for these mirror-image estimates, though in turn it begs other questions (e.g., are exporters the principal agent or importing countries’ how do multinational firms’ sourcing decisions across global supply chains matter?).

Estimates from Modern Difference-in-Difference Panel Methods

Tables 1 and 2 record the key results of our more sophisticated approach to estimating high-tech export shortfalls in changing and differentiated environments.\(^{21}\) They also provide orientation for the ensuing detail.

Table 3 records US estimates for the mid-00s, and table 4 records comparable estimates for our nine exporter rivals in high-tech sectors. These include four traditional rich-country rivals at the top of table 4, and five emerging rivals grouped at the bottom. Each column across the two tables reflects a norm-setting gravity regression for that sector alone, and the right-hand column aggregates the estimates from the seven different high-tech sectors. Rows in each table are usually grouped in triples, with the top-most of the three rows representing companies accede to these demands in order to capture the sale or establish a joint venture. ... [A] very high percentage of China’s exports (more than 50 percent) originate from foreign-invested enterprises. These are often eligible for US export license exceptions.

21. Sundaram and Richardson (2013) describe the full underlying detail in the statistical results that generate these tables.
measured exports (real data) and the next two rows representing estimated (residual) export shortfalls (negative entries) or over-exports, from two alternative norm-setting approaches.

The perceived security-threat status of importing countries and of entities within them22 underlies the two norm-setting approaches, and also the high-level division of the rows in each table into high-threat destinations (tier 4), moderate-threat (tier 3), and no-threat (tiers 1, 1+2). Every country uses administrative judgment in its export-control regime to assess the intensity of a foreign buyer’s threat to national security. These administrative judgments are the institutional underpinning of our statistical method, in which we expect to find important differences using our difference-in-difference method. We expect greater shortfalls in exporters and for sectors with thoroughgoing and strict control regimes, and greater shortfalls to importing countries that are greater security threats.

Our specific choice of classification by tiers reflects the history of multilateral and American export controls. Early in the post-Cold War era, the United States and its Wassenaar-Arrangements partners recreated and refined categories and procedures for dual-use export controls that were focused on proliferation and terrorist threats (see note 8 above). Shortly thereafter, the United States devised a very specific categorization of importing countries, by degree-of-security threat, which applied formally to high-performance computers, but was also highly correlated with security breakdowns used for other sectors.23 Tier 1 countries in the categorization included trusted trading partners, largely western in outlook, with their

<table>
<thead>
<tr>
<th>High-tech subsector</th>
<th>Industrial chemicals</th>
<th>Chemical products</th>
<th>Metal products</th>
<th>Machinery</th>
<th>Electrical machinery</th>
<th>Transport equipment</th>
<th>Scientific equipment</th>
<th>Total Exports/shortfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured exports to tiers 1 + 2</td>
<td>63,900</td>
<td>40,800</td>
<td>17,100</td>
<td>123,000</td>
<td>115,000</td>
<td>132,000</td>
<td>43,800</td>
<td>535,600</td>
</tr>
<tr>
<td>Measured exports to tier 2</td>
<td>12,042</td>
<td>5,034</td>
<td>1,772</td>
<td>25,177</td>
<td>33,176</td>
<td>11,638</td>
<td>7,399</td>
<td>96,239</td>
</tr>
<tr>
<td>Shortfall—zero by norm-setting assumption</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measured exports to tier 3</td>
<td>6,680</td>
<td>1,830</td>
<td>1,060</td>
<td>16,100</td>
<td>10,400</td>
<td>11,300</td>
<td>3,850</td>
<td>51,220</td>
</tr>
<tr>
<td>Shortfall to less-trusted tier 3 (norm = 2)</td>
<td>3,210*</td>
<td>679</td>
<td>615*</td>
<td>8,295*</td>
<td>—</td>
<td>8,092*</td>
<td>1,400*</td>
<td>22,290</td>
</tr>
<tr>
<td>Shortfall to less-trusted tier 3 (norm = 1+2)</td>
<td>3,296</td>
<td>—</td>
<td>567</td>
<td>8,533</td>
<td>4,471</td>
<td>7,628</td>
<td>1,353</td>
<td>25,847</td>
</tr>
<tr>
<td>Measured exports to tier 4</td>
<td>16</td>
<td>27</td>
<td>22</td>
<td>238</td>
<td>298</td>
<td>228</td>
<td>59</td>
<td>886</td>
</tr>
<tr>
<td>Shortfall to high-threat tier 4 (norm = 2)</td>
<td>−280*</td>
<td>−348</td>
<td>−1,495*</td>
<td>−12,900*</td>
<td>−6,663*</td>
<td>−4,674*</td>
<td>−2,494</td>
<td>−28,854*</td>
</tr>
<tr>
<td>Shortfall to high-threat tier 4 (norm = 1+2)</td>
<td>−267*</td>
<td>−392</td>
<td>−1,628*</td>
<td>−12,160*</td>
<td>−5,238</td>
<td>−3,10</td>
<td>−2,543*</td>
<td>−27,337</td>
</tr>
<tr>
<td>US total measured exports in ISIC sector</td>
<td>70,596</td>
<td>42,657</td>
<td>18,182</td>
<td>139,338</td>
<td>125,698</td>
<td>143,528</td>
<td>47,709</td>
<td>587,706</td>
</tr>
<tr>
<td>Estimated sectoral export shortfall (norm = 2)</td>
<td>2,930</td>
<td>331</td>
<td>−880</td>
<td>−4,606</td>
<td>−6,663</td>
<td>3,418</td>
<td>−1,094</td>
<td>−6,564</td>
</tr>
<tr>
<td>Estimated sectoral export shortfall (norm = 1+2)</td>
<td>3,029</td>
<td>−392</td>
<td>−1,061</td>
<td>−3,627</td>
<td>−767</td>
<td>2,318</td>
<td>−1,190</td>
<td>−1,690</td>
</tr>
</tbody>
</table>

ISIC = International Standard Industrial Classification
— = imprecision, including inability to detect any export abnormality. More exactly, the range of statistically significant coefficients (90, 95, and 99 percent confidence intervals) all include zero, signaling a lack of any statistically significant export shortfall or overage.
* = a very significant coefficient (p<0.01 or p<0.05).

Notes on entries: Negative numbers indicate shortfalls, positive numbers indicate over-exports. Shortfalls are estimated from normal exports to the default tier 2 countries (norm = 2) or to tier 1 and 2 countries together (norm = 1+2).
Notes on regressions: (1) Regressions include 169 importing countries and 10 exporting countries for 11 years. N = 9240. (2) Standard errors are clustered at the country-pair level. (3) All specifications include gravity controls distance, importer GDP per capita and importer population in logs. (4) All specifications include exporter by year and importer fixed effects.
## Table 4  Estimated 2004 rival-exporter export shortfalls and over-exports (millions of 2005 US dollars)

<table>
<thead>
<tr>
<th>ISIC</th>
<th>Traditional &quot;rival&quot; exporters</th>
<th>France, Germany, United Kingdom, and Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Industrial chemicals</td>
<td>Chemical products</td>
</tr>
<tr>
<td>351</td>
<td>Measured exports to tiers 1 + 2</td>
<td>133,900</td>
</tr>
<tr>
<td>352</td>
<td>Measured traditional exports to tier 2</td>
<td>20,671</td>
</tr>
<tr>
<td>381</td>
<td>Shortfall—zero by norm-setting assumption</td>
<td>17,730</td>
</tr>
<tr>
<td>382</td>
<td>Traditional rival shortfall to less-trusted tier 3 (norm = 2)</td>
<td>-1,716</td>
</tr>
<tr>
<td>383</td>
<td>Traditional rival shortfall to less-trusted tier 3 (norm = 1+2)</td>
<td>- —</td>
</tr>
<tr>
<td>384</td>
<td>Measured traditional exports to tier 3</td>
<td>17,730</td>
</tr>
<tr>
<td>385</td>
<td>Traditional rival shortfall to less-trusted tier 3 (norm = 1+2)</td>
<td>- —</td>
</tr>
<tr>
<td></td>
<td>France shortfall (norm = 2)</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>France shortfall (norm = 1+2)</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Germany shortfall (norm = 2)</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Germany shortfall (norm = 1+2)</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>UK shortfall (norm = 2)</td>
<td>-1,716*</td>
</tr>
<tr>
<td></td>
<td>UK shortfall (norm = 1+2)</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Japan shortfall (norm = 2)</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Japan shortfall (norm = 1+2)</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Measured traditional exports to tier 4</td>
<td>702</td>
</tr>
<tr>
<td></td>
<td>Traditional rival shortfall to high-threat tier 4 (norm = 2)</td>
<td>697</td>
</tr>
<tr>
<td></td>
<td>Traditional rival shortfall to high-threat tier 4 (norm = 1+2)</td>
<td>699</td>
</tr>
<tr>
<td></td>
<td>France shortfall (norm = 2)</td>
<td>132*</td>
</tr>
<tr>
<td></td>
<td>France shortfall (norm = 1+2)</td>
<td>133*</td>
</tr>
<tr>
<td></td>
<td>Germany shortfall (norm = 2)</td>
<td>371*</td>
</tr>
<tr>
<td></td>
<td>Germany shortfall (norm = 1+2)</td>
<td>372*</td>
</tr>
<tr>
<td></td>
<td>UK shortfall (norm = 2)</td>
<td>86*</td>
</tr>
<tr>
<td></td>
<td>UK shortfall (norm = 1+2)</td>
<td>86*</td>
</tr>
<tr>
<td></td>
<td>Japan shortfall (norm = 2)</td>
<td>108*</td>
</tr>
<tr>
<td></td>
<td>Japan shortfall (norm = 1+2)</td>
<td>108*</td>
</tr>
</tbody>
</table>

(continues)
own export-control systems, for which license exceptions and streamlined processing of many types were common. Tier 2 countries lacked one or another of the tier 1 bonds-of-trust, but were nevertheless judged to be low security risks. Tier 3 countries included countries judged to be security risks in at least one dimension. And tier 4 included countries judged to be risky in every dimension.

Risky tier 3 countries included China, India, Russia, many ex-Soviet Republics, Pakistan, Vietnam, and much of Africa, the Balkans, Central Asia, and the Middle East. Table 5’s illustrative membership emphasizes countries that “graduated,” most of them from neutral tier 2 to trusted tier 1 (the two tiers were consolidated in 2001), but for the Baltic countries, from

<table>
<thead>
<tr>
<th>ISIC</th>
<th>351</th>
<th>352</th>
<th>381</th>
<th>382</th>
<th>383</th>
<th>384</th>
<th>385</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hi-tech subsector</td>
<td>Industrial chemicals</td>
<td>Chemical products</td>
<td>Metal products</td>
<td>Machinery</td>
<td>Electrical machinery</td>
<td>Transport equipment</td>
<td>Scientific equipment</td>
<td>Exports/shortfall</td>
</tr>
<tr>
<td>Traditional total measured exports in ISIC sector</td>
<td>152,332</td>
<td>140,349</td>
<td>62,980</td>
<td>377,734</td>
<td>302,466</td>
<td>495,421</td>
<td>92,082</td>
<td>1,623,363</td>
</tr>
<tr>
<td>Estimated sectoral export shortfall (norm = 2)</td>
<td>-1,019</td>
<td>-6,493</td>
<td>-7,596</td>
<td>-19,846</td>
<td>3,965</td>
<td>-161,124</td>
<td>-2,376</td>
<td>-194,490</td>
</tr>
<tr>
<td>Estimated sectoral export shortfall (norm = 1+2)</td>
<td>699</td>
<td>2,441</td>
<td>-3,171</td>
<td>-17,147</td>
<td>7,811</td>
<td>-78,909</td>
<td>600</td>
<td>-87,676</td>
</tr>
<tr>
<td>Emerging rival exporters</td>
<td>Brazil, China, India, Israel, Mexico*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measured exports to tiers 1 + 2</td>
<td>35,109</td>
<td>14,373</td>
<td>34,795</td>
<td>157,983</td>
<td>186,180</td>
<td>70,599</td>
<td>25,102</td>
<td>524,140</td>
</tr>
<tr>
<td>Measured emerging exports to tier 2</td>
<td>10,633</td>
<td>4,907</td>
<td>7,815</td>
<td>41,317</td>
<td>54,345</td>
<td>10,954</td>
<td>5,530</td>
<td>135,501</td>
</tr>
<tr>
<td>Shortfall—zero by norm-setting assumption</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measured emerging exports to tier 3</td>
<td>6,035</td>
<td>1,651</td>
<td>2,951</td>
<td>6,749</td>
<td>7,731</td>
<td>2,682</td>
<td>909</td>
<td>28,707</td>
</tr>
<tr>
<td>Emerging rival shortfall to less-trusted tier 3 (norm = 2)</td>
<td>-14,819*</td>
<td>-1,922*</td>
<td>-18,527*</td>
<td>-22,929*</td>
<td>-16,490*</td>
<td>-24,609*</td>
<td>-1,467*</td>
<td>-100,764</td>
</tr>
<tr>
<td>Emerging rival shortfall to less-trusted tier 3 (norm = 1+2)</td>
<td>-21,310*</td>
<td>-2,864*</td>
<td>-24,244*</td>
<td>-33,312*</td>
<td>-32,645*</td>
<td>-30,518*</td>
<td>-1,802*</td>
<td>-146,696</td>
</tr>
<tr>
<td>Measured emerging exports to tier 4</td>
<td>576</td>
<td>192</td>
<td>368</td>
<td>989</td>
<td>757</td>
<td>913</td>
<td>142</td>
<td>3,937</td>
</tr>
<tr>
<td>Emerging rival shortfall to high-threat tier 4 (norm = 2)</td>
<td>—</td>
<td>—</td>
<td>364*</td>
<td>980*</td>
<td>740*</td>
<td>902*</td>
<td>138</td>
<td>3,125</td>
</tr>
<tr>
<td>Emerging rival shortfall to high-threat tier 4 (norm = 1+2)</td>
<td>—</td>
<td>—</td>
<td>363</td>
<td>977*</td>
<td>727</td>
<td>899*</td>
<td>138</td>
<td>3,103</td>
</tr>
<tr>
<td>Emerging rival total measured exports in ISIC sector</td>
<td>41,720</td>
<td>16,216</td>
<td>38,113</td>
<td>165,721</td>
<td>194,668</td>
<td>74,194</td>
<td>26,153</td>
<td>556,785</td>
</tr>
<tr>
<td>Estimated sectoral export shortfall (norm = 2)</td>
<td>-14,819</td>
<td>-1,922</td>
<td>-18,163</td>
<td>-21,949</td>
<td>-15,750</td>
<td>-23,707</td>
<td>-1,329</td>
<td>-97,639</td>
</tr>
<tr>
<td>Estimated sectoral export shortfall (norm = 1+2)</td>
<td>-21,310</td>
<td>-2,864</td>
<td>-23,882</td>
<td>-32,335</td>
<td>-31,918</td>
<td>-29,620</td>
<td>-1,665</td>
<td>-143,593</td>
</tr>
</tbody>
</table>

ISIC = International Standard Industrial Classification
*Each of the five emerging rival exporters’ regression coefficients on the dummy variables for tier 3 and for tier 4 is constrained to be the same. All other gravity-equation coefficients are free to vary across the five exporters. This restriction is loosened in Sundaram and Richardson (2013), table 6. See footnote 33 and 34 for the most insightful results.

Notes on entries: Negative numbers indicate shortfalls, positive numbers indicate over-exports. Shortfalls are estimated from normal exports to the default tier 2 countries (norm = 2) or to tier 1 and 2 countries together (norm = 1+2). — = imprecision, including inability to detect any export abnormality. More exactly, the range of statistically significant coefficients (90, 95, and 99 percent confidence intervals) all include zero, signaling a lack of any statistically significant export shortfall or overage.

* denotes a very significant coefficient (p<0.01 or p<0.05).

Notes on regressions: (1) Regressions include 169 importing countries and 10 exporting countries for 11 years. N = 9240. (2) Standard errors are clustered at the country-pair level. (3) All specifications include gravity controls distance, importer GDP per capita and importer population in logs. (4) All specifications include exporter by year and importer fixed effects.

risky tier 3 to lower-risk tiers 1 and 2. Such graduations play an important identification role in our statistical work, because they imply expected gains after graduation in high-tech exports to these newly safer destinations, taking as given the fundamental and intuitive premise that export controls discourage at least some exports (and the graduations obviously help to answer the question “how much export discouragement?”).

Correspondingly, the cross-section foundation for our approach to identifying (estimating) the effects of export controls on exports is to treat either tiers 1 and 2 or tier 2 alone as a near-control-free norm, then to estimate the abnormal differences in exports to otherwise comparable tiers 3 and 4 destinations, differences across high-tech sectors, across the United States and its major-rival exporters, across importers who shift tiers in our data sample, and even to some extent across time. In examining all these differences-in-differences, we control for (that is, we purge away the effects of) country size, prosperity, and uniqueness, country proximity-to-exporter, and other accepted determinants of trade, as dictated by the well-established gravity research literature.

To summarize, our maintained assumption is that security-oriented export control systems have only random and minimal effects on exports to trusted, low-risk importing countries. Risky tier 3 importers, by contrast, and very risky tier 4 importers, ought to differ (from tier 1 and 2 importers and from each other) by having unusually low imports of high-tech products from exporters with controls.

In our estimates, they do differ, usually as expected, but often with unexpected detail.

### ESTIMATES FOR SMALL HIGH-THREAT IMPORTERS, INTUITIVE ILLUSTRATIVE RESULTS

Export controls discourage large amounts of high-tech exports to high-threat importers in intuitive ways. The tier 4 rows in tables 1 and 2 quantify this obvious statement, and illustrate how to read the tables.

They also illustrate our study’s most important interpretative conclusions, especially the elusive margins of substitution by which security targets can maintain at least some access (the foreign availability margin), and by which exporters can respect controls without losing too many overall export sales (a margin that we might dub the customer arbitrage margin).

<table>
<thead>
<tr>
<th>Years</th>
<th>Tier 1</th>
<th>Tier 2</th>
<th>Tier 3</th>
<th>Tier 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996–1999</td>
<td>(+) Austria, Finland, Iceland, Liechtenstein, Mexico, Monaco, New Zealand, Switzerland.</td>
<td>(–) Austria, Finland, Iceland, Liechtenstein, Mexico, Monaco, New Zealand, Switzerland.</td>
<td>(+) Argentina, Brazil, Czech Republic, Hungary, Poland</td>
<td>(–) Estonia, Romania</td>
</tr>
<tr>
<td>2000</td>
<td>(+) Argentina, Brazil, Czech Republic, Hungary, Poland</td>
<td>(–) Argentina, Brazil, Czech Republic, Hungary, Poland</td>
<td>(+) Estonia, Romania</td>
<td>(–) Estonia, Romania</td>
</tr>
<tr>
<td>2001</td>
<td>(+) All countries that were earlier tier 2</td>
<td>(–) Lithuania</td>
<td>(–) Lithuania</td>
<td></td>
</tr>
<tr>
<td>2002–2004</td>
<td>(+) Latvia</td>
<td>(–) Latvia</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(+)= addition to tier
(–)= graduation from tier

Source: Sundaram and Richardson (2013), table 1a.
thus also help raise and answer new questions about the efficacy of export controls.

Measured US high-tech exports to tier 4 importers in table 3 are close to zero—that is no surprise when the embargoes work. Just below measured exports in each row’s triads are estimated gravity-equation residuals from our statistical regression. These estimates imply that denied US exports are roughly 15 to 70 times larger than the near-zero measures, depending on sector (for example, in ISIC 351, measured industrial-chemical exports of $16 million fall well short of statistically expected normal imports of $283 million to $292 million).29

Then from table 4, rival exporters’ measured aggregate high-tech exports, to the same high-threat tier 4 importers, are $11.623 billion and $3.937 billion, respectively for traditional and emerging rivals (from the right-most column). Estimated non-shortfalls from export norms appear immediately below them, revealing a striking quantitative conclusion: Rivals’ measured high-tech exports are almost entirely abnormal. That is, they are almost entirely unexpected in statistical terms, wholly outside the norm. As table 4 shows, estimated excess exports for traditional rivals are almost identical to their actual measured exports, and for emerging rivals they come very close ($3.125 billion vs. $3.937 billion).

A straightforward interpretation is at hand. In a magically secure tier 4 market without (any need for) controls, American high-tech exports would virtually drive out European and Japanese rivals, and also strongly outcompete emerging-country rivals. Our estimates cannot reject the hypothesis that competitively dominant US high-tech exporters lose the entire markets of tier 4 importers to competitively inferior rival exporters. (But, as we will see below, tier 3 markets present striking mirror-image differences, compensatory for strongly competitive US exporters and bleak for our rivals.)

Tables 1 and 2 together do suggest that risky importers are deprived. Export controls work globally, volatile critics notwithstanding. High-threat tier 4 destinations lose (arguably from major-country export controls30) close to half of the access that they would otherwise have to high-tech imports. Their measured imports (from the right-most column) are $16.4 billion (0.886 + 11.623 + 3.937); but this measure falls well short of estimated normal imports ($30.611 billion in one approach to norm-setting, $29.291 billion in the second).

Table 4 shows that traditional rivals’ exports to tier 3 fall well short of the expected norm, and their tier-3 shortfalls are many times larger than their estimated over-exports to tier 4.

Table 3 suggests that in almost every high-tech sector, US exports to moderate-threat tier 3 destinations are abnormally and significantly (in statistical terms) high in the mid-2000s. Both bases for defining normalcy (tier 2 base and tiers 1 and 2 base) yield this surprising finding in five sectors. In those five sectors, supernormal exports (positive entries in the short-fall rows) range from 36 percent to 72 percent of measured exports.31 In the other two sectors, statistically significant estimates of supernormal exports also appear, though only for one base, not for the other. Summed across the seven sectors, US exporters over-export to tier 3 by $22 billion to $26 billion per year, according to our estimates.

But table 4 suggests the opposite—dramatically—for rival exporters. Their mid-2000s exports to moderate-threat tier 3 destinations show large shortfalls. Traditional rivals under-export in the seven high-tech sectors by $99 billion to $206 billion in the mid-2000s (right column, fifth and sixth rows). Emerging rivals under-export by $101 billion to $147 billion. The few exceptions to near-ubiquitous shortfalls have some casual plausibility: Germany is estimated exceptionally to under-export electrical machinery (ISIC 383) to these high-risk destinations, and for one base also in chemical products (ISIC 352). Though the base group for defining normal exports does here make a modest quantitative difference to the estimates,32 it makes no difference qualitatively.

29. In 2005 dollars. In the absence of appropriate sector-by-sector price indexes, we use a crude approach to deflation, but arguably better than nothing. We deflate every sector’s value data by the 2005 US overall wholesale price index.
30. Since the 10 major exporters on which we focus represent only 50 to 60 percent of worldwide high-tech exports, it is likely that minor, opportunistic rogue exporters provide at least a fraction of the high-tech exports denied by export controls in the focus-10. Thus the denied-exports calculations in this sentence might best be seen as an upper bound. In principle, our method could be expanded to cover any number of rival exporters, however cumbersome that would be in practice and interpretation.

31. 0.36 = 1400/3850 in ISIC 385. 0.72 = 8092/11300 in ISIC 384.
32. By the standards (norms) of tier 2 importers, where traditional European rivals and Japan have performed especially well, their under-performance in the moderate-risk tier 3 import markets is bleakly striking. But when tier 1 and

Estimates for Large, Moderate-Threat Importers, Surprising Mirror-Image Results

Moderate-threat importers in tier 3 are far more important quantitatively—roughly 15 times in measured high-tech trade—than high-threat tier 4 importers. Tier 3 importers include China, India, and Russia, all of which are large traders, as well as Egypt, Pakistan, Vietnam, many former Soviet Republics, and most Middle-Eastern countries, including Israel.

Our estimates of export shortfalls in tier 3 countries provide far more unexpected detail and nuance than those for tier 4. In fact, they are different in surprising mirror-image ways:

- US high-tech exports to tier 3 importers are larger than expected according to the gravity-equation norm, almost enough to offset US export shortfalls to tier 4.
- Traditional-rival and emerging-rival exports to tier 3 fall well short of the expected norm, and their tier-3 shortfalls are many times larger than their estimated over-exports to tier 4.

Emerging-rival under-export by $101 billion to $147 billion. The few exceptions to near-ubiquitous shortfalls have some casual plausibility: Germany is estimated exceptionally to under-export electrical machinery (ISIC 383) to these high-risk destinations, and for one base also in chemical products (ISIC 352). Though the base group for defining normal exports does here make a modest quantitative difference to the estimates, it makes no difference qualitatively.
Moderate-threat tier 3 importers do under-import large amounts of high-tech products from our focus-10 exporters summed together, from $219 billion to $285 billion annually in the mid-2000s. Export controls and other security-motivated restraint thus seem to work to deprive them of cutting-edge technologies and goods, as they also worked for high-threat tier 4 destinations. Estimated tier 3 import shortfalls from the focus-10 exporters are comparable in size to their measured imports.

It is revealing to refine the moderate-threat tier 3 results by importer.33

- In Chinese markets, neither US nor emerging-rival exporters as a group34 over-export, though they do well relative to Japan and European rivals, who severely under-export in the seven high-tech sectors.35
- In Indian markets, roughly the same broad patterns appear among the focus-10 exporters as in China.
- But in the rest of tier 3—Russia and its former Cold War partners, the Middle East, Vietnam, among others—the United States exports far larger amounts of high-tech products than the norm; Britain, Japan, and emerging exporters export far less than the norm; and French and German exports are mostly around the norm (that is, their high-tech exports are insignificantly different from the norm). Global and European geo-politics, as well as American war efforts in the mid-2000s, may contribute to these patterns of super-exports to non-China, non-India tier 3 security threats.36

OVER-SUMMARY

The surprising summary of these results is that American exporters in the mid-2000s—relative to their rivals—are highly competitive in importer markets that are large, and that are moderate security threats subject to fairly strict export controls in high-tech sectors. By contrast, the 1993 cross-section study found near opposite results—US export shortfalls in high-threat importer destinations that were larger than those of traditional exporter rivals. That conclusion remains in the current study only for the tiny group of embargoed tier 4 importers.

Related Estimates and Overall Reliability

Some of the more surprising results above may be related to the first of several ancillary estimates.

Trends in Comparative Advantage

Our difference-in-difference approach allows us to estimate differences across the 11 years of our data, specifically year-over-year export trends in high-tech exports.37 The strongest trend growth across the seven sectors is in electrical machinery (ISIC 383) and in chemicals (ISIC 351–52), and is especially strong for Britain, Germany, the United States, China, and Mexico among our focus-10 exporters. Japan, uniquely, reveals negative trend export growth, except in transport equipment (ISIC 384).

These estimated trends are arguably reflections of changing comparative advantage—relative competitive advantage. The

33. These results are not shown in tables 1 and 2, and come from a follow-up set of comparable regressions. See Sundaram and Richardson (2013), table 6.
34. In the follow-up statistical work (previous note), Brazil, Israel, and Mexico over-export to both China and India in most high-tech sectors, according to our estimates. However, their over-exports are largely offset for the aggregate of our five emerging-country exporters by China-India bilateral under-exports. Brazil, Israel, and Mexico also over-export to trusted tier 1 markets, where China and India do not over-export, and European exporters seriously under-export.
35. The exception is that Germany over-exports to China in machinery sectors (ISIC 382–383).
36. In 2004 Chinese, Indian, and other high-tech imports were, respectively, 42 percent, 6 percent, and 52 percent of measured tier 3 imports from our focus-10 exporters.
37. To be precise, “trends not captured by momentum in other determinants of exports”—every gravity-equation norming regression has a time-varying constant term (dummy variable), by sector, for each exporter. Del Gatto et al. (2011) use gravity-equation approaches and constant-market-shares analysis to analyze US comparative advantage trends across all sectors, not just high-tech sectors.
changes in comparative advantage may be more fundamentally explained by strong global supply-chain deepening in electrical machinery and chemicals/pharmaceuticals,38 deepening that is pursued most strongly by the five exporters in the previous paragraph. Except for Britain, these are precisely the exporters that our current study finds to be least susceptible to high-tech export shortfalls in moderate-threat tier 3 import markets. That correspondence invites the sensible hypothesis that exporters who are on the cutting edge of dynamic high-tech sectors, who have especially strong productivity growth in those sectors, who have integrated them aggressively into global supply chains, would find themselves able to respect export controls when necessary, yet recover forgone exports in less tightly controlled importer markets (and in less tightly controlled subsectors of our broad three-digit sectoral aggregates).

Somewhat more surprising is that US exporters lead all others on these cutting-edge trends, according to our estimates.

**Sectoral Differences**

In contrast to these time trends, there are only a few qualitative differences in our results from sector to sector, and these differences tend to be quantitatively small. It therefore seems acceptable to treat high-tech sectors together as a dynamic, yet relatively homogeneous, aggregate. The most important of the sectoral differences is the statistical volatility of estimates in the electrical machinery sector (ISIC 383), which is volatile for every exporter. In this sector, specification differences matter,39 especially our choice of “norm for normal” import market. These differences caused considerable variability in estimated ISIC 383 coefficients, and in their statistical significance.40

**Reliability**

The estimates on which this Policy Brief is based are selected from large set of alternatives, many of which are summarized in Sundaram and Richardson (2013). Our selections reflect a qualitative consensus among these alternatives and our sense of what rendered the most sensible interpretations.

We also estimated cross-section gravity equations on

- more narrowly defined sub-aggregates of our broad sectors;41
- different data sets for years after 2004 but before the late 2000s financial crisis.42
- a shadow panel data set of trade-oriented sectors that were roughly comparable to our industrial sectors and that updated their reach to 2011.43

Our estimates from all these alternatives did not differ much in the patterns of their estimates from those that are the focus of this Policy Brief. They seem to have only small impacts on our preferred data and estimates, driven as they are by differences—differences across 7 sectors, 10 exporters, 11 years, and 169 importers.44

**INTERPRETATIONS AND CONCLUSIONS**

Export controls and licensing systems to undergird national and international security have been a longstanding part of trade regimes around the world. Though their targets have changed over the decades, their integral core has not—countries and groups that pose security threats should be denied free

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39. See Sundaram and Richardson (2013) for alternative specifications to the preferred variants on which this Policy Brief is based.

40. In the most anomalously extreme example, an estimated export shortfall of as much as 25 percent of American exports in electrical machinery (ISIC 383, made up of industrial motors and generators, communications equipment, semiconductor devices, and home appliances) was entirely concentrated on the most trusted tier 1 importer markets (when tier 2 was taken to be the norm). It implied a seven-sector shortfall as large as 7 percent of US broad high-tech exports. This troublesome shortfall, however, entirely disappears when the gravity norm is taken to be trusted tier 1 and tier 2 markets taken together, which was actually the US administrative norm after 2001 (see table 5 above and Sundaram and Richardson (2013)).

41. The categories included: equipment such as cameras, fiber optic cables, night-vision, and other optical components (e.g., image intensifiers, low-light imaging equipment) (in Standard Industrial Classification, or SIC, categories 3812, 3823, 3827, 3844, 3845, 3851, and 3861); machinery and components such as machine tools, semiconductor etchers, and aircraft parts made of composite materials (SIC categories 3541, 3542, 3545, 3674, and 3728); computers (SIC 3571); and munitions such as missiles, rockets, and tanks (SIC 3761, 3764, 3795).

42. We ran cross-sectional gravity equations for 2006 using data from the OECD (Organization for Economic Cooperation and Development) and cross-sections for earlier years using NBER (National Bureau of Economic Research) data and SITC (Standard International Trade Classification) data.

43. These results underlie the 2011 summary at the end of the overview section above, and are described in Sundaram and Richardson (2013). When this shadow data was divided into a comparable time-span (1994–2004) and an updated time-span (2005–2011), Chow tests on whether the US export coefficients changed on tier 3 were rejected in every sector. Chow tests on whether peer export coefficients changed on tier 3 were rejected in 30 out of 35 cases, and rejected in every case for tier 4 coefficient estimates. When tier coefficients from the entire shadow data set, 1994–2011, were subjected to a broad Chow test for equality with the tier coefficients in our primary 1994–2004 data set, equality was almost always accepted at the usual levels of statistical significance.

44. Certain trends, however, might sap our fair degree of confidence, however. For example, in the mere five years between 2004 and 2009 (preliminary data), US multinational firms’ proportion of R&D (research-and-development) employment located abroad surged from 16 percent to 27 percent of their global R&D employment (NSB 2012, 3–59 and 60).
access to cutting-edge technologies, and to the goods, services, and workers in which such technologies are embodied.

Export controls require an exporter to sacrifice high-tech exports. That is simply a fact of life—and a costly fact of life because of enormous administrative and compliance costs (Richardson (1993), 43–44, 130) and to the degree that exporting sectors reflect the relatively most productive and dynamic sectors in every country’s overall economy (the principle of comparative advantage).

**European rivals and Japan, and even five emerging-economy rival exporters of high-tech products, are estimated to recover in high-threat markets only a small fraction of the high-tech exports they lose (relative to the United States) in moderate-risk markets.**

The more interesting questions are quantitative. Which exporters bear the greatest sacrifices of high-tech exports for the sake of security? Which importers are most successfully targeted? How do answers to these questions change over the decades (or differ across sectors)?

Answers in the current study differ from those in a similar study from 20 years ago. In the early 1990s, US exporters were estimated to bear a disproportionate share of losses, roughly 5 percent of its expected high-tech exports, compared to its traditional rivals and export-control partners.

Recently, we find almost the opposite, using more sophisticated and more powerful statistical methods. We estimate US high-tech export losses to be only 1 percent or less of its normal high-tech potential. US exporters seem to be able to recover most of the high-tech exports that they do indeed lose in the highest-threat importer markets, by abnormal super-exports to moderate-risk importers. In sharp contrast, European rivals and Japan, and even five emerging-economy rival exporters of high-tech products, are estimated to recover in high-threat markets only a small fraction of the high-tech exports they lose (relative to the United States) in moderate-risk markets.

These results are somewhat surprising. The explanation that we find most persuasive is that in the past 20 years American exporters have widened their competitive high-tech advantage over traditional rivals, especially those from France and Japan, and have maintained much of their high-tech advantage over even emerging rivals who are admittedly catching up slowly, including export rivals from China. Among other things, these advantages have arguably allowed the United States to enforce and respect export-control structures, but “arbitrage around them” better than their rivals, often using the flexibility that is enhanced by global supply chains. At the corporate level, this arbitrage involves concentrating effort and resources on relatively less-controlled high-tech sub-aggregates in the seven broad sectors that we study,45 and on relatively more trusted customers (including their own affiliates) in more trusted importing countries. At the government-oversight level, this involves concentrating effort and resources on the products and customers (entities) that pose the greatest security threats, and devising creative refinements of licensing procedures for more trusted customers and for products that are widely available in world markets. Precisely that spirit drives the ambitious current American reform of its export-control regime, and seems to have successfully driven its procedural reforms during the 2000s.

We also find that, globally, export controls may still work arguably well in denying the highest-technology goods and services to targeted importers. Importers that are deemed threatening to security are estimated to under-import in high-tech sectors by about $250 billion per year in the mid-2000s. Those losses are roughly half of their expected normal high-tech imports in a better world without security concerns.

**REFERENCES**


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45. It is arguable, though not inevitable, that relatively less-controlled sub-aggregates are less intrinsically innovative than the more tightly controlled sub-aggregates. In that case, there would be a socially costly innovation shortfall in addition to our estimated export shortfall. In the extreme of this case, our focus-10 exporters might lose their most innovative sub-aggregates to yet-to-emerge exporters. Anecdotal testimony collected as part of this study, however, suggests the opposite: The highest-tech activities are almost never exported (outsourced), but kept close at hand by both firms and governments.


Recent US export controls seem to deter US high-tech exports considerably less. As percentages of seven broad industrial categories of high-tech exports, estimated American export shortfalls from national security controls have fallen from roughly 5 percent in the early 1990s to slightly over 1 percent in the mid-to-late 2000s. Ongoing reform of American national-security export controls would seem to have only modest effects on the level of US high-tech exports. American exporters seem to have developed a distinctive competitive ability to shift their sales efforts flexibly among customers an 2. Expansion of export, re-export and transfer (in-country) controls for military end use - intended use or military end-users in CN, RU or VE. The new rule expands the restrictions on exports for military end-use and military end-users in CN, RU or VE by expanding the: Content Intended for FedEx Express Customers Only. â€¢ Licensing requirements for CN to include â€œmilitary end-users,â€ in addition to â€œmilitary end-useâ€. The new regulations remove License Exception CIV for national security-controlled items that will be exported, re-exported or transferred (in-country) to Country Group D:1. Therefore, beginning June 29, 2020, exporters will no longer be able to ship national security-controlled items to D:1 countries without a BIS review and license. Q&A. Q1.