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Sizing Up US Export Disincentives for a New Generation of National-Security Export Controls

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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

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

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 Trefler (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 common-sense 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'."[5]

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 controls[6] 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."[7]

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of 1 percent for every 1 percent productivity-growth edge that exporting sectors have over other sectors. This magnitude is *not* small when compounded—succeeding generations are 6 to 8 percent better off from export doubling for every 1 percent productivity-growth edge that export sectors might have.

4. See McKinsey Global Institute (2010) for a well-documented perspective along these lines. See also Aghion, Boulanger, and Cohen (2011), Jensen (2011), Rodrik (2011), and Spence and Hlatshwayo (2011).

5. The idea that American microeconomic policies of many kinds, internal and external, might have inadvertently impaired American exports was introduced prominently by C. Fred Bergsten in 1988.

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.

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

Industrial chemicals	Chemical products	Metal products	Non-electric machinery	Electrical machinery	Transport equipment	Scientific equipment	Total
7.6	1.6	1.2	12.4	—	12.3	2.7	**37.9**
–0.6	–0.8	–4.4	–8.5	–13.1	–7.9	–5.8	**–41.2**
7.0	**0.8**	**–3.2**	**3.9**	**–13.1**	**4.4**	**–3.2**	**–3.4**

Notes: Coefficients from 1994–2004 industrial sector ISIC regressions applied to synthetic 2011 ISIC data (Synthetic 2011 ISIC = 2011/2004 SITC x 2004 ISIC). See text for validity and close comparability to 1994–2011 traded-goods SITC regressions.

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

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

Industrial chemicals	Chemical products	Metal products	Non-electric machinery	Electrical machinery	Transport equipment	Scientific equipment	Total
3.2	0.7	0.6	8.3	—	8.1	1.4	**22.3**
–0.3	–0.3	–1.5	–12.9	–6.7	–4.7	–2.5	**–28.9**
2.9	**0.3**	**–0.9**	**–4.6**	**–6.7**	**3.4**	**–1.1**	**–6.6**

Notes: Coefficients from 1994–2004 industrial sector ISIC regressions applied to 2004 ISIC data, as below, tables 3–4.

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

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,[8] 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).

The 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

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. Multinational 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 3 of the 1993 book. The quantitative estimates made up chapters 4 and 5 of the book.

10. Accessed May 21, 2013 at http://www.defense.gov/speeches/speech.aspx?speechid=1453.

> 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 critical[12] 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.

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 then 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, the United States and its nine principal exporter-rivals[17]—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).

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, 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, coverage that 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 appendix), and the TechAmerica Foundation (2011) conception is narrower still (and focused on our ISIC 383 and 385, electrical equipment and instruments).

17. France, Germany, Japan, and the United Kingdom (traditional rival/peers) and Brazil, China, India, Israel, and Mexico (emerging rival/peers). The emerging five are those that appear in Bureau of International (BIS) foreign availability reports in more than two of our seven sectors for all 11 years of our data.

18. Exact measures for our focus-10 exporters 2004 are in the margins of tables 1 and 2 below. Growth rates from 2005–2011 for world-wide high-tech exports (of chemicals, office and telecommunications equipment, and automotive products) come from WTO (2012, 90, 95, and 114).

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]

The obvious takeaway from these primitive cross-section results is *change!* The security challenges and environments had obviously changed over the decades, as had the attractiveness and dynamism of various import destinations, the competitiveness and comparative advantage of US export rivals, and the export-control regime itself.

The modern methods and data described above fortunately provide an attractive vehicle for setting expected-export norms that are allowed to change over time, and that change differently for rival exporters and for alternative importer destinations. Our current study's "panel" of cross-section gravity equations over 11 years, and the "difference-in-difference" approach to analyzing patterns in gravity-equation residuals, are ideally suited to estimating the impact of export controls in a setting of multiple and differentiated changes over time.

The most striking and robust difference that emerges is the way American and rival shortfalls mirror each other in high-tech exports. American shortfalls are large in the highest-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

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 distinctively rapid US inclusion of Chinese affiliates in global supply chains contribute? Maybe, but maybe not. According to the BIS annual reports, China does account for a roughly stable 80 percent share of US exports to controlled destinations during the entire decade of the 2000s. And according to a candid summary in appendix G to BIS (2003):

> In ... 1999 BIS conducted a study that examines the extent to which access to the Chinese market is conditioned upon technology transfers, including those related to the establishment of turnkey plants and facilities. The study found that the Chinese government routinely seeks to obtain technology from foreign bidders through formal and informal means. Such technology transfer occurs in the form of local content requirements, investment requirements, establishment of R&D facilities, and other concessions. U.S. and other Western 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.

Table 3 Estimated 2004 US export shortfalls and over-exports (millions of 2005 US dollars)

ISIC	351	352	381	382	383	384	385	
High-tech subsector	**Industrial chemicals**	**Chemical products**	**Metal products**	**Machinery**	**Electrical machinery**	**Transport equipment**	**Scientific equipment**	**Total Exports/ shortfall**
Measured exports to tiers 1 + 2	63,900	40,800	17,100	123,000	115,000	132,000	43,800	535,600
Measured exports to tier 2	12,042	5,034	1,772	25,177	33,176	11,638	7,399	96,239
Shortfall—*zero* by norm-setting assumption								
Measured exports to tier 3	6,680	1,830	1,060	16,100	10,400	11,300	3,850	51,220
Shortfall to less-trusted tier 3 (norm = 2)	3,210*	679	615*	8,295*	—	8,092*	1,400*	22,290
Shortfall to less-trusted tier 3 (norm = 1+2)	3,296	—	567	8,533	4,471	7,628	1,353	25,847
Measured exports to tier 4	16	27	22	238	298	228	59	886
Shortfall to high-threat tier 4 (norm = 2)	–280*	–348	–1,495*	–12,900*	–6,663*	–4,674*	–2,494	–28,854*
Shortfall to high-threat tier 4 (norm = 1+2)	–267*	–392	–1,628*	–12,160*	–5,238	–5,310	–2,543*	–27,537
US total measured exports in ISIC sector	70,596	42,657	18,182	139,338	125,698	143,528	47,709	587,706
Estimated sectoral export shortfall (norm = 2)	2,930	331	–880	–4,606	–6,663	3,418	–1,094	–6,564
Estimated sectoral export shortfall (norm = 1+2)	3,029	–392	–1,061	–3,627	–767	2,318	–1,190	–1,690

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.

Source: COMTRADE. See Sundaram and Richardson (2013).

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 them[22] 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 high-tech export 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

22. American export-control requirements differ not only by importing country, but also by business and agency within the country, so-called entities. Large, multinational corporate affiliates in a country are generally far more trusted, for example, than businesses controlled, in part, by the country's military. The latter face higher control hurdles before being authorized to import a good or technology. Military and intelligence agencies in general face higher hurdles than civil agencies.

23. See the 1995–2005 Foreign Policy Reports of the US Commerce Department's Bureau of Industry and Security. The US Export Administration Regulations (EAR) maintain Country Groups (A, B, D, E—C is reserved) that match closely the trusted-to-threatening continuum of the computer tiers 1, 2, 3, and 4.

Table 4 Estimated 2004 rival-exporter export shortfalls and over-exports (millions of 2005 US dollars)

Traditional "rival" exporters
France, Germany, United Kingdom, and Japan

ISIC	351	352	381	382	383	384	385	
Hi-tech subsector	**Industrial chemicals**	**Chemical products**	**Metal products**	**Machinery**	**Electrical machinery**	**Transport equipment**	**Scientific equipment**	**Total Exports/ shortfall**
Measured exports to tiers 1 + 2	133,900	127,840	56,400	313,300	255,400	448,200	79,100	1,414,140
Measured traditional exports to tier 2	20,671	13,468	6,667	45,541	60,776	44,384	14,404	205,912
Shortfall—*zero* by norm-setting assumption								
Measured traditional exports to tier 3	17,730	11,830	6,270	60,510	45,540	43,340	12,380	197,600
Traditional rival shortfall to less-trusted tier 3 (norm = 2)	–1,716	–7,160	–7,905	–23,765	2,443	–164,977	–2,975	–206,054
Traditional rival shortfall to less-trusted tier 3 (norm = 1+2)	—	1,767	–3,480	–21,066	6,289	–82,774	—	–99,264
France shortfall (norm = 2)	—	–3,264	–1,067	—	—	–26,271*	–1,146	–31,748
France shortfall (norm = 1+2)	—	—	—	—	—	–8,799*	—	–8,799
Germany shortfall (norm = 2)	—	—	—	—	5,765	—	—	5,765
Germany shortfall (norm = 1+2)	—	1,767*	—	—	6,289*	—	—	8,056
UK shortfall (norm = 2)	–1,716*	–3,896*	–1,802*	–6,688*	–3,322	–10,299*	–1,829*	–29,552
UK shortfall (norm = 1+2)	—	—	—	—	—	–4,782*	—	–4,782
Japan shortfall (norm = 2)	—	—	–5,036*	–17,077	—	–128,407*	—	–150,520
Japan shortfall (norm = 1+2)	—	—	–3,480*	–21,066*	—	–69,193*	—	–93,740
Measured traditional exports to tier 4	702	679	310	3,924	1,526	3,881	602	11,623
Traditional rival shortfall to high-threat tier 4 (norm = 2)	697	667	309	3,919	1,522	3,853	598	11,564
Traditional rival shortfall to high-threat tier 4 (norm = 1+2)	699	673	309	3,920	1,523	3,865	600	11,589
France shortfall (norm = 2)	132*	242*	60*	697*	346*	1,889*	111*	3,478
France shortfall (norm = 1+2)	133*	246*	60*	697*	347*	1,895*	112*	3,490
Germany shortfall (norm = 2)	371*	243*	137*	2,157*	800*	1,181*	304*	5,192
Germany shortfall (norm = 1+2)	372*	244*	137*	2,158*	800*	1,184*	304*	5,198
UK shortfall (norm = 2)	86*	150*	75*	628*	213*	108*	111*	1,370
UK shortfall (norm = 1+2)	86*	152*	75*	628*	213*	108*	112*	1,375
Japan shortfall (norm = 2)	108*	32*	37*	437*	163*	675*	72*	1,524
Japan shortfall (norm = 1+2)	108*	32*	37*	437*	163*	678*	72*	1,527

(continues)

Table 4 Estimated 2004 rival-exporter export shortfalls and over-exports (millions of 2005 US dollars) *(continued)*

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

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 footnotes 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.

Source: COMTRADE. See Sundaram and Richardson (2013).

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 5 Countries that switch American security tiers, 1994–2004

<table>
<tr><th>Years</th><th>Tier 1</th><th>Tier 2</th><th>Tier 3</th><th>Tier 4</th></tr>
<tr><td>1996–1999</td><td>(+) Austria, Finland, Iceland, Ireland, Liechtenstein, Mexico, Monaco, New Zealand, Switzerland.</td><td>(–) Austria, Finland, Iceland, Ireland, Liechtenstein, Mexico, Monaco, New Zealand, Switzerland.</td><td></td><td>(+) Cuba, Iran, Iraq, Libya, North Korea, Sudan, Syria.</td></tr>
<tr><td>2000</td><td>(+) Argentina, Brazil, Czech Republic, Hungary, Poland</td><td>(–) Argentina, Brazil, Czech Republic, Hungary, Poland</td><td></td><td></td></tr>
<tr><td></td><td></td><td>(+) Estonia, Romania</td><td>(–) Estonia, Romania</td><td></td></tr>
<tr><td>2001</td><td colspan="2">(+) All countries that were earlier tier 2
(+) Lithuania</td><td>(–) Lithuania</td><td></td></tr>
<tr><td>2002–2004</td><td colspan="2">(+) Latvia</td><td>(–) Latvia</td><td></td></tr>
</table>

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

Source: Sundaram and Richardson (2013), table 1a.

risky tier 3 to lower-risk tiers 1 and 2.[24] 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[25] 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.[26] In examining all these differences-in-differences, we control for (that is, we purge away the effects of) country size, prosperity, and uniqueness,[27] 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).[28] The results

24. See Sundaram and Richardson (2013) for illustrative estimates of the trade created when an importer graduates from a lower to higher tier.

25. We prefer the latter, tier 2 conception of our norm, for reasons discussed under "reliability" below, though our overall estimates at the aggregate level, and even for most sectors, differ very little between the two "norming" approaches.

26. We discuss below the conclusions we can draw from including exporter-by-year variables (dummy variables).

27. Every importing country's unique time-constant trade-pattern anomalies are absorbed into a country-specific importer intercept (dummy variable) that does not vary over time (Sundaram and Richardson (2013) does include alternative estimates that rest on importer-by-time effects). For example, the tendency for China to import more than India over our entire time period because of relatively accelerated openness is captured by a uniquely large intercept (Sundaram and Richardson's (2013) alternative estimates also calculate unique bilateral intercepts, higher-than-normal when the trading pair have negotiated preferential cross-border access to each other).

28. Koopman et al. (2010) can be read to suggest that multinational companies with long and diversified supply chains (self-insurance through both sourcing and distribution redundancies) can take advantage of numerous arbitrage opportunities that are not available to other firms, and that the growth and dominance of China and Mexico in global processing trade (85 percent of world-wide processing exports, according to page 17) might facilitate both kinds of arbitrage. On Mexico in this light, see also De La Cruz, Koopman, and Wang(2011).

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, voluble critics notwithstanding. High-threat tier 4 destinations lose (arguably from major-country export controls[30]) 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).

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.

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.

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 shortfall 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 over-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.

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*

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 group[34] 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]

tier 2 importers are instead taken as the norm, the bar for comparison is set lower (because traditional exporters' performance in trusted tier 1 markets is undistinguished, featuring many instances of export shortfalls, though less so for Japan). Therefore by the lower standards of tier 1 + tier 2 importers taken together, traditional-exporter underperformance in tier 3 markets is less bleak. Their estimated average shortfalls in moderate-risk tier 3 markets are almost half as bleak, as are exporter-by-exporter and sector-by-sector comparisons across the two default norms. The volatile electrical machinery sector (ISIC 383) is the source of more than three-quarters of the smaller shortfall for traditional rivals when the comparison bar is set lower (tier 1 and 2). For emerging-exporter rivals, the comparison across the two norms is a near-mirror of the pattern for traditional rivals. Emerging-exporter rivals have *not* performed as well as European and Japanese exporters in tier 2 import markets, but their relative performance is much better in trusted tier 1 importer markets, and correspondingly, better in tier 1 + 2 markets taken together. Thus by the undistinguished standards of tier 2 importers, emerging-exporter underperformance in the moderate-risk tier 3 importer markets is modest. But by the standards of tier 1 and 2 importers together, emerging-exporters' underperformance in less-trusted tier 3 markets is considerably larger—almost 50 percent larger shortfalls on average (and, by sector, from roughly 20 percent larger to near-100 percent larger in volatile electrical machinery exports).

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).

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

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

38. See De La Cruz, Koopman, and Wang (2011), Dean, Fung, and Wang (2011), and Koopman et al. (2010), especially page 21 passim.

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 strictures, 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

Aghion, Philippe, Julian Boulanger, and Elie Cohen. 2011. *Rethinking Industrial Policy.* Policy Brief 2011/04**,** June. Brussels: Bruegel.

Anderson, James E. 2011. The Gravity Model. Forthcoming in *Annual Review of Economics* 3. Available at https://www2.bc.edu/james-anderson/GravityModel.pdf, (accessed September 10, 2012).

Bergsten, C. Fred. 1988. *America in the World Economy: A Strategy for the 1990s*. Washington: Institute for International Economics.

Bergsten, C. Fred. 2011. The United States in the World Economy. Speech delivered at the Chautauqua Lecture Series, "The US Economy: Beyond a Quick Fix," August 12. Available at http://www.petersoninstitute.org/publications/papers/print.cfm?researchid=1905&doc=pub, (accessed November 1, 2011).

Bergstrand, Jeffrey H. 1985.The Gravity Equation in International Trade: Some Microeconomic Foundations and Empirical Evidence. *The Review of Economics and Statistics* 67 (August): 474–81.

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.

Bradford, Scott C., Paul L. E. Grieco, and Gary Clyde Hufbauer. 2005. The Payoff to America from Global Integration. In *The United States and the World Economy: Foreign Economic Policy for the Next Decade*, ed. C. Fred Bergsten. Washington: Peterson Institute for International Economics.

BIS (Bureau of Industry and Security). Various Years. *Annual Report to the Congress for Fiscal Year.* Washington: US Department of Commerce.

De La Cruz, Justino, Robert B. Koopman, and Zhi Wang. 2011. *Estimating Foreign Value-Added in Mexico's Manufacturing Exports.* USITC Office of Economics Working Paper No. 2011-04A. Washington: US International Trade Commission.

Dean, Judith, K. C. Fung, and Zhi Wang. 2011. How Vertically Specialized is Chinese Trade? *Review of International Economics* 19, no. 4: 609–625.

Del Gatto, Massimo, Filippo di Mauro, Joseph Gruber, and Benjamin R. Mandel. 2011. The Revealed Competitiveness of U.S. Exports. Board of Governors of the Federal Reserve System, International Finance Discussion Papers No. 1026. Washington.

Frankel, Jeffrey A., with Ernesto Stein and Shang-Jin Wei. 1997. *Regional Trading Blocs in the World Economic System*. Washington: Institute for International Economics.

Hufbauer, Gary Clyde and Rita M. Rodriguez, eds. 2001. *The Ex-Im Bank in the 21st Century: A New Approach?* Washington: Institute for International Economics, Special Report 14, January.

IUST (*Inside U.S. Trade*). Weekly, an *Inside Washington* publication. www.InsideTrade.com.

Jensen, J. Bradford. 2011. *Global Trade in Services: Fear, Facts, and Offshoring*. Washington: Peterson Institute for International Economics.

Koopman, Robert, William Powers, Zhi Wang, and Shang-Jin Wei. 2010. *Give Credit Where Credit is Due: Tracing Value Added in Global Production Chains.* NBER Working Paper No. 16426. Cambridge, Massachusetts: National Bureau of Economic Research.

Lewis, Howard III and J. David Richardson. 2001. *Why Global Commitment Really Matters.* Washington: Institute for International Economics.

Mann, Catherine L., assisted by Jacob Funk Kierkegaard. 2006. *Accelerating the Globalization of America: The Role of Information Technology*. Washington: Institute for International Economics.

McKinsey Global Institute. 2010. *How to Compete and Grow: A Sector Guide to Policy*, March. Available at http://www.mckinsey.com/insights/mgi/research/productivity_competitiveness_and_growth/how_to_compete_and_grow (accessed May 15, 2013).

Melitz, Marc J. and Daniel Trefler. 2012. Gains from Trade when Firms Matter. *Journal of Economic Perspectives* 26, no. 2 (Spring): 91–118.

Noland, Marcus. 1998. U.S.-China Economic Relations. In *After the Cold War: Domestic Factors and U.S.-China Relations*, ed. Robert S. Ross. Armonk, New York: M. E. Sharpe.

NRC (National Research Council of the National Academies). 2009. *Beyond "Fortress America" National Security Controls on Science and Technology in a Globalized World*. Washington: National Academies Press.

NSB (National Science Board). 2012. *Science and Engineering Indicators 2012*. Arlington, VA: National Science Foundation (NSB 12-01). Available at http://www.nsf.gov/statistics/seind12/ (accessed May 23, 2012).

OECD (Organization for Cooperation and Development). 2001. *Knowledge-Based Industries*. Paris: Directorate for Science, Technology, and Industry/Economic Analysis Statistics.

Richardson, J. David. 1993. *Sizing Up U.S. Export Disincentives*. Washington: Institute for International Economics.

Richardson, J. David and Karin Rindal. 1995. *Why Exports Really Matter!* Washington: Institute for International Economics.

Richardson, J. David and Karin Rindal. 1996. *Why Exports Really Matter—More!* Washington: Institute for International Economics.

Rodrik, Dani. 2011. *The Globalization Paradox: Democracy and the Future of the World Economy*. New York: W. W. Norton.

Shenai, Neena. 2010. *Export Control Reform 2010: Transforming the Legal Architecture of Dual-Use and Defense Trade Controls.* AEI Working Paper #163. Washington: American Enterprise Institute.

Spence, Michael and Sandile Hlatshwayo. 2011. *The Evolving Structure of the American Economy and the Employment Challenge*. New York: Council on Foreign Relations, Maurice R. Greenberg Center for Geoeconomic Studies.

Sundaram, Asha and J. David Richardson. Forthcoming 2013. *Peers and Tiers and US High-tech Export Controls: A New Approach to Estimating Export Shortfalls.* PIIE Working Paper. Washington: Peterson Institute for International Economics.

TechAmerica Foundation. 2011. *Cyberstates 2011*. Available at www.techamerica.org (accessed May 15, 2013).

Wallerstein, Mitchel B. 2009. Losing Controls: How U.S. Export Restrictions Jeopardize National Security and Harm Competitiveness. *Foreign Affairs* 88, no. 6 (November/December): 11–18.

WTO (World Trade Organization). 2012. *International Trade Statistics 2011.* Geneva.