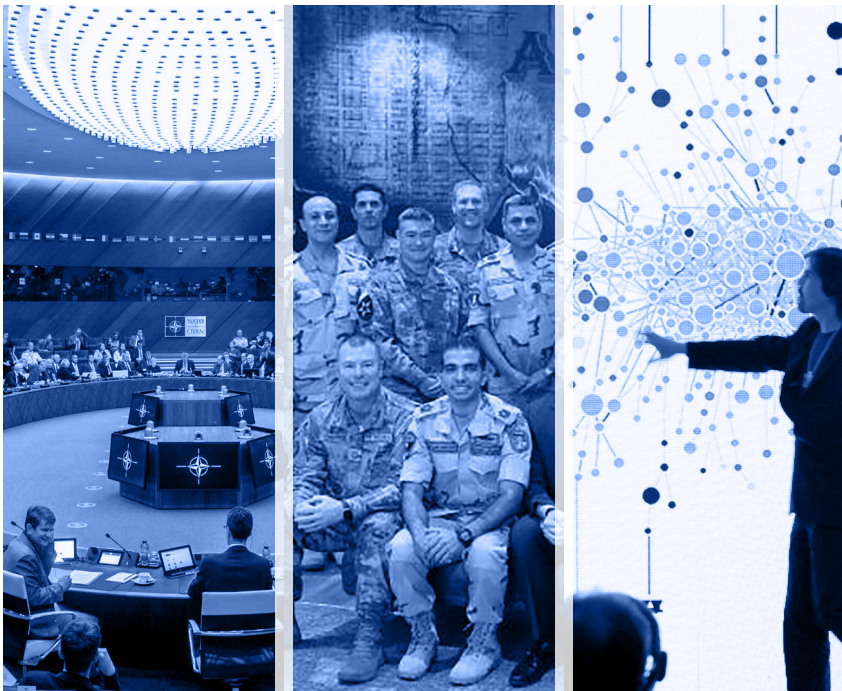




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U.S. Alliance and Partner Networks

A Network Analysis of Their Health and Strength



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About This Report

The Office of the Secretary of Defense (OSD) asked the RAND Corporation to assess the health and strength of the network of U.S. allies and partners. OSD also requested assessments of the degree to which that network's health and strength shifted over time and how it compares with the networks of China, Iran, the Democratic People's Republic of Korea, and Russia, the four principal state-based U.S. competitors identified in the 2018 U.S. National Defense Strategy. To complete this assessment, we used several datasets to represent three network layers focused on the diplomatic, military, and economic elements of national power. We employed a multimethod approach to this analysis, using four analytical techniques: network analysis, interdependence analysis, combinatorial optimization, and simulation.

This report can be of value as U.S. leaders approach the task of assessing and updating the U.S. national security and defense strategies. The Controlled Unclassified Information (limited-release) version of this report identifies countries that are key to the U.S. network of partners and allies and that represent points of potential vulnerability to the U.S. network and to those of its competitors. It identifies countries on which U.S. policy-makers might wish to focus to strengthen the U.S. network going forward. It also identifies areas in which adjustments to U.S. and allied resource allocations might strengthen deterrence to prevent future conflict. At the request of OSD, individual country names have been removed from this version of the report intended for unlimited public distribution. We have replaced those country names with "country X," and, to keep the reader from figuring out what country any letter represents, we have intentionally not replaced any country with the same letter throughout the report. That is, "country A" in one place is not the same as "country A" elsewhere in the report. The purpose in doing so is to provide readers insight into the methods used in this research without the distraction of some of the more thought-provoking results.

This report is intended for both national security decisionmakers and readers interested in international affairs; it assumes some familiarity with national security topics.

The research reported here was completed in June 2021 and underwent security review with the sponsor and the Defense Office of Prepublication and Security Review before public release.

RAND National Security Research Division

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For more information on the RAND International Security and Defense Policy Program, see www.rand.org/nsrd/isdp or contact the director (contact information is provided on the webpage).

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Summary

The 2017 National Security Strategy (White House, 2017), 2018 National Defense Strategy (NDS) (Office of the Under Secretary of Defense for Policy, 2018), and, more recently, the 2021 Interim National Security Strategic Guidance (Biden, 2021) have all emphasized the importance of strengthening alliances and attracting new partners in an era of strategic competition with such countries as China and Russia. U.S. alliances and partnerships take many forms but collectively form a network that can increase the United States' influence, promote such values as democracy and rule of law, reduce regional instability, and deter aggression.¹ U.S. competitors also have networks of allies and partners, which they can use to exert their own influence and shape, disrupt, or co-opt the rules-based international order established after World War II.

In this report, we describe our assessment of the health and strength of U.S. networks and those of U.S. competitors. We used primarily a method called *network analysis*, in which we analyzed not just the relationships or connections among actors—in this case, individual countries—but the

¹ For such a central concept in U.S. foreign policy, the United States' networks of alliances and partners cannot be easily defined. That is because of the variety of forms that these relationships take, including formal alliances with mutual-security guarantees; relationships without de jure guarantees but in which U.S. actions suggest de facto treatment as allies; other designations, such as *major non-North Atlantic Treaty Organization ally*, that lack any security guarantee component but confer special status; and formal and informal variants of partnerships. In this study, to capture this variety of relationships, we framed U.S. networks of alliances and partners broadly to capture a wide snapshot of the network of nations with which the United States cooperatively interacts and that it influences across the diplomatic, military, and economic elements of power. Given the difficulties in terminology here, we typically refer to these groupings as *the U.S. network*. Readers might therefore see nations that are not typically considered U.S. allies treated as such in places in this report. Similarly, when comparing the principal U.S. competitors identified in the 2018 NDS, some of which have a wide variety of relationships but few formal allies, we sought to map a broader network to the extent that extant data sources allow and, given the definitional complexities, typically refer to these simply as *U.S. competitor networks* or with similar terms.

relationships' structure as well. We examined three types of connections between countries, which we called *network layers*:

- **diplomatic** pledges of military support through treaties or related documents
- **military** activities, captured through arms sales and joint military exercises
- **economic** activities, such as international trade in general merchandise, key commodities, and strategic minerals.²

Within each of these network layers, we used **network analysis** to look at the number of **connections** that each country had. As we explain in the "Network Analysis" section of Chapter 1, connections can bolster the power that a country enjoys within the overall structure of a network because of the number of links the country has with other countries in the network. Network analysis also allowed us to assess countries' **centrality** within a network by measuring the extent to which a country connects to parts of the network that are relatively disconnected overall. For example, the United States serves as a bridge between multiple countries and alliance systems in Asia, Latin America, and Europe. Although the United States' military and economic strength, its attractiveness to other nations, and other factors no doubt set conditions that allow it to achieve this central position, network analysis offers a method to measure the ways in which this position confers benefits on the United States. In a star network, in which a single most-influential completely connected node lies at the center, that node has the greatest possible network centrality score of 1, or 100 percent. A network centrality of 0 percent indicates that the node is part of a network in which all nodes are isolates. We measured countries' network connections and centrality in each of the diplomatic, military, and economic layers listed above.

Building on our network analysis, we used a technique called **interdependence analysis** to help analyze the diplomatic (military alliance) net-

² We also conducted some initial analysis on an information layer, focusing on information flows from state-owned international broadcasters, but did not collect sufficient data to include this layer in our study.

work layer. This method allowed us to go beyond looking at network connections and centrality by analyzing four inputs that we describe in detail in Appendix A: alliance commitments, national capabilities (i.e., military capabilities and other indicators of national strength), potential future opponents (i.e., countries with the opportunity and will to threaten a set of countries), and the strength of those potential future opponents. For the diplomatic network layer, we measured the extent to which other states depend on each country (who is a big dog?) for their defense against potential opponents, as well as the extent to which each country depends on other countries (who is in need?). Adding these measures allowed us to assess an overall balance of dependence (i.e., does A need B more, or does B need A more?). For example, our measurements suggest that, in 2017, country A depended on the United States for 27 percent of the deficit between its own national capabilities and those of its potential opponents. The United States, by contrast, depended on country A for only 3 percent of its deficit, mostly indirectly. We looked at the change in countries' interdependence between 1989 and 2017. Decisionmakers in a country experiencing large change in its level of interdependence might have cause to contemplate their country's position in the international system and the continuing value of existing alliance ties to that country. For example, country B appears to have undergone relatively little change, perhaps thanks to its history of consistent interdependencies with other countries and relatively low level of armament. We discuss these methods and assess interdependence among a wide variety of countries in this report.

We measured the **robustness** of each alliance network against potential deliberate disruption or *directed attack* and competitors' ability to disrupt each other's networks (like the game Jenga). We used **combinatorial optimization** to measure networks' robustness against disruption over time. We did this by following changes to network cohesion that occurred if we removed differing combinations of nodes from each network. The network formed by a collective-defense alliance, such as the North Atlantic Treaty Organization, is said to be *complete* because every node has a link with every other node, representing the member states' mutual-alliance commitments. Complete networks are very robust. If nodes are removed from the network, multiple redundant paths still exist by which to get from one remaining node in the network to another. A complete network is cohesive; it has zero

fragmentation. A network consisting entirely of *isolate* nodes having absolutely no connection whatsoever to any of the other nodes in the network is the opposite extreme; it is completely fragmented. Fragmentation measures a network's cohesion between these two extremes.

Finally, we used the diplomatic (military alliance) network layer to simulate various possible future conflict scenarios. The scenario starting conditions were chosen based on feedback from RAND security experts about what scenarios have been prominent in past discussion with defense clients. The simulations modeled the degree to which conflicts spread (i.e., contagion) across alliance connections based on defensive or offensive pacts.

Many commentaries on international relations focus on current events. Our analysis takes a longer-term perspective. We chose points at which to measure U.S., allied, partner, and competitor networks that represent notable turning points in the international system:

- **1989** to capture the state of the world at the end of the Cold War
- **2000** to capture the changes to the international system that took place after the end of the Cold War but before the September 11, 2001, terrorist attacks on the United States
- **2017** to capture changes that followed the 9/11 attacks but before the changes introduced by the 2018 NDS. Also, 2017 was the most recent year for which we could access sufficient data.

We looked at all networks but focused particularly on the networks of the United States and the individual networks of China and Russia.

Findings

It is important to note that our calculations are based on datasets, which are described in Chapter 1. Thus, our findings are subject to whatever limitations these data present. This report and its appendixes describe our methods in far greater depth. The techniques used are also subject to a significant series of limitations. Those limitations are enumerated in detail at the end of the introduction and in each subsequent chapter of this report. The findings presented here are not intended to supplant more-familiar qualitative analy-

ses or the views of regional experts or in-country personnel, who might have a better “fingertip feel” for the direction in which the winds are blowing in any region or in any given U.S. bilateral relationship. However, this assessment could offer additional and differing insights into longer-term questions of where and how the U.S. network of alliances and partners is strong and can be leveraged or is weak and must be bolstered. Although we believe that the analysis was innovative and provides new ways of thinking about networks of allies and partners, it is a complement to, not a substitute for, qualitative expert assessments.

Given the exploratory nature of this research, readers should not be beguiled by the apparent precision of the results generated by the analyses presented below either; it is the relative size, direction, and magnitude of those results rather than their somewhat spurious precision that are potentially important. Each of the datasets employed in this study provides a snapshot of a network layer that is important. Moreover, looking at the combination of those network layers provides readers with insights into trends in the health and strength of the U.S. network across time.

The primary purpose of this study was to test the assumption that the United States could continue to rely on the influence conferred on it by its extensive network of allies and partners when formulating and executing its grand strategy in an era of great-power competition.

The picture that emerges from this report is one of continued U.S. diplomatic and military strength, lower U.S. economic influence, growing Chinese power, and declining Russian power. China owes its expanding power principally to the economic growth that it achieved in the past two decades. Although it is important to acknowledge the strategic advantages conveyed to China by its economic growth trajectory, it is also worth recognizing some of China’s continuing economic limitations. Even though China was the leading trading partner by value in two-thirds of the world’s bilateral trading relations in 2017, the United States’ network of allies and partners was 1.8 times more central to the global trade network than China and its then 66 Belt and Road Initiative partners. In the economic sphere, the U.S. network of allies and partners should—properly managed—be able to continue to play a leading role in shaping the overall environment. This is important because it is from this economic environment that the United States’ leading competitor, China, draws much of its power.

Nine out of ten countries that were key to trade between the rest of the world and the competing great powers and their allies and partners in 2017 were U.S. allies. More than two-thirds of the countries that were key players in trade in key commodities and strategic minerals were U.S. allies. And China's network of trade with its 66 Belt and Road Initiative partners was almost four times more vulnerable to deliberate disruption than the network of trade between the United States and its partners and allies.

That is not to say that the advantages that this network provided the United States in the military realm were inconsiderable. The universe of countries with military alliances remained 12 times more militarily dependent on the United States than on China in 2017. U.S. allies were, at that time, on average, significantly more dependent on the United States than China's allies were on China. Moreover, military dependence on the United States had been growing since the end of the Cold War. That growth allowed the U.S. network of partners and allies to continue to remain most central to military dependence in all six regions of the world, whereas it remained most central to trade in only half of the regions of the world. Furthermore, in 2017, China's and Russia's alliance networks were twice and 1.5 times, respectively, more vulnerable to deliberate disruption than that of the United States.

Military dependence on China rose significantly between 1989 and 2017. By 2017, China had replaced Russia in second place as the country on which allies depended most, on average, militarily in all regions of the world. This surge in military dependence on China means that there are no grounds for complacency, despite the United States' apparent continuing ability to shape the global economic and military environments when working closely and cooperatively with its network of allies and partners.

Forty-three percent of countries with military alliances in 2017 experienced a 50-percent or greater change in their level of dependence on other countries between 1989 and 2017. These changes might have given many international decisionmakers on security issues cause to reconsider both their place in the post-World War II international security system and the continuing value of existing alliance ties to their countries. What was true of the global alliance system was even truer for the U.S. network of allies and partners. Forty-six percent of them experienced similar-size changes in their interdependence. For decisionmakers in these countries, the interna-

tional security landscape was in flux. Although many commentators speak about the U.S. alliance network as largely static and durable, these changes in dependence suggest that policymakers should pay careful attention to the strength of the network and their approach to individual countries where these shifts are significant.

This report should be of value as U.S. leaders approach the task of assessing and updating the U.S. national security and defense strategies. A limited-release version identifies countries that are key to the U.S. network of partners and allies and that represent points of potential vulnerability to the U.S. network and to those of its competitors. It identifies countries on which U.S. policymakers might wish to focus in strengthening the U.S. network going forward. It also identifies areas in which adjustments to U.S. and allied resource allocations might strengthen deterrence of future conflict.

Can the United States continue to rely on the advantages conferred on it by its network of partners and allies in formulating its grand strategy? The analyses reported here suggest that, for the time being, the answer appears to be an emphatic “Yes!” However, they also show that there are no grounds for complacency. If the United States wishes to be able to continue to rely on these advantages, there is much work to be done.

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Introduction

Continuing support from allies and partners has been one of the most-consistent assumptions underpinning U.S. national security and defense strategy since 1945 (Brands et al., 2017).¹ The 2018 NDS emphasized “Strengthening Allies and Attracting New Partners” as one of its three foundational lines of effort (Office of the Under Secretary of Defense for Policy, 2018, p. 8). Former U.S. Secretary of Defense James N. Mattis attached high priority to this issue and depicted the stakes in stark terms:

From our very beginnings, allies have been critical to our nation’s survival. So I just see myself in the continuing tradition of how we look at allies. History is very, very clear to me, and not just about America. Nations with allies thrive, and nations without them die, so it’s real simple. (Mattis, 2019)

The 2021 Interim National Security Strategic Guidance reinforced this perspective as a priority of the Biden administration, identifying the United States’ “broad and deep network of partnerships and alliances” as a key source of national power (Biden, 2021, p. 6). Yet if the key role of allies and partners has been among the most-consistent elements of recent U.S. strat-

¹ There are, of course, critical differences between the United States’ formal alliances and its partnerships, which are discussed later in this chapter. Although these categories of relations are clearly different and involve different obligations, each also confers certain advantages. And the network created by both categories can create benefits that exceed those that would accrue from either category alone. Given the 2018 U.S. National Defense Strategy’s (NDS’s) injunction to focus on both groups of nations, for the purposes of this study, we looked across the entirety of these networks. In most cases, for simplicity, we use the term *network* to refer to this totality of formal and informal relationships.

egy, it is also one that has been increasingly challenged. China and Russia—the principal competitors identified in the 2018 and 2021 strategies²—both seek to undermine the United States’ networks of allies and partners. Russia actively seeks to undermine the North Atlantic Treaty Organization (NATO), whether by means of competition for qualitative military advantage in certain scenarios, by conducting surprise snap exercises on NATO’s borders, or through activities in cyberspace designed to undermine the cohesion of U.S. and European societies.³ China, meanwhile, seeks to sow doubt among U.S. allies in Asia about the United States’ staying power and to portray the United States as retreating from the world stage (Blackwill, 2020). Recent U.S. administrations have emphasized that allies and partners must carry a greater share of the international security burden. President Donald Trump was not shy about expressing his view that the United States had been getting a raw deal from its allies and partners,⁴ threatening at times to remove U.S. forces stationed abroad (Schmitz, 2020), pressuring allies to increase their share of the costs of local U.S. presence significantly (Gaouette, 2019), and even hinting that U.S. security guarantees might not be so inviolable if allies’ defense spending did not improve (Sanger and Haberman, 2016). The Biden administration has been less confrontational but clear about the importance of burden-sharing.⁵

At the root of many criticisms bemoaning the United States’ alliances is an implicit assumption that the fairness of the relative burdens assumed by the states that are party to alliances is the central measure of merit for those alliances’ utility for the United States. Those who hold to more-traditional understandings of alliances argue that fairness is less relevant:

² Although U.S. strategy documents often treat China and Russia together as “great powers,” U.S. leaders have made clear that China is their priority. For example, see McLeary, 2019. For this reason, although the text that follows discusses issues that are relevant globally, it often dwells most heavily on China-related issues.

³ Innumerable sources detail this issue. For example, see Van Herpen, 2014. For a shorter commentary germane to this study that makes this point, see Wilson, 2019.

⁴ Many people have documented this issue. For one example, see Wright, 2016.

⁵ See U.S. Secretary of State Antony Blinken’s assertion that, “[w]hen our allies shoulder their fair share of the burden, they’ll reasonably expect to have a fair say in making decisions” (Blinken, 2021).

The more important question is whether the United States benefits from alliances more than it gives up. They argue that the United States benefits disproportionately from being the leader of such a large network, even if it must shoulder a greater share of the burdens associated with membership in that network.⁶ In the case of the European allies of the United States, the traditional understanding of these networks' utility had little to do with transactions or even support of the United States by these countries but rather centered on the value of the local presence of the United States as a powerful hegemon in preventing Europe from descending into further conflicts of the kind that characterized much of European history prior to and including World War II (Scheidel, 2019; Fix and Giegerich, 2019). Proponents of this school of thought argue that the United States should, of course, encourage its allies to contribute more to alliances but that allies will always have mixed incentives to contribute so long as a U.S. guarantee of their security remains in place. Those who take this view argue that the benefits of stability and increased U.S. influence nonetheless far outweigh the costs and that such stability and influence accrue disproportionately to the United States' advantage.

These arguments, however, largely assume a degree of preponderant U.S. power. For many national security practitioners, U.S. alliances and partnerships have taken on a new and particular importance recently as both allies and partners assessed the implications of China's rise—a dynamic that has now become the dominant concern of U.S. national security policy discourse. In the past 40 years, China has undergone an unprecedented transformation, rising from a poor, isolated state to become the world's largest or

⁶ This understanding of alliances corresponds to classical game theory predictions of a snowdrift game, in which a stronger party can achieve an outcome more quickly and from which weaker parties then benefit. The payoff structure is seen as analogous to the strongest person digging a waylaid car from beneath a snowdrift. Everyone wants to get moving, and the strongest person can dig out the car fastest, so the strongest person does it even though the other riders will benefit without paying the cost, hence rendering the transaction "unfair." Waiting for a weaker player to dig out the car only delays the strongest person, however, so it is always in the strongest person's interest to dig out the car themselves regardless of fairness. The point is that debates about transactional fairness can completely miss traditional understandings of alliance utility for the United States when it plays a role as a *de facto* hegemon. See, for example, Kümmerli et al., 2007.

second-largest economy,⁷ among many other superlatives (Morrison, 2019). China has eclipsed the United States as the primary trading partner for two-thirds of the world's nations, reversing a dominant position occupied by the United States only 20 years ago (Johnson, 2019). Beijing's Made in China 2025 goals made clear its intent to dominate areas of key technology that it believed to be essential to China's future growth (Jourdan, 2018). And for the military domain, most observers believe that U.S. conventional deterrence of conflict in the Indo-Pacific region—a bulwark of regional stability on which numerous countries have traditionally placed their trust—is eroding (Colby, 2019).

As U.S. strategists have become seized of these trends, two countervailing dynamics have unfolded. First, predictions of U.S. decline have proliferated, along with suggestions about how to manage that decline (see, e.g., Haass, 2019; Cooley and Nexon, 2020; Zakaria, 2019; and Allison, 2018). Yet, as former U.S. Secretary of State George P. Shultz once observed, such pessimism is not an option for U.S. policymakers.⁸ As a result, a broad consensus has emerged among Washington's political establishment that the United States must move purposefully to compete with China (Fontaine, 2019). And as policymakers see other U.S. advantages eroding, they increasingly take comfort in those advantages that they believe to be enduring. The U.S. network of alliances and partnerships is often in the top spot on that list. The result frequently is a chorus of voices from across the political spectrum eager to reaffirm this article of faith (King, 2019).

Yet, as the Polish American writer and diplomat Czesław Miłosz once noted, “Man tends to regard the order he lives in as natural” (Krastev, 2017, p. 107). The assumptions that people hold dearest are the very ones for which people can be blindest to changes. It could be that the United States' network of alliances and partnerships not only remains robust today but rests

⁷ Whether China is currently the world's largest or second-largest economy depends on how one measures. If measured based on purchasing-power parity, China surpassed the United States in 2015. See, for example, International Monetary Fund, 2020.

⁸ Retrenchment is, however, an option. A key argument of adherents of the restraint school of U.S. grand strategy is that restraint would encourage or enable allies and partners to do more, without necessarily undermining their relationships with the United States. For an exposition of this philosophy, see Posen, 2014.

on a dense network of interconnections and interdependence that is durable and difficult to break.⁹ Previous RAND analysis, for example, examined the health of the international order more broadly and found that, despite clear strains, it is surprisingly resilient (Mazarr et al., 2017). It could also be that the increasingly assertive postures that Russia and China have recently assumed will drive the United States' European and Asian allies toward the United States' network (see, for example, Smith, 2019).¹⁰

But blind faith that the strength of U.S. alliances and partnerships with the United States will endure, even as countries seek to balance China, could also leave U.S. strategists in for a nasty surprise. As Ivan Krastev observed of the blindness in Brussels to centripetal tendencies in the European Union,

The architects of the European project have fooled themselves into believing that avoiding mentioning the “D” word [disintegration] is a surefire way to prevent it from happening. For them, European integration was like a speed train—never stop and never look back. Making the European Union's disintegration unthinkable was the preferred strategy over making integration irreversible. (Krastev, 2017, p. 3)

If the United States is to continue to count on its networks of alliances and partners as a bedrock element of its grand strategy, it must be clear-eyed about the health and durability of those networks. Whether, how, and where those networks are under strain is a subject of intense debate.

⁹ Zeev Maoz has been the pioneer in using network analysis to explore international relations (IR). We owe much to his groundbreaking work in this discussion of different types of network ties analysts use to scrutinize alliances. See Maoz, 2006; Maoz, 2009; and Maoz, 2011.

¹⁰ For further discussion of the evidence on balancing and “bandwagoning” on the part of Asian powers confronted with China's rise, see Roy, 2005. The Comprehensive and Progressive Agreement for Trans-Pacific Partnership, signed in March 2018, despite the withdrawal of the United States from a predecessor agreement, is an example of continuing efforts of Asian countries to balance the economic rise of China. It is worth noting that this agreement was forged despite the absence of the United States as a signatory, indicating that certain member states saw a need to bolster existing U.S. Pacific-area military alliance ties with an additional agreement.

As with the political debates mentioned above, there is no shortage of commentators who will marshal evidence and anecdotes in support of their preferred position. In Europe, some who believe that the United States' alliances are fraying will point, for example, to French president Emmanuel Macron's comment that the NATO alliance is "brain dead," nations working with China to create work-arounds to U.S. objections at the World Trade Organization (Brunsden, 2020), or European nations' decision to seek to create an alternative to the Society for Worldwide Interbank Financial Telecommunication (Farrell and Newman, 2020). Yet others argue that the United States and its European allies remain mostly aligned on grand strategy (Wilson, 2019) and that NATO has newfound purpose and cohesion as Russia's national security posture has become more threatening (Zengerle and Chiacu, 2019).

A similar debate is underway in Asia. A 2020 analysis by Australia's Lowy Institute rated China as the most diplomatically influential nation in Asia (Lowy Institute, 2020).¹¹ A former U.S. national intelligence officer for Asia judged U.S. primacy in Asia to be "a thing of the past" and argued that the United States' Asian allies are already adjusting their foreign policies to hedge against an unreliable U.S. future role in the region (Heer, 2019). Commentators on the other side of this argument have noted that, despite these trends, polling suggests that people across Asia trust the United States more than they trust China (Silver and Devlin, 2020; Cha, 2020) and that recent Chinese behavior—whether its aggressiveness in the South China Sea (Denmark, Edel, and Mohandas, 2020), its treatment of ethnic minorities (Zenz, 2019), its coercive economic practices vis-à-vis its neighbors (see, e.g., Snyder, 2016), its recent crackdown in Hong Kong (Ramzy and Yu, 2020), or its assertiveness during the coronavirus pandemic (Ward, 2020)—has negatively affected China's relationships across Asia and soured world opinion against China (Wuthnow, 2020). Yet others have noted that what states really want are the benefits both of U.S. security guarantees and of trade with China and that nations simply try to avoid being forced to choose between the two (Stromseth, 2019). It is hard to say which of these competing dynamics will prove dispositive over the long run; in this project, we

¹¹ The authors of that report concluded that the United States was still the most powerful nation in Asia but that China was quickly catching up.

aimed to leverage network analysis to bring additional perspectives and evidence to these debates.

Defining *Network of Allies and Partners*

For such a central concept in U.S. national security policy, the United States' network of allies and partners cannot be easily defined. That is because of the variety of forms that these relationships take. In scholarly studies, alliances can take the form of mutual-defense agreements of various sorts (e.g., offensive, defensive, defined by a geographical area, symmetric, asymmetric), as well as pacts that fall short of legal commitments to mutual defense (e.g., treaties of amity, nonaggression, neutrality, or consultation pacts) (see, for example, Leeds, 2003, and Morrow, 1991). In the United States' case, in addition to legally binding mutual-defense treaties, such designations as *major non-NATO ally* (MNNA) exist. The nations designated by the U.S. Congress in this manner are states that receive special "allied" status despite the fact that neither party provides security guarantees to the other (Bureau of Political-Military Affairs, 2021). Then there are relationships, such as those between the United States and Taiwan or Israel, that some argue involve the United States having made *de facto* security guarantees even if it has not made them *de jure* (Beckley, 2015). Finally, quasi-alliances exist in which countries have made both direct and indirect security commitments to one another without formalizing them in a treaty.

U.S. partners can be identified via formal designations, such as NATO's "enhanced opportunity partners" (NATO, 2020), can leverage agreements that are less formal or far-reaching that bring nations closer together short of formal alliance (e.g., information-sharing agreements) or can operate as informal partnerships in which states cooperate on certain issues in the absence of any formal agreement. As shown in Figure 1.1, in this study, to capture this variety of relationships, we framed U.S. networks of alliances and partners broadly.¹²

¹² In our definition of *military alliance*, we follow that of Stephen M. Walt:

An alliance is a formal or informal commitment for security cooperation between two or more states. Although the precise arrangements embodied in different alli-

FIGURE 1.1

Defining *Ally* and *Partner*

NOTE: SCO = Shanghai Cooperation Organisation. JME = joint military exercise. *Rio Pact* is a short reference to the Inter-American Treaty of Reciprocal Assistance and Final Act of the Inter-American Conference for the Maintenance of Continental Peace and Security, signed on September 2, 1947, in Rio de Janeiro. This treaty remains in force to this day and, importantly, includes Cuba as a member state. The Organization of American States, the official depository of ratifications of the Rio Pact, shows Cuba as having ratified the treaty and the United States as having done so as well. There is no record on the official depository's website of the suspension of Cuba's membership, either via unilateral action by the United States or via a Cuban renunciation.

We included three types of allies:

- countries with which the United States has legally binding security guarantees and countries that have quasi-alliances due to security commitments that fall short of formal treaty commitments that they have made to one another (e.g., SCO member states)¹³

ances vary enormously, the defining feature of any alliance is a commitment for mutual military support against some external actor(s) in some specified set of circumstances. This concept includes both formal alliances—where the commitment is enshrined in a written treaty—and informal, *ad hoc* agreements based either on tacit understandings or some tangible form of commitment, such as verbal assurances or joint military exercises. (Walt, 1997, p. 157)

Because of their very nature, we do not examine secret treaties, even though many, both tacit and explicit, existed during the period under examination in this study.

¹³ We considered SCO a quasi-alliance because (1) it involves counterterrorism security cooperation commitments between its member states; (2) its members conduct regular joint military exercises together; and (3) its members have discussed merging SCO with the Collective Security Treaty Organization (CSTO), a formal collective-defense alliance.

- countries that are de facto U.S. allies by virtue of either
 - signals of intent to defend them made by U.S. policymakers or codified in U.S. law (Taiwan)¹⁴
 - past U.S. military intervention in their behalf (e.g., Israel, Kuwait, Saudi Arabia) (i.e., countries in defense of which the United States would *probably* intervene in a future conflict regardless of the presence or absence of a formal, legally binding security commitment)
- countries designated as MNNAs under U.S. law (e.g., Afghanistan, Egypt). Although these countries have been designated allies by the U.S. Congress, no formal legally binding treaty commitment exists; it is an open question whether the United States would intervene in their defense in times of conflict. However, we chose to interpret this designation as a statement of intent (i.e., that the United States would *possibly* intervene in these countries' defense in the event of conflict, despite the lack of a formal treaty commitment to do so).¹⁵

We excluded partners of any form from this definition of *ally*. By this definition, in 2017, the United States had 65 allies, whereas its competitors had 17. Full listings of the countries considered allies of the United States and its competitors during the periods under examination in this study are given in a series of figures later in this chapter and a series of tables in Appendix B.

We also used a broader definition of *allies and partners* when examining JMEs and arms sales. In this instance, any country that bought or sold arms from a given country or participated in a JME with that country was considered an ally or partner.

When examining international trade, we included all 66 partner states under Beijing's Belt and Road Initiative (BRI) in 2017. In the United States' case, we stuck with the 65 allies that we identified using the approach described above.

¹⁴ The Taiwan Relations Act (Pub. L. 96-8, 1979, codified at 22 U.S.C. Ch. 48) requires the U.S. government both to provide defensive arms to Taiwan and to maintain the ability to assist Taiwan in the event of foreign aggression against it.

¹⁵ Relevant statutes include 22 U.S.C. Section 2751, 22 U.S.C. Section 2321k, and 10 U.S.C. Section 2350a.

We adopted this approach for three reasons. First, the U.S. Department of Defense commissioned this study to further its goal of assessing and adapting the 2018 NDS; given the 2018 NDS's enjoiners to "strengthen alliances and attract new partners," a broader framing of alliances that extended beyond mutual-security guarantees seemed appropriate when answering this question.

Second, a broad concept of U.S. networks allows comparisons with competitors that a focus on formal treaty alliances would not offer. For example, many of the competitors have few, if any, formal allies (Bo, 2016)—a fact in which U.S. experts often seem to take comfort (Wyne, 2014). Yet some of the competitors have strong or growing partner networks, and those networks confer influence, regardless of whether they extend to include formal security guarantees. Additionally, given the study's focus on the insights that network analysis can yield, capturing a broader picture of U.S. networks makes sense.

If we are to gauge real progress toward the 2018 NDS's goals, we must therefore have this broader picture in mind. Given the definitional nuances at play here, we typically refer to this group of U.S. alliance and partnership relationships hereafter as the *U.S. alliance system* or the *U.S. alliance network*.

Research Questions, Approach, and Methodology

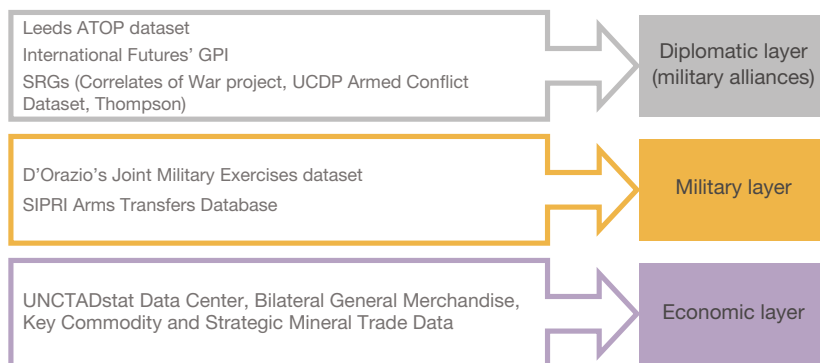
The goal of this study was to bring new methods and different types of evidence to bear on the question of the relative strength and health of U.S. networks of allies and partners. We used network analysis to draw quantitative conclusions about the health and fragility of the U.S. alliance system, both over time and relative to the four principal competitors identified in the 2018 NDS (China, Iran, the Democratic People's Republic of Korea [DPRK], and Russia). To do this, we had to answer three basic research questions:

- How do the cohesion, interdependence, robustness, and stability of U.S. and competitor alliance and partner networks compare over time?
- Which are the strongest and weakest links and nodes in those networks?

- What strategies can be used to strengthen networks of partners and allies and to disrupt competitor networks?

Quantitative analysis of alliance relationships of the kind undertaken in this study is a very well-established methodological approach within the IR discipline. A search on the referenced Leeds Alliance Treaty Obligations and Provisions (ATOP) dataset (Leeds, undated) yields more than 18,000 hits. Quantitative analyses that make use of network analysis to study alliance relationships empirically are less prevalent. We were able to identify only a handful. Maoz's book *Networks of Nations* appears to have been groundbreaking in adapting social network analysis (SNA) techniques to IR theory (Maoz, 2011). Cranmer, Desmarais, and Menninga used an exponential random graph model to analyze interdependence in alliance networks and to estimate covariates' effects on alliances (Cranmer, Desmarais, and Menninga, 2012). Matthew Jackson and Stephen Nei used network analysis of the ATOP dataset to investigate the role of networks of alliances in preventing multilateral interstate wars. They found that, without trade, no network of alliances is stable (Jackson and Nei, 2015). Jackson and Nei stated, "There is a literature that adapts . . . balance theory . . . to examine network patterns of enmity. The ideas in those works build upon notions of the form that 'the enemy of my enemy is my friend'" (Jackson and Nei, 2015, p. 15278, citing Hiller, 2012; Rietzke and Roberson, 2013; and König et al., 2015). Otherwise, the literature on the use of network analysis to study the strength and health alliances appears to be quite sparse.

As shown in Figure 1.2, to answer the research questions posed above, we gathered data describing three elements of national power—diplomatic, military, or economic (DME)—of the United States and its competitors. (We also attempted to examine the information element of national power but did not find enough datasets that could be leveraged to do so.) We chose to look across elements of national power as a lens through which to approach the research questions posed because this is the primary approach adopted by the U.S. Department of Defense in its declared military doctrine (Joint Chiefs of Staff, 2017, p. I-12). We used eight relatively well-known datasets to model U.S. and competitor networks along these dimensions of national power. We term each dimension of national power modeled a *network layer*.

FIGURE 1.2**Data Sources Used for Each Network Layer**

SOURCES: Leeds, undated; Moyer and Markle, 2018; Stinnett et al., 2002; Uppsala Conflict Data Program, undated; Thompson, 2001; D'Orazio, 2013; SIPRI, undated a; United Nations (UN), undated; UN Conference on Trade and Development, undated.

NOTE: GPI = Global Power Index. SRG = strategic reference group. UCDP = Uppsala Conflict Data Program. *International Futures* is a short reference to the Frederick S. Pardee Center for International Futures.

For the diplomatic network layer, we used Leeds's ATOP dataset (Leeds, undated), examining treaty allies, quasi-allies, de facto allies, and MNAs described above (together, *allies*). The ATOP dataset has been widely used by other researchers and is considered reliable. We also used International Futures' GPI (Moyer and Markle, 2018), the Correlates of War project's geographical contiguity file (Stinnett et al., 2002), the UCDP Armed Conflict Dataset, and Thompson's list of strategic rivals (Thompson, 2001) to construct a matrix of countries' potential future opponents with which to calculate military interdependence within this layer (Moyer and Markle, 2018; Pettersson, Högladh, and Öberg, 2019; Thompson, 2001). For the military network layer, we used one other well-known dataset and one less well-known dataset: (1) the SIPRI Arms Transfers Database (SIPRI, undated b);¹⁶ and (2) Vito D'Orazio's Joint Military Exercises dataset (D'Orazio, 2013). In these two instances, we examined any countries that traded in arms or engaged in JMEs with one another. These latter two datasets are not highly

¹⁶ See also "Definition of Military Expenditure" at SIPRI, undated c.

correlated with the military alliance dataset that we used in the diplomatic network layer and thus provide important complementary information. We used the UN's Comtrade database (UN, undated) to build and analyze an economic network layer consisting of

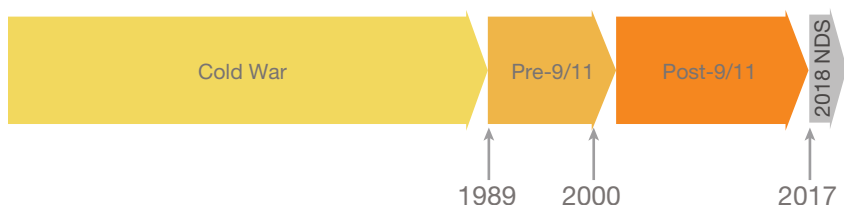
- general merchandise trade networks
- networks of trade in key commodities
- networks of trade in strategic minerals.

In this network layer, we examined trading relationships between China and its 66 BRI partners, the DPRK's single ally (China), Iran and its five allies, Russia and its 11 allies, and the United States and its 65 allies. We also scrutinized trade between those five groups and the rest of the world (ROW).

To draw longer-term conclusions about the depth, stability, and vulnerability of U.S. and U.S. competitor networks, we gathered data from three distinct periods, as illustrated in Figure 1.3:

- **1989**, to measure the scope of the network at the end of the Cold War, just before the “unipolar moment” of unrivaled U.S. power¹⁷
- **2000**, to capture the scope of the U.S. ally and partner networks at this unipolar moment but before the terrorist attacks of 9/11 altered U.S. security policy
- **2017**, the last year for which reasonably complete data were available at the time that our initial findings were presented to the U.S. Department of Defense and before the United States retooled its defense strategy to adapt to reemerging great-power competition.

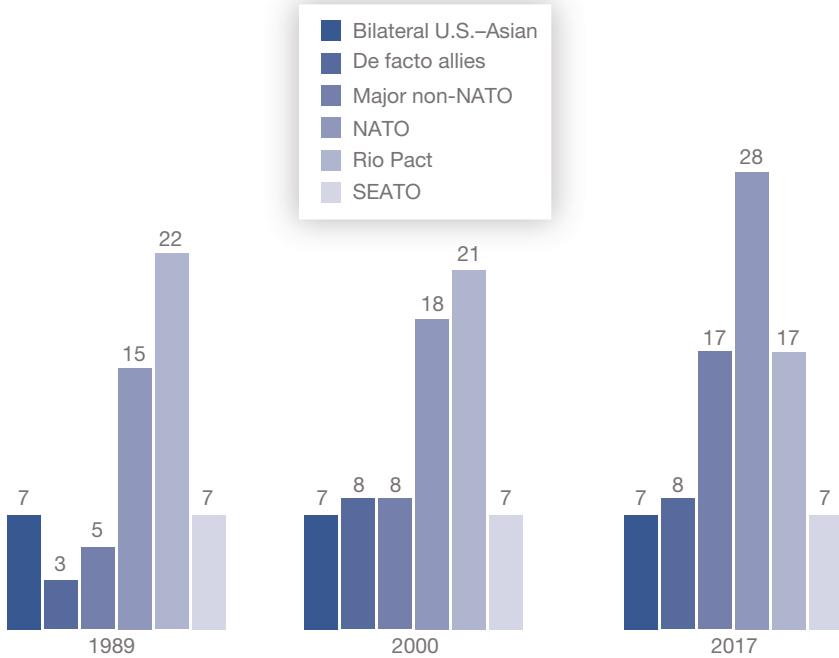
¹⁷ It could be argued that the Soviet system had already begun to atrophy by 1989 and that the choice of this year for measurement therefore might not adequately represent the strength of that system, when it was at its apogee. However, with its alliances fixed and significant arms exports and military exercises ongoing, the only network layer likely to be affected significantly by the exact choice of year is the economic layer. As witnessed by intelligence agencies' failure to detect the impending economic collapse of the Union of Soviet Socialist Republics (USSR), measuring the true value of Communist-bloc countries' economic activity in any given year—let alone 1989—was an inexact science at best.

FIGURE 1.3**Points of Time at Which Networks Were Measured**

This report examines the connections and centrality of DME networks of ties between countries or groups of countries at two basic levels of aggregation or analysis:

- To ensure that we captured important relationships that might extend beyond the boundary of any single country's alliance network or any group of countries' networks of allies and partners, our first level of analysis was that of those networks' positions within the overall *global* ecosystem of overlapping alliances and partnerships. In 2017, 131 states, among 254 nations and territories in the international system, had alliance relationships that remained in force. Those alliances created 2,058 alliance ties between nations.
- To produce information of potential operational value to the U.S. Department of Defense's unified combatant commands, we also analyzed connections and the centrality of network ties within each of six individual *regions* of the world.

Figures 1.4 and 1.5 show the United States' allies, as defined above, for the years 1989, 2000, and 2017. (The data underlying each figure are provided in tables in Appendix B.) Because these allies all have a common ally in the United States, we treated these countries as belonging to a single U.S. alliance network, even though that system consists of several multi-lateral and bilateral alliances. For each network layer, we analyzed relations between the U.S. alliance system and the other alliance systems. We also examined the importance of individual members of the U.S. alliance system within each network layer.

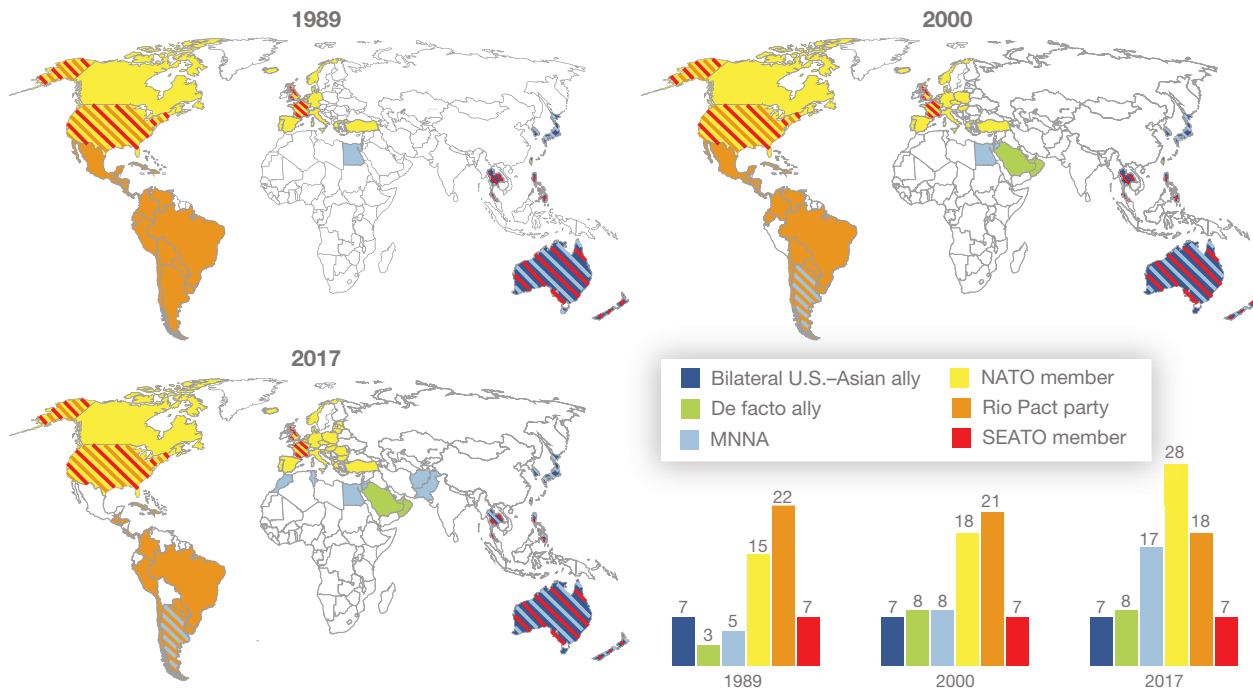
FIGURE 1.4**U.S. Allies, 1989, 2000, and 2017: Summary of Unique Numbers of Allies**

NOTE: SEATO = Southeast Asia Treaty Organization. The total numbers of U.S. allies in 1989, 2000, and 2017 were 47, 55, and 65, respectively. The numbers in the bar charts do not sum to these totals because certain allies (Australia, France, Great Britain, Israel, Japan, South Korea, Kuwait, New Zealand, Philippines, Thailand, and Taiwan) are double-counted because they belonged to more than just one category of ally.

Figures 1.6 and 1.7 show the allies of each of the four U.S. competitors identified in the 2018 NDS for the years 1989, 2000, and 2017 (China, the DPRK, Iran, and Russia). In this case, too, we treated each U.S. competitor's alliances as forming a single system, even though those systems also consist of several multilateral and bilateral alliances. Here too, for each of the network layers, we analyzed relations between those alliance systems and the other alliance systems in that layer. We examined the importance of individual members of each alliance system within each network layer. Finally, because of increased signs of cooperation and coordination between U.S. competitors, we also ana-

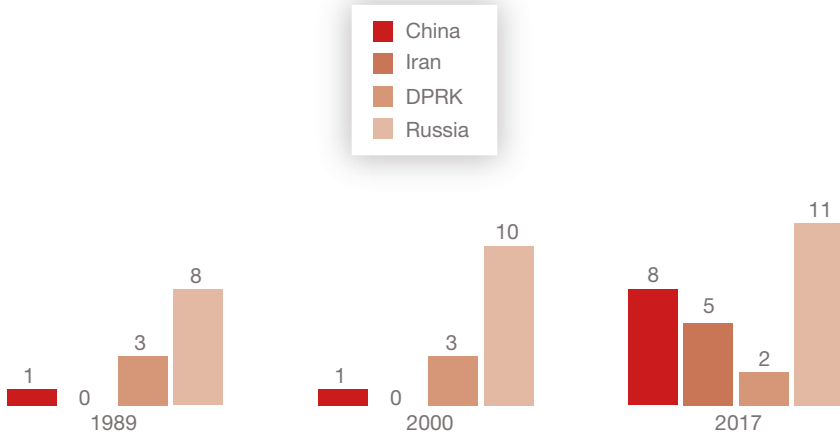
FIGURE 1.5

U.S. Allies, 1989, 2000, and 2017: Summary Map of Unique Numbers of Allies



NOTE: The total numbers of U.S. allies in 1989, 2000, and 2017 were 47, 55, and 65, respectively. The numbers in the chart do not sum to the totals because certain allies (Australia, France, the UK, Israel, Japan, South Korea, Kuwait, New Zealand, the Philippines, Thailand, and Taiwan) are double-counted because they belonged to more than one category of ally.

FIGURE 1.6

U.S. Competitors' Allies, 1989, 2000, and 2017: Summary

NOTE: The total numbers of competitors' allies were 11, 13, and 17 in 1989, 2000, and 2017, respectively. The numbers in the figure do not sum to these total because China, India, Kazakhstan, North Korea, Kyrgyzstan, Pakistan, Russia, Syria, Tajikistan, and Uzbekistan belonged to multiple alliances.

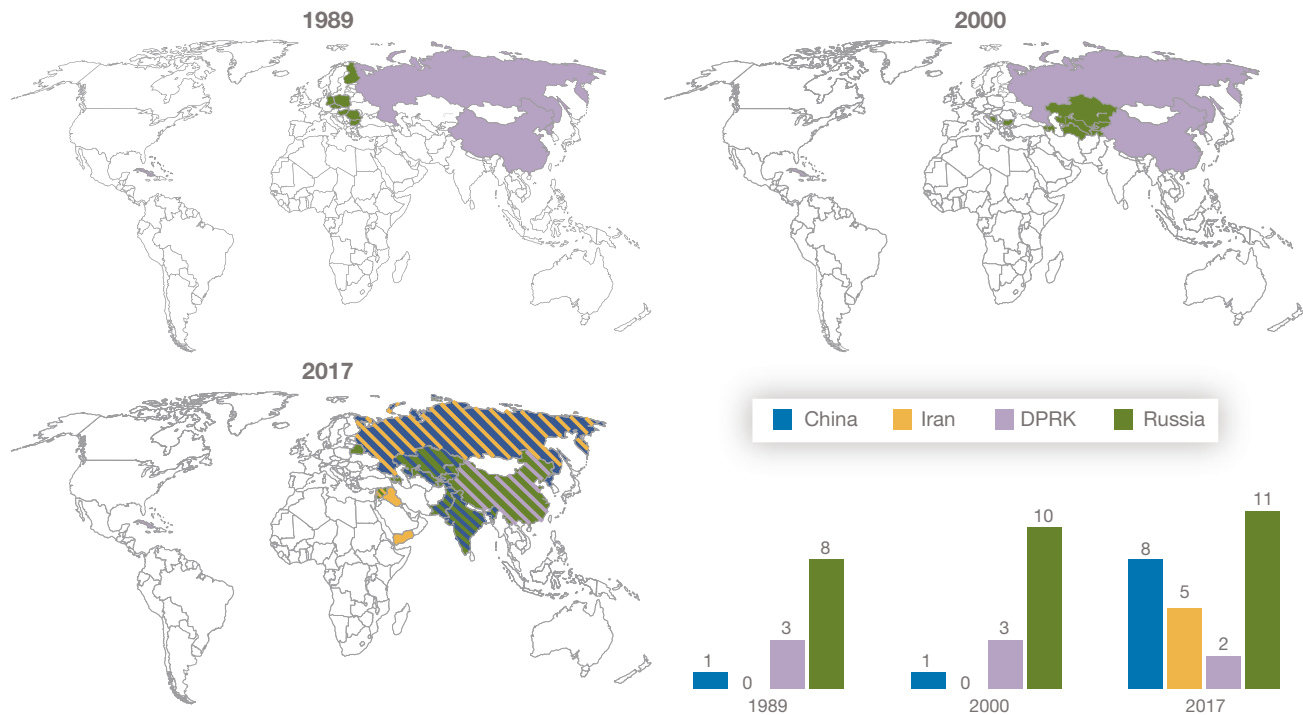
lyzed the relations between the *combined* competitors' alliance systems and other alliance systems and actors in each network layer.

As mentioned, when analyzing the economic network layer, we chose to extend the definition of *partner* for China beyond China's alliance with the DPRK and its quasi-alliance with the seven other SCO member states to include all 66 partner states under Beijing's SCO. We did this only for 2017 because the BRI had not yet been launched in 1989 and 2000.¹⁸ The BRI member states included in that analysis were the quasi-allies of China that

¹⁸ BRI was first announced by Chinese leader Xi Jinping in September and October 2013 during visits to Kazakhstan and Indonesia. According to World Bank, 2018,

China proposed the Belt and Road Initiative (BRI) . . . to improve connectivity and cooperation on a transcontinental scale. . . . [P]rojects in all sectors that are already executed, in implementation, or planned are estimated to amount to US\$575 billion. . . . If completed, BRI transport projects could reduce travel times along economic corridors by 12%, increase trade between 2.7% and 9.7%, increase income by up to 3.4% and lift 7.6 million people from extreme poverty.

FIGURE 1.7
U.S. Competitors' Allies, 1989, 2000, and 2017



NOTE: The total numbers of competitors' allies in 1989, 2000, and 2017 were 11, 13, and 17, respectively. The numbers in the figure do not sum to these totals because China, India, Kyrgyzstan, Kazakhstan, the DPRK, Pakistan, Russia, Syria, Tajikistan, and Uzbekistan belonged to multiple alliances.

were also partners under SCO: India, Kazakhstan, Kyrgyzstan, Pakistan, Russia, Tajikistan, and Uzbekistan (Chin and He, 2016).

By the end of this data-gathering exercise, we had constructed three snapshots in time for the network layers described. Each of the three network layers consists of countries (variously termed *nodes* or *vertices* by network scientists) and relationships between countries (termed *edges*, *links*, *arcs*, or *ties*). Relationships between countries can involve both direction and weight:

- A link establishing that exports flow from country A to country B is an example of a *directed* relationship. The dollar value of exports from country A to country B is an example of a *weight* that might attach to a directed link.
- A link indicating the presence or absence of diplomatic relations between two countries is an example of an *undirected* relationship. A Boolean value of 0 or 1, indicating the presence or absence of diplomatic relations, is an example of a weight that might apply to an undirected relationship.

As shown in Figure 1.8, we adopted a mixed-method approach to this research. We applied four methods of analysis to the network layers that we constructed:

- network analysis
- interdependence analysis
- combinatorial optimization
- conflict simulation.¹⁹

Network Analysis

In the IR field, Robert Keohane and Joseph Nye were early in “focusing on networks or relations among states and how these have reshaped the key features of international relations in the modern era” in the late 1970s (Maoz,

¹⁹ We did not apply each analytical method listed to every network layer; rather, we applied them to each network layer selectively.

FIGURE 1.8**Analytical Methods Employed**

Network analysis • Connections (nodal degree) • Betweenness centrality	Interdependence analysis • Dependence of others on one country • Dependence of one on all others • Country's interdependence • Country's dependence balance
Combinatorial optimization • Fragmentation method • Distance-weighted fragmentation method	Conflict simulations • China versus Vietnam in South China Sea • China versus Taiwan • Russia versus NATO in the Baltics • Russia versus Ukraine

NOTE: Nodal degree is the power that a node (e.g., a country) enjoys within the overall structure of a network thanks to the number of links that it has with other nodes in the network.

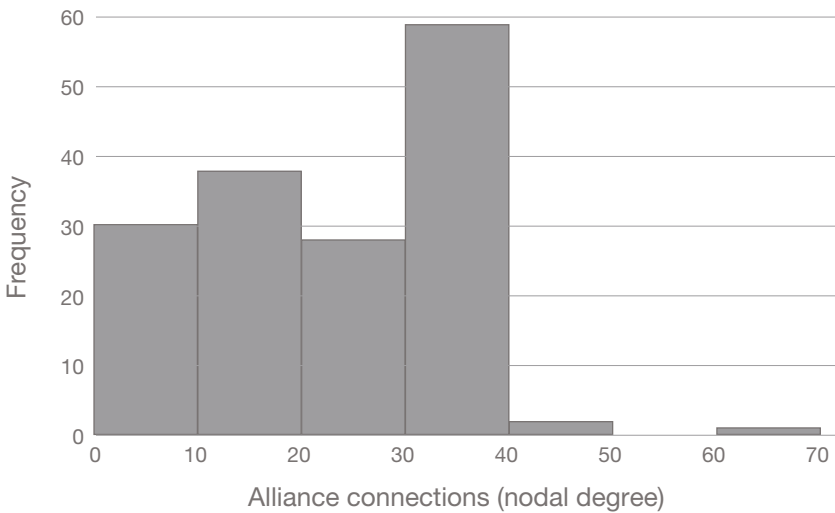
2011, citing Keohane and Nye, 1977). The use of SNA methods became more mainstream in the IR field in the 1990s.²⁰ Maoz explained that a country's IR consist of a set of international networks that can be discretionary or nondiscretionary, and cooperative or conflictual. They also span multiple domains: alliances, diplomatic relations, international organization membership, trade, foreign direct investment, and cultural networks. Network analysis offers a myriad of measurements by which analysts can assess and describe the position and influence of nodes in networks with differing structures. We chose to focus on just two such yardsticks: nodal degree and betweenness centrality.

Simply put, nodal degree is the power that a node (e.g., a country) enjoys within the overall structure of a network thanks to the number of links that it has with other nodes in the network. For network scientists, one of the most-basic and most-widely employed ways of describing any network is to plot a histogram of its degree distribution. The number of links per node is plotted on the horizontal axis, and the frequency of nodes with the given number of links is plotted on the vertical axis (Borgatti, Everett, and Johnson, 2013, p. 164; Newman, 2010, p. 126; Newman, 2018, p. 313).

²⁰ For an assessment of the value of SNA approaches to IR theory, see Hafner-Burton, Kahler, and Montgomery, 2009.

Figure 1.9 shows the degree distribution of the ATOP dataset used in the diplomatic (military alliance) network layer analyzed in this report; it shows that countries' most-frequent numbers of alliance ties lie between 30 and 40 and that circa 60 countries enjoyed this number of ties in 2017. (For lists of the 2017 allies of the United States and its four competitors, see the tables in the previous section of this chapter.)²¹ In essence, this measure of

FIGURE 1.9
Degree Distribution of the 2017 Global Military Alliance Network



SOURCE: Leeds, undated.

²¹ ATOP defines *alliance* as “a formal agreement among independent states to cooperate militarily in the face of potential or realized military conflict” (Leeds, undated, p. 5). ATOP limits its universe of cases to written agreements with legal force. ATOP includes independent states and excludes unilateral decrees, empires, and nonstate actors. An alliance can take any of five forms in the ATOP data:

- defensive
- offensive
- neutral
- nonaggression
- consultation pact.

Because of the differences between these types of alliances, we included in our dataset only alliances that obligate (or obligated) some action by their member states (i.e.,

network power is about the importance of connections. For simplicity, we use the term *connections* instead of *nodal degree* or *nodal degree centrality* to describe this measure of network power going forward.²²

Having connections is not enough, however. A node's position within the overall structure of a network also helps to determine the extent to which it is influential. Betweenness centrality is a measure that applies to nodes that takes their respective network positions into account.²³ It measures the number of shortest paths (*geodesics*) between nodes in a network that cross a given node. Shortest paths reflect the minimum number of steps through a network that must be taken to go from one node to another node among nodes that are not connected directly. The shortest-path concept is central to the well-known parlor game "six degrees of Kevin Bacon." The number of shortest paths that pass through a node is called *node betweenness centrality*. A comparable measure can be calculated for edges by considering the number of shortest paths that must go through any given edge or link that connects nodes. This is termed *edge betweenness centrality*.

To what degree is betweenness centrality, a concept developed for the analysis of social networks, applicable to networks of alliances between nation-states? The number of nation-states is limited, and they all have multiple connections to one another that can be expanded or contracted on demand, to be sure. However, adopting a realist approach under which formal, legally binding alliance ties are the most reliable in times of conflict, Maoz examined Austria-Hungary's July 28, 1914, decision to declare war on Serbia to explain the value of this concept to IR theory. If Austria-Hungary

offensive and defensive pacts). We extended the ATOP dataset to include de facto and quasi-allies of the kind just described.

²² For further, more-detailed discussion of connections or nodal degree centrality, see Wasserman and Faust, 1994, Section 5.2.1; Jackson, 2008, p. 20; Maoz, 2011, Section 2.5; and Newman, 2018, Section 7.7.

²³ Many other measures of centrality or influence within networks exist. We chose to focus on betweenness centrality for two principal reasons:

- Among the various measures, betweenness centrality is most robust to changes in network structure, such as those caused by coding errors.
- Many of the other measures of centrality are highly correlated with the betweenness-centrality metric (Newman, 2018, p. 173; Borgatti, Everett, and Johnson, 2013, Chapter 10).

were to decide to go to war, it could rely on three alliance connections (with Germany, Italy, and Romania). If, however, Austria-Hungary should succeed in persuading Italy to join the conflict, Italy had the potential to get as many as five of its allies to help Austria-Hungary (France, Japan, Russia, Spain, and the UK). This made Italy rather central to the 1914 military alliance network. Betweenness centrality measures this brokerage role of a node (or country), given its position within the overall network structure (in this case, the military alliance) (Maoz, 2011, Section 2.5).

The essence of this part of the analysis is that, even if a country's military and economic strength or its attractiveness might confer much of its influence, the structure of its network connections and its position in the network also give it advantages beyond what those measures of military, economy, or aspects of a country's soft power alone might indicate. In theoretical terms, a node or link through which large numbers of geodesics flow occupies a strategic position in the overall structure of a network. Those controlling such nodes or links can control access to additional resources (such as the recruitment of additional allies in times of conflict) or the passage of information that is exchanged through them. They can therefore extract rents in exchange for facilitating the brokerage of access to resources or information across these network nodes or links.²⁴ For simplicity, we refer to node and edge betweenness centrality as *centrality* throughout the rest of this report.²⁵

Interdependence Analysis

Interdependence analysis is the name we have given to a methodology devised by Professor Zeev Maoz of the University of California, Davis (Maoz, 2006; Maoz, 2009; Maoz, 2011), that we adapted for the purposes of analyzing the diplomatic (military alliance) network layer. Interdependence

²⁴ The classic text on betweenness and brokerage, central tenets of network analysis, is Burt, 2005. See also Wasserman and Faust, 1994, p. 173.

²⁵ There is no direct connection or trade-off between a country's number of network connections and that country's centrality in the network in question. Centrality is much more proximately dictated by the differing structures of countries' networks.

analysis allows us to go beyond looking at network connections and centrality by analyzing three inputs:

- alliance commitments
- national capabilities
- the capabilities of potential future opponents.

Chapter 2 describes the method by which these metrics are used in this report to calculate countries' interdependence. Appendix A contains a detailed mathematical explanation. We use interdependence analysis to calculate five measures of allied interdependence:

- the degree to which all the 131 countries in the international system that had military alliances in 2017 depended on one single focal country (e.g., the United States). Formally, Maoz termed this measure *out-dependence*.
- the degree to which a single focal country in that group depended on all the other countries with alliances at that point in time. Formally, this metric is termed *ondependence*.
- the degree to which a country is militarily self-reliant versus militarily dependent on others, regardless of the direction of those dependencies. Formally, this is termed *monadic interdependence*.
- the net outcome (i.e., how much the state under investigation either depends on other states or is depended on by other states—whether it is a net security provider or a net security consumer). In this case, the direction of the dependencies matters. Formally, this metric is termed the *monadic-interdependence balance*.
- a combination of the previous two metrics to measure the change in interdependence of individual military alliance network member states over time.²⁶

²⁶ As discussed in Chapter 2, a country's levels of interdependence with its allies depend on five factors:

- the content and structure of the country's alliance network
- the country's power
- the group of potential future opponents that the country faces

Combinatorial Optimization

Combinatorial optimization involves measuring a network's vulnerability to or robustness against a technique that network scientists term *directed attack*: changes to network cohesion that occur as specific combinations of nodes that are optimally disruptive of the network are removed.²⁷ Following a method devised by Steve Borgatti of the University of Kentucky, we used combinatorial optimization to identify the optimal set of nodes that should be removed from an alliance network in order to maximize that network's disruption.

The network formed by a collective-defense alliance, such as NATO, is said to be *complete*. It is complete because every node in the network has a link with every other node, representing the member states' mutual-alliance commitments. Complete networks are very robust.²⁸ If links or nodes are removed from the network, multiple redundant paths exist by which to get from one remaining node in the network to another. A complete network is cohesive; it has zero fragmentation.²⁹ A network consisting entirely of *isolate* nodes having absolutely no connection whatsoever to any of the other nodes in the network is the opposite extreme; it is completely fragmented or has a fragmentation of 1. Fragmentation measures a network's cohesion between these two extremes.

-
- the cumulative power of those potential future opponents
 - the cumulative power of the country's allies.

Change in any one or more of these five factors over time will change a country's interdependence with its allies. Instability can occur when a country's levels of interdependence change markedly in the face of such changes. The way this measure was calculated is summarized in Chapter 2. A detailed mathematical explanation is given in Appendix A.

²⁷ For more on directed attack of networks, see Newman, 2010, Section 16.3.

²⁸ We define *robustness* as a country's ability to maintain its levels of interdependence with other countries in the international system of alliances over time, despite major intervening changes in the structure of the international system.

²⁹ That, at least, is what the logic of network science tells us. Viewed through a political lens, the real-world implications might be quite different. A state's exit from NATO's military structure (as France did in 1967) might cause political reverberations that would create doubt, discord, and concern, leaving NATO somewhat more vulnerable than the quantitative measures developed by network science alone would indicate.

Because of the complete nature of collective-defense alliance networks, such as the NATO alliance, significantly disrupting such networks can be a higher hurdle to clear than doing so with less complete networks. However, for networks that are close to but fall short of being complete, if the number of links that must be crossed to move from one node in a network to another (to recruit additional allies, as in the Austro-Hungarian example cited above) is sufficiently large, a network can be considered fragmented for all practical purposes. Distance-weighted fragmentation measures network fragmentation of this kind.³⁰ We use both approaches to network disruption in the analyses described in this report.

Simulation

We used the diplomatic (military alliance) network layer to simulate various possible future conflict scenarios.³¹ The scenario starting conditions were chosen based on feedback from RAND security experts about which scenarios have been prominent in past discussion with defense clients.

³⁰ Formal mathematical definitions of *fragmentation* and *distance-weighted fragmentation* are given in Borgatti, 2006. Great and regional powers, such as France, Germany, or the United States, would have a greater impact on network cohesion if removed from the NATO network than the removal of a smaller power, such as, for example, Montenegro. This is explainable in network terms. The most-capable states attracted alliance partners by reason of their greater capabilities at the time of those alliances' inception, the 1950s (a central tenet of the capability-aggregation school of alliance formation and dissolution). Those states' capabilities led to greater numbers of alliance ties, which, in turn, endowed those countries with greater centrality in the overall global military alliance network. When their removal is examined in a context that is broader than that of the NATO alliance alone, this greater global network centrality is the reason that such states' removal has disproportional impact compared with the removal of a less capable NATO alliance member state. This shows the importance of defining the network boundary when conducting network analyses.

³¹ We simulated

- a threatened Chinese invasion of Taiwan
- China seizing an island in the Spratly Islands chain in the South China Sea from Vietnam
- a Ukrainian attempt to recapture territory previously occupied by Russia and its proxies
- a Russian incursion into the Baltic states.

The simulations model the degree to which conflicts spread (i.e., contagion) across alliance connections based on defensive or offensive pacts. We chose the diplomatic (military alliance) network layer for these simulations because these international agreements are pledges or signals of intent to come to another country's aid in a conflict. Other network layers have less-clear and -direct bearing on conflict contagion. Additionally, prior research by Brett Ashley Leeds has established that, historically, countries have come to the aid of a single bilateral ally about 75 percent of the time (Leeds, 2003). Although the concept of conflict contagion might be controversial, alliances exist to create conflict contagion. If an alliance does not draw an ally into conflicts in which the ally would otherwise be uninvolved, there would be no purpose for that alliance.

SNA provides a rich set of theories and methods for modeling contagious phenomena on networks (Matthews et al., 2013; Leenders, 2002). In our simulation, we modeled the contagion process as the average of receiver effects (i.e., a country's likelihood of joining a conflict is a function of the proportion of its allies from which it is receiving a conflict-initiation signal because they have joined the conflict) and sender effects (i.e., a country's likelihood of eliciting an ally to join a conflict by sending a conflict signal is a function of the number of allies that the ally target has in its own alliance network). Both these processes likely occur: Receiver effects occur because receiver countries should attend to their exposure to additional alliance requests (outstretched hands), while sender effects occur because sender countries can bring maximal leverage on only a finite number of allies. This process also corresponds to the average of Maoz's outdependence and ondependence measures.

Once this setup is complete, the simulations proceed with few other rules being enforced. We assumed a 75-percent chance of contagion across a single isolated bilateral relation. This meant, however, that the aggregate chance of contagion on the actual alliance structure ended up being much lower than 75 percent in most cases. Consider the simple example of the receiver effects on a country with five allies, one of which joins a conflict. The resulting chance of the receiver joining is $75 \text{ percent} / 5 = 15 \text{ percent}$. Because of this property, although two-step contagions of conflict are theoretically possible (i.e., the ally of my ally—such as those of Italy mentioned

above—joins my conflict), we never observed two-step contagions in our simulated scenarios.

This observation points to a final important aspect of the conflict simulations: that a primary purpose for doing them is to look for novel and insightful emergent properties. An emergent property of a simulation is a group-level outcome that is not directly encoded as a rule by the researcher; instead, it results from the interaction of rules specified for the interactions of individual agents in the model (the agents in this case are countries in the alliance network). We never encoded a rule that two-step contagions of conflict could not happen, and they are theoretically possible, but the rules encoded for individual countries, combined with the empirical facts of the actual alliance network, meant that two-step contagions never emerged as a phenomenon in our simulations. In Chapter 5, we document plausible and expected emergences, including that two-step contagions are unlikely and that NATO will act as a whole bloc, which lend credibility to the simulation model. We also document unexpected emergences—principally, that the simulations suggest that two-front wars are likelier outcomes from scenarios than most practitioners seem to assume—which are the complementary value added of simulations in comparison to qualitative or statistical analyses. Simulations force the policymaker and researcher to consider emergent outcomes that are plausible, even likely, given criteria that have been instantiated into the simulation model.

Limitations and Caveats

The methodological approaches just described offer some unique insights from network science that differ from most other analyses of the U.S. network of allies and partners, but with those approaches come several limitations and shortcomings. Those limitations are documented in this section.

The quantitative approach to measuring interdependence within the diplomatic network layer that we used implicitly favors the neorealist capability-aggregation model of alliance formation and dissolution and the underlying assumptions about the nature of the international system to which the neorealist school of thought subscribes. Competing autonomy–

security trade-off and regime-change models of alliance formation and dissolution do exist.³²

The methodology used to calculate military interdependence is blind to varying qualitative levels of threat that might be posed both across groups of potential opponents and across time. It also assumes that countries will make contributions to their alliances that are in strict proportion to their relative national power. A large positive or negative change in a country's military dependence score (which we suggest might make that country's alliance ties more or less stable) might not be the only way of measuring the presence or absence of vulnerability in an alliance. It is conceivable that a country's continuing membership in an alliance would be quite friable, even though the country's levels of military dependence on other countries had remained relatively stable over time.

Significant time lags are often involved between the conclusion or abrogation of defense treaties and events on the ground. Mutual-defense treaties between India and Pakistan and between Cuba and most of the countries in Latin America are still technically in force, even though the likelihood of any side's compliance with them, if called on to comply, might be rather low. The datasets used in this study might therefore lag in reflecting reality on the ground.

The datasets capture only formal, public networks between national actors; they do not capture long-standing informal or covert alliances or partnerships, including those with subnational actors (e.g., Iran's long-standing relationship with Lebanese Hezbollah). Iran's relationship with Hezbollah started as a covert relationship between a nation-state and a subnational actor in the 1980s and was formalized at the level of nation-states and reflected in the ATOP dataset only in 2008.

³² The capability-aggregation model of alliance formation essentially has countries accrue allies until their own capabilities, when added to those of their allies, exceed those of the countries' potential opponents. The autonomy–security model has countries try to balance capability accumulation of this kind with the loss of autonomy that results from entering alliances. The regime-change school argues that changes of regime can also have a significant impact on alliance formation and dissolution. For a description of the differences between the capability-aggregation and autonomy–security trade-off models of alliance formation and dissolution and exposition of the empirical evidence for the latter, see Morrow, 1991, and Siverson and Starr, 1994.

Given the computational complexity of the combinatorial optimization method of exploring network disruption, we cannot guarantee that our approach provides a global maximum in network disruption; there might be sets of nodes that are not identified by our search, although their removal would be maximally disruptive. The computational time required for combinatorial optimization increases exponentially as a function of the number of data points (i.e., it is a nondeterministic polynomial-hard [NP-hard] problem). This means that the time required to find the optimal set of nodes to remove from a network increases exponentially (actually, in binomial time) with the number of nodes to be removed. For this reason, we used heuristics to determine sets of nodes to remove from the network; the size of the network we considered precludes brute-force methods of calculation in which every possible permutation is examined. There is a risk, however, that the heuristic employed (e.g., the greedy algorithm used in this case) will identify a suboptimal local maximum as opposed to the overall global maximum in the objective function (in this case, network disruption) that it is seeking to maximize.

Because of the lack of adequate datasets, no attempt has been made to evaluate national information operations in cyberspace or on social media. However, both areas have become important recent arenas of great-power competition and are worthy of additional research.

For the military network layer, we measured U.S. centrality over time by evaluating the networks that are traceable from arms sales and from JMEs. These two variables provide a complement to military alliance commitments captured in the diplomatic layer, but they are not a comprehensive picture of U.S. military relationships or influence. No dataset can capture the totality of U.S. interactions with allies and partners, which occur globally in thousands of contexts every day, extend from the ministerial to the tactical, and, in many cases, exist even in the absence of proximate activity. Furthermore, the exercise data have been compiled from two separate and not strictly comparable sources.

Our economic analysis does not take foreign direct or portfolio investment stock or flows into account. Nor does it include any attempt to capture the operations of multinational corporations. These data are not as clean as they could be. No attempt was made to capture technological competition. And the results given for China are not strictly comparable over time

because of our decision to use China's 66 BRI partners as the comparison group for 2017, as opposed to just its eight allies, all but one of which (the DPRK) are also BRI partners.³³

The conflict scenarios that we examined are highly stylized; as explained in Chapter 5, the scales have been tipped by the removal of certain nodes (countries) and by boosting certain links (alliance ties) for the simulations to be more reflective of historical patterns of allied intervention on behalf of other countries than would otherwise be the case. The simulations are purely deterministic in nature, make no effort to take qualitative factors into account, involve no simulation of economic sanctions, and use a single, constant threshold value to determine when countries will become involved in a conflict. What constitutes a country's participation in a simulated conflict is very broad. We also assumed that alliances were of equal value. However, when forced to choose, a country, such as Russia, might, for instance, opt to prefer its alliance with China over a consultation pact with Vietnam rather than sit on the sidelines because it has ties to each.

As further elaborated in Chapter 7, we calculated the network depth to which the United States had access in each country in 2017 per U.S. dollar in assistance that the United States provided to that country between 1989 and 2017.³⁴ We subjectively chose the median value of the access to network depth per dollar of assistance provided to allied and partner countries as a benchmark for assessments. We made no attempt to determine what an appropriate benchmark value by which to assess U.S. returns on investment might be *ex ante*, given any number of objective nonstatistical criteria that might be derived from IR theory to define such a benchmark. As a result,

³³ As discussed above and listed in Table B.9 in Appendix B, China's eight allies are the DPRK, with which China has a formal alliance, and the seven other member states of SCO. We consider China's relationships with SCO members to be quasi-alliances because

- they involve counterterrorism security cooperation commitments between its member states
- SCO members conduct regular joint military exercises together
- merging SCO with the CSTO, a formal collective-defense alliance, has been under discussion.

³⁴ Assistance includes arms sales and security cooperation.

we make no policy recommendations based on this initial but nevertheless interesting measure.

Because of the limitations just outlined, readers should not be beguiled by the apparent precision of the results generated by the analyses presented in this report; it is the relative size, direction, and magnitude of those results rather than their somewhat spurious precision that are potentially important. *We nonetheless believe that the results presented here paint a meaningful picture.* Each of the datasets employed in this report provides a snapshot of a network layer that is important. Moreover, looking at the combination of those network layers provides readers with insights into trends in the health and strength of the U.S. network across time.

As a result of the limitations just described, the findings presented here are not intended to supplant more-familiar qualitative analyses or the views of regional experts or in-country personnel, who might have a better “finger-tip feel” for the direction in which the winds are blowing in any region or in any given U.S. bilateral relationship. However, this assessment might offer additional and differing insights into longer-term questions of where and how the U.S. network of alliances and partners is strong and can be leveraged or is weak and must be bolstered.

This points us to the final question examined in this introduction: Having elaborated a bestiary of methodological limitations to our analyses, why should policymakers and strategists take heed of the findings in this report? We used quantitative analytical techniques to analyze empirical data on military alliances at three inflection points during the recent development of the international system. The report thus looks at long-term trends, as opposed to attempting to respond to tactical developments of the short-term policy agenda. The methods by which its analyses were conducted are transparently laid out. Consequently, their analytic rigor can be tested; their results can be both audited and replicated. The report can therefore serve as a useful basis for further scientific study and refinement of the analysis of alliance networks.

The report’s findings are also largely in line with conclusions that have been reached by other researchers using qualitative modes of analysis. The report thus provides both a useful confirmation of those qualitative analytical conclusions and an additional quantitative indication of the directions and orders of magnitude involved in the effects described by qualita-

tive analyses. Those quantitative measures can help policymakers assess the degree of urgency or policy priority to assign to challenges identified.

The analyses described in this report provide a reasoned method by which to identify allies that have undergone changes in interdependence of a magnitude that could pose concern and require increased policymaker attention. They also provide senior policymakers with a defensible and extendable method by which to select allies on which they should focus. Senior cabinet-level policymakers have repeatedly requested a curated selection of this kind, only to be confronted with an all-allies-should-be-treated-equally response. A limited-release version of this report helps show such readers why some allies are more equal than others and who they might be.

The report should be of use to policymakers in identifying countries on which to focus to thwart competitors' attempts to undermine U.S. alliance networks. At the same time, the report identifies weak nodes and links in competitors' alliance networks. The report uses historical data to provide policymakers with empirically based, reasoned insights into the prudent future allocation of resources for JMEs. The report identifies a prioritized list of countries with which U.S. policymakers can work to stymie competitors' future attempts to use their influence in networks of general merchandise trade and trade in key commodities and strategic minerals for purposes of economic coercion—whether in times of peace or conflict.

The report is transparent about factors that have not been considered and the methodological limitations that were involved when reaching the conclusions provided. This transparency allows policymakers, strategists, and other readers to be informed consumers of the analytical product and to attach a discount or a premium to the report's findings and recommendations, as they deem appropriate.

Report Organization

The remainder of this report is divided into six chapters:

- Chapters 2 through 4 analyze the DME network layers described above by applying one or more of the four analytical methodologies described.

- Chapter 5 describes four conflict simulations that we conducted.
- Chapter 6 integrates these results to calculate countries' network depth and to identify countries that are core and peripheral to the U.S. network of allies and partners.
- Chapter 7 presents the report's conclusions.
- The appendixes contain a detailed explanation of the methodologies used to calculate the results presented, a decoding of the International Organization for Standardization (ISO) two-letter country codes used in certain figures in this report, and data supporting the analysis.

The Diplomatic Network Layer

We evaluated three datasets for use in modeling the diplomatic network layer:

- bilateral diplomatic relations
- intergovernmental organization (IGO) membership
- military alliances.

Because they offered greater opportunities to measure interdependence, we chose to focus on military alliance relationships alone.¹ The published dataset that most closely matched our operational definition of alliances given

¹ We obtained the data for diplomatic relationships and IGO membership, intending to use them for the diplomatic network layer. We also constructed clique overlap matrices for both and plotted these in a visualization. The networks of relationships for the former were very dense. Although the diplomatic relations network did show the United States and several key allies to be very central, that was about it. Much the same can be said of the IGO graph, which we transformed from an affiliation matrix to an adjacency matrix for purposes of analysis before reaching this conclusion. We initially thought of including arms sales, military exercises, and alliances into one military network layer. However, that would not have permitted us to run Maoz's interdependence calculations in a clear, transparent, and replicable fashion. We therefore separated Maoz's calculations out and put them in the diplomatic network layer under the logic that alliances are

- negotiated by diplomats
- the most consequential and most binding form of diplomatic relationships that countries can have.

We do not believe that it would be appropriate to use diplomatic ties to run Maoz's interdependence analysis because, under that approach—because diplomatic ties are so numerous—each country would be defined more by the countries with which it lacks diplomatic relationships than by the differing number and power of its allies and potential opponents.

in Chapter 1 is the data collected in Leeds, undated, updated to 2017. The dataset is called ATOP (Leeds, 2018). We extracted and adjusted data from this dataset for 1989, 2000, and 2017. Then, in three steps, we analyzed the United States' and its competitors' alliance networks by examining

- differing levels of alliance connections and network centrality²
- change in historical levels of allied interdependence
- the networks' vulnerability to deliberate disruption or directed attack.

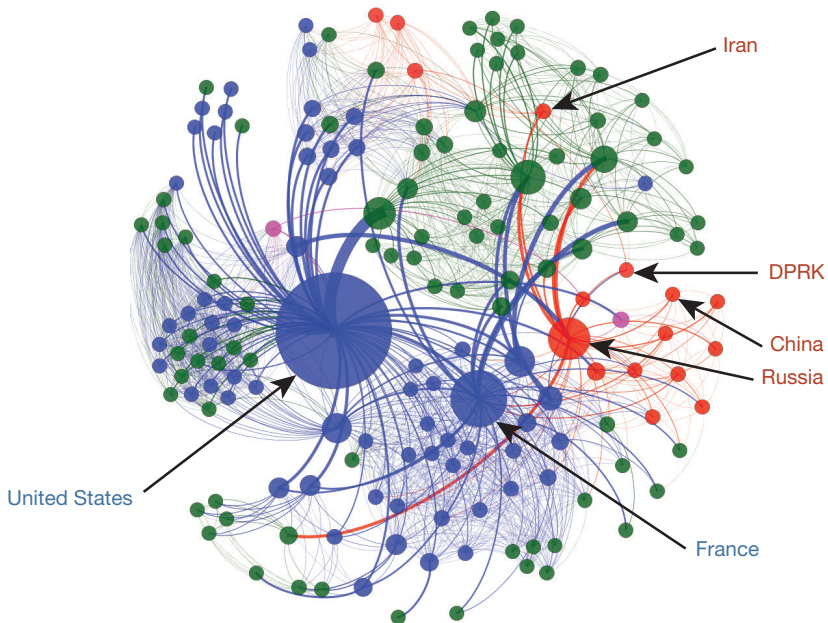
Overall, a picture emerges in which the United States continued to dominate as the global security provider in 2017. Forty-six percent of U.S. allies were at a point at which they might have had cause to reassess the value of their alliance commitments in addressing the security challenges that they were facing. The other picture that emerges is that of a surge in power on the part of China between 2000 and 2017. By a wide margin, China replaced Russia as the country on which regional allies on average were second most dependent. That said, in 2017, China's alliance network remained sparse, significantly more vulnerable to deliberate disruption than that of either Russia or the United States, and China remained on the periphery of the global military alliance network. It is possible to discern a group of countries that might be amenable to U.S. and allied attempts to wean them out of close orbit with China and Russia. They might be motivated to do so out of a desire for greater strategic autonomy or because of their relative resource poverty. However, because they are landlocked and heavily economically dependent on China and Russia, there is a limit to the inroads that one can expect to achieve via any such allied *démarches*.

Figure 2.1 is a visualization of the global military alliance network in 2017.³

² Recall that we use the term *connection* as shorthand for nodal degree or nodal degree centrality—the number of alliance links that a country has to other countries. We use the term *centrality* as shorthand for node or edge betweenness centrality. Both terms are explained in Chapter 1.

³ Unless noted otherwise, two graph visualization packages were used to produce these visualizations: We used Gephi (Gephi, undated) to generate eigenvector centrality measures for each node and then exported the graph to Cytoscape (Cytoscape, undated) via a GraphML data file.

FIGURE 2.1

The Global Military Alliance Network in 2017

SOURCE: Leeds, undated.

NOTE: Each circle represents a node, or country. Each line represents an alliance link. The size of each circle reflects that country's centrality within the alliance network—the larger the circle, the larger the centrality. Blue circles and lines represent U.S. allies and their alliance ties. Red circles and lines represent the allies and alliance ties of China, Russia, Iran, and the DPRK. Green circles and lines represent nonaligned countries and their alliance ties. Purple circles and lines represent countries that are aligned both with the United States and with China, Russia, Iran, and the DPRK. The width of a line connecting two nodes reflects the betweenness centrality of that alliance tie—the thicker the line, the greater the importance of that link in the network.

Note the dominant roles of France and the United States. France is connected to two alliance clusters in Africa and in the Middle East and North Africa. The United States provides a bridge between two alliance clusters representing NATO and the countries of the Rio Pact. The United States also has an important alliance with country C that serves as a bridge to an African alliance cluster. The United States also has many “pendant” alliance relationships in which it is a country's sole ally. A link from Cuba to the DPRK to Russia connects the Latin American alliance cluster to the cluster of alliance ties between Central Asian countries, Russia, and China.

Connections and Centrality

Network science allows us to examine both the centrality of individual countries and the combined centrality of groups of countries that make up networks within the overall global ecosystem of 2,058 overlapping military alliance ties in 2017.⁴

Alliance Network Connections and Centrality at the Global Level

As shown in Table 2.1, in 2017, the United States' network of 65 military allies had the greatest number of connections per ally (26) and the greatest centrality (55 percent) within the global military alliance system. Russia, with 11 allies, placed second; each of its allies had an average of ten connections. The centrality of Russia's alliance network within the global system of alliances (2.4 percent) lay 53 percentage points behind that of the United States.⁵ China, with one ally and seven SCO quasi-allies with an average of eight alliance connections each, placed third, with a global military alliance network centrality of 1.5 percent (54 points behind the United States). Iran, with five allies with an average of 14 connections, and the DPRK, with just two allies with an average of 14 connections, both barely registered in terms of global military alliance network centrality (1 percent and close to 0 percent, respectively).⁶

⁴ The technical term for the latter of these two measures is *group betweenness centrality*. For an explanation of how it is calculated, see Everett and Borgatti, 1999; Brandes, 2008; and Wasserman and Faust, 1994.

⁵ As a reminder, normalized betweenness centrality can range in value from 0 for a network of unconnected isolate nodes to 1 for a "star" or "hub-and-spoke network" (i.e., from 0 percent to 100 percent).

⁶ Thanks to its alliance with Cuba, the DPRK had a higher average and a lower dispersal of numbers of alliance connections than China's eight allies. Cuba, another DPRK ally, on paper, had 29 Latin American allies because Cuba had not abrogated the 1947 Rio Pact, a multilateral military alliance treaty between the United States and 23 Latin American and Caribbean signatory states (17 of which remain parties). There is an argument that the Rio Pact should not count at all, given that states take no notice of it in their actual behavior. About the only evidence that it might be important is that some states (such as Mexico) withdrew from it in the early 2000s over U.S. post-9/11 policies.

TABLE 2.1

**U.S. Competitors' Alliance Centrality and Connections,
1989–2017**

Country	Centrality (Group Alliance)	Allies' Numbers of Alliance Connections			
		Maximum	Minimum	Average	Standard Deviation
1989					
China	0.1504	3	1	2.00	1.00
DPRK	0.1387	23	1	9.00	8.60
Russia	0.0196	9	1	6.20	2.23
United States	0.5572	55	1	18.75	9.52
2000					
China	0.0000	2	1	1.50	0.50
DPRK	0.0156	22	1	8.50	8.38
Russia	0.0494	9	1	5.73	3.41
United States	0.7474	60	1	22.61	11.15
2017					
China	0.0153	11	2	8.44	2.59
DPRK	0.0000	20	3	14.00	7.79
Iran	0.0111	20	3	14.00	7.79
Russia	0.0244	33	3	10.17	7.17
United States	0.5504	79	1	26.94	12.81

SOURCE: Leeds, 2018.

NOTE: Connection within the global military alliance system is nodal degree—a country's number of regional alliance relationships. Centrality is 0 for a node or country if none of the shortest paths connecting nodes in the network (geodesics) pass through that node; it is 1 if all of the shortest paths pass through that node, such as in a star network.

The centrality of the alliance networks of the United States and Russia rose significantly by 2000, only to subside to close to Cold War levels by 2017. Between 1989 and 2000, the centrality of China's alliance network collapsed because of changes in the global military alliance structure brought on by the demise of the Warsaw Pact;⁷ it had recovered to just above its Cold War level by 2017, after China added seven SCO quasi-allies in 2001.

China

Between 1989 and 2000, China saw no change in its number of allies; its sole military alliance with the DPRK with two other alliance connections (Russia and Cuba) remained intact. Due mainly to the demise of the Warsaw Pact, the Chinese alliance system's centrality within the global network fell by 15 percent (from 15 percent to almost 0 percent). Between 2000 and 2017, China added seven SCO quasi-allies. Consequently, the average number of connections between China's allies rose (from one to eight). The Chinese alliance network's centrality within the global system of military alliances also rose from almost 0 percent to just above 1.5 percent, far below its Cold War level.

Russia

Between 1989 and 2000, Russia gained eight allies in the post-Soviet space and lost six allies in Eastern Europe, for a net gain of two (from eight to ten) allies. Russia appears to have replaced the former Soviet republics' strong obligations toward Moscow as constituent parts of the USSR with the next-best substitute available: alliance ties. The average number of connections between Russia's allies fell from six to five. The shedding of its Eastern European allies and acquisition of allies in the post-Soviet space boosted the Russian alliance network's centrality in the global military alliance system by almost 3 percent. Between 2000 and 2017, Russia added five and lost four allies for a net gain of one ally (from ten to 11). The

⁷ *Warsaw Pact* is a short reference to the Treaty of Friendship, Co-Operation and Mutual Assistance Between the People's Republic of Albania, the People's Republic of Bulgaria, the Hungarian People's Republic, the German Democratic Republic, the Polish People's Republic, the Romanian People's Republic, the USSR, and the Czechoslovak Republic, signed in 1955 in Warsaw.

average number of alliance connections of Russia's allies doubled (from five to ten). However, the changing structure of the global military alliance network caused the Russian alliance system's centrality within that network to fall by just under 3 percent, leaving it slightly above its level at the end of the Cold War.

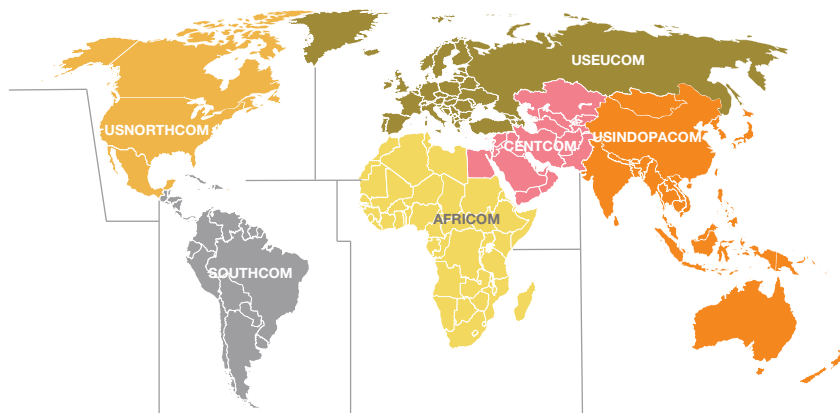
United States

Between 1989 and 2000, the United States added three NATO allies, five de facto allies, and one MNNA and lost one Latin American ally, for a net *gain* of eight (from 47 to 55) allies. The average number of connections of its allies rose (from 18 to 22). With the termination of the Warsaw Pact in July 1991, the United States' alliance system's centrality within the global network of military alliances rose by 20 percentage points (from 55 percent to 75 percent). Between 2000 and 2017, the United States added ten NATO allies and five MNNA and lost five Latin American allies, for a net gain of ten (from 55 to 65) allies. The average number of connections of its allies rose by four (from 22 to 26). However, as the U.S. alliance system grew more dispersed and fragmented, its centrality in the global military alliance system fell by 20 percentage points (from 75 percent to 55 percent, with rounding) to end slightly (0.68 percentage point) below the level where it stood at the end of the Cold War.

Alliance Network Connections and Centrality at the Regional Level

We ignore the development of network connections for a moment to focus solely on alliance networks' centrality within six regions of the world corresponding to the areas of responsibility (AORs) of the U.S. Department of Defense's unified combatant commands (see Figure 2.2). We found that the U.S. alliance network's centrality dominated in all six regional AORs.

U.S. European Command (USEUCOM), U.S. Africa Command (AFRICOM), and U.S. Northern Command (USNORTHCOM) were the commands in which the U.S. alliance network had the highest centrality within the global military alliance system in 2017 (see Table 2.2). USPACOM, a primary region of focus of the 2018 U.S. NDS; CENTCOM; and SOUTHCOM were the regions in which the U.S. alliance network had

FIGURE 2.2**Countries Assigned to U.S. Unified Combatant Commands' Areas of Responsibility**

SOURCE: U.S. Department of Defense, 2011, Section 941.

NOTE: SOUTHCOM = U.S. Southern Command. CENTCOM = U.S. Central Command. USINDOPACOM = U.S. Indo-Pacific Command (until June 2018, U.S. Pacific Command, or USPACOM).

the least centrality.⁸ The Russian alliance network's greatest centrality in 2017 was in CENTCOM; its centrality in USEUCOM and USPACOM lagged significantly. The Chinese alliance network's greatest centrality in 2017 was in USPACOM; its centrality in CENTCOM was marginal.

Table 2.3 organizes these numbers by region as opposed to by country. In USEUCOM, after experiencing a surge from 60 percent to 75 percent between 1989 and 2000, as the United States added ten further allies, the U.S. alliance network's centrality fell by 11 points to 64 percent, 4 percentage points above its Cold War level. Russian alliance network centrality in USEUCOM, by contrast, surged from near 0 to 11 percent after the end of the Cold War and then relapsed to just above 1.5 percent between 2000 and 2017, leaving Russia 63 points behind the United States in network centrality. In USPACOM, the United States led Russia by 45 points in terms of the centrality of its alliance network; China trailed far behind

⁸ In June 2018, USPACOM became USINDOPACOM. In this report, we use *USPACOM* in most instances because they refer to the entity before this change.

TABLE 2.2

Changes in Regional Network Centrality, 1989–2017

Country and Combatant Command	Year		
	1989	2000	2017
China	0.1504	0.0000	0.0153
CENTCOM	0.0000	0.0000	0.0076
USPACOM	0.1504	0.0000	0.0112
DPRK	0.1387	0.0157	0.0000
SOUTHCOM	0.1669	0.0155	0.0007
USPACOM	0.1375	0.0156	0.0004
Iran	0.0000	0.0000	0.0111
CENTCOM	0.0000	0.0000	0.0111
Russia	0.0196	0.0494	0.0244
CENTCOM	0.0000	0.0000	0.0404
USEUCOM	0.0000	0.1063	0.0150
USPACOM	0.1531	0.0309	0.0119
United States	0.5572	0.7474	0.5504
AFRICOM	0.0000	0.0000	0.5120
CENTCOM	0.5143	0.4606	0.4860
SOUTHCOM	0.4633	0.3142	0.4370
USEUCOM	0.6015	0.7481	0.6447
USNORTHCOM	0.5201	0.4455	0.5115
USPACOM	0.4952	0.4279	0.4924

SOURCE: Leeds, 2018.

NOTE: *Centrality* refers to group betweenness centrality for the countries in the given regional system of alliances within the global military alliance network. It is 0 for a node or country if none of the geodesics pass through that node; it is 1 if all of the geodesics pass through that node, such as in a star network.

TABLE 2.3**U.S. Competitors' Regional Network Centrality, 1989–2017**

Combatant Command and Country	Year		
	1989	2000	2017
AFRICOM			
United States	0.0000	0.0000	0.5120
CENTCOM			
China	0.0000	0.0000	0.0076
Iran	0.0000	0.0000	0.0111
Russia	0.0000	0.0000	0.0404
United States	0.5143	0.4606	0.4860
SOUTHCOM			
DPRK	0.1642	0.0153	0.0007
United States	0.4948	0.3449	0.4334
USEUCOM			
Russia	0.0000	0.1063	0.0150
United States	0.6015	0.7481	0.6447
USNORTHCOM			
United States	0.5201	0.4455	0.5115
USPACOM			
China	0.1504	0.0000	0.0112
DPRK	0.1375	0.0156	0.0004
Russia	0.1531	0.0309	0.0119
United States	0.4952	0.4279	0.4924

SOURCE: Leeds, undated.

NOTE: *Centrality* refers to group betweenness centrality for the countries in the given regional system of alliances within the global military alliance network. It is 0 for a node or country if none of the geodesics pass through that node; it is 1 if all of the geodesics pass through that node, as in a star network.

at practically the same level as Russia. In CENTCOM, the United States led Russia by 45 points but at levels lower than those during the Cold War. From 1989 to 2017, thanks to its newfound membership in SCO and its new de facto alliance with Syria, Russia experienced an increase in its alliance network's centrality in the CENTCOM AOR from near 0 percent to 4 percent.

Interdependence and Changes in Interdependence

We now look at a related but different concept: military *interdependence* between individual countries or groups of countries (alliance networks). Adapting a methodology devised by Maoz,⁹ for each of the years 1989, 2000, and 2017, we compared the power¹⁰ of each of the countries in the international system with alliances with the combined power of that country's group of potential future opponents.¹¹ Where potential opponents' combined power exceeded that of the focal state, the focal state's allies' combined capabilities were assumed to be available to "top up" the difference. In such cases, using each ally's proportional contribution to the total power of the focal state's allies, we calculated the share of the focal country's deficit in power that was contributed by each of its allies.

Let us say, for example, that country X's GPI score is 40 percent of the combined GPI scores of its potential future opponents (its SRG). Each of country X's allies contributes to making up the 60-percent deficit in propor-

⁹ Besides the interdependence scores examined in this report, examples of new network analytical measures introduced by Maoz for the purposes of applying network analysis to IR theory include sensitivity interdependence, vulnerability interdependence, network polarization, SRGs, and clique membership overlap. See Maoz, 2011.

¹⁰ As measured by the International Futures GPI; see Moyer and Markle, 2018.

¹¹ For each state, its SRG of potential future opponents consists of the set of neighboring countries, regional powers, and major powers with global reach that met either of these conditions:

- had a militarized interstate dispute (MID) with the focal state within the past decade (as defined in the Correlates of War dataset; see Palmer et al., 2020)
- is a strategic rival of the focal state that does not meet the first condition (as defined by Thompson, 2001).

tion to its contribution to the total GPI score of the alliance. If the United States, for example, contributes 65 percent of country X's allies' total GPI score, the United States is responsible for 65 percent of country X's 60-percent power deficit (i.e., 39 percent [$0.65 \times 0.60 = 0.39$] of the power deficit). By this measure, country X is directly dependent on the United States to make up 39 percent of the 60-percent power deficit that it has versus its potential future opponents, at first order. A country's levels of interdependence with its allies depend on five factors:

- the focal country's power
- the group of potential future opponents that the focal country faces
- the cumulative power of the focal country's potential future opponents
- the content and structure of the country's alliances
- the cumulative power of the country's allies.

Change in one or more of these five factors over time will change a country's interdependence with its allies. Using this methodology (which is described in further mathematical detail in Appendix A), for each pair of countries, A and B, in the global set of 131 countries with alliance relations in 2017, we calculated two dependence scores that measure the extent to which country A depends on country B militarily and vice versa. The two scores are not necessarily symmetrical. Country A can depend on country B more than country B depends on country A.

Because the dataset traces all the ties connecting members of the global ecosystem of overlapping military alliance networks, analysis need not be limited to simply measuring direct military interdependence. It is possible to take all the second- and higher-order alliance ties of country A beyond the first tie to country B (up to a theoretical maximum of 130 additional alliance network ties) into account to calculate the total direct and indirect military interdependence between the two countries. When only the first alliance tie between country A and country B is considered in calculating interdependence, we term the resulting dependence score the *first-order* or *direct* dependence of country A on country B (and vice versa). When all additional existing ties are considered, we term the resulting dependence score the *final-order* dependence of country A on country B. For example, in 2017, country D's direct dependence on the United States was 20 percent. When all indirect ties

were also considered, country D's dependence on the United States increased to 27 percent (this would be its final-order dependence).

We calculated the dependence scores for all possible country pairs in a 131-by-131 *dependence matrix*, consisting of 17,161 elements. The diagonal entries in the matrix represent each country's dependence on itself. The rows and columns of this matrix were used to calculate four additional aggregate measures of interdependence that go beyond measuring dependence between individual country pairs, or *dyads*:

- The rows of the dependence matrix can be used to calculate the military dependence of a single country on all other countries. Measures of a single country's dependence on the other 130 countries in the global military alliance network occupy the columns of that country's row in the matrix. Maoz termed this measure, which is normalized to range between 0 and 1, *ondependence*.
- The columns of the dependence matrix can be used to measure the degree to which the other 130 states in the global military alliance system depend on a single country (e.g., the United States). Each row of the "US" column gives a country's level of dependence on the United States. This measure too can take on values between 0 and 1. Maoz dubbed this measure *outdependence*.
- The sum of a country's ondependence and outdependence, expressed as a fraction of the sum of its ondependence, outdependence, and self-dependence, determines the extent to which other countries play a role in a country's overall military interdependence at all. This measure does not take the direction of the dependencies into account. Its theoretical range is between 0 and 1. Countries scoring 0 are militarily independent of other countries. Countries scoring 1 are totally militarily dependent on other countries. Maoz named this measure *monadic interdependence*.
- We can also take the direction of a country's military dependencies on other countries into account to calculate net dependence. The difference between a country's outdependence and ondependence as a fraction of the sum of its ondependence, outdependence, and self-dependence tells us whether a country is a net security provider or consumer. This number ranges in value between -1 and 1. A score of

-1 indicates maximum dependence as a consumer of security provided by other countries, whereas a high positive score (e.g., the United States with a score of 0.61, or 61 percent in 2017) indicates a role as a high net provider of security to others. A score of 0 means that the given country is neither a net provider nor a net consumer of security. Maoz called this measure a country’s *monadic-interdependence balance*.

All four of these measures can have first-order and final-order values and can be compared across varying periods of time.¹²

Using a practical example, Table 2.4 illustrates the use of the six interdependence measures just described. As stated, in 2017, country E depended on the United States for 27 percent of the deficit between its own national capabilities and that of its SRG. The United States, by contrast, depended on country E for only 3 percent of its deficit. In that same year, ROW depended on the United States for 46 percent of its combined deficit in national capabilities versus its combined SRGs of potential opponents. The United States depended on ROW for only 0.6 percent of its deficit in national capabilities versus its SRG, and that score was due mostly to indirect effects. Other countries accounted for just more than 60 percent of the United States’ mili-

TABLE 2.4
U.S. Military Dependence Scores in 2017

Metric	Dependence Relationship	Percentage
Dependence	Country E on the United States	27
	United States on country E	3
Outdependence	ROW on the United States	46
Ondependence	United States on ROW	<1
Monadic interdependence	Percentage role of others in U.S. dependence ^a	63
Monadic-interdependence balance	Direction of U.S. military dependence	61

^a U.S. dependence is the difference between its GPI and the cumulative GPI of its SRG.

¹² As stated above, in Appendix A, we provide a detailed mathematical description of the methods used to calculate the aggregate interdependence scores.

tary interdependence. And in 2017, the United States remained a strong net provider of security to other countries (61 percent).

The United States' and Its Competitors' Global Interdependence

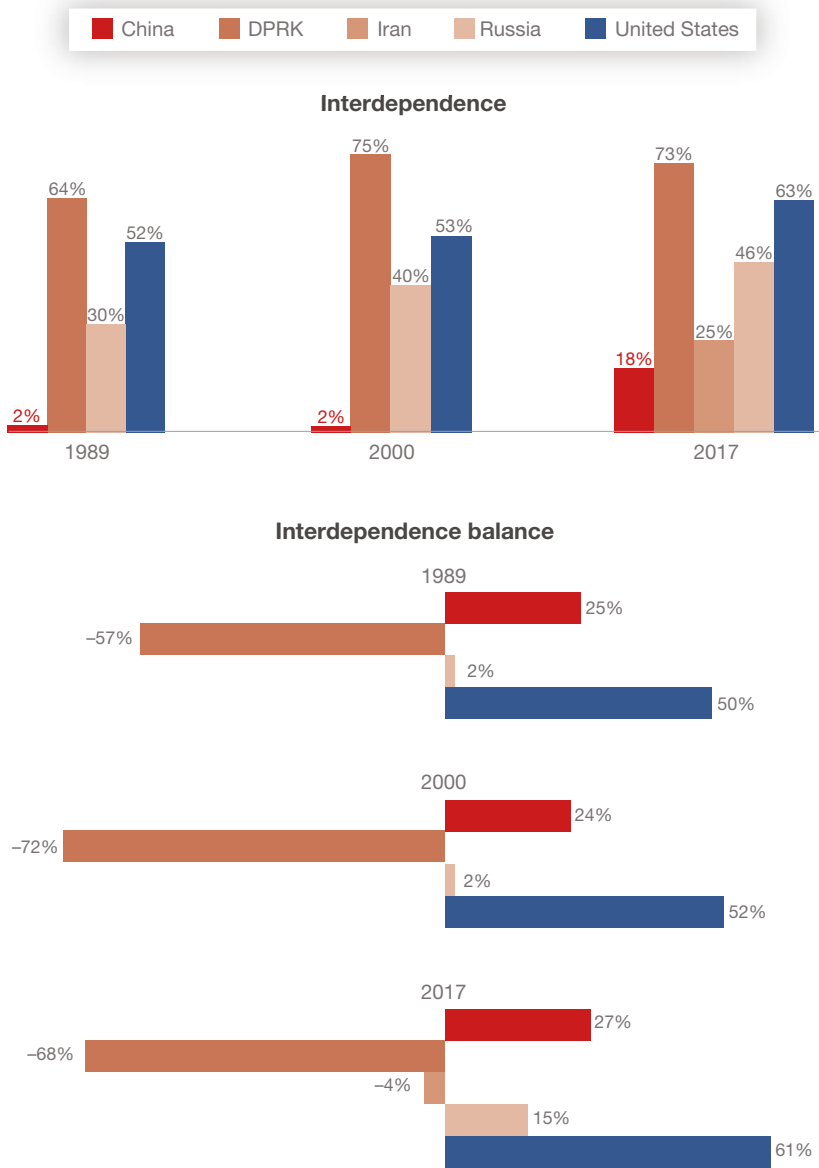
As shown in the top panel of Figure 2.3, in 2017, of the four competitors plus the United States, the DPRK remained the most interdependent with other countries at a level of 73 percent, because of its heavy reliance on China. The United States' dependence on other countries grew steadily from a level of 52 percent in 1989 to 63 percent in 2017. Russian interdependence with other countries grew steadily as well. It rose from a level of 30 percent at the end of the Cold War to 46 percent in 2017. China was the least interdependent with other countries of this group in 2017. However, it was also the country that showed the greatest increase in interdependence; between 1989 and 2017, its interdependence rose ninefold.¹³

The bottom panel of Figure 2.3 shows that, of this group, the DPRK alone had a negative interdependence balance and was thus a net consumer of security between 1989 and 2017. And it became slightly more of a consumer of security with time. The United States was by far the largest net supplier of security of the group (61 percent). Its role as a net provider of security rose steadily after the end of the Cold War. The United States' lead over its nearest competitors as a net provider of security remained relatively steady. Russia's role as the second-most important net provider of security in this group remained stable. China's role as a security supplier, by contrast, expanded.

The top panel of Figure 2.4 shows that, in 2017, collectively, the 130 countries that made up the remainder of the global military alliance system were 12 times more militarily dependent on the United States than on Russia, its nearest competitor. They were 17 times more dependent on the United States militarily than on China. And dependence on the United States rose during the period under examination. Dependence on Russia fell by just under 1 percent—presumably the result of Russia's shedding its

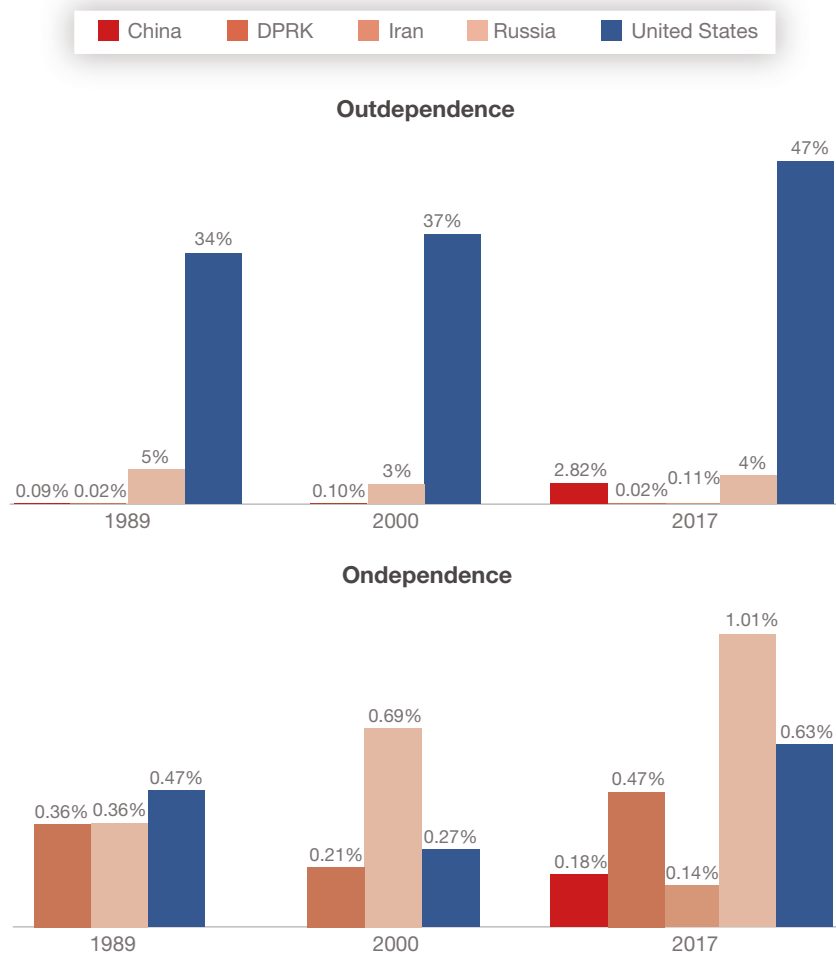
¹³ All dependence scores presented are final-order scores that take both direct and all indirect dependence effects into account.

FIGURE 2.3
Monadic Interdependence, 1989, 2000, and 2017



SOURCE: Leeds, undated.

FIGURE 2.4

Outdependence and Ondependence, 1989, 2000, and 2017

SOURCE: Leeds, undated.

Eastern European Cold War allies. The reverse was true of China, which saw global dependence on it rise from a fraction of 1 percent in 1989 to close to 3 percent in 2017.

The bottom panel of Figure 2.4 shows that, of these five countries, Russia was the most dependent militarily on all the other countries. That depen-

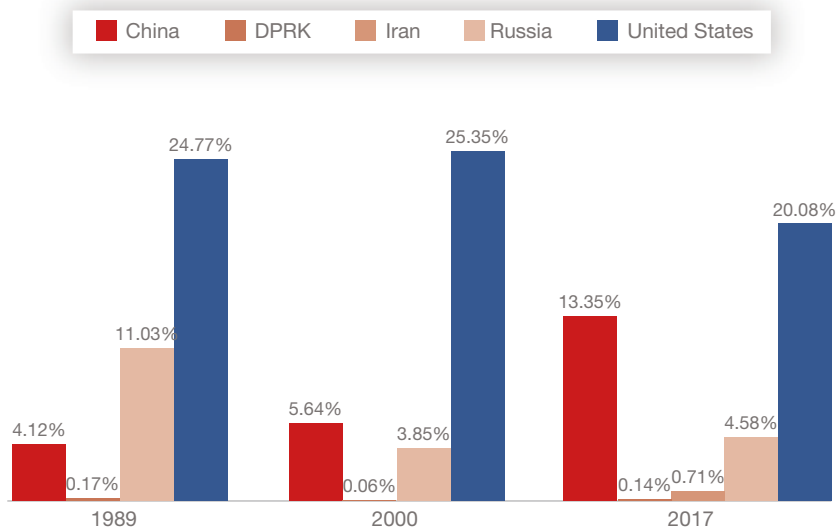
dence tripled by 2017, but it remained at a relatively low level of 1 percent. After initially falling after the end of the Cold War, U.S. dependence on other countries rose to 1.5 times its previous rather low level but remained very low at 0.6 percent. China too experienced a significant increase in its military dependence between 1989 and 2017. In the end, however, China remained the least militarily dependent of this group on other countries.

Dependence on the United States and Its Competitors by Their Allies

As shown in Figure 2.5, on average, the United States' allies were 20 percent dependent on it in 2017. Individual allies' dependencies ranged between 19 percent and 31 percent. However, in two cases, they were less than 1 percent. China's allies, by contrast, on average, were 13 percent dependent on China in the same year (within a narrower range of 11 percent to 14 percent). Russian allies' average dependence was just under 5 percent within a similar limited range. In the other two cases (the DPRK

FIGURE 2.5

U.S. Allies' Average Dependence, 1989, 2000, and 2017



SOURCE: Leeds, undated.

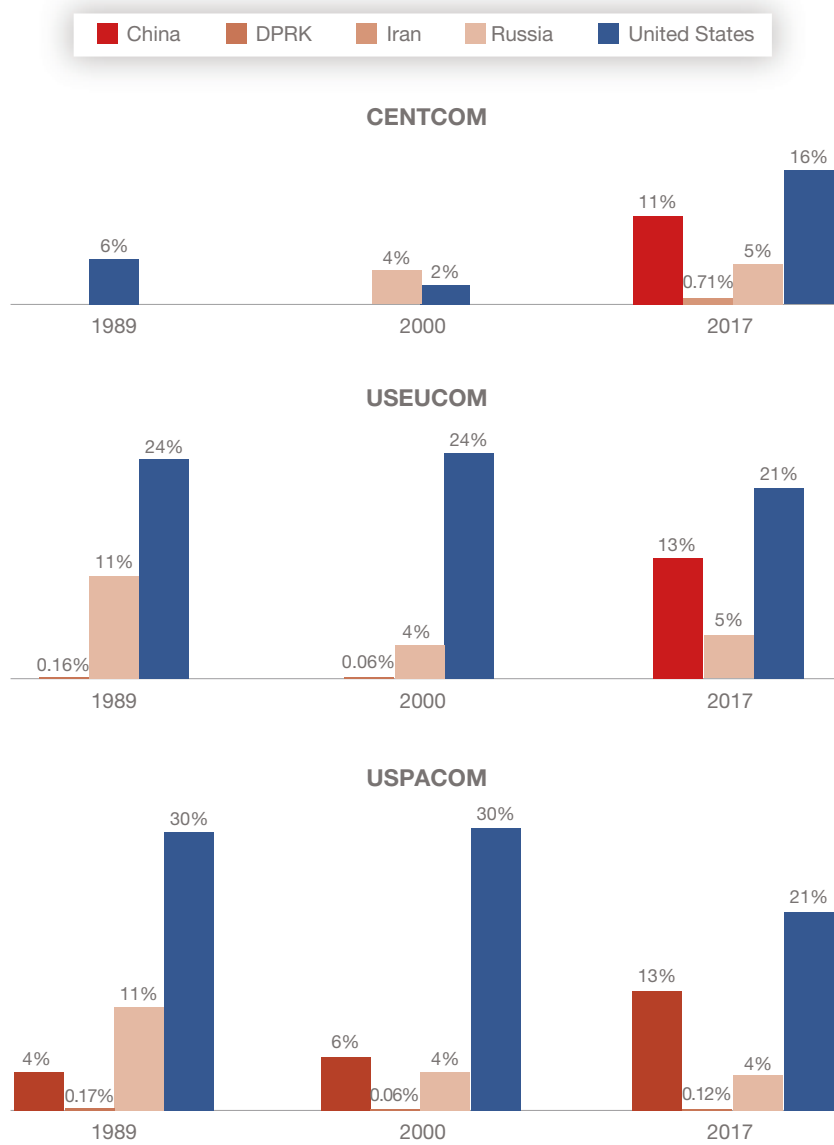
and Iran), average allied dependence was less than 1 percent. Dependence on China grew markedly as well. However, dependence on Russia at first fell significantly as it shed allies after the end of the Cold War and then rose slightly as Russia entered new alliances (SCO and the CSTO) for a net 1989–2017 loss.

Figure 2.6 provides a breakdown of allies' average dependence on the United States and on its competitors in three regions of the world: the CENTCOM, USEUCOM, and USPACOM AORs. Dependence on China was greater than on Russia in 2017 but still below dependence on the United States in every case. Because one USEUCOM state—Russia—was allied with and 13 percent dependent on China in 2017, compared with three USEUCOM states allied with and dependent on Russia by an average of 4.6 percent, allied states in USEUCOM are shown to be more dependent on China than on Russia. China's relatively strong showing in the CENTCOM region was likely due to gains in Central Asia (China's SCO quasi-allies). China has no allies in either SOUTHCOM or AFRICOM. When comparing average regional dependence across time, the jump in dependence on China between 2000 and 2017 and its supplanting of Russia in second place are striking. The declines between 1989 and 2017 in dependence on Russia in USEUCOM and USPACOM are not surprising, but the rise in dependence on Russia in CENTCOM is notable.

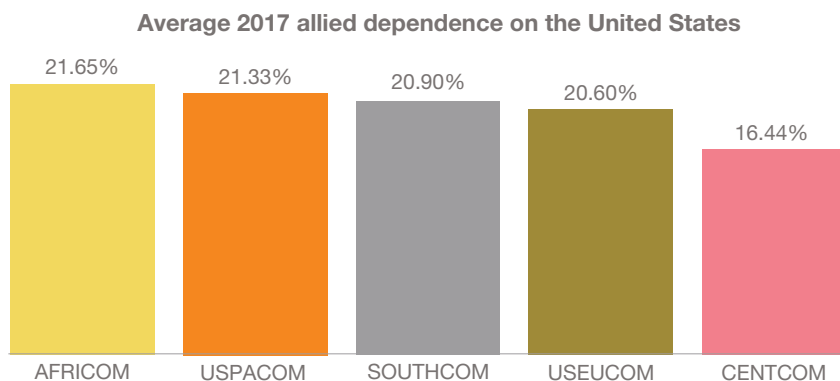
We now examine the dependence of allies of the United States and of allies of the United States' competitors in detail. Starting with the United States and sticking to the regional level of analysis, we can see from the top panel of Figure 2.7 that African and Pacific allies were, on average, most dependent on the United States in 2017. USEUCOM and CENTCOM were the AORs in which allies were least so.

The bottom panel of Figure 2.7 shows that, as a general proposition, regional powers were less dependent on the United States. In the USEUCOM AOR, countries A, B, C, D, and E were most dependent on the United States in 2017. Countries F, G, H, I, J, and K were least so. In USPACOM, countries L and M were most dependent; countries N and O were least so. In SOUTHCOM, countries P, Q, R, S, and T were most dependent; countries U, V, W, X, and Y were least so. In CENTCOM, countries Z, A, B, C, and D were most dependent; countries E, F, G, H, and I were least so.

FIGURE 2.6
U.S. Allies' Average Dependence, by Region, 1989, 2000, and 2017



SOURCE: Leeds, 2018.

FIGURE 2.7**U.S. Allies' Average Dependence on the United States, by Region, 2017**

Most dependent	Least dependent
USEUCOM	USEUCOM
Countries 1–5	Countries 1–6
USPACOM	USPACOM
Countries 1–3	Countries 1–3
SOUTHCOM	SOUTHCOM
Countries 1–5	Countries 1–5
CENTCOM	CENTCOM
Countries 1–5	Countries 1–6

SOURCE: Leeds, undated.

As shown in Figure 2.8, it was the USEUCOM and USPACOM AORs in which China's allies were, on average, most dependent on China in 2017. CENTCOM's AOR was the region in which China's allies were, on average, least dependent on China. However, the difference in dependence on China across regions was small. In Russia's case, CENTCOM's and USEUCOM's AORs were the regions in which Russia's allies were, on average, most dependent on Russia in 2017. However, dependence on Russia was circa one-third of the dependence on China in USPACOM's AOR and half that of China in CENTCOM's and USEUCOM's AORs.

Figure 2.8 shows a consistent jump in dependence on China across all three theaters between 2000 and 2017. This jump is attributable to two factors:

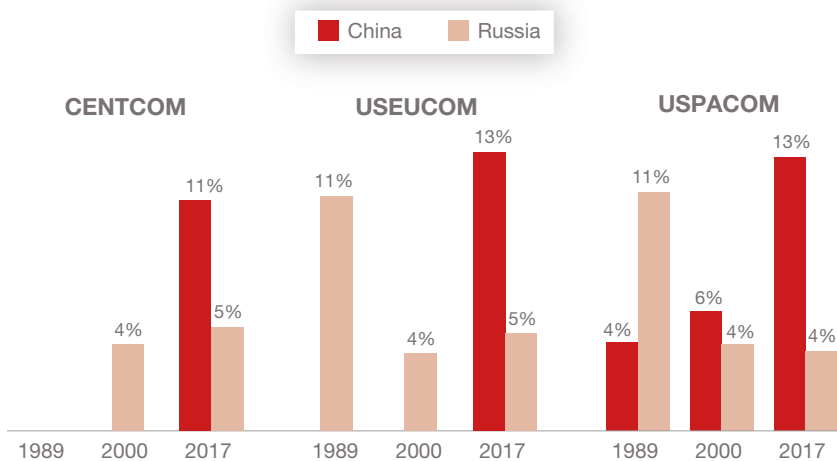
- the rise in China's GPI score between 2000 and 2017
- China's acquisition of seven quasi-allies from SCO.

Since the end of the Cold War, dependence on Russia has risen in CENTCOM's AOR. Russia was China's only USEUCOM-area ally in 2017. In USPACOM's AOR, the DPRK was most dependent on China, while country F was least so. In CENTCOM's AOR, country G was most dependent on China, and country I was least so. The development of allied levels of interdependence with the competitors is summarized in Tables B.15 through B.18 in Appendix B.

In addition to looking at the countries that were most dependent on the United States and its competitors over time, we identified those countries on which they were most dependent during the same period. Apart from itself, countries H, I, J, and K, in that order, were the countries on which the United States was most dependent in 2017. This top tier of four countries is followed by a tier of five countries that, unsurprisingly, includes countries E, F, and G

FIGURE 2.8

Allies' Average Dependence on China and Russia, by Region, 1989, 2000, and 2017



SOURCE: Leeds, undated.

but also includes countries L and M. The levels of U.S. dependence are uniformly small, ranging from just over 3 percent to just under 1 percent. U.S. dependence on countries J, K, and L grew the most between 1989 and 2017, whereas U.S. dependence on itself, countries M, N, and O fell the most.

Because of China's membership in the SCO quasi-alliance, after itself, China depended most on Russia and India, with Pakistan running a distant third. These levels of dependence too were not very high. Those three countries were also the ones where China saw the greatest gains in dependence between 1989 and 2017. It is worth noting that China's indirect dependence on the United States increased marginally during the same period and that its dependence on the DPRK fell during that time frame.¹⁴

Russia depended almost four times (3.74 times) more on China than China depended on Russia. France, Germany, and United States were the next-most important countries, but, in all three cases, indirect effects are responsible for the results. Because it joined the SCO in June 2001, Russia's direct dependence on SCO member states China and country P grew most between 1989 and 2017. Countries Q, R, S, T, and U experienced the greatest declines in direct or indirect Russian dependence. These changes are summarized in Table 2.5.

Even though the levels of the great powers' dependence on other countries in 2017 were small, ranging from 5.76 percent to 0.09 percent, it is instructive to examine where those top dependencies overlapped. Figure 2.9 shows that countries V, W, and X figured in the list of the ten countries on which all three of the principal competitors depended most. The United States and countries Y and Z appeared in both China's and Russia's top-ten lists, whereas countries A and B figured in the top-ten lists of both Russia and the United States. If there were to be competition for countries' allegiances between the United States and its principal competitors, these are the countries that would likely be the subjects of such competition.¹⁵

¹⁴ China was indirectly dependent on the United States because of its quasi-alliance with country C via SCO. That country was dually aligned, being at the same time a U.S. MNNA.

¹⁵ As explained in Appendix A, the interdependence figures cited here take into account both direct dependence between country pairs and indirect dependence that results from the interconnectedness of the alliance network. As a result, countries with no direct alliance ties are indirectly dependent on one another to a small degree.

TABLE 2.5

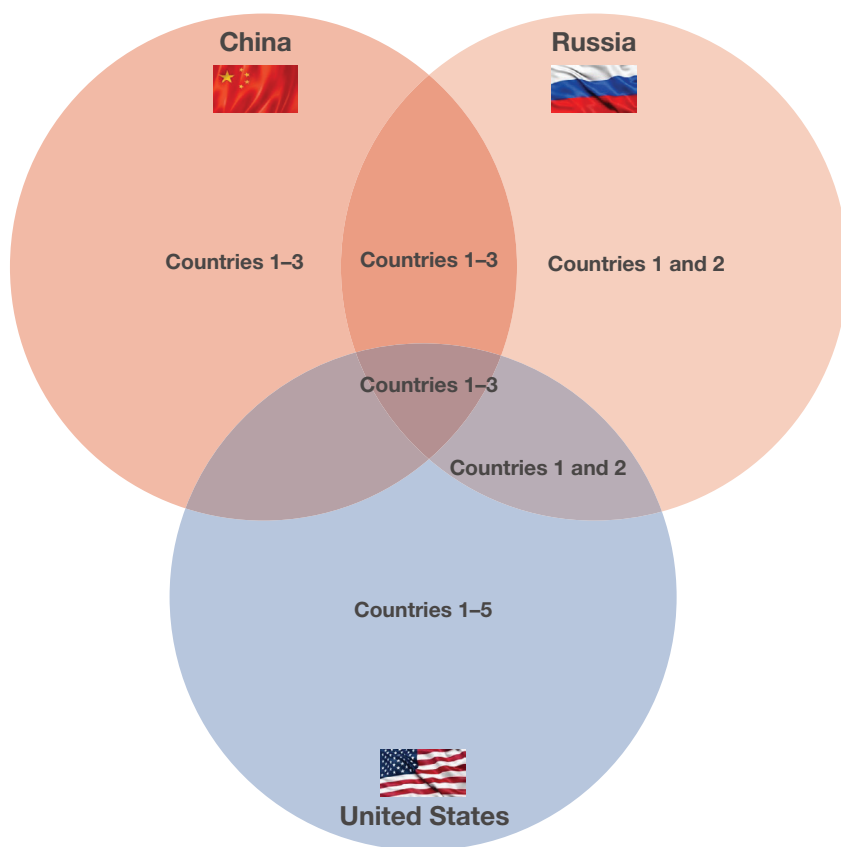
China's, Russia's, and the United States' Dependence on Other Countries as Percentages: On Which Greatest Dependences, 2017

China's Dependence		Russia's Dependence		The United States' Dependence	
Country	Percentage Dependent	Country	Percentage Dependent	Country	Percentage Dependent
China	14.08	China	13.06	United States	27.94
Russia	3.49	Russia	5.76	Country 1	3.19
Country 1	2.49	Country 1	5.53	Country 2	3.18
Country 2	0.59	Country 2	5.44	Country 3	2.84
Country 3	0.29	Country 3	4.45	Country 4	2.79
Country 4	0.20	Country 4	3.25	Country 5	1.41
Country 5	0.20	Country 5	2.44	Country 6	1.22
Country 6	0.20	Country 6	1.66	Country 7	1.17
DPRK	0.12	Country 7	1.12	Country 8	0.95
Country 7	0.09	Country 8	0.87	Country 9	0.94

SOURCE: Leeds, undated.

FIGURE 2.9

Overlaps in Top Chinese, Russian, and U.S. Dependencies in 2017



SOURCE: Leeds, undated.

Changes in Countries' Global Military Interdependence

As mentioned earlier, five factors can lead to changes in the level of interdependence between countries in the global military alliance system:

- A country can experience a big gain in its power, as measured by its GPI score. Alternatively, a country can suffer a loss in power.
- The group of potential opponents that a country faces can change. This was the case for Russia when NATO added members in Eastern Europe

after the end of the Cold War. It was also the case for the United States after the SCO was formed in June 2001.

- The cumulative power of those opponents can change. U.S. potential opponents' cumulative power was dragged down by the decline in Russia's GPI score between 1989 and 2017. However, this was more than offset by the rise in China's GPI score during the same period.
- The size and composition of the alliances on which a country might call to offset any deficit between its own power and the cumulative power of its potential opponents can change. In the U.S. case, 18 allies were added between 1989 and 2017. Russia lost seven Communist-bloc allies immediately after the end of the Cold War but gained 11 CSTO and SCO allies and quasi-allies thereafter.
- The cumulative power of those allies can change, similarly to how the changes can occur in potential opponents' cumulative power described above.

Big changes in a country's military interdependence force national security establishments to either accept their changed vulnerability and reliance on others for their defense or consider making fundamental changes in security policy to adjust to those changes. Accepting vulnerability or dependence is likely to cause stress because a nation's ability to provide for its security changes significantly. If changes are made (e.g., via rearmament), there is a risk that those moves will unleash reactive moves on the part of potential opponents. In other words, changes in force posture undertaken to relieve increased military interdependence driven by a greater capability deficit than that of a country's potential opponents can unleash a *security dilemma*; that, in turn, can increase the risk of future conflict (Maoz, 2011).¹⁶ Joining, leaving, or forming an alliance is one way of adjusting to

¹⁶ Shiping Tang wrote,

John Herz, who originally coined the term "security dilemma," elaborated it as follows: "Groups and individuals who live alongside each other without being organized into a higher unit . . . must be . . . concerned about their security from being attacked, subjected, dominated or annihilated by other groups and individuals. Striving to attain security from such attacks, they are driven to acquire more and more power in order to escape the effects of the power of others. This, in turn, renders the other more insecure and compels them to prepare for the worst. Because no state can ever feel entirely secure in such a world of competing units, power

large changes in military interdependence without potentially unleashing a security dilemma.¹⁷

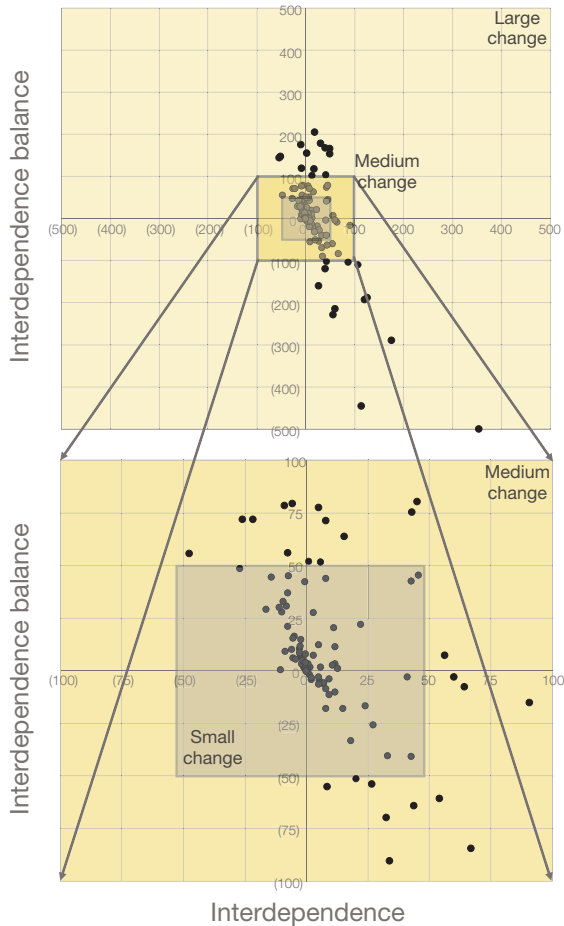
We suggest that large changes over time in a country's interdependence with other countries in the global military alliance system (*monadic interdependence*) and its position as a net provider or consumer of security (*monadic-interdependence balance*) might indicate that a country has been confronted with the question of how to adapt to rising or falling deficits of its own power versus the combined power of its potential future opponents. Confronted by such a question, it seems likely that policymakers would reassess the value of existing alliances or consider forming a new alliance tailored to the demands of their changed security environment. To determine whether any countries were in fact potentially confronted by such a question in 2017, we plotted the 1989–2017 change in countries' *monadic interdependence* (the degree to which they depend on other countries for their security at all) against the 1989–2017 change in their *monadic-interdependence balance* (the measure of whether they are net security consumers or providers).

The results of this exercise are shown in Figure 2.10. The horizontal axes show the percentage of positive or negative change in countries' interdependence with other countries between 1989 and 2017 (i.e., percentage change in their monadic interdependence). The vertical axes show the positive or negative percentage change in countries' role as net security providers or

competition ensues, and the vicious circle of security and power accumulation is on. (Tang, 2009, p. 590, citing Herz, 1951, p. 157)

¹⁷ When a country's dependence on other countries rises, its risks of *entanglement* (being forced to adopt policies it would otherwise not adopt) or *entrapment* (having an ally drag it into a war that it would otherwise avoid) rise and its autonomy falls. The autonomy–security trade-off model of alliance formation and dissolution predicts that a state might consider breaking an existing alliance tie after an increase in dependence for these reasons. Conversely, the capability-aggregation model of alliance formation and dissolution suggests that, when a country's dependence on other countries falls, because of the shift in the balance of power, it no longer has as great a need for the capabilities provided by allies. This provides another reason a state might consider abrogating an alliance after a shift in its dependence (Morrow, 1991, p. 916). “Following a major shift in the distribution of power, each state will identify its set of potential alliance partners and seek an alliance with the state that it perceives to be the most ‘fit’” (Cranmer, Desmarais, and Kirkland, 2012, p. 305).

FIGURE 2.10
Changes in Countries' Interdependence, 1989–2017



SOURCE: Leeds, undated.

NOTE: The horizontal axes show the percentage of positive or negative change in countries' interdependence between 1989 and 2017. The vertical axes show the percentage of positive or negative change in their monadic-interdependence balance in the same period. The figures show small change (between 0- and 50-percent change in either or both, in gray), medium change (between 51- and 100-percent change in either or both, in darker yellow), and large change (101-percent or greater change in both interdependence and balance, in lighter yellow). In the lower panel (which is a zoom into the medium-change area), for example, country D experienced an approximate 50-percent increase in dependence on allies between 1989 and 2017. At the same time, it experienced a 75-percent positive increase in its monadic-interdependence balance, making it more of a net security provider than it had been in 1989. By contrast, country E (below and to the right of center of the gray shading) experienced a relatively small increase in its interdependence with other countries but also saw a big negative increase in its interdependence balance: It became a greater net consumer of security between 1989 and 2017.

consumers in the same period (i.e., percentage change in their *monadic-interdependence balance*). The figure is divided into three zones representing

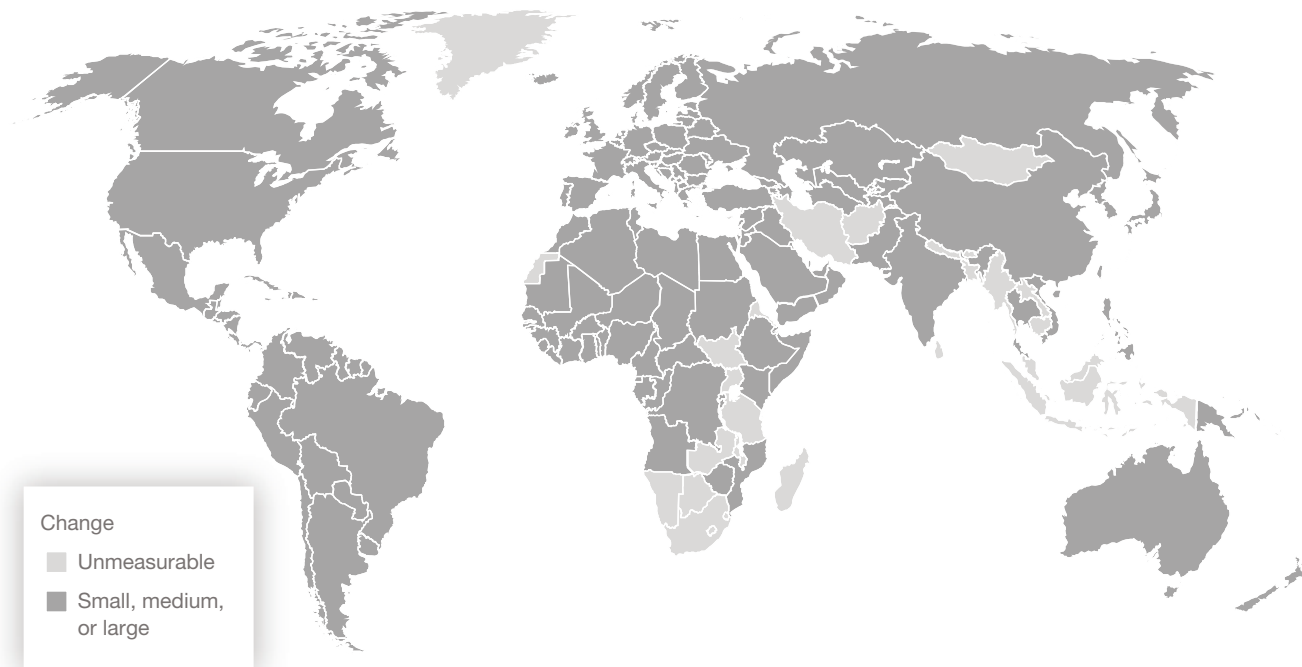
- **small change** (between 0 and 50 percent, in interdependence and interdependence balance from 1989 to 2017)
- **medium change** (between 51 and 100 percent during the same period on both measures)
- **large change** (101 percent or greater on both measures).

As shown in Figure 2.11, most of the large change in interdependence was observed in Africa. The next-largest grouping of countries experiencing large changes in interdependence occurred in USPACOM's AOR, countries F, G, and H. In USNORTHCOM's AOR, both countries I and J have experienced large changes, while, in CENTCOM's AOR, countries K, L, M, and N experienced large changes in their interdependence between 1989 and 2017.

Countries that experienced large changes in their interdependence between 1989 and 2017 are potentially of concern. Changes in interdependence could cause policymakers in those countries to feel a need to reassess the value of new or existing alliance ties to their country. Sixteen U.S. allies (24 percent) found themselves in this position in 2017, versus five countries allied with the competitors (26 percent) and ten nonaligned countries.¹⁸ The latter two groups of countries could present the United States with opportunities either to wean countries into a more distant orbit around the United States' competitors or to win new allies. The former group of countries could represent potential challenges to the long-term integrity of the U.S. alliance system. U.S. policymakers might wish to investigate in greater detail what changes in the underlying factors driving these countries' interdependence scores led to the large changes in interdependence that they experienced. These analyses could then be used to fashion policy responses. The box after Figure 2.11 provides a detailed examination of one such large change in interdependence between 1989 and 2017.

¹⁸ In addition to the prospect of individual countries deciding to change their alliance alignments, there is a chance that multiple countries would choose to do so in succession. For more on such "cascading" or "herding" network effects, see Easley and Kleinberg, 2010, Chapter 16.

FIGURE 2.11
Map of Change in Countries' Interdependence, 1989–2017



NOTE: Countries that are unmeasurable did not have alliance relationships.

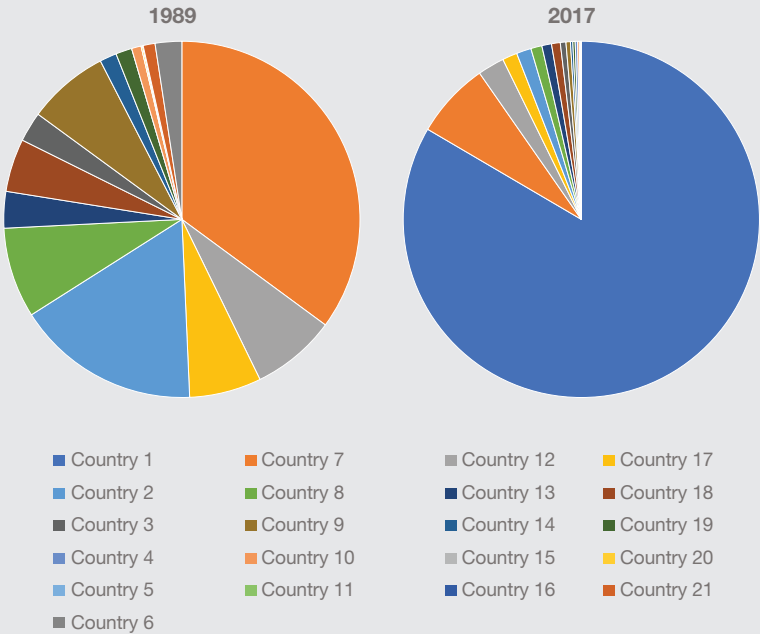
Examining the Underlying Causes of Big Changes in Country O's Interdependence

By working the interdependence calculation for a given country in reverse, we can identify the reasons for a change in a country's level of interdependence and its interdependence balance over time. Between 1989 and 2017, country O experienced a large (greater than 100-percent) change in its overall level of interdependence and moved from its position as a net provider of security to that of a net consumer of security that depended on its allies to a greater degree. How did this happen? Country O's GPI score rose from 0.00274 to 0.00289 (5 percent). Country O's group of potential future opponents remained unchanged; however, their combined power rose by a larger amount than country O's did, from 0.05 to 0.06 (20 percent). This confronted country O with a power deficit that grew from 0.04726 to 0.05711 (21 percent). Between 1989 and 2017, country O lost two allies and gained three. Thanks largely to the addition of the United States as an ally, country O's allies' combined GPI score rose from 3.36 in 1989 to 27.26 (711 percent) in 2017. As shown in Figure 2.12, the share of the total country O-allied power that each ally contributed changed significantly as well.

Each of the countries with alliances has both a column and a row associated with it in the matrix that we used to calculate dependence between country pairs. Each entry in the *row* of the matrix corresponding to country O gives country O's dependence on the country in the corresponding column, including—where the column is country O itself—country O's self-reliance. When we calculated the matrix, each of country O's allies was allocated a share of country O's power deficit. The share allocated to each ally is proportional to its share of the combined power of all of country O's allies and was entered into its column in the country O row of the matrix. Because there was a significant increase in country O's power deficit, a significant increase in allies' total power, and a significant change in the mix of allied contributions to that total power, the shares allocated to each ally—country O's direct dependence on that ally—can be expected to have undergone a significant increase between 1989 and 2017.

By raising this dependence matrix to a power equal to the number of participants in the global military alliance system (131), the row and

FIGURE 2.12
The Combined Power of Country N’s Allies, 1989 and 2017



SOURCE: Leeds, undated.

column entries changed from giving the direct dependence of country O on the country in question (and vice versa) to giving the final-order dependence between these countries, a number that takes all direct and indirect dependencies between countries into account. Because of the interconnectedness of allies within this overall system, the already-significant changes outlined above are amplified as they propagate across the entire system of 130 potential additional dependencies due to this move.

To measure the impact of the changes just described, we subtracted country O’s self-reliance from the sum of all entries in the country O row of the dependence matrix to determine the level to which country O depends on its allies. This sum is expressed as a percentage of the maximum value that the sum of those entries could theoretically take

(as is standard for SNA), yielding country O's level of dependence on all other countries in the global military alliance network—its ondependence. The combination of (1) country O's power deficit, (2) the changed composition of its alliances, (3) the changed cumulative power of those allies, (4) the change in country O's allies' proportional contributions to that total power score, and (5) the amplifying effect of taking all direct and indirect dependencies into account caused the raw sum of country O's reliance on other countries to rise about 880 percent at final order between 1989 and 2017. After normalization, following the calculation methodology for ondependence given in Appendix A, we found that country O's ondependence, or dependence on all other countries, rose 961 percent between 1989 and 2017. By contrast, country O's self-reliance increased by just 17 percent.

The country O column of the dependence matrix indicates the degree to which all other countries depend militarily on country O. Using the same procedure just described for ondependence, we expressed the sum of all the entries in this column net of country O's self-reliance as a percentage of the maximum theoretical value that sum could take. This gave us a measure of the degree to which country O was depended on by all other countries in the global military alliance system each year, its outdependence. Between 1989 and 2017, the changes in capabilities, relative contributions, and alliance structure discussed caused other countries' dependence on country O to rise 87 percent. This was due to country O's own increase in power and due to the indirect effects caused by the significantly greater combined power of country O's allies in 2017.

Country O's degree of dependence on other countries regardless of the direction of the dependencies (monadic interdependence) is simply the ratio of its ondependence plus its outdependence to the sum of its ondependence, outdependence, and self-reliance. Because of the changes described, country O's level of reliance on other countries rose by circa 100 percent between 1989 and 2017.

To determine the net direction of country O's overall dependence, the numerator of the monadic-interdependence calculation is changed to subtract ondependence from outdependence. Because country O's dependence on other countries rose so sharply between 1989 and 2017 (more than 900 percent), the numerator in this calculation becomes negative, and country O's dependence balance falls from 0.05 in 1989 (indicating

that country O was a small net provider of security at the time) to -0.46 (indicating that country O by 2017 had become a rather large net consumer of security). This is how country O simultaneously came to provide less support to its allies and to depend on them to a greater degree.

NOTE: Although we have not chosen to do so here, those interested could drill down even further in this analysis by identifying which of the five dimensions (listed in Appendix A) of country O's GPI score changed, by how much, and why.

Alliances' Vulnerability to Deliberate Disruption

In addition to examining changes in countries' military interdependence over time, we examined the vulnerability of the alliance networks of the United States and its competitors to deliberate attempts at their disruption. As mentioned, a network in which all nodes are connected to each other is termed *complete*. Multilateral military alliance networks, such as NATO, are complete. Each alliance member makes a security guarantee to the others, meaning that every node in the alliance network is connected to all the other nodes by an obligation of this kind. Such networks are very robust against deliberate attempts at their disruption. They are robust because, even if a few nodes or links between nodes are removed, multiple redundant paths remain by which to get from one remaining node in the network to another.¹⁹ The opposite extreme is a network in which every node is an isolate that has no connection whatsoever with any other node in the network. *Fragmentation* is a measure of a network's cohesiveness; it takes on a value that ranges between 1 and 0 between these two respective extremes.²⁰

Fragmentation analysis is a method devised by Steve Borgatti at the University of Kentucky that uses combinatorial optimization to identify the optimal combination of nodes that should be removed from a network to

¹⁹ In this example, we consider all nodes equally important. As discussed in Chapter 1, they are not, in reality.

²⁰ For a mathematical definition of fragmentation, see Borgatti, 2006.

achieve the maximum possible increase in its fragmentation (this is termed a *directed attack* on a network). A country (node) or combination of countries (nodes) is removed from an alliance network when any one of the following conditions is true:

- The country has not complied with a particular existing alliance obligation.²¹
- The country has renounced some set or subset of those obligations.²²
- The country has defected from an existing obligation by banding together with one or more other countries to set up alternative security arrangements.²³
- The country has defected from a commitment to an existing alliance system to join a rival alliance system (i.e., it has switched sides).

It is unrealistic to expect to be able to remove the top country (e.g., the United States, China, or Russia) from an alliance network that has been built around that country. Consequently, it is the countries that have the greatest *additional* impact on an alliance network's fragmentation *after* the top country has been removed that matter (we refer to this as the network's *incremental network fragmentation*).

²¹ An example of this is Albania's renunciation of its Warsaw Pact membership in 1961. The Gulf Cooperation Council countries' failure to come to the immediate military aid of Kuwait after it was invaded by Iraq in 1990 is another example of failure to honor an alliance obligation.

²² The United States' 1963 warning to Turkey that it would not consider its NATO Article 5 commitment to defend Turkey as legally binding if Turkey unleashed a military conflict with Greece to resolve the question of disputed sovereignty over the island of Cyprus is an example of abrogating part of an alliance obligation. France's 1966 withdrawal of its troops from the NATO military command structure is another example. Russian Deputy Foreign Minister Georgi Kunadze's declaration during a January 1993 visit to Pyongyang that Russia would assist the DPRK in line with its treaty obligations only if the latter had been the subject of an unprovoked attack is yet another example.

²³ An example of this would be a purely European collective-defense system in lieu of NATO.

There are two approaches to directed network attack:

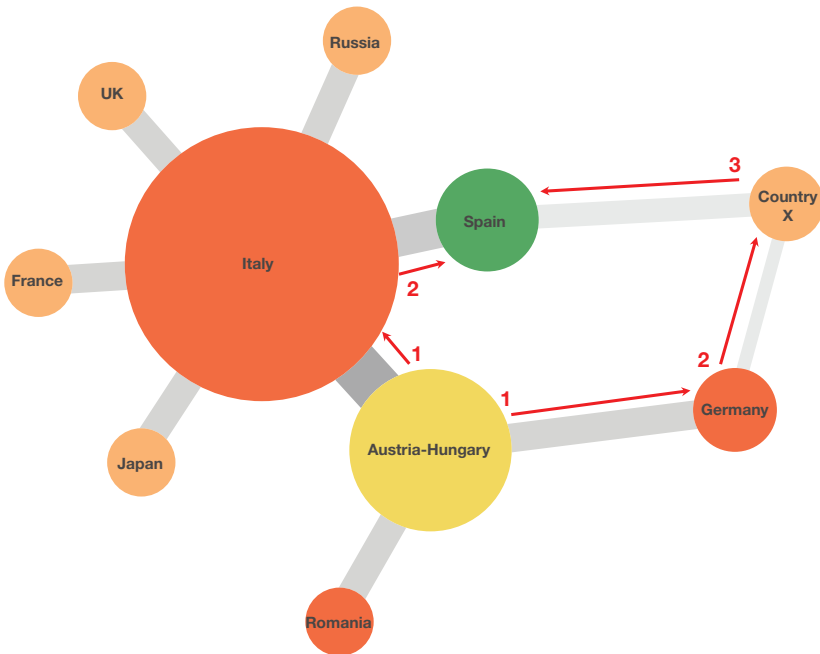
- One involves maximizing network fragmentation by removing nodes or countries (the *fragmentation approach*). This is relevant to disrupting alliance networks in most cases.
- The second involves disrupting a network by removing links between nodes (the *distance-weighted fragmentation approach*). This approach, although it applies to a narrower subset of cases, is a less onerous method of network disruption than a non-distance-weighted fragmentation approach.

The example of Austria-Hungary's 1914 decision about whether to go to war with Serbia shows how indirect alliance ties can be important. For Austria-Hungary, Italy's ability to persuade one or more of its five allies (Russia, the UK, France, Spain, and Japan) to join Austria-Hungary, Germany, Italy, and Romania in declaring war on Serbia was potentially decisive to the conflict's outcome and endowed Italy with a central role in that alliance network due to its key structural position. In this instance, as shown in Figure 2.13, in addition to activating its direct alliance tie to Italy, Austria-Hungary sought to activate one or more of a set of indirect alliance ties from Italy to Italian allies that were located a second step or link away from Austria-Hungary in the alliance network.

If the alliance link between Italy and Spain in this network is removed, there is no path from Austria-Hungary to Spain, and Austria-Hungary cannot hope to enlist Spain on its side in the war with Serbia by activating Italy's alliance tie with Spain.

In the version of Austria-Hungary's alliance network depicted in Figure 2.13, we have added a second, fictitious path from Austria-Hungary to Spain across the alliance network that involves three steps via an additional country X instead of the two steps from Austria-Hungary to Spain via Italy. The more steps across the network there are between them, the lower the chance that Austria-Hungary can enlist Spain on its side. This is because, at each step, there is a significant probability that Austria-Hungary will fail to activate that alliance tie. The larger the number of alliance ties that must be activated or steps across the network that must be taken (in this instance, three instead of two), the lower the probability of success.

FIGURE 2.13

A Putative Austro-Hungarian Alliance Network

NOTE: Each circle represents a node, or country. The size of each circle reflects that country's centrality within the alliance network—the larger the circle, the larger the centrality. The color of each circle represents the node or country's eigenvector centrality, an indication of how well-connected each country's allies are. The colors lie on a continuum from red (lowest) to green (highest). Each line represents an alliance link. The width and darkness of each line reflects the betweenness centrality of each alliance tie. The darker and thicker the line, the greater the betweenness centrality of that edge in the network. The numbers indicate the number of steps across the network that are required to reach Spain from Austria-Hungary.

Distance-weighted fragmentation (ranging in value from 0 for completely fragmented to 1 for a complete network) measures the extent to which a network has been fragmented by eliminating shorter paths between nodes of the kind represented by the two-step link from Austria-Hungary to Spain shown in Figure 2.13. As stated above, this approach to network fragmentation can be applied in scenarios in which disrupting the activation of indirect alliance ties is important. We used both approaches to network disruption in our analysis.

The data table in Figure 2.14 shows that, when the less onerous distance-weighted fragmentation approach is used, China's (5.41 percent) and Russia's (3.76 percent) military alliance networks are more susceptible to disruption

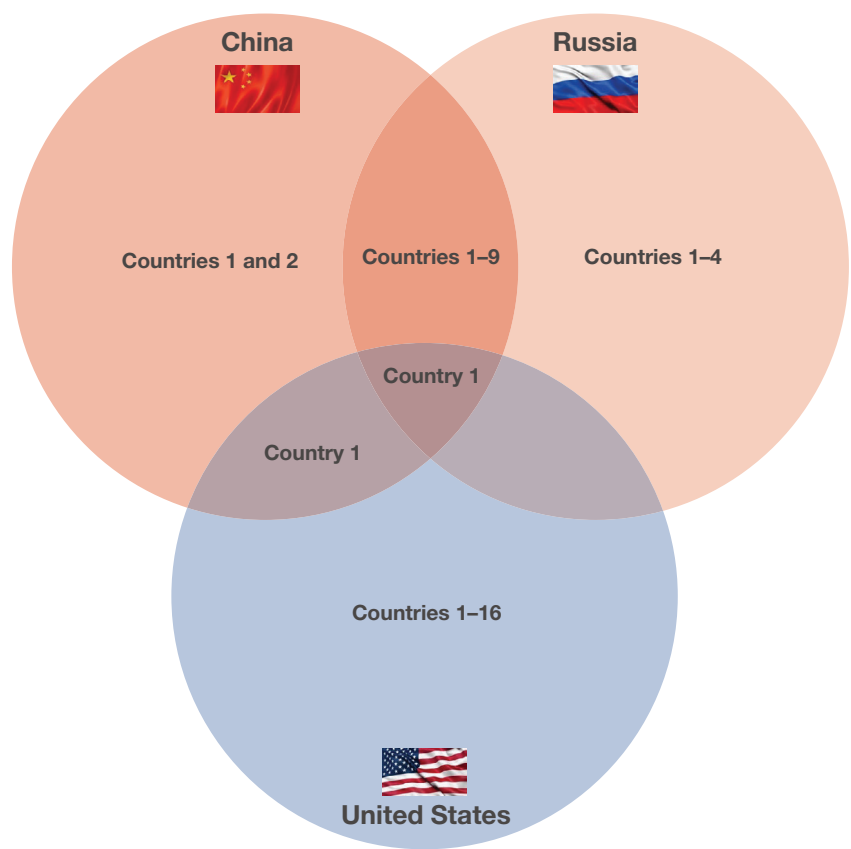
than that of the United States (2.18 percent). When the more onerous fragmentation approach is used, China's alliance network remains more susceptible to disruption than that of the United States, whereas Russia's is less so. We used the equally weighted results from both approaches to network disruption to construct a combined prioritized list of countries to remove from each country's alliance network to achieve that network's maximum disruption. We compared the lists of countries to remove in each case and found areas of overlap. They are shown in the Venn diagram in Figure 2.14. It shows that country P plays a key role in disrupting any of the three alliance networks. Countries Q, R, S, T, U, V, W, X, and Y, in that order, are key to disrupting both the Chinese and the Russian alliance networks. Cuba is important to both China's and the United States' alliance networks (because of Cuba's membership in the Rio Pact and its alliance with the DPRK). The other countries listed in the nonoverlapping parts of the diagram are important to disrupting the given alliance network alone, in the order shown.

The methods used in these analyses have limitations. The quantitative approach to measuring interdependence within the diplomatic network layer that we used above implicitly favors the neorealist capability-aggregation model of alliance formation and dissolution and the underlying assumptions about the nature of the international system subscribed to by the neorealist school of thought. Competing autonomy–security trade-off and regime-change models of alliance formation and dissolution do exist.²⁴

The methodology used to calculate military interdependence is blind to varying qualitative levels of threat that could be posed both across groups of potential opponents and across time. It also assumes that a country will make contributions to its alliances that are in strict proportion to its relative national power. A large positive or negative change in a country's military interdependence scores might not be the only way of measuring the presence or absence

²⁴ The capability-aggregation model of alliance formation essentially posits that countries accrue allies until their own capabilities, when added to those of their allies, exceed those of the country's potential opponents. The autonomy–security model holds that countries try to balance capability accumulation of this kind against the loss of autonomy that results from entering alliances. The regime-change school argues that changes of regime can have a significant impact on alliance formation and dissolution. For a description of the differences between the capability-aggregation and autonomy–security trade-off models of alliance formation and dissolution and an exposition of the empirical evidence in favor of the latter, see Morrow, 1991, and Siverson and Starr, 1994.

FIGURE 2.14
The Vulnerability of Alliance Networks to Disruption in 2017



Country or alliance system	Fragmentation rate, as a percentage ^a	
	Distance-weighted fragmentation rate ^a	Fragmentation rate ^a
China	5.41	10.00
Russia	3.76	4.32
Iran	2.30	3.27
United States	2.18	6.90
U.S. competitors combined	1.04	2.03

^a Percentage rate by which network fragmentation increases per ally removed using either the fragmentation or the distance-weighted fragmentation measures of network disruption.

of vulnerability in an alliance. It is conceivable that a country's continuing membership in an alliance could be quite friable even if the country's levels of military dependence on other countries remained relatively stable over time.

Significant time lags are often involved between the conclusion or abrogation of defense treaties and events on the ground. Mutual-defense treaties between India and Pakistan and between Cuba and most of Latin America are still technically in force, even though the likelihood of any side's compliance with them, if called on to comply, might be rather low.²⁵ The datasets used in this study could therefore lag in reflecting reality on the ground.

The datasets capture only formal, public networks between national actors; they do not capture long-standing informal or covert alliances or partnerships, including those with subnational actors (e.g., Iran's long-standing relationship with Lebanese Hezbollah). Iran's relationship with Hezbollah started as a covert relationship between a nation-state and a subnational actor in the 1980s and was formalized at the level of nation-states and reflected in the ATOP dataset in only 2008.

Given the computational complexity of the combinatorial optimization method of exploring network disruption, we cannot guarantee that our analyses provide a global maximum in network disruption; there might be sets of nodes not identified in our search that, if removed, would create greater disruption. The computational time required for combinatorial optimization increases exponentially as a function of the number of data points (i.e., it is a nondeterministic polynomial-hard [NP-hard] problem). This means that the time required to find the optimal set of nodes to remove from a network increases exponentially (actually, in binomial time) with the number of nodes to be removed. For this reason, we used heuristics to determine sets of nodes to remove from the network; the size of the network we considered precluded brute-force methods of calculation in which every possible permutation would be examined. There is a risk, however, that the heuristic employed (e.g.,

²⁵ The Organization of American States, the official depository of ratifications of the 1948 Rio Pact, shows both the United States and Cuba as having ratified the treaty. There is no record on the official depository's website of the suspension of Cuba's membership, either via unilateral action by the United States or via a Cuban renunciation (Department of International Law, undated; see also Inter-American Treaty of Reciprocal Assistance and Final Act of the Inter-American Conference for the Maintenance of Continental Peace and Security, 1947).

the greedy algorithm used in this case) identified a suboptimal local maximum as opposed to the overall global maximum in the objective function (in this case, network disruption) that it sought to maximize.²⁶

Despite these limitations, the analysis above produced several interesting results. In 2017, the 131 countries making up the global military alliance system were 12 times more dependent on the United States than on its nearest competitor, Russia. They were 13 times more dependent on the United States than on China. U.S. allies were almost twice as dependent on Washington as China's allies were on Beijing. However, military dependence on China rose strikingly between 1989 and 2017. As a result, China replaced Russia in second place as the country whose allies were, *on average*, most dependent on it in each region of the world. On average, China's allies were between two and three times more dependent on China than Russia's were on Russia. That said, China's alliance network was twice as vulnerable to deliberate disruption in 2017 than that of the United States; Russia's was 1.5 times more vulnerable. Forty-six percent of U.S. allies experienced medium (between 51- and 100-percent) or large (greater than 100-percent) change in their interdependence between 1989 and 2017. This suggests that a considerable number of U.S. allies might have had reason to ponder the value of continued alliance ties with the United States in 2017. By contrast, 31 percent of the competitors' allies experienced medium to large changes in interdependence during the same period. Of 202 countries and territories analyzed, 131 had alliance ties. Just over two-fifths of these 131 (56, or 42 percent) of all 161 countries in the global military alliance system in 2017 also experienced medium to large changes in their interdependence. This suggests that, in 2017, questions as to that system's continued relevance might have been quite prevalent in decisionmakers' minds.

²⁶ For more detail on the use of heuristics in solving optimization problems, see Kochenderfer and Wheeler, 2019.

The Military Network Layer

In this chapter, we use data on arms sales and JMEs to model the military network layer of the United States and its allies, partners, and competitors. Arms sales and JMEs both serve as signals that major powers can use to express support for allies, partners, and other states (McManus and Nieman, 2019). Of course, no two datasets can capture the totality of military interactions between allies and partners, which occur globally in thousands of contexts every day, extend from the ministerial to the tactical, and, in many cases, exist even in the absence of proximate activity (for example, U.S. extended deterrence guarantees have a value even in the absence of combined activities). That said, arms sales and JMEs capture two common and important military interactions between states in addition to the alliance ties that exist between them. Moreover, they differ substantially from diplomatic pledges of military support and thus add an important complement to the diplomatic layer that improves our picture of the U.S. ally and partner network in the military domain.

We used one well-known dataset on arms transfers from SIPRI, one equally well-known dataset from the International Institute for Strategic Studies (IISS), and one less well-known dataset from D’Orazio, the latter two covering JMEs. We looked at the global military arms sales and JME networks from three angles:

- activity volume and the number of partners or connections
- the centrality within the global military exercise and arms sales networks of each of the United States, its allies and partners, and its competitors
- the vulnerability of these networks to disruption.

We found that, in comparison with the competitors identified in the 2018 NDS, the United States and its allies enjoy positions within these networks that give them significant influence and means by which to advance their strategic interests.

The global arms sales market is broad but centralized with the United States at its core, in stark contrast to a tightly centralized, easily fragmented competitor arms sales network. The small core of the competitors' arms sales network has implications for the extent to which those competitors—especially China and Russia—can leverage this aspect of their network positions in competition with the United States. China does not rank among the top ten in terms of arms sales connections. Russia ranks eighth, but its lower levels of connections mean that Russia is, on the margin, more vulnerable to states opting to look elsewhere for their arms imports.

NATO dominates all other actors in JMEs across all three periods measured. Although NATO experts are, rightly, continuously pushing to improve NATO's interoperability given the inherent difficulties of conducting complex operations among multiple nations, the joint combat proficiency signaled by NATO's relative dominance of the JME space is significant and likely boosts the deterrent power of the NATO alliance in the eyes of other nations (Benson and Clinton, 2016).

China's increasing JME network influence should not be taken as an indicator of an attendant increase in the cohesion of the competitors' JME network or of that network's potential utility to China as an instrument by which to wield power with China at its center. Of the seven multinational exercises China joined in 2017, three involved either the United States or its allies. Russia's role in the JME space declined significantly; by 2017, Russia figured among the least connected states in the JME space.

Both arms sales and JMEs serve as signals of investment in the security of partner states. Arms sales bolster the military capabilities of receiving states. Exercises entail direct monetary costs to participants (costly signals) and can boost interoperability, combat proficiency, and, by extension, the deterrent value of alliances. Although the alliance commitments captured in the diplomatic network layer are perhaps the clearest indicator of states' investments in one another's security, arms transfers and JMEs are measures that states can take in response to particular threats, and they characterize a network of states that are short of mutual-defense arrangements but nonetheless

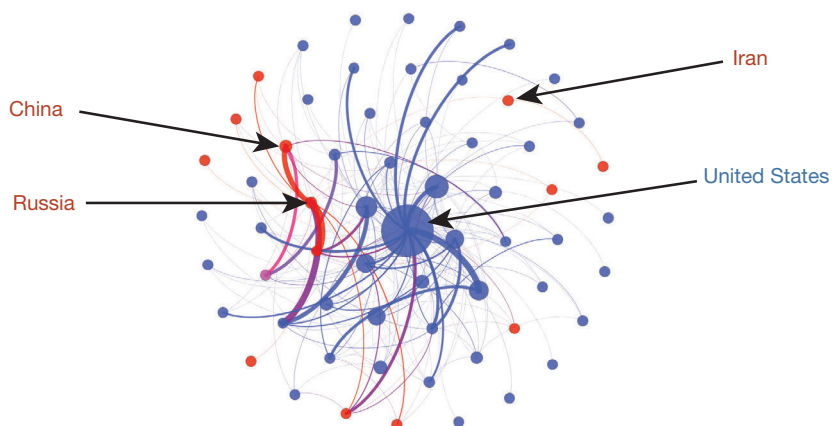
enjoy significant connectivity, collaboration, and partnership (McManus and Nieman, 2019). These measures thus provide some insight into the evolution and intensity of states' security relationships with one another.

The Global Arms Sales Network

Arms sales between countries represent more than just economic exchange. They can also establish and deepen military cooperation, construct hierarchical geopolitical relationships, facilitate interoperability between allied and partnered states, and act as a policy lever in managing regional balances of power. Larger arms sales create a “lock-in” effect because of the need to receive spare parts, maintenance, and other forms of support. Although states that buy small arms or other basic goods can easily switch vendors, states that purchase complex weapon systems, such as fighter aircraft, have fewer options unless they are willing to write off their prior investments or risk operating without a reliable source for spare parts and maintenance.¹ Arms sales are thus one useful indicator of the robustness, size, and depth of activity within military networks, including between allied nations, over time. They can also provide detailed information on the most-active states in the arms trade market, the regions with the largest inflows of arms, and the bilateral and multilateral relationships that form the basis of the global arms trade. One illustration of how the arms trade can provide insight into the U.S. alliance architecture is the U.S.-developed Aegis missile defense system leading countries B and C to engage in multilateral security coordination (Caverley and Kapstein, 2016).

Figure 3.1 is a visualization of the global network of international arms transfers in 2017. The visualization is laid out according to the same scheme introduced for the visualization of the global military alliance network in Figure 2.1 in Chapter 2. The United States is the central player across all periods under examination, in terms of both the number of unique trading

¹ African nations' need to maintain Soviet-era weapon systems purchased during the Cold War that they are “locked in” to is one of the main reasons that these nations turn to the DPRK for affordable maintenance services. That, in turn, allows the DPRK to finance its nuclear weapon and missile programs.

FIGURE 3.1**The Global Network of International Arms Transfers in 2017**

SOURCE: SIPRI, undated b.

NOTE: Each circle represents a node, or country. Each line represents a link. The size of each circle reflects that country's centrality within the network—the larger the circle, the larger the centrality. Blue circles and lines represent U.S. allies and their ties. Red circles and lines represent the allies and ties of China, Russia, Iran, and the DPRK. Green circles and lines represent nonaligned countries and their ties. Purple circles and lines represent countries that are aligned both with the United States and with China, Russia, Iran, and the DPRK. The width of a line connecting two nodes reflects the betweenness centrality of that tie—the thicker the line, the greater the importance of that link in the network.

partners (connections) and total volume of trade. The United States and its allied states represent the most-central states in the global arms sales network. Figure 3.1 shows the United States (US) and its allies countries D, E, F, G, H, and I all clustered relatively tightly together at the center of the network. Russia is the only competitor that ranked among the top ten arms traders in recent years. As can be seen in Figure 3.1, it occupied a relatively peripheral position in the global network of international arms transfers in 2017. In each period examined, Russia's arms trade had the highest proportion of total volume to unique trading partners, indicating Russia's centrality in a smaller network relative than the arms trade network involving U.S.-allied states.

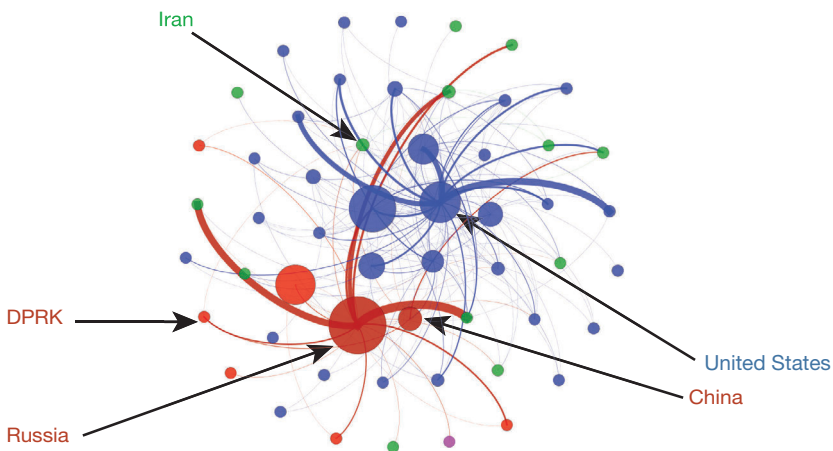
Most states that have seen the greatest increases in the number of unique arms trading partners (connections) between 2000 and 2017 are aligned with the United States, although the European market has seen smaller increases in total volume, including a decrease in both the size and volume

of country J's arms trade. Notably, China saw a drop in total volume even as its number of partners in the arms trade increased during the same period.²

States with centrality in the arms sales network can act as brokers or as channels through which information and relationships are most likely to flow—and that position confers some degree of additional influence. As shown in Figure 3.2, in 1989, the United States stood as the state with the second-greatest network centrality in the global arms sales network, although other nations occupied positions not far behind. The USSR was similarly situated as the leading broker in the international arms trade; Romania and China were also in the top ten. Table 3.1 lists the most-central countries in the international arms sales network in 2017 and the top gainers and losers between 1989 and 2017.

FIGURE 3.2

The Global Network of International Arms Transfers in 1989



SOURCE: SIPRI, undated b.

NOTE: Each circle represents a node, or country. Each line represents a link. The size of each circle reflects that country's centrality within the network—the larger the circle, the larger the centrality. Blue circles and lines represent U.S. allies and their ties. Red circles and lines represent the allies and ties of China, Russia, Iran, and the DPRK. Green circles and lines represent nonaligned countries and their ties. Purple circles and lines represent countries that are aligned both with the United States and with China, Russia, Iran, and the DPRK. The width of a line connecting two nodes reflects the betweenness centrality of that tie—the thicker the line, the greater the importance of that link in the network.

² Countries K and L also saw notable increases in arms trade volume.

TABLE 3.1

Changes in Arms Sales Centrality and Connections, 1989–2017

Country	Centrality		Change in Centrality	Connections	
	1989	2017	1989–2017	1989	2017
1	0.0005	0.0222	0.0217	10	5
2	0.0022	0.0069	0.0048	11	8
3	0.0017	0.0173	0.0156	13	10
4	0.0296	0.0271	–0.0026	24	25
5	0.0993	0.0182	–0.0811	29	24
6	0.0368	0.0183	–0.0184	24	20
7	0.0000	0.0054	0.0054	7	4
8	0.0108	0.0077	–0.0031	13	12
9	0.0533	0.0321	–0.0212	19	26
10	0.0823	0.1062	0.0239	53	40
Top gainers in centrality, 1989–2017					
1	0.0005	0.0222	0.0217	10	5
2	0.0017	0.0173	0.0156	13	10
3	0.0000	0.0049	0.0049	7	2
4	0.0000	0.0054	0.0054	7	4
5	0.0823	0.1062	0.0239	53	40
Top losers in centrality, 1989–2017					
1	0.0337	0.0047	–0.0290	10	12
2	0.0993	0.0182	–0.0811	29	24
3	0.0792	0.0000	–0.0792	2	6
4	0.1290	0.0025	–0.1265	13	18
5	0.0415	0.0005	–0.0410	7	12

SOURCE: Leeds, undated.

By 2000, the global arms sales network had become more diffuse, with more actors serving as potential brokers or connections between states among the U.S.-allied and competitor networks. However, the ten most-

central states in 2000 were part of the U.S. alliance network; China, country M, and Russia also played central roles. Although, by 2000, the United States had assumed a less important gatekeeping role, key members of its broader alliance network still served as the most-important hubs in the global arms sales network.

In recent years, the United States has reoccupied a more central position between disparate parts of the international arms sales network alongside allies that had played similar roles in previous periods (nine of the top ten brokers in 2017 were U.S. allies). Countries N and O had emerged as connective hubs by 2017. Notably, China is the only state in the competitors' arms sales network to figure in the top tier of brokers in 2017 (it places 14th), and—as in 2000—Russia occupies a role somewhere in the middle (18th of 27). Russia's arms trade is substantial in volume but takes place with fewer individual countries than that of other major actors in this market. Although Russia can leverage its position as a high-volume exporter, its lower network connectedness than that of other exporters means that it is less able to derive power from serving as an intermediary between otherwise-loosely connected states.

The robustness of the U.S. arms sales network has increased over time, although the increase is modest. The initial removal of the United States, a central supplier, causes a substantial initial increase in network fragmentation. Unlike in JMEs, states do not participate in the arms market in such a balanced manner; the set of suppliers is far smaller than the set of buyers in the arms market, while it is easy for many states to participate in joint exercises. In all three periods, the four most-influential nodes in the arms sales network after the United States are allied countries P, Q, R, and S. The 2017 global arms sales network was noticeably more robust than in 2000 and slightly more robust than it was at the end of the Cold War.

The same is true of Russia's removal from the combined competitors' network in 2017; the network is almost completely fragmented after Russia's removal. The competitors' network is thus less robust at the top end than it was in 1989, but it fragments just as quickly on the removal of the three most-influential nodes. The competitors' arms sales network is too sparse in 2000 to calculate the network statistics. Of the 11 intracompetitor arms transfers recorded in 2000, seven involved Russia as the exporter. The 2000 competitors' network was both small and fragmented in the absence of Russia.

The Joint Military Exercise Network

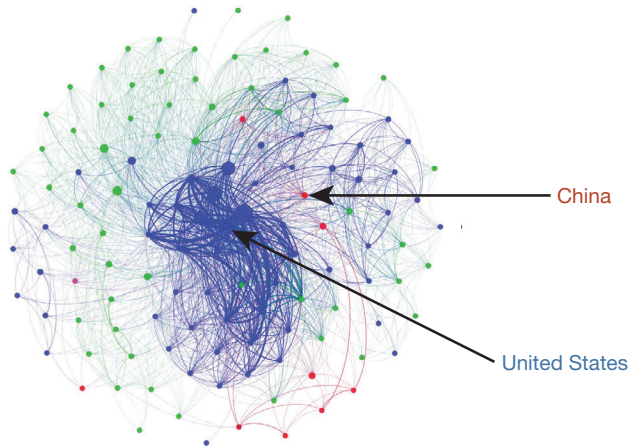
JMEs are a type of cooperation distinct from the underlying relationships that are captured in the diplomatic network layer and arms transfers. In this context, *JME* is defined as an activity in which “militaries from more than one state interact in such a way as to enhance their ability to carry out military operations” (D’Orazio, 2013, p. 14). D’Orazio executed the first systematic attempt at quantifying JMEs. He found that about 43 percent of all dyad-years (e.g., U.S.–Saudi Arabia–2004) with JMEs between 1971 and 2006 had neither formal alliances in place nor recorded arms transfers (D’Orazio, 2013). More generally, D’Orazio found that there were many more years in the data with alliances than there were years with arms transfers or JMEs. The addition of JMEs to the diplomatic layer and arms sales thus captures an important, distinct aspect of allies’ and partners’ relationships.

Figure 3.3 is a visualization of the 2017 JME network. The visualization is laid out according to the same scheme introduced for the visualization of the global military alliance network in Figure 2.1 in Chapter 2. The United States has the most individual JME partners (connections), as well as the most exercises across all partners.

Figure 3.4 uses a network analytical measure termed *modularity*³ to divide the 2017 JME network into four clusters. Nodes and links belonging to each of the clusters identified using the modularity score are assigned the same color. Apart from this one difference, the visualization presented in Figure 3.4 is the same as all others presented in this text. The size of each node reflects its centrality, as does the thickness of each tie. As Figure 3.4 confirms, NATO partners dominate the top ten states in terms of both connections and centrality across all periods under examination. The relatively high levels of interoperability and expected future combat proficiency signaled by this fact likely boost the deterrent power of the NATO alliance (Benson and Clinton, 2016). In 2017, within the competitors’ alliance system, countries S and T were among the ten states with the fewest network connections. Among U.S. allies and partners, countries U, V, and W have

³ This quantity, Q , is called the modularity and is a measure of the extent to which like is connected to like in a network. It is strictly less than 1, takes a positive value if there are more edges between vertices of the same type than we would expect by chance, and takes a negative value if there are fewer (Newman, 2018, Section 7.13.1).

FIGURE 3.3

The Joint Military Exercise Network in 2017

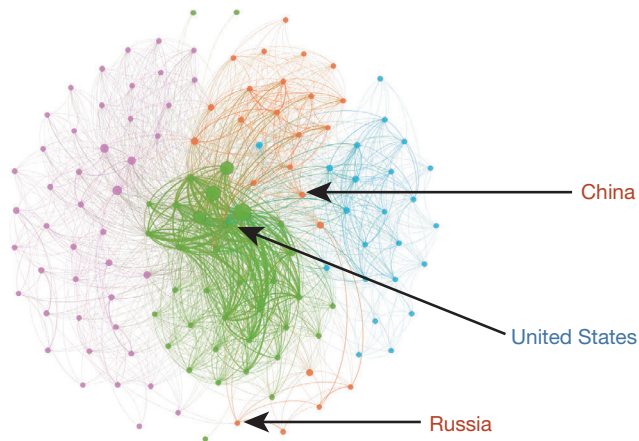
SOURCES: D'Orazio, 2013; IISS, 2016; IISS, 2018.

NOTE: Each circle represents a node, or country. Each line represents a link. The size of each circle reflects that country's centrality within the network—the larger the circle, the larger the centrality. Blue circles and lines represent U.S. allies and their ties. Red circles and lines represent the allies and ties of China, Russia, Iran, and the DPRK. Green circles and lines represent nonaligned countries and their ties. Purple circles and lines represent countries that are aligned both with the United States and with China, Russia, Iran, and the DPRK. The width of a line connecting two nodes reflects the betweenness centrality of that tie—the thicker the line, the greater the importance of that link in the network.

the fewest JME connections, alongside smaller West Indies and Caribbean states. Changes in JME connections and numbers of exercises between 2000 and 2017 also favor the U.S. alliance network. Countries X, Y, and Z had the greatest gains in connections, while countries A, B, and C saw the largest increases in the total number of exercises.

Russia is among the least connected states in 2017, having moved from its middle position in this list in 2000. Russia's eigenvector centrality, a measure of how well-connected Russia's exercise partners are, underlines how Russia has declined as a central actor in the JME network. Russia placed among the top ten in eigenvector centrality in 2000 but among the least connected states in 2017.⁴

⁴ Eigenvector centrality accounts for how connected a network node's partners are—in other words, how influential one's friends are. For a definition of *eigenvector centrality*, see Wasserman and Faust, 1994, p. 214.

FIGURE 3.4**Partitioning the 2017 Joint Military Exercise Network**

SOURCES: D'Orazio, 2013; IISS, 2016; IISS, 2018.

NOTE: Each circle represents a node, or country. Each line represents a link. The size of each circle reflects that country's centrality within the network—the larger the circle, the larger the centrality. Blue circles and lines represent U.S. allies and their ties. Red circles and lines represent the allies and ties of China, Russia, Iran, and the DPRK. Green circles and lines represent nonaligned countries and their ties. Purple circles and lines represent countries that are aligned both with the United States and with China, Russia, Iran, and the DPRK. The width of a line connecting two nodes reflects the betweenness centrality of that tie—the thicker the line, the greater the importance of that link in the network.

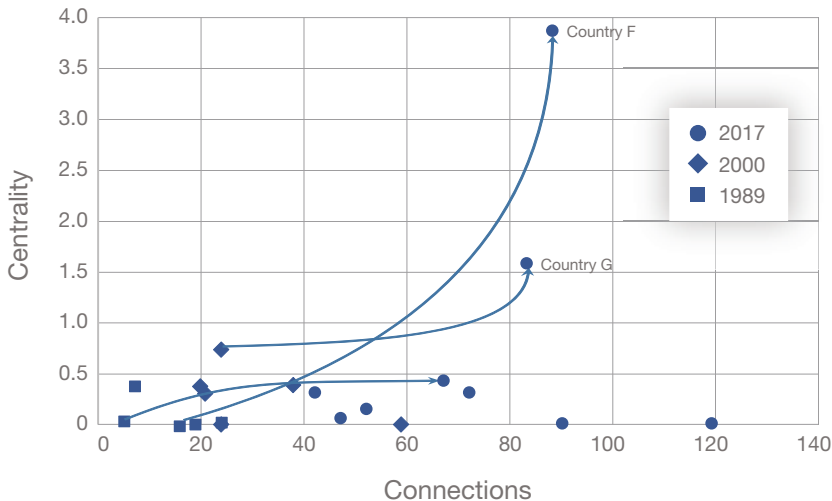
The United States holds the dominant position when it comes to JME network centrality across all three periods under examination. The United States' position as the most central state in this network solidified between 2000 and 2017. Countries B and C's centrality also increased. Country D and Russia became slightly less central over this period, while country E became more so, with the second-largest gain in JME network centrality score among the set of states in the analysis and the fourth-highest overall network centrality score. Country E's increase in network centrality seems unexpected at first glance, and further investigation suggests that it is driven largely by the country's participation in multinational peacekeeping exercises with the United States and NATO partners.⁵

⁵ For details on two exercises, see Howard, 2016, and Pon, 2016.

As shown in Figure 3.5, both countries F and G saw marked increases in their JME network centrality between 2000 and 2017 and between 1989 and 2017, respectively. In both cases, centrality increased as result of the broader number of partners with which countries F and G chose to conduct military exercises. Between 2000 and 2017, country F's number of partners rose from the low 20s to more than 80. In country G's case, just under 20 partners in 1989 became more than 80 partners in 2017. As discussed in Chapter 6, for country G, the resulting rise in JME network centrality appears to have gone some way toward offsetting its losses in centrality in the diplomatic (military alliance) and arms sales network layers.

In the competitors' networks, China saw the largest gains in JME network connections and network centrality. China did not have any recorded exercises in 2000; by 2017, it had the most unique exercise partners and the most total exercises in the competitors' network. China's increasing net-

FIGURE 3.5
Changes in Joint Military Exercise Network Connections and Centrality, 1989–2017



SOURCES: D'Orazio, 2013; IISS, 2016; IISS, 2018.

NOTE: Each year is assigned a separate shape to assist in distinguishing between data points.

work influence should not be interpreted as indicating, however, an attendant increase either in the cohesion of the competitors' JME network or of its utility as an instrument by which to wield power with China at its center; of the seven multinational exercises in which China participated in 2017, three involved either the United States or its allies. Country H saw the second-greatest increase in connections during the same period and scored behind only China in 2017. Table 3.2 lists the top countries in the JME network in 2017 in terms of network centrality and the top gainers and losers between 1989 and 2017.

The JME network of the United States and its allies is more robust than the competitors' network, a fact that is consistent with the allied network's large number of highly connected and influential actors. We used the fragmentation method (explained in Chapter 2) to analyze the cohesion of the two networks. Our analysis showed that the U.S. network has grown more robust over time as the United States and its partners have enlarged the circle of states with which they engage in military exercises. Compared with 2000, the U.S. JME network fragments at about the same *rate* in 2017, but the *level* of fragmentation is substantially lower.

In order, countries I, J, and K cause the most fragmentation if removed from the U.S. JME network in 2017. Country I's removal would cause a 7.5-percent increase, followed by 5- and 4-percent increases by the removal of countries J and K, respectively. The competitors' network fragments much more quickly, in part because of the smaller size of the network. The most-central actors to the competitors' exercise network are, in descending order, Russia, China, and country L (again because of its participation in peacekeeping exercises). The network's fragmentation increases to 60 percent after these actors are removed and is completely fragmented after six are removed.⁶ In comparison to the U.S.-aligned JME network, the competitors' JME network is quite fragmented beyond its most-central actors.

The overall picture across these three periods is a broad but centralized arms market with the United States at its core and a tightly centralized, easily fragmented U.S. competitor arms trading network. Although the U.S.-centered network has become slightly more robust over time, the

⁶ The remaining three states are countries M, N, and O, in that order.

TABLE 3.2

Changes in Joint Military Exercise Centrality and Connections, 1989–2017

Country	Betweenness Centrality		Change in Centrality	Connections	
	1989	2017	1989–2017	1989	2017
1	0.0005	0.0421	0.0415	14	64
2	0.0000	0.0355	0.0355	8	104
3	0.0006	0.0104	0.0098	7	47
4		0.0084	0.0084		36
5		0.0134	0.0134		44
6	0.0000	0.0087	0.0087	13	52
7		0.0155	0.0155		43
8		0.0194	0.0194		45
9	0.0000	0.0481	0.0481	13	73
10	0.0011	0.0614	0.0603	18	110
Top gainers in centrality, 1989–2017					
1	0.0005	0.0421	0.0415	14	64
2	0.0000	0.0355	0.0355	8	104
3		0.0194	0.0194		45
4	0.0000	0.0481	0.0481	13	73
5	0.0011	0.0614	0.0603	18	110
Top losers in centrality, 1989–2017					
1	0.0104	0.0007	–0.0097	10	43
2	0.0022	0.0000	–0.0022	20	91
3	0.0008	0.0003	–0.0005	2	15
4	0.0002	0.0000	–0.0002	7	30
5	0.0188	0.0019	–0.0169	16	61

SOURCES: D'Orazio, 2013; IISS, 2016; IISS, 2018.

NOTE: A blank entry indicates no JME. In some cases, such as South Africa, the gain is large because it starts from a previous level of 0.

U.S. competitors' system has grown notably more fragile. The small core of the competitors' arms sales network has implications for the extent to which competitors—especially China and Russia—can leverage their network positions in competition with the United States. As mentioned above, despite its sizable sales volume, Russia's lower levels of connections mean that it is, on the margin, more vulnerable to states opting to look elsewhere for their arms imports. China does not rank among the top ten in terms of arms sales connections. Network centrality scores similarly favor the U.S.-centered arms sales network. U.S. competitors' relatively low levels of network centrality in 2017 potentially limit their ability to use their role as an intermediary in the global arms sales network as a means of exerting influence in other arenas.

The JME network of the United States and its allies is also more robust than the competitors' network. Although the deterrent impact of NATO's role in the JME networks provides comfort, NATO's dominance highlights this network's weakness in Asia. This suggests that rebalancing future exercise activity to favor that region might be in order, to support U.S. efforts to deepen its partnerships and strengthen conventional deterrence in Asia.

Taken together, this network layer presents a network architecture in the military domain in which U.S. connections far outstrip those of other actors, and, although its centrality has waxed and waned, the United States occupied a general position as the central hub of these military activities, with its close allies most often occupying some of the most-central positions beyond the U.S. network. In short, at least in this network layer, the strength and influence of the United States appeared unparalleled and enduring; although the rapidly changing dynamics in the international environment bear constant monitoring, this suggests prospects for continued strength going forward.

The Economic Network Layer

Arguably, economic power is what makes it possible for nations to exert influence via any of the other three elements of national power. In this chapter, we examine the economic layer of the global alliance and partnership system. First, we explain our reasons for choosing to focus on trade in general merchandise, key commodities, and strategic minerals. Then we examine the connections and centrality that the United States, its allies, and its competitors possess in the global network of merchandise trade. We examine each alliance network's centrality within trading networks in six regions of the world. We examine each alliance system's trading networks' vulnerability to deliberate disruption. At the request of the Office of the Secretary of Defense (OSD), we close by paying particular attention to the vulnerability of networks of trade in key commodities and strategic minerals.

We found that, even though China took first place by value of trade in two-thirds of global bilateral trading relations in 2017, the United States' and its allies' and partners' centrality to world trade remained almost twice (1.8 times) that of China and its BRI partners in 2017. Centrality confers influence, and, by this measure, the U.S. network of allies and partners was significantly more influential in the world trading system than the network formed by China and its BRI partners. This fact is a testament to the value of well-connected (or, rather, well-positioned) allies and partners. The U.S. alliance network was more central to trade than China and its BRI partners in Europe and the Americas. China and its BRI partners were more central to trade in the Pacific, the CENTCOM AOR, and sub-Saharan Africa. In these latter three cases, China's lead was a relatively narrow one of between 0.09 and 0.3 percentage points.

The network of trade between China and its BRI partners was four times more vulnerable to deliberate disruption than that of the United States and

its allies in 2017. Nine of the ten countries most important to trade between ROW and the networks of the United States and its allies and partners and between the competitors' networks and their allies and partners were U.S. allies. This suggests that the United States might have leverage to restrict that trade in the event of crisis or a conflict with one or more of its competitors. Five U.S. allies are key to trade between China and its BRI partners. Four more countries that are key to this trade are not aligned with either the United States or its competitors. This indicates that there is also potential for the United States to disrupt trade between China and its BRI partners in the event of a crisis or conflict. Although China might have leverage over U.S. allies via the threat of disrupting trade in key commodities and strategic minerals, the United States might have greater scope than is generally understood to work with its allies and partners to develop effective countermeasures.

We focused on three types of trade:

- **general merchandise trade:** The constant 2017-dollar value of these flows gives an indication of the overall condition and strength of bilateral trading relations between each country pair. It also suggests the relative economic influence that each country in such dyads might be able to bring to bear on the other.
- **key commodities:** We scrutinized trade in crude oil because access to energy supplies remains a key measure of countries' economic dependence on one another. In times of crisis or war, antagonists can be expected to attempt to interdict energy supplies to their opponents. It is therefore important to measure dependence on energy supplies in attempting to prevent future conflict.¹ Secure food supplies are also

¹ The 1973 and 1979 oil crises provide ample historical precedent to expect crude oil exports to be used to achieve political, military, and economic leverage in future conflicts. The 1973 oil crisis took the form of an embargo by Organization of the Petroleum Exporting Countries (OPEC) members; it was imposed on countries perceived as having assisted in the defense of Israel after the surprise attack that Egypt launched on Israel that unleashed the 1973 Yom Kippur War, so called because of the day of its inception, one of the Jewish high holidays. The 1979 oil crisis occurred after revolution in Iran. The subsequent outbreak of the 1980–1988 Iran–Iraq War led to drastic cuts in crude oil production and a spike in oil prices.

vital to a country's continued ability to prosecute a war. Future belligerents can be expected to make attempts at interdicting each other's food supplies. We chose to focus on trade in two major staple commodities to measure the security of food supplies:

- Because of its predominant consumption in Asia, rice was the first commodity we chose.²
- Because its consumption predominates elsewhere, wheat was the second.³
- **strategic minerals:** Major economies, such as those of the United States, its allies, and its peer and near-peer competitors, depend on the domestic mining or importation of minerals for the manufacture of many of the high-technology products that are a source of their comparative economic advantage. China holds a dominant position in the production of many of these minerals. China has already demonstrated a willingness to coerce or exert political leverage on its competitors by deliberately disrupting, in times of crisis, the export of key minerals of which it is the sole or dominant exporter.⁴ China can be expected to make use of this leverage over other countries again in any future conflict. For this reason, at the request of OSD, we examined networks of trade in 28 minerals that the U.S. Department of the Interior identified as strategically important to U.S. defense production (Fortier et al., 2018; see also National Minerals Information Center, 2020).

² China became dependent on imports of rice in 2013 ("China Expected to Become World's Largest Importer of Rice," 2013).

³ During the Cold War, trade in wheat with the USSR and Council for Mutual Economic Assistance states was a recurring bone of political contention. The issue of grain trade was particularly acute in 1972. In that year, because the Soviet wheat harvest failed, the USSR was forced to buy wheat from the United States. The U.S. government mistakenly sold wheat to the USSR at subsidized prices, thereby exacerbating a global wheat shortage and driving up prices.

⁴ In September 2010, China displayed its displeasure at a series of gray-zone altercations (i.e., below the threshold of open military conflict) that had taken place between Japanese and Chinese vessels in the East China Sea the previous month by banning the export of rare-earth metals to Japan. This act of coercive trade diplomacy highlighted the fact that China plays a key role in the production and trading in a large number of minerals that are strategic for the national defense of the United States and its allies (Bradsher, 2010).

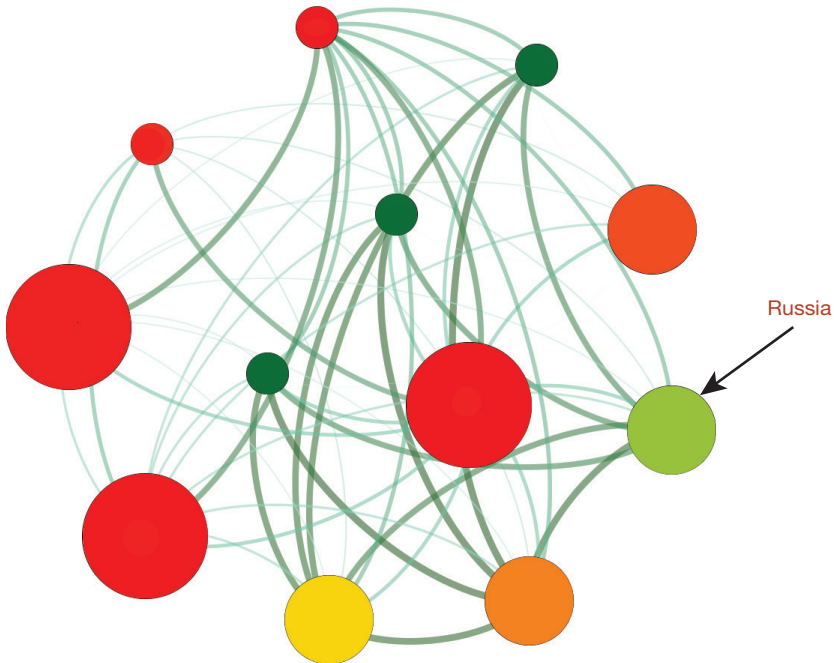
As explained in Chapter 1, in our analysis of the economic network layer, we chose to broadly frame the network to include all the trading partners of each of the competing alliance networks. Looking only at formal allies would have vastly understated the economic influence of China, which has only eight allies and quasi-allies. In China's case, we chose instead to examine the economic influence that it exerted in global trading networks via its association with 66 countries that participated in its BRI in 2017.⁵ Those partners are listed in Appendix B. Because the Chinese government announced the BRI only in 2013, for data prior to that year, we used China's formal military allies as the comparison group.

The global network of general merchandise trade is much denser (there are many more trading connections between countries) than the military alliance, arms sales, or JME networks examined above. Individual countries' ability to exert influence via a central brokerage position connecting disconnected parts of the network is generally much more limited in the global general merchandise trade network than it is for the other three networks that we have scrutinized so far (a centrality of 10 percent would be a good score in this network, compared with individual country scores of more than 40 percent in the military alliance network layer). Because it is so dense, the network of trade in general merchandise is also much harder to disrupt than other networks. As a general proposition, intra-alliance trade should be easier to disrupt than a group of allies' or partners' trade with the far greater number of countries and territories constituting ROW.

Skippping the cases of trade between the DPRK and its two allies and trade between Iran and its five allies, Figure 4.1 depicts the still relatively sparse network of general merchandise trade between Russia and its allies. As before, the size of the nodes denotes the centrality of the given country to trade between allies. In this relatively limited network, countries P, Q, R, and S are most central. Each node's color is an indicator of its eigenvector

⁵ According to World Bank, 2018,

China proposed the Belt and Road Initiative (BRI) in 2013 to improve connectivity and cooperation on a transcontinental scale. . . . [P]rojects in all sectors that are already executed, in implementation, or planned are estimated to amount to US\$575 billion. . . . If completed, BRI transport projects could reduce travel times along economic corridors by 12%, increase trade between 2.7% and 9.7%, increase income by up to 3.4% and lift 7.6 million people from extreme poverty.

FIGURE 4.1**Trade in General Merchandise Between Russia and Its Allies in 2017**

SOURCE: UN, undated.

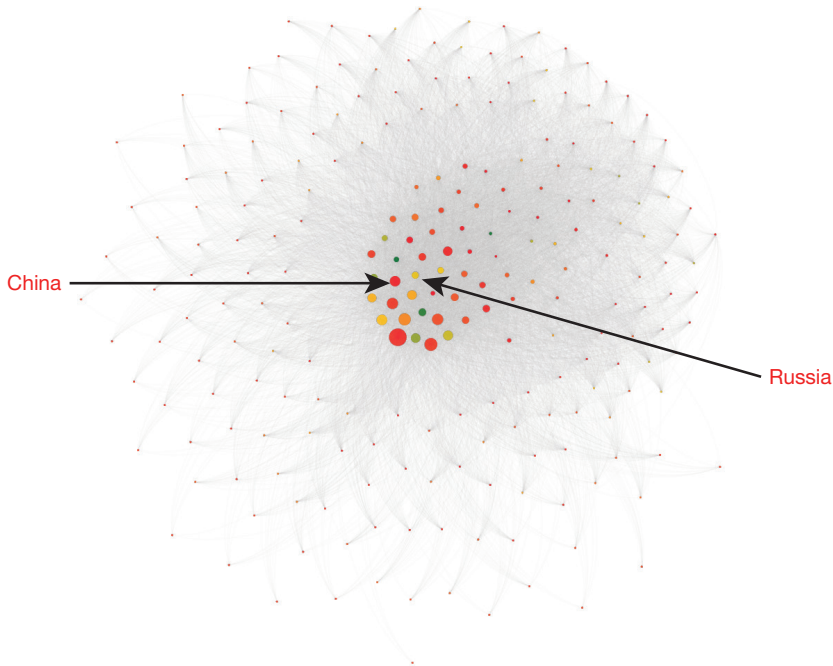
NOTE: Each circle represents a node or country. Each node's color is an indicator of its eigenvector centrality: Green denotes a country whose network neighbors are well connected. Red indicates poor connections. The width and darkness of a line linking two allies indicate the centrality of that link—the thicker and darker the link, the more central it is to the network. This visualization was created in the Gephi graph visualization package (Gephi, undated).

centrality: Green denotes a country whose network neighbors are well connected. Red indicates poor connections. In the network of trade in general merchandise *between Russia and its allies only*, countries T, U, and V are most connected. China and countries W, X, and Y are least connected. The width and darkness of a line linking Russian allies indicate the centrality of that link—the thicker and darker the link, the more central it is to the network.

Figure 4.2 shows the somewhat more complex case of general merchandise trade between China and its 66 BRI partners in 2017. Countries Z and A are among the most-central nodes; they have the least well-connected trad-

FIGURE 4.2

Trade in General Merchandise Between China and Its Belt and Road Initiative Partners in 2017



SOURCE: UN, undated.

NOTE: Each circle represents a node or country. Each node's color is an indicator of its eigenvector centrality: Green denotes a country whose network neighbors are well connected. Red indicates poor connections. The width and darkness of a line linking two allies indicate the centrality of that link—the thicker and darker the link, the more central it is to the network. This visualization was created in the Gephi graph visualization package (Gephi, undated).

ing partners. The strength of ties to country B and those between countries C and D, between countries E and F, and between countries G and H is also notable.

Connections and Centrality in General Merchandise Trade

As a reminder, the country at the heart of a star or hub-and-spoke network has the greatest possible network centrality, scoring 1 (or 100 percent); an

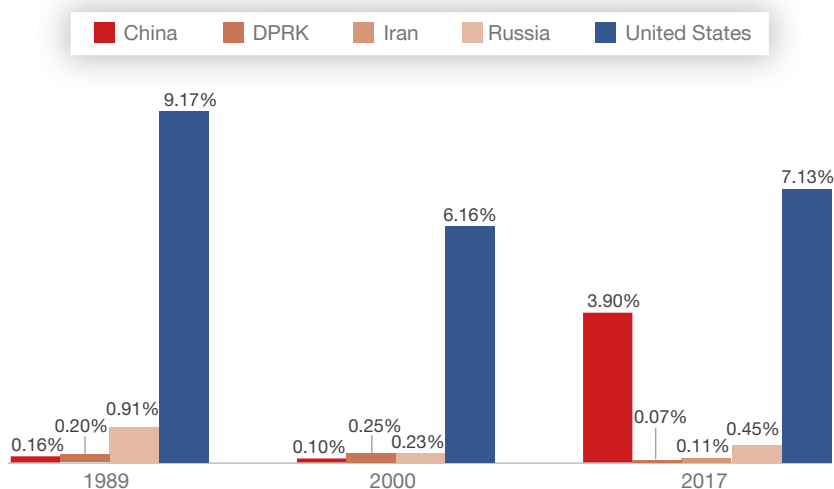
isolate node that has no connections with any other countries whatsoever has the lowest possible network centrality score of 0. We examined connections and network influence in the global general merchandise trading network in each of two ways:

- the connections and centrality of each alliance network within the overall global system of merchandise trade
- the alliance network's centrality to general merchandise trade networks within each of six regions of the world.

U.S., Allied, and Competitor Networks in Global Merchandise Trade

Figure 4.3 shows that the United States' network of 65 allies and partners (7.13 percent), followed by the economic network of China and its 66 BRI partners (3.9 percent), enjoyed the greatest average centrality in the world network of merchandise trade in 2017. Russia placed a distant third, while Iran and the DPRK took equally distant fourth and fifth places, respectively. The higher level of network centrality of China and its BRI partners in 2017 (3.9 percent) is notable, as is the decline in the centrality of the U.S., Russian, and DPRK alliance networks between 1989 and 2017.

In 2017, the centrality of the United States and its partners and allies in the system of world trade (7.13 percent) was 1.8 times that of China and its 66 BRI partners (3.9 percent). Between 1989 and 2017, as globalization progressed and the previously autarkic Communist-bloc economies became integrated into the world trading system, the United States' allies' average number of trading partners rose by 48. However, this expansion in trading contacts came at the cost of a decline in the group's overall centrality in a world trading system in which, prior to the end of the Cold War, the Western bloc of countries had significant influence (it fell from 9 percent to 7 percent). Most of the change described occurred between 1989 and 2000. In that period, U.S. allies' average number of trading connections with ROW rose by 35. The group's centrality to world trade fell from 9 percent to 6 percent before recovering to 7 percent in 2017. In 1989, China's alliance network consisted of countries with lower average numbers of trading connections and lower network centrality; it took up the rear of the pack of competitors identified in the 2018 NDS. By 2017, China

FIGURE 4.3**Ally and Partner Networks' Centrality in Global Trade, 1989, 2000, and 2017**

SOURCE: UN, undated.

and its BRI partners had, on average, trading connections with 169 countries (versus 136 in 1989), and their centrality to global trade reached 3.9 percent. Russia's influence in the network of world trade was never high because of the presence of an autarkic Communist trading system, the Council for Mutual Economic Assistance, that Russia constructed and led during the Cold War. As Russia shed Eastern European states and garnered post-Soviet states as allies after the end of the Cold War, its allies' centrality to world trade fell by half, from 0.9 percent to 0.45 percent. Table 4.1 summarizes these developments and provides the relevant data for Iran and the DPRK. Figure 4.3 illustrates the data.

Competing Alliance Networks' Centrality in Regional Merchandise Trade

In 2017, the United States and its network of allies and partners led in centrality to regional trade in half of the regions of the world (Europe, North America, and South America). China and its BRI partners led in the remain-

TABLE 4.1

The United States and Its Competitors' Trading Connections and Centrality, 1989, 2000, and 2017

	Number of Allies' Alliance Connections ^a					
Year and Country	Maximum	Minimum	Median	Mean	Standard Deviation	Alliance's Centrality ^b
1989						
China	182	90	136.00	136.00	46.00	0.0016
DPRK	182	90	102.00	119.00	36.81	0.0020
Iran	0	0	0.00	0.00	0.00	0.0000
Russia	187	90	140.00	135.56	31.68	0.0091
United States	195	67	157.50	144.22	39.23	0.0917
2000						
China	209	136	172.50	172.50	36.50	0.0010
DPRK	209	136	181.50	177.00	28.13	0.0025
Iran	0	0	0.00	0.00	0.00	0.0000
Russia	196	82	100.00	122.73	41.56	0.0023
United States	227	98	188.00	179.34	34.44	0.0616
2017						
China ^c	231	66	174.00	169.06	44.03	0.0390
DPRK	214	113	124.00	150.33	45.24	0.0007
Iran	202	95	109.00	135.20	40.82	0.0011
Russia	224	86	154.50	160.42	46.88	0.0045
United States	233	112	200.50	192.03	35.24	0.0713

SOURCES: Leeds, undated; UN, undated.

^a Nodal degree, or a given ally's number of regional trading relationships.

^b Group betweenness centrality for the regional members of a given alliance network within the world trading system. It is 0 for a country if none of the geodesics passes through that node; it is 1 if all of the geodesics pass through that node, such as in a star network.

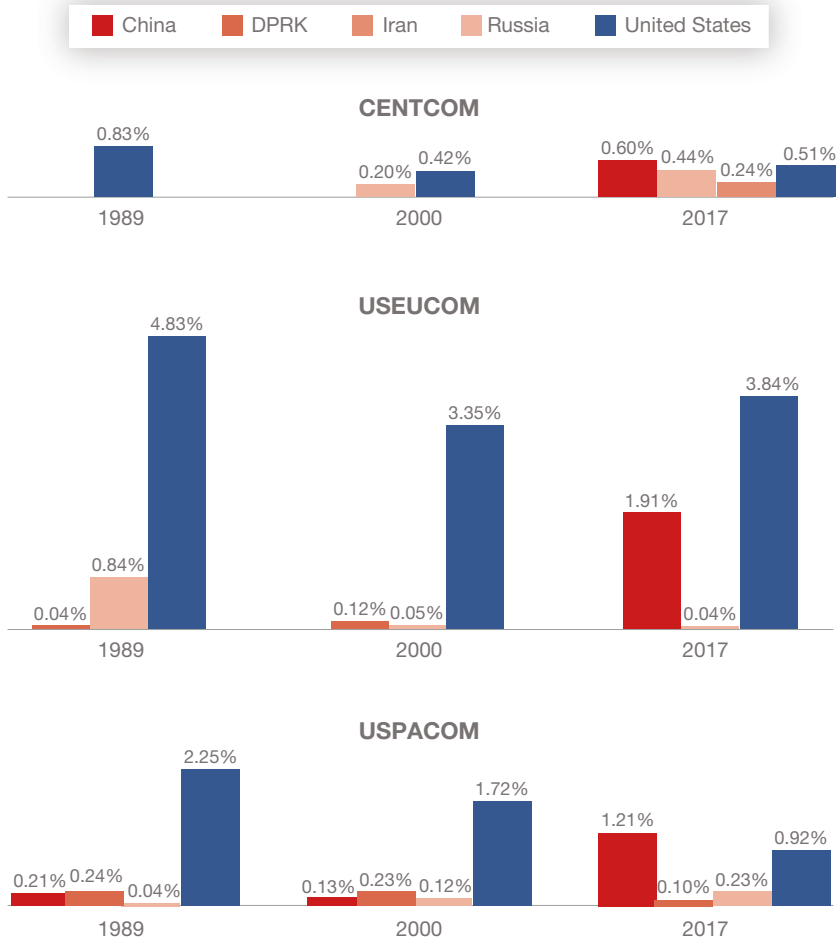
^c In 2017, China and its BRI partners are being measured.

ing three (the CENTCOM AOR, the Pacific, and Africa) by a smaller margin. Between 1989 and 2017, the group centrality to regional trade of the United States, its allies, and its partners declined in all six regions of the world. The Chinese group's greatest gains in centrality to world trade between 1989 and 2017 were in Europe and the Pacific. Russian allies enjoyed their greatest group centrality to world trade in 2017 in the CENTCOM AOR. This was due to Russia's acquisition of seven new quasi-allies in SCO. Russia's allies and partners' group network centrality in the Pacific was half of that in the CENTCOM AOR. The centrality of Russian allies in Europe to world trade was quite small. The greatest decline in the centrality of Russian allies to world trade between 1989 and 2017 was in Europe, where Russia shed its Eastern European allies. Russia's allies achieved small gains in the CENTCOM AOR and the Pacific. Figure 4.4 illustrates and Table 4.2 lists countries' regional allies' centrality to world trade. Table 4.3 lists the alliance networks most central to world trade in each region.

The General Merchandise Trade Networks' Vulnerability to Disruption

In times of conflict, belligerents will attempt to disrupt trade between the opposing camps and between neutral and nonbelligerent nations. Rules of war regulate commercial relations between states during armed conflict; they provide that neutral states cannot assist belligerents via the provision of war materiel but may otherwise trade freely with them (Convention [II] with Respect to the Laws and Customs of War on Land and Its Annex, 1899, Chapter VII, Article 6). Because the definition of *war-related goods* is broad, belligerents have historically sought to interdict commerce between other belligerents and neutral and nonbelligerent states. Furthermore, belligerents have also sought to disrupt trade between groups of countries (allies) on the opposing side of a conflict. For these reasons, we adopted two approaches to analyzing the vulnerability to disruption of alliance systems' networks of merchandise trade:

1. First, we looked at the vulnerability to disruption of an alliance system's trade with ROW (i.e., neutral and nonbelligerent states).

FIGURE 4.4**Ally and Partner Networks' Centrality in Regional Trade, 1989, 2000, and 2017**

SOURCE: UN, undated.

TABLE 4.2

The United States and Its Competitors' Regional Allies' Global and Regional Network Centrality to World Trade, 1989, 2000, and 2017

Country and AOR	1989		2000		2017		Percentage Change in Centrality	
	Centrality ^a	Connections ^b	Centrality ^a	Connections ^b	Centrality ^a	Connections ^b	1989–2017	2000–2017
China ^c	0.0016	136	0.0010	172	0.0390	169	3.74	3.80
AFRICOM	0.0000	0	0.0000	0	0.0015	174	0.15	0.15
CENTCOM	0.0000	0	0.0000	0	0.0060	145	0.60	0.60
USEUCOM	0.0000	0	0.0000	0	0.0191	193	1.91	1.91
USPACOM	0.0021	136	0.0013	173	0.0121	162	1.00	1.08
DPRK	0.0020	119	0.0025	177	0.0007	150	−0.13	−0.18
SOUTHCOM	0.0003	94	0.0008	152	0.0001	120	−0.02	−0.07
USEUCOM	0.0004	98	0.0012	166	0.0000	0	−0.04	−0.12
USPACOM	0.0024	126	0.0023	180	0.0010	164	−0.14	−0.13
Iran	0.0000	0	0.0000	0	0.0011	135	0.11	0.11
CENTCOM	0.0000	0	0.0000	0	0.0007	150	0.07	0.07
Russia	0.0091	135	0.0023	122	0.0045	160	−0.46	0.22
CENTCOM	0.0000	0	0.0020	120	0.0044	156	0.44	0.23
USEUCOM	0.0084	146	0.0005	124	0.0004	165	−0.80	−0.02

Table 4.2—Continued

Country and AOR	1989		2000		2017		Percentage Change in Centrality	
	Centrality ^a	Connections ^b	Centrality ^a	Connections ^b	Centrality ^a	Connections ^b	1989–2017	2000–2017
USPACOM	0.0004	98	0.0012	166	0.0023	179	0.19	0.11
United States	0.0917	144	0.0616	179	0.0713	192	–2.04	0.97
AFRICOM	0.0033	179	0.0018	164	0.0014	175	–0.19	–0.04
CENTCOM	0.0083	124	0.0042	153	0.0051	164	–0.32	0.09
SOUTHCOM	0.0095	102	0.0096	143	0.0095	159	0.01	–0.00
USEUCOM	0.0483	162	0.0335	193	0.0384	210	–0.99	0.49
USNORTHCOM	0.0102	157	0.0057	197	0.0041	195	–0.61	–0.16
USPACOM	0.0225	146	0.0172	180	0.0092	179	–1.33	–0.81

SOURCE: UN, undated.

^a Group betweenness centrality for the countries in the given regional system of alliances within the global military alliance network. This is 0 for a country if none of the geodesics passes through that node; it is 1 if all of the geodesics pass through that node, such as in a star network.

^b Within the global military alliance system = average nodal degree, or allies' average number of regional trading relationships.

^c In 2017, China and its BRI partners are being measured.

TABLE 4.3

The United States and Its Competitors Most Central to World Trade in Each Region, 1989, 2000, and 2017

AOR and Country	Regional Network Centrality						Percentage Change in Centrality	
	1989		2000		2017			
	Centrality ^a	Connections ^b	Centrality ^a	Connections ^b	Centrality ^a	Connections ^b	1989–2017	2000–2017
AFRICOM								
China ^c	0.0000	0	0.0000	0	0.0015	174	0.15	0.15
United States	0.0033	179	0.0018	164	0.0014	175	−0.19	−0.04
CENTCOM								
China ^c	0.0000	0	0.0000	0	0.0060	193	0.60	0.60
Iran	0.0000	0	0.0000	0	0.0024	148	0.24	0.24
Russia	0.0000	0	0.0020	120	0.0044	156	0.44	0.23
United States	0.0083	124	0.0042	153	0.0051	164	−0.32	0.09
SOUTHCOM								
DPRK	0.0003	94	0.0008	152	0.0001	120	−0.02	−0.07
United States	0.0095	102	0.0096	143	0.0095	159	0.01	−0.00
USEUCOM								
China ^c	0.0000	0	0.0000	0	0.0191	193	1.91	1.91
DPRK	0.0004	98	0.0012	166	0.0000	0	−0.04	−0.12

Table 4.3—Continued

AOR and Country	Regional Network Centrality						Percentage Change in Centrality	
	1989		2000		2017		1989–2017	2000–2017
	Centrality ^a	Connections ^b	Centrality ^a	Connections ^b	Centrality ^a	Connections ^b		
Russia	0.0084	146	0.0005	124	0.0004	165	−0.80	−0.02
United States	0.0483	162	0.0335	193	0.0384	210	−0.99	0.49
USNORTHCOM								
United States	0.0102	157	0.0057	197	0.0041	195	−0.61	−0.16
USPACOM								
China ^c	0.0021	136	0.0013	173	0.0121	162	1.00	1.08
DPRK	0.0024	126	0.0023	180	0.0010	164	−0.14	−0.13
Russia	0.0004	98	0.0012	166	0.0023	179	0.19	0.11
United States	0.0225	146	0.0172	180	0.0092	179	−1.33	−0.81

SOURCE: UN, undated.

^a Group betweenness centrality for the countries in the given regional system of alliances within the global military alliance network. This is 0 for a country if none of the geodesics passes through that node; it is 1 if all of the geodesics pass through that node, such as in a star network.

^b Within the global military alliance system = average nodal degree, or allies' average number of regional trading relationships.

^c In 2017, China and its BRI partners are being measured.

2. Second, we examined the vulnerability of trade between nations within an alliance.

In network analytical terms, *disruption of trade* means the removal of a certain node or a given link from a trading network. In armed conflict, elimination of a node (the *fragmentation* approach)⁶ can take the form of (1) an embargo or blockade of a country or (2) regulations prohibiting trade with enemy nations.⁷ The elimination of a link (the *distance-weighted fragmentation* approach) might include military action to interdict commerce between certain belligerent states and neutral or nonbelligerent states. The unrestricted submarine warfare that Germany conducted in the North Atlantic to interdict trade between the United States and the UK during both the First and Second World Wars is an example.

The fragmentation approach to trade network disruption involves eliminating nodes (countries) from the trade network. In network analytical terms, this means that the country and all of its trading links with other countries are removed from the network. Removal of a node not only blocks trade with a country's immediate trading partners but also stops reexports (paths of more than one step that goods can take across the global supply chain involving the country removed). In practical terms, this would mean enforcing a hermetic and total blockade of a country's trade with all of its trading partners. This can be difficult and expensive to implement in practice, particularly when it comes to trading partners that share a land border. For this reason, in our analysis of the vulnerability of general merchandise trade networks, we focused on the second available approach to their disruption.

Distance-weighted fragmentation is an alternative approach that we used in recognition of the practical difficulties involved in implementing the fragmentation approach to disrupting trade networks. Like in the example of Austria-Hungary's alliance relationships in Chapter 2, the theory is that, by interdicting shorter, direct paths between trading partners, one forces goods to take longer paths across the world trading network to get from

⁶ One example is the U.S. 1962 blockade or "quarantine" of Cuba. The distance-weighted fragmentation approach, by contrast, focuses on the elimination of edges.

⁷ An example of the latter would be the 1917 U.S. Trading with the Enemy Act (as codified at 50 U.S.C. Chapter 53).

one country to another. The network becomes fragmented because of the extra number of steps across the network that goods have to take. At a certain point, if the number of steps required becomes large enough, the network becomes completely fragmented for all practical purposes. Distance-weighted fragmentation (a measure that ranges in value between 0 and 1) measures the success achieved in disrupting a network using this approach. This approach too has its limitations. Links between countries sharing a land border can be interdicted only with some difficulty, and our analysis was not capable of taking this limitation into account.

We recorded the rate at which the fragmentation of each network increased as additional nodes (countries) or links were removed. Trading networks whose fragmentation increases at a high rate as additional nodes or links are removed can be considered more vulnerable to disruption than networks for which the rate of growth in fragmentation per additional node or link removed is lower.

Table 4.4 shows the differing rates of network fragmentation achieved. The rate of fragmentation of the United States' and its competitors' alliance systems' trade with ROW is uniform at 0.15 percent per country removed from that network. The rates of fragmentation are equal for all five countries because—in each case—the removal of the top ten nodes in their alliance networks has minimal impact on a 2017 world general merchandise trading network consisting of 235 countries and territories with 16,691 trading links between them.

The story is different for the smaller networks of general merchandise trade between allies. With just two allies (China and Cuba), of the com-

TABLE 4.4
Differing Rates of Trading Networks'
Fragmentation 2017, as Percentages

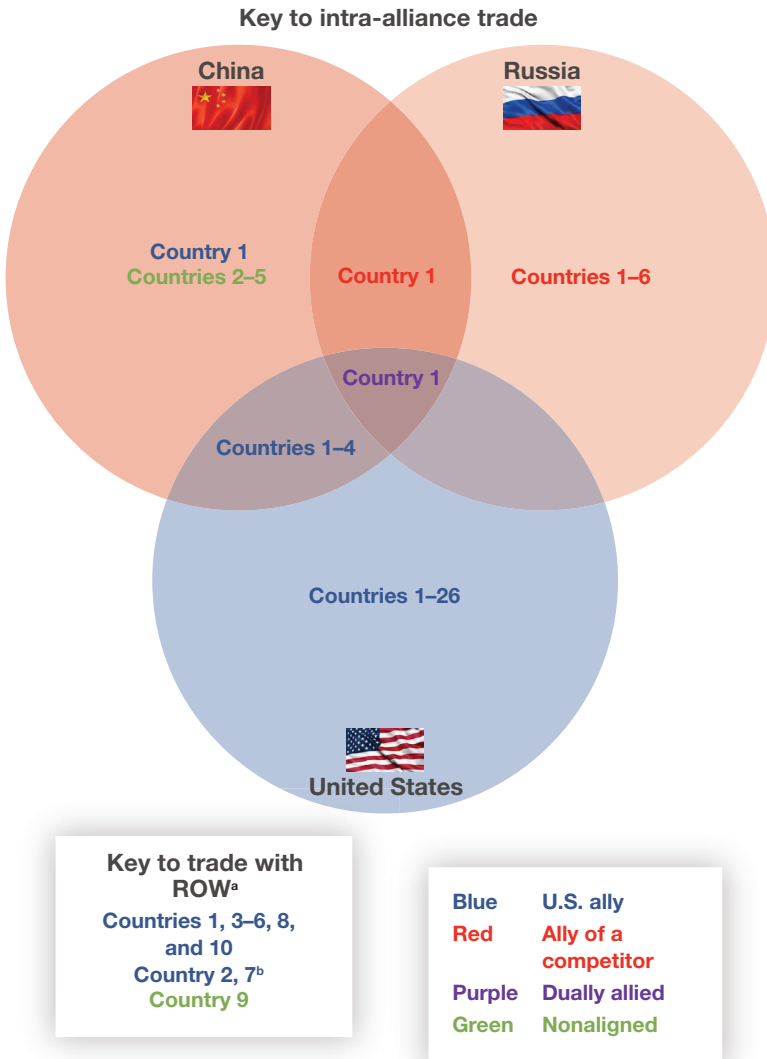
Country	Trade with ROW	Intra-Alliance Trade
China	0.15	0.20
DPRK	0.15	100.00
Iran	0.15	58.33
Russia	0.15	10.62
United States	0.15	0.05

petitors' networks, the DPRK's licit intra-alliance trading network is most vulnerable to disruption. However, it is very unlikely that attempts to disrupt trade between China and the DPRK, which share a land border, would succeed. Iran's intra-alliance network of trade with its one ally (Russia) and four de facto allies (Iraq, Lebanon, Syria, and Yemen) is the next-most vulnerable of the competitors' networks of trade with their allies. Here, again, it is worth pointing out that Iran shares a border with two of those five allies (Iraq and Russia). Trade across those borders might be much less difficult to interdict in theory than in practice. Russia's network of trade with its allies takes third place in terms of its vulnerability to deliberate disruption. Russia shares borders with four of its 11 allies. China's network of trade with its BRI partners is much more robust against attempts at disruption. It shares land borders with ten of its 66 BRI partners. The United States' network of inter-allied trade is most robust. The United States shares a land border with just one of its 65 allies: Canada.

Figure 4.5 shows a prioritized list of countries that were key to trade between the alliance networks of the United States and its competitors and ROW in 2017. It also shows countries that were key to intra-alliance trade. Nine of the ten countries most important to trade between alliance networks and ROW were U.S. allies, indicating that the United States might have leverage to restrict that trade in the event of crisis or conflict with its competitors. The Venn diagram in Figure 4.5 shows prioritized lists of countries that are key to trade within alliance networks and the network formed by China and its BRI partners.

The Venn diagram shows that country I, a country that is dually aligned both with the United States and with its competitors, is key to trade within all three networks—specifically, those of China, Russia, and the United States. Country J, a quasi-ally of the competitors, is important to trade within both the Chinese and Russian intra-alliance trading networks. Countries K, L, M, and N, all U.S. allies, are key to trade within both the U.S. and Chinese networks of allies and partners. It is also worth noting that the remaining five countries that are key to trade within the network of trade between China and its BRI partners are either U.S. allies or nonaligned. This suggests that opportunities might exist for the United States to disrupt trade between China and its BRI partners in the event of a crisis or conflict. Two U.S. allies, countries N and O, are key both to disrupting China's trade with

FIGURE 4.5
Countries That Were Key to Trade in 2017



SOURCE: UN, undated.

^a Countries are ranked in descending order of importance to network disruption.

^b Country that is key both to alliances' trade with ROW and to intra-alliance trade.

its BRI partners and to disrupting U.S. and competitors' alliance networks' trade with ROW.

Vulnerability of Trade in Key Commodities and Strategic Minerals

In addition to examining the vulnerability to disruption of competing alliances' networks of general merchandise trade, at the additional request of OSD, we looked at the role of allies and partners in competitors' potential future repeat attempts at disrupting networks of trade in key commodities and strategic minerals. Figure 4.6 gives an overview of the 29 networks of trade in strategic minerals (here, including uranium) in 2017 that we examined individually and combined. Note the variety of their densities and structures. Note also how the sparsity of the network of recorded trade in uranium (third from left, bottom row) suggests that data might be missing.

Figure 4.7 shows the vulnerability to deliberate disruption of international trade in three key commodities and 28 key commodities and strategic minerals (excluding uranium) (Fortier et al., 2018; see also National Minerals Information Center, 2020). The vertical axis shows the degree to which the network of trade is fragmented when the top trader in that commodity or mineral trading network is removed from the network, an effect we term *initial network fragmentation*. The horizontal axis shows the average rate of additional network fragmentation that occurs as further countries are removed from each network; we term this latter measure *incremental network fragmentation*. The most vulnerable commodity and mineral trading networks are those in the top right corner of the figure that are characterized by high initial and incremental network fragmentation. The commodities and minerals least vulnerable to deliberate attempts to disrupt trade in them are those closest to the bottom left corner of the graph.

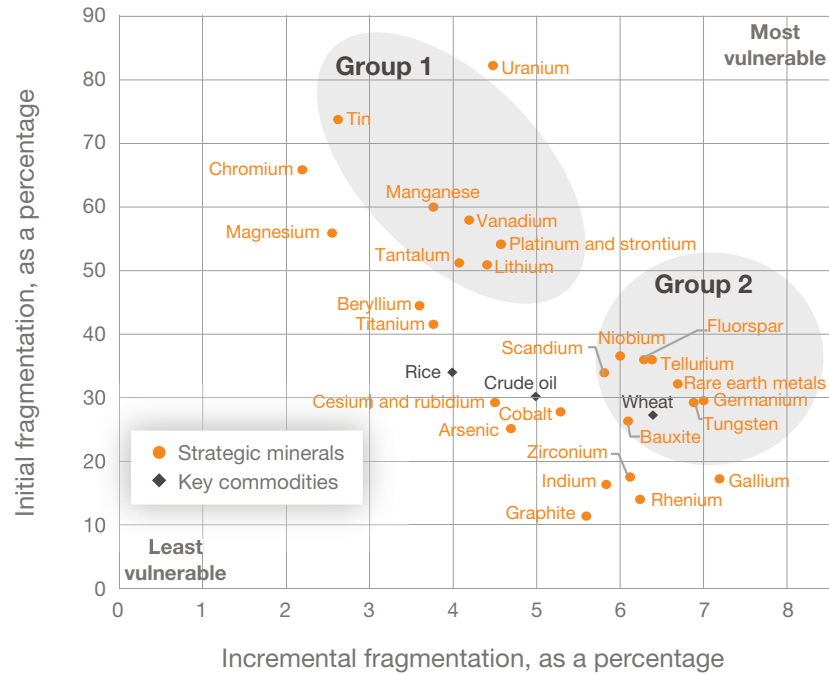
The commodities and minerals most vulnerable to deliberate attempts to disrupt trade cluster into two groups, labeled "Group 1" and "Group 2" in Figure 4.7. The figure also shows a clear gap in the vulnerability levels of minerals in group 1 and group 2 and minerals of lower vulnerability, such as chromium, magnesium, beryllium, and zirconium. Uranium is a special case because of its importance to attempts to acquire nuclear weapons; we

FIGURE 4.6
Strategic Commodity and Mineral Trading Networks Examined



SOURCE: UN, undated.

FIGURE 4.7
Vulnerability of Commodity and Mineral Trading Networks



SOURCE: UN, undated.

NOTE: The vertical axis shows the degree to which the network of trade is fragmented when the top trader in that commodity or mineral trading network is removed from the network, an effect we term *initial network fragmentation*. The horizontal axis shows the average rate of additional network fragmentation that occurs as further countries are removed from each network; we term this latter measure *incremental network fragmentation*. The most-vulnerable commodity and mineral trading networks are those in the top right corner of the figure that are characterized by high initial and incremental network fragmentation.

omitted uranium from this analysis because of doubts about the completeness of UN data on trade in this strategic mineral (see Figure 4.6).

Group 1 consists of networks of trade in strategic minerals in which the removal of one top trading partner can cause a very high *initial* level of network fragmentation (50-percent fragmentation or more). In six of the seven cases highlighted in this first group, that top trading partner is China. Should China choose to cease to participate in trade in these commodities with some or all trading partners, it could cause significant disruption to

global trade in each of these strategic minerals.⁸ In most cases, China is also the top international producer of the mineral in question. This dims the prospect that another producer might step in in the short term to fill the gap in supplies created by China. To protect the United States and its allies from shortages of these commodities artificially created by China for purposes of pressure or coercion, it might be important to identify the other countries that are key to the network of trade in those commodities and take steps to secure their cooperation in boosting production should China attempt to interfere with supplies, as it has done in the past.

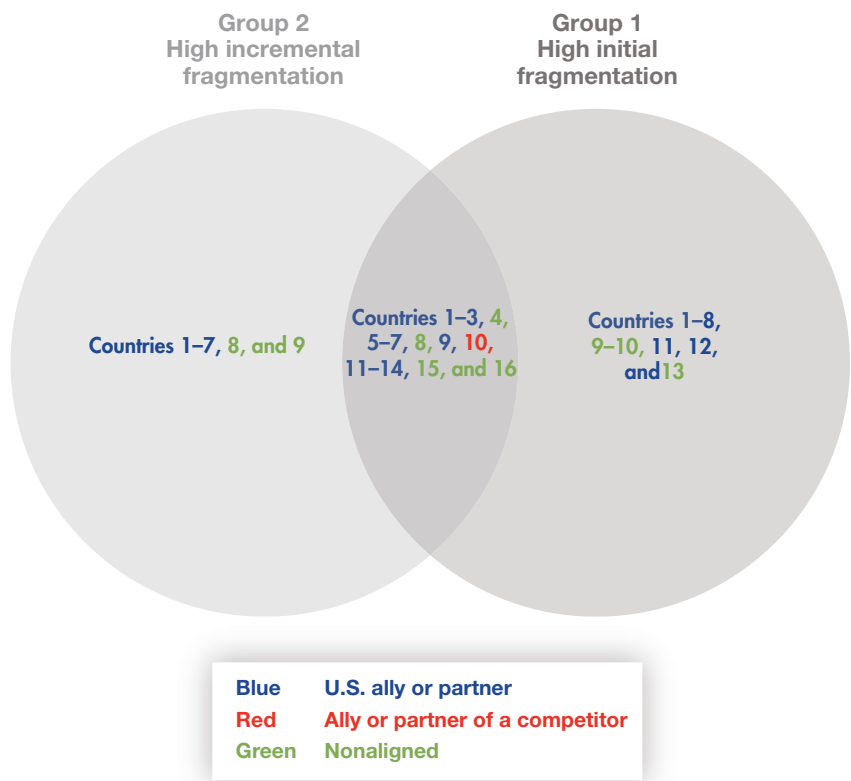
Group 2 highlighted in Figure 4.7 consists of networks of trade in commodities and minerals that are highly vulnerable to *incremental network fragmentation*. In seven of the nine cases highlighted, China is the leading trader once again. However, in this instance, what matters less is the *initial* trading network fragmentation that China might be able to cause in times of conflict. What matters more here is the *overall* fragility of the network of trade in the given commodity or mineral. Like in the case of the first group, it might be important to identify countries that are key to the network of trade in these materials to be able to consider steps to bolster the resilience of those networks.

The Venn diagram in Figure 4.8 contains prioritized lists of countries that are key to disrupting trade in each of the two groups (group 1 with high *initial network fragmentation* and group 2 with high *incremental network fragmentation*) highlighted in Figure 4.7. Because they are key to both groups' networks' *initial* and *incremental* levels of fragmentation, we consider the countries in the intersection in the Venn diagram (group 1 $\cap$ group 2) to be the highest-priority countries to deal with when protecting networks of trade in key commodities and strategic minerals. More than two-thirds (11) of those 16 countries are U.S. allies.

The upshot of this analysis is that, although China is at the top of most networks of trade in strategic minerals (and thus has significant leverage),

⁸ As mentioned, in September 2010, China displayed its displeasure at a series of gray-zone altercations that had taken place between Japanese and Chinese vessels in the East China Sea the previous month by banning the export of rare-earth metals to Japan. This act of coercive trade diplomacy highlighted the fact that China plays a key role in the production and trading in many minerals that are strategic for the national defense of the United States and its allies (Bradsher, 2010).

FIGURE 4.8
Priority Countries in Protecting Commodity and Mineral Trade



SOURCE: UN, undated.

most of the other key players are U.S. allies. This suggests that, although China might have leverage over U.S. allies via the threat of disrupting trade in key commodities and strategic minerals, the United States might have greater scope than is generally understood to work with its allies and partners to develop effective countermeasures.

The analyses presented in this chapter have several limitations. They are limited to trade flows, when foreign direct investment, portfolio investment, multinational corporation profit repatriation, and other measures (e.g., rights to data, intellectual property) are also of relevance to measuring international economic influence. There are commodities other than crude

oil, rice, and wheat that are important to international food supplies—sugar and palm oil, for example. The quality of the Comtrade dataset used for the analysis is known to be lower than that of other datasets that contain less recent data. Apples-to-apples comparisons are also complicated by the fact that China's 66 BRI partners, not its eight formal and quasi-allies, are used as the comparison group for 2017. Our analysis of the UN Comtrade dataset examined primarily U.S. and competitor networks' connections and network centrality, when other analytical approaches, such as core-periphery analysis, and other measures, such as closeness or eigenvector centrality, could provide additional insights into the near-complete networks of international trade. And there is always the risk that the greedy algorithm heuristic used to identify the optimal combination of countries to remove when disrupting networks chose a suboptimal combination of countries.

Although it is important to acknowledge the strategic advantages conveyed to China by its recent economic growth trajectory, it is also worth recognizing some of China's continuing economic limitations. As this report has shown, even though China was the leading trading partner by value in two-thirds of the world's bilateral trading relations in 2017, the United States' network of allies and partners was 1.8 times more central to the global trade network than the network of China and its 66 BRI partners was. In the economic sphere, the U.S. network of allies and partners should—properly managed—be able to continue to play the leading role in shaping the overall environment. This is important because it is from this economic environment that the United States' leading competitor, China, draws much of its power.

Nine out of ten countries that are key to trade between ROW and the competing great powers and their allies and partners are U.S. allies. More than two-thirds of the countries that are key players in trade in key commodities and strategic minerals are U.S. allies. And China's network of trade with its 66 BRI partners was almost four times more vulnerable to deliberate disruption in 2017 than the network of trade between the United States and its partners and allies was.

Conflict Simulations

In this chapter, we report the results of running four simulations of potential future conflicts on the diplomatic (military alliance) network layer that we constructed in Chapter 2. First, we explain how simulation can complement the analyses conducted so far, why it might be useful, and the criteria we used in selecting potential future conflicts to simulate. Next, we summarize the methodology we used in conducting the simulations and explain the reasoning behind some of the choices that we made in constructing it. We also describe the limitations of the simulation methodology, providing caveats about how to interpret results and warnings about how to interpret the appearance of apparently extraneous outlier results. Finally, we describe each of the four conflict scenarios, the results of the simulation, and the policy implications that might flow from them.

The Why and How of Simulation

The simulations that we conducted were the most experimental part of our research, created to stimulate out-of-the-box thinking, especially about the potential risks of conflict contagion. The analysis presented here is meant to complement, not replace, more-traditional qualitative methods. Although, in the next chapter of this report, we synthesize all the network layers described above, for the purposes of simulating cooperation in a crisis or conflict, judging the likelihood of response to extant diplomatic pledges is most germane, so we focused our analysis on the diplomatic layer. We believe that, with additional work, this approach could be applied to all three network layers we have described in this report. That said, although we have tried to show that these networks might influence how allies and

partners act, these simulations are not dispositive. The cases presented here should not be interpreted as predictive but rather as thought-provoking.

The simulations complement the statistical analyses of military alliances in the diplomatic network layer because simulations afford a greater ability to assess emergent properties that derive from the total network structure. An emergent effect is an analytical result that surfaces because of a modeling exercise that was not expected when a model was first constructed, usually because it is a product of interactions among the individual components of the model. An emergent property of a simulation model is not encoded explicitly by the modeler. For example, one emergent property of the simulations that follow is that we never observed any two-step contagions of the kind described in Chapter 2, in which an ally of an ally joins a conflict. Such two-step contagions are theoretically possible in the simulation, but the rules for behavior specified for each country, combined with the structure of the alliance network, precluded two-step contagions.

Although, in the analysis described in Chapter 2, we rigorously assessed the individual node-level characteristics of countries and their positions in the global military alliance network, we did not assess how interactions among nodes in the alliance network might produce emergent dynamics, such as conflict contagion. Simulations are a standard and preferred method within network science for understanding these emergent effects (Shalizi and Thomas, 2011) and have been used in several prior RAND reports covering analyses of network data (Nowak, Matthews, and Parker, 2017; Welburn et al., 2020; Karimov and Matthews, 2017).

As mentioned above, the diplomatic (military alliance) network layer involves a theoretical maximum of 17,969 possible dyadic alliance relationships (one-third of the 51,483 connections within all three layers, as explained in Chapter 1). The structure also implies a maximum of 130 “walks” across network links that are theoretically possible starting from each node (i.e., country).¹ Clearly, a great number of interactions is possible in a network of

¹ *Walk* refers to a path across a network created by taking repeated steps. Starting at some specified initial node, at each step of the walk, we choose between the links attached to the current node, move along the chosen link to the node at its other end, and repeat. Walks are normally allowed to go along links more than once, visit nodes more than once, and retrace their steps along links just traversed (Newman, 2018).

this size. Simulation is one way of identifying possible interconnections and relationships that might not be spotted in qualitative analyses of such an enormous sample space. Simulation has the additional advantages of replicability and rigor: Assumptions, underlying data, and the simulation methodology used can all be presented in a fashion that is transparent, auditable, and repeatable.

To focus the simulations on plausible starting scenarios, we informally elicited potential future conflict scenarios to simulate from defense analysts. We identified consensus among analysts around the value of simulating four scenarios involving China and Russia, the two principal competitors identified in the 2018 U.S. NDS. The recommended scenarios were as follows:

- a crisis in the Taiwan Strait as China prepares to invade Taiwan
- a conflict in the South China Sea unleashed by China's seizing an island in the Spratly Islands chain over which Vietnam claims sovereign control
- a spike in the conflict between Russia and Ukraine unleashed by a Ukrainian initiative to retake territory previously lost to separatists mobilized, sponsored, and directed by Russia
- a Russian military incursion into the Baltic states.

Each simulation scenario involves an initial set of countries that are party to the conflict being simulated. We simulated the potential for the diffusion of that conflict across the global military alliance network to include participation by one or more additional countries. The way in which we did so was by attaching an estimate of the probability of alliance compliance to each of the links in the military alliance network we previously constructed from the ATOP dataset. We used a Bayesian approach to calculate the probabilities.²

Under a Bayesian approach, we started with a subjective estimate of the probability of an event—in this case, the probability that a country will comply with its alliance obligations. We know from previous analysis of the historical record that countries linked through a single bilateral alliance tie comply with

² For introductory texts on Bayesian approaches to network analysis, see Neapolitan, 2004, and Fenton and Neil, 2019.

their alliance obligations with a frequency of approximately 75 percent, on average (Leeds, 2003, p. 803).³ We term this our *subjective prior estimate* of the probability of a country's compliance with its alliance obligations. We next used new information about the alliance relationship in question to update our initial estimate of compliance. The new information that we used was the average of the ondependence and outdependence scores (described in Chapter 2) that we calculated for each country. This average is a proxy measure of the degree of a country's entanglement in military alliances.

The resulting second probability estimate is termed our *subjective posterior estimate* of the probability of a country's compliance with its alliance obligations. The result is an updated estimate of the probability that a country will comply with its alliance obligations that balances the effects of its receiving conflict start signals from some allies but also no-conflict signals from other allies. To understand how this plays out, consider the simple example of the receiver effects on a country with five allies, one of which joins a conflict. The resulting posterior estimate of the receiver joining is $75 \text{ percent} / 5 = 15 \text{ percent}$.

The simulation is thus highly simplified, but it is grounded in two facts: the structure of formal alliances and the predictive value of those alliances for conflict contagion. We note that alliance ties likely should not be conceived of as causing conflict contagion in the real world. Alliances are simply social signals, directed mainly at the countries not in the alliance, about how the two countries intend to behave in a conflict. That is, an alliance between countries A and B is a signal they are sending to all other countries (not A or B) that, if one should be attacked, the other will come to its aid. Why countries A and B have made this decision about how to behave, and hence sent the alliance social signal, is surely derived from a complex set of causal interactions, including diplomatic overtures, public commitments, personal relationships, and economic entanglements. We did not attempt to understand these causally. Instead, the simulations used the

³ This baseline probability estimate suffers from the risk that it might be nonstationary (i.e., that the probability of alliance compliance has changed substantially because of a drop in the frequency of conflict in the post-World War II era). This risk can be mitigated by rerunning the simulations using differing baseline probability estimates. Time and resources did not permit us to do this in this project.

known predictive value of alliance ties, and each country's structural position in the diplomatic (military alliance) network layer, to understand how conflicts are likely to percolate, given a country's own public signals about its alliance commitments.

In the simulations, each country observes whether its alliance connections are involved in the conflict on the United States' side, are involved on a competitor's side, or are uninvolved. Each country then averages across these signals, and, if its subjective posterior probability of compliance with its alliance obligations exceeds 75 percent, that country will become involved in the conflict in some way (as noted, this might include a variety of forms of participation short of actual conflict, including logistics, intelligence, or other quiet support). In short, the more alliance-dependent a country is on other countries involved in the starting conflict scenario, the greater the deemed likelihood of it observing its military alliance obligations.

In addition to attaching probabilities to the global military alliance network's links, we removed certain links and adjusted the weights (probabilities) attached to others. We eliminated from the network countries that had historically always been neutral or failed to assist other countries, despite formal alliances that they might have had. We also removed certain alliance links after we determined that their presence had generated highly anomalous simulation results. Specifically, we removed the U.S. alliances with countries P and Q as recent aberrations that would be unlikely to operate soon as full alliances. Similarly, we removed a formal on-paper quasi-alliance between country R and China because China had most recently backed country S in country S's disputes with country R. We removed a related formal alliance between countries R and S because we judged it implausible that this alliance would be honored, given the recent history of conflict between these two nations. There could well be other examples in the dataset, like those just cited, of alliances that, for equally valid substantive reasons, ought to be excluded. However, because their continued presence in the dataset did not cause clearly anomalous results, we chose not to look for or eliminate them.

We also increased the weights attached to alliance ties (i.e., the probability of intervention in favor of an ally) between the United States and country T tenfold and between the United States and country U fivefold based on these two countries' consistent patterns of support to the United States during mil-

itarized disputes above and beyond the United States' other allies. Because country V has followed country U's lead in recent conflict, we increased the probability of country V's intervention in support of country U (the edge weight) tenfold. At this initial stage of analysis, the goal was simply to make a crude adjustment to the simulation to make it more reflective of historical patterns of behavior, after they failed to show up in the simulation's initial runs. In a next step, a more refined series of adjustments could be developed and applied to a broader set of countries. This next step was not taken during the analysis conducted for this report because of time and resource constraints.

We also constructed the simulations to make binary predictions rather than provide scalar scores of the probability of a country's participation in the conflicts simulated. This approach is responsive to critiques that past strategic analyses, most often emanating from the U.S. intelligence community, provided scores and probabilities for unique events. It also is consistent with empirical analyses of past intelligence forecasting that show that outcome accuracy had a highly nonlinear relationship to the forecast probability, with essentially a hard break at 50 percent. Although David Mandel and Alan Barnes showed that intelligence forecasts were surprisingly accurate, they also showed that the scalar probabilities assigned to them were inaccurate (Mandel and Barnes, 2014, Figure 1). For example, an event assigned a prior probability of .6 was, post hoc, no less likely to happen than an event assigned a probability of .8. An event assigned a prior probability of .4 generally did not happen and did not happen at roughly the same post hoc rate as did events with prior probabilities of .2. Essentially, the only predictive value, post hoc, of these forecasts was whether they were greater or less than .5. Dhimi and colleagues suggested both greater use of exact numerical probabilities and greater communication with policymakers in terms that translate analyst findings into statements with meaning for policymakers within their decision processes (Dhimi et al., 2015, Table 1).

In the case of alliance strategy, we think that binary predictions that spell out clear case scenarios are meaningful constructs from the standpoint of policymakers. This is true even though scalar probabilities underlie our models. A binary prediction that creates a scenario of country involvement conforms to the more familiar case-study approach from the hermeneutic traditions of social science but, in our case, differs because we can specify precisely why each model made the predictions it did. These predictions might be incor-

rect, but they are specifiable. These binary predictions that build scenarios are readily interpretable in language already understood by policymakers.

We note that use of numerical probabilities might be a better forecasting approach in many other policy areas that involve more repeated events that are not single-trial scenario cascades. Probabilities are useful for repeated games, such as blackjack, sovereign debt defaults, preparedness plans for natural disasters (e.g., hurricanes and earthquakes), and guarding against the still-relatively frequent occurrence of terrorism, civil unrest, and civil war. Our task, however, was to meaningfully anticipate how countries in a strategic network would respond to a hypothetical conflict onset. In such a context, the difference between 65-percent and 53-percent probabilities of an event can be virtually uninterpretable for a policymaker who has only one opportunity to make a critical decision, possibly under considerable time pressure.

Thus, we crafted the simulations to result in sets of entirely deterministic binary outcomes (participates in the conflict/does not participate in the conflict) with the only contingency being the set of countries involved in the initial conflict and the structure of the alliance network that percolates away from them. The simulations took no account of a potential plethora of other qualitative considerations, such as relationship strength between national leaders or which country might have the moral upper hand in the court of public opinion, in a given simulated conflict scenario.

Caveats

It is important to explain what we mean by *additional countries* beyond the initial parties engaged in a simulated conflict. When we highlight a simulation result, such as the fact that country W's alliance tie with Russia is activated, causing it to participate in a simulated future Russian incursion into the Baltic states on Russia's side, that does not necessarily mean that we are predicting that country W will send troops to the Suwałki Gap between Poland and Belarus in support of Russia. A country's engagement in a simulated conflict can include a wide variety of possible activities, including diplomatic support,⁴ intelligence support, economic support, logistical sup-

⁴ Diplomatic support could consist of vocal diplomatic support, reticence, unvoiced opposition, or active opposition. For example, although country X actually siding with

port, arms sales, and basing. It could also include active participation of military forces in the simulated conflict.

Even with this explanation, a finding of this sort would be surprising to some readers; again, this finding is not predictive of actions country *W* might take but rather should highlight that the nature of country *W*'s network connections might be more complex than U.S. policymakers account for, so country *W* might be less likely to endorse U.S. requests or engage actively in ways the United States would like, because country *W* has ties to Russia that U.S. policymakers are less likely to factor into their own calculations than is, perhaps, warranted. Highlighting these network effects, and the tendencies they might create, is useful even if not predictive.

Several smaller countries are so dependent on their protecting states that they repeatedly appear as participants in the simulation results. This is true of small island nations that are highly dependent on the United States. In most cases, these countries' inclusion in the list of simulated conflict participants can be ignored. In certain other cases, however (e.g., the Taiwan and Vietnam scenarios), the real estate that these smaller nations can place at the disposal of conflict participants can be quite valuable, and their inclusion in the list of participants in the simulated conflict should therefore not be discounted.

It should be clear from the above that the simulations described below are quite simple and highly stylized. They were run using such limiting assumptions and simplifications that they could not possibly capture all the complexity and qualitative factors involved when one state makes the momentous decision about whether to participate in a military conflict in support of another.

Note that, because there was some question as to their relevance, we ran these simulations both with and without consultation pacts considered to be alliances:

Consultation pacts do not specifically commit the members to active military support of one another in the event of conflict, but they do commit the members to attempt to develop coordinated action. Con-

Russia in a Ukraine crisis might seem implausible, country *X* might refuse to condemn what other nations would qualify as highly condemnable actions. See, for example, Radyuhin, 2014, or Chaudhury, 2020.

sultation pacts obligate members to communicate with one another in the event of crises that have the potential to result in military conflict with the goal of creating a joint response. While more vague in their commitments to joint action than defense pacts and offense pacts, consultation pacts do announce formally the intention of the allies to cooperate against military threats. (Leeds, 2005, p. 12)

We believe that the simulations provided interesting insights, even though we do not use the results from conducting them to make any policy recommendations. They helped us identify possible interconnections and dependencies within the very large global military alliance network sample space that traditional qualitative analysis might miss. In doing so, the simulations broadened the envelope of analysis by providing experts with hints at additional matters potentially worth considering that might not have been identified through hermeneutic modes of analysis. Furthermore, the assumptions and methods by which the results presented were derived are clearly spelled out. This allows the credibility of results to be tested by audits that identify their underlying causes; it also allows the simulations to be replicated, adapted, and improved by other researchers. The same cannot always be said of qualitative analyses.

China Mobilizes to Invade Taiwan

Conflict Initiation

China begins massing forces and threatens to invade Taiwan. The United States makes four requests of potential partner countries: (1) participate in a military coalition by providing forces, (2) contribute to a joint naval task force and commit military aircraft to deter China, (3) provide logistics or intelligence support for coalition military forces, and (4) impose severe economic sanctions on China.

Simulation Results

With Consultation Pacts Considered Alliances

Eight countries participate on the United States' side. Six countries participate on China's side. See Table 5.1 in the discussion section of this chapter.

Without Consultation Pacts Considered Alliances

Six countries participate on the United States' side. Seven countries participate on China's side.

Discussion

The simulation produced results that are rooted in the varying military alliance network topologies of China and the United States. Even though the United States has many more allies in total than China does, a smaller proportion of U.S. allies are activated under this scenario than of China's allies. This arises because China's alliances are structured to elicit assistance around a narrow set of conflicts that it is likely to encounter.

NATO participation in the conflict is not activated, even though the United States and country X are involved. That NATO is not activated is an emergent property of our conflict simulation parameters, and the network structure is such that NATO is activated in our simulations when at least four NATO members are involved in an initial conflict onset. As explained above, emergent properties are not explicitly programmed anywhere in the simulation, nor did the modeler for the simulation know that it would produce the results that it did after coding the initial simulation mechanics. We thought that NATO might not be activated by such a simplistic simulation under appropriate conditions where it perhaps should be. Initially, we thought that it might be necessary to encode NATO as its own node and with its own special rules. The simple model mechanics for posterior estimates of conflict contagion, combined with the empirical structure of the NATO alliance subnet, reliably result in all NATO member states activating only when four or more NATO member states join a conflict.

We found that this emergent property of the model produced consistently plausible results across all our simulations. Despite the United States' and country X's involvement in the China-Taiwan conflict scenario, the simulated conflict takes place outside NATO's AOR north of the Tropic of Cancer and is not one that involves a direct threat to the territorial integrity of multiple NATO member states. Thus, it is not plausible qualitatively that NATO would be activated by a China-Taiwan conflict even if both the United States and country X were to ally with Taiwan. A similar scenario played out in the 2003 U.S.-Iraq war. Although both the United States

and country X participated in a “coalition of the willing,” NATO was not activated. Preserving the territorial integrity of member states is arguably the most important of the three foundational purposes of the NATO alliance.⁵ The simulation’s underlying assumptions appear to have accurately reflected this basic purpose of alliances. The converse is also plausible. It is difficult to imagine that four or more NATO countries could all join a conflict for any reason other than an attack on a NATO member’s territory. Given an attack on a NATO member’s territory, and four NATO members joining a conflict, it is difficult to conceive that NATO would not be activated. Thus, the converse of this simulation emergent property also seems to mimic the behavior of the real world even with its admittedly simplistic underlying simulation mechanics.⁶

The participation of countries Y and Z in the conflict was triggered because each has only one alliance connection—to the United States. Thus, any action taken by the United States has a dominant role in the actions of countries Y and Z, based only on network topology. Country Y’s participation in the simulated conflict is also consonant with recent country Y moves to deepen cooperation with country A and the United States in the Indo-Pacific region, in response to rising threats from China and the DPRK. Country Y’s participation in a conflict of this kind would likely cause significant domestic political turmoil in country Z concerning the use of country Z forces overseas. Country Y intervened significantly in the United States’ support during the 1964–1975 conflict in Vietnam; its intervention closer to home in a simulated conflict over Taiwan is therefore conceivable but must be weighed against country Z’s considerable trade ties with China that would be put at risk by doing so.

⁵ NATO’s three foundational purposes were immortally summarized by UK Prime Minister Winston S. Churchill’s chief military assistant during World War II, General Hastings “Pug” Ismay. They were to “keep Russia out, America in, and Germany down” (Hennessy, 1989, p. 412).

⁶ The likeliest trigger is not the involvement of four NATO members in the conflict but a direct Chinese attack on the territory of any NATO member. So, for example, a Chinese attack on Hawaii or Guam during the conflict, not implausible given the U.S. military assets there, would be grounds for the United States to request Article V support from NATO, regardless of how many other member states had joined at that point.

The participation in one form or another of Russia and former Soviet states that continue to maintain a strong connection with Russia is notable. This might be a surprising result for some researchers, but we believe that it is conceivable both given the formal obligations entailed in membership in the SCO quasi-alliance and in the recently emergent reality of stronger Chinese–Russian politico-military alignment and cooperation.⁷ Furthermore, the contagion of the conflict to the Russian sphere of influence fits with Chinese military strategy that theorists generally agree to be adaptive: Entrap the other party (the United States) in a two-front conflict while maintaining responsibility for only a single front.

We tested two assumptions in all the simulations about the role of consultation pacts. One assumption is that they function largely like defensive or offensive alliances (i.e., they are signals to parties outside the consultation pact that the pact members intend to defend or at least not attack each other's forces). This assumption makes sense for a consultation pact worded as consultative, rather than explicitly defensive, not to signal anything different about the presence of an alliance but to mollify either internal or international political pressures. Alternatively, some researchers might view a consultation pact as being an honest signal of a wholly different type of promise to coordinate forces.

In this specific China–Taiwan conflict scenario, assuming away the consultation pact activates country B to ally with China. This is because country B has a consultation pact with the United States. If this consultation

⁷ Alexander Korolev measured Chinese–Russian cooperation according to objective criteria and concluded that “China and Russia have now developed strong military alignment, if not a full-fledged alliance” (Korolev, 2020, p. 760). The cooperation encompasses an expanded bilateral trading relationship after Western nations imposed sanctions on Russia in the wake of its annexation of Crimea and sponsorship and direction of a separatist insurgency in eastern Ukraine—particularly, oil sales from Russia to China. It includes coordinated information operation activities in cyberspace and wide-ranging military cooperation. The military cooperation includes a comprehensive mechanism for military consultations; expanded military technical cooperation initiatives; military personnel exchanges; a robust series of peacekeeping, naval, missile defense, and strategic exercises; joint bomber patrols; and trilateral exercises with Iran. China and Russia have also cooperated to create alternatives to Western-dominated international institutions. For more detail, see Gorenburg, 2020, and Paszak, 2020.

pact is interpreted to be a signal that country B is unlikely to engage in a conflict against the United States, which seems plausible, that leads country B to remain neutral in the simulation because it receives conflicting contagion signals from the United States and China. Excluding consultation pacts leads to country B receiving the conflict-onset signal only from China without the counteractive signal from the United States, leading to greater conflict contagion.

Russia's participation in this simulated conflict raises the specter that the United States could be confronted by a conflict that expands into two fronts and involves both Russia and China because of a Chinese initiative to invade Taiwan. This raises a gnarly prospect for defense planning because sizing and shaping U.S. forces to prosecute wars against two great powers simultaneously is likely possible only with *significant* increases in defense spending beyond current levels—a prospect that appears politically unlikely, regardless of the peacetime administration in power at the time of this writing. Given the low probability that the United States will increase military spending to this level in peacetime, the importance of holding U.S. allies and partners close becomes all the greater.

China Seizes a South China Sea Island Claimed by Vietnam

Conflict Initiation

China uses an exaggerated Vietnamese provocation as the rationale for seizing an island feature in the Spratly Islands chain in the South China Sea that Vietnam claims and then restricts maritime access in the region. The United States démarches China to cease and desist, increases deployments to the region, and asks partners to (1) support a freedom-of-navigation naval task force and (2) impose severe economic sanctions on China.

Simulation Results

With Consultation Pacts Considered Alliances

Eleven countries participate on the side of the United States. Eight countries participate in support of China.

Without Consultation Pacts Considered Alliances

Vietnam has only a single alliance, with Russia, and this alliance is a consultation pact. Thus, without consultation pacts being considered important, Vietnam has no allies and must contest China on its own.

Discussion

The simulation reveals that Russia could become activated in this scenario along with its allies in the Middle East, Iran, and Syria. For the United States, besides stalwart allies, such as countries C and D, the alliances in the Southeast Asia region are too disconnected to activate any coherent bloc of allies on behalf of the United States.

Russia Mobilizes to Oppose Ukrainian Attempts to Recover Territory

Conflict Initiation

The Ukrainian military mounts a significant operation to recapture some of its territory (not including Crimea). However, the Russian government masses its forces near the border with Ukraine and threatens to annex more Ukrainian territory. The United States organizes a military coalition to protect Kyiv and territory east of the Dnipro River and calls on its allies to commit to imposing severe economic sanctions if Russian forces—including “little green men”⁸—cross the Ukrainian border.

Simulation Results

With Consultation Pacts Considered Alliances

Ten countries participate in support of the United States. Nine countries participate in support of Russia.

⁸ This expression refers to troops deliberately outfitted in uniforms bearing no signs indicating their country of origin so as to confound identification of the attacker and a rapid response to the attack.

Without Consultation Pacts Considered Alliances

All of Ukraine's alliances, including its alliance with the United States, are consultation pacts. As a result, if consultation pacts are excluded, Ukraine will have no allies in this scenario. The United States and other countries are predicted to abandon Ukraine to Russian retaliation.

Discussion

The participation of countries E, F, G, and H seems out of place at first, but they participate because, as the simulation predicts, China will become engaged on Russia's side. The lack of engagement of individual NATO countries (as opposed to the alliance as a whole) in this scenario is notable. The NATO alliance does not engage at the outset because the scenario initiation specifies that NATO does not engage. A different question is why individual NATO members do not engage more even in the absence of a NATO engagement. NATO constitutes a completely connected network, in which all members are tied to all other members. This network structure affords strong defense capabilities when the whole alliance is activated, but it results in high on- and outdependencies among the NATO members such that they tend to either all act or all not act. The lack of a military response by individual NATO member states to Russia's 2014 annexation of Crimea can be seen as a recent real-life case that supports this simulation's results. The simulation highlights an intrinsic socio-structural weakness of an alliance like NATO that is the shadow image of its strength. Once activated, it acts as one, but, inactivated, it "inacts" as one, and members individually and collectively end up simply looking on as Russia retaliates.

Although they are nominally nonaligned, countries I and J side with Russia and China in this simulation. This is a plausible result because these two countries have alliance ties with China and Russia. Regional experts might reasonably think that the importance of the United States to both these countries as they look to balance against China would outweigh participation in a conflict far from their borders, where their interests are peripheral. Here again, it should be noted that participation can take many forms and that these simulations do not provide a dispositive prediction so much as flag where network structures might create sympathies and antipa-

thies that policymakers might not adequately appreciate but should incorporate into their considerations.

NATO Defends the Baltic States Against a Russian Incursion

Conflict Initiation

Russia mounts an incursion into the Baltic states. NATO allies reach consensus to invoke Article V of the North Atlantic Treaty (North Atlantic Treaty, 1949), triggering their military intervention in defense of their Baltic allies, and begin deploying troops and providing the full range of military support.

Simulation Results

With Consultation Pacts Considered Alliances

Forty-seven countries, including all NATO member states, participate in support of the United States. In addition to the 30 nations of NATO, 17 countries participate. Seven countries participate in support of Russia.

Without Consultation Pacts Considered Alliances

Forty-two countries, including all NATO member states, participate in support of the United States. In addition to the 30 nations of NATO, 12 countries participate. Eleven countries participate in support of Russia.

Discussion

The results shown in Table 5.1 indicate that the simulation represents the NATO alliance reasonably well. NATO is not its own node in the simulation, nor is any NATO effect enforced in any other way. Instead, any time at least four NATO countries engage in a joint conflict, as an emergent property of the conflict contagion rules, the structure of the NATO alliance induces the entire alliance to activate and participate in the conflict.

Country K is triggered because of the combined influence of bilateral alliances that it has with countries L, M, and N and a few others, which

TABLE 5.1

Countries Participating in Simulated Conflicts

Russia Mounts an Incursion into the Baltic States	Ukraine Attempts to Recapture Territory Previously Occupied by Russia and Its Proxies	China Threatens Invasion of Taiwan	China Seizes an Island in the Spratly Islands from Vietnam
Side with the United States			
All NATO members plus countries 1–5, 6, ^a 7, 8, ^a 9, 10 ^a , 11–15, and 16 ^a	Countries 1–9 ^a	Countries 1–2, 3, ^a 4–6, 7, ^a and 8	Countries 1–11 ^a
Side with Russia		Side with China	
Countries 1–3, ^a 4–7, 8–9, ^a 10–11, and 12–13 ^a	Countries 1–9 ^a	Countries 1–6 and 7 ^b	Countries 1–8 ^a

^a Participates only when consultation pacts are considered alliances.

^b Participates only when consultation pacts are not considered alliances.

include some Baltic countries, such as country O. These alliance relationships sum up to a sufficient influence that network calculations predict that country K will participate in the simulated conflict on behalf of NATO. Country K does not have an alliance with the United States. Also worth noting is that any one of these ties does not in itself add up to enough to trigger country K under the simulated parameters.

Country P is triggered through the same kind of summed influence from several European powers that causes country K's involvement. Like with country K, country P's ties to countries Q, R, and S and Baltic countries, such as country T, make the difference. Like country K, country P has no military alliance with the United States.

These results are consistent with the continuing ability, if deterrence fails, of NATO and the U.S. alliance network to respond to the kind of conflict for which they were originally designed—an existential territorial threat from a near-peer state actor. In response to such a threat, NATO and its allies present an overwhelming joint alliance response to the aggressor.

Like in the Vietnam scenario, country U's participation is activated because the United States is country U's only alliance tie. The United States, based on network structure alone, has a significant effect on country U's actions. Note that the reverse is not true. Because the United States has many

other alliances, an action by country U has only a relatively small influence on U.S. actions in terms of effects because country U's influence is counterbalanced by the many other "outstretched hands"; that said, other factors in international politics could amplify these impulses, especially given the closeness of the U.S.–country U alliance and the critical importance of country U for the United States.

Other non-NATO countries are activated to participate on the side of Russia in this simulation. Country V is activated because of its large number of alliance relationships with the authoritarian states that the simulation has participating in the conflict. Again, we are not trying to imply that country V would deploy troops to Poland's Suwałki Gap, but rather the reality that old ties could create hesitation or reticence from country V that the United States might not anticipate. Fundamentally, the point here is that network effects present a flag that should prompt U.S. experts to ask why country V would show up in a scenario such as this one and what, if anything, to do about it.

Excluding consultation pacts alters the non-NATO inclusions in the conflict somewhat by reducing the number of countries that aid NATO and increasing the number that aid Russia. Most of these countries, however, are marginal to the conflict. Countries W, X, Y, and Z all side with Russia when consultation pacts are excluded because their various consultation pacts with NATO members, including the United States, do not mitigate the conflict-onset signal they receive from Russia. Country A is lost as a Russian ally because country A's alliance with Russia is a consultation pact; thus, when these are excluded, country A does not receive any signal in the model to join the conflict.

Limitations of the Simulation Results

Because of their simplified nature and underlying assumptions, the simulations that we conducted were highly stylized. Consequently, they have several limitations, including the following:

- being limited to the diplomatic (military alliance) network layer alone when the U.S. countermeasures postulated for three out of four conflict scenarios involve economic sanctions

- the somewhat subjective elimination of neutral nodes or changes in the weighting or probabilities attached to specific strong historical alliance ties
- the somewhat subjective choice of the threshold at which alliance ties activate a country's participation in a simulated conflict and the risk of nonstationarity in a number that is derived from a dataset that includes both pre- and post-World War II conflicts and thus does not account for the lower incidence of conflict in the post-World War II period
- the broad definition of *participation* in a simulated conflict
- the simulations' inability to predict whether a nation would choose one alliance over another when confronted by conflicting alliance ties
- failure to consider important qualitative aspects, such as which belligerents occupy the moral high ground in particular conflict scenarios and the current-day strength of the political relationships among various leaders.

Nonetheless, the simulations generated potentially novel insights and give pause for further thought. The results highlight the very real risks that conflicts, once started, rarely unfold as their participants predict. In three out of four cases, the simulations suggest that there is a significant risk that a regional conflict will spread to involve actors not often contemplated, or at a minimum that the United States might not receive support that it would have expected. This effect emerges in the simulations from the structure of the networks themselves, and it likely is not merely a happy accident for U.S. competitors China and Russia. Rather, it could reflect highly strategic choices, particularly by China, in the placement of alliance ties to maximally entangle the United States should a conflict arise.

These simulations and the effects created by network structures provide a lens into the fact that network dynamics can create conditions to seek subtle support that might otherwise be unlikely but might also create conditions that might generate hesitancy on the part of countries deemed potential supporters that U.S. officials might not anticipate. Countries B and C, for example, participate in unanticipated ways in the conflicts simulated. This result could serve as a cue to analysts to look more deeply into both countries' motivations and interests when facing such a decision. Consider-

ing these results could provide new avenues of investigation for opportunities to nudge other nations toward U.S.-desired outcomes.

The simulations highlighted the importance of the choice of how to treat consultation pacts. If these pacts are excluded from consideration, the simulations indicate, both Ukraine and Vietnam will be left bereft of assistance in the Ukrainian and Spratly Islands scenarios simulated. Because they confront countries with the quandary of having to choose between competing alliance obligations, consultation pacts dampen conflict contagion when they are included in the simulations. The opposite is true when they are excluded: Country D participates in the Taiwan scenario where previously it would not have; in the Baltic scenario, fewer third parties support NATO, and more countries support Russia. The analyses of the diplomatic (military alliance) network layer in Chapter 2 do not include consultation pacts.

Network Depth and Core

Only once we had analyzed the three network layers described in Chapters 2 through 4 could we turn to addressing questions of network depth, core countries, and U.S. value for money in its relationships with allies and partners. In this chapter, we use two approaches to establishing countries' overall significance in networks of allies and partners:

- We first identified a list of countries that appeared to be core, semiperipheral, and peripheral to the United States' network.
- We then used a second network-depth method to develop a measure of whether the United States is receiving good or poor value for money in terms of the access to network depth that its assistance dollars facilitate in any given country.

Comparing this latter measure with a measure of military burden-sharing developed in a preceding study of alliances allowed us to identify allied countries that might be underappreciated when judged by their share of the burden of collective defense alone. Many countries, it turns out, make significant contributions to the U.S. network of allies and partners along azimuths of national power other than contributions of funds, equipment, and personnel to alliances' military structures.

For each network layer (diplomatic, military, or economic [DME]), we listed the top ten countries according to a variety of key qualitative indicators.

- For the diplomatic (military alliance) network layer, we ranked countries by the number of their alliance connections, their network centrality, the change in their interdependence, and their importance to disrupting the competitors' and U.S. alliance networks.

- We ranked military network layer countries by similar criteria, applying them to the JME and arms sales networks.
- We ranked countries in the economic network layer by their network centrality and by their importance to disrupting alliances' trade with ROW and one another and their importance to disrupting networks of trade in key commodities and strategic minerals.

We aggregated ranking scores in each network layer to yield a single ranking score for each country in that network layer. We then aggregated these network layer scores to provide a single score that ranked countries across all three network layers. This allows us to drill down three levels from this top-level score to scores for each network layer and to scores within each network layer.

Tables 6.1 through 6.4 show the results of this exercise. Table 6.1 shows country E to be top rated across all three network layers in 2017. It also shows that country E owed this position primarily to its scores in the economic and military network layers. In the diplomatic network layer (Table 6.2), country E's alliance connections, centrality, and key role in disrupting the U.S. alliance network were the principal components of its diplomatic network layer score. Country E owed its military network layer score (Table 6.3) primarily to its key roles in disrupting both the JME and arms sales networks.

Why did country E appear at the top of this list in 2017, whereas the United States did not? Country E topped the list because it was more important to the military (joint exercise and arms sales) and economic network layers than the United States was. Although the United States had many JME and arms sales partners and was more central than country E to the arms sales network, country E was important to more of the key facets of these networks that we investigated than the United States was. Country E was key to both networks' disruption, whereas the United States was not. In both the JME and arms sales networks, country E played a more central role than the United States. In the economic network layer, the United States played a key role in the disruption of networks of trade in key commodities and strategic minerals. However, country E's importance to that trade was more than double that of the United States. Furthermore, country E was highly central to the general merchandise trade network, key to dis-

TABLE 6.1

**Top Countries in the Global Military Alliance Network:
Summary, 2017**

Country	Layer			Total Score
	Diplomatic	Military	Economic	
1	0.18	0.75	0.75	1.25
2	—	0.78	0.78	0.96
3	—	0.49	0.49	0.85
United States	0.21	0.35	0.35	0.76
4	—	0.69	0.69	0.70
5	0.01	0.31	0.31	0.48
6	0.07	0.40	0.40	0.46
7	0.01	0.33	0.33	0.42
8	—	0.39	0.39	0.39
9	0.01	0.29	0.29	0.30
Russia	0.10	0.05	0.05	0.30
10	—	0.14	0.14	0.29
11	0.13	0.07	0.07	0.27
12	0.04	0.13	0.13	0.25
13	—	0.24	0.24	0.24
14	0.03	0.20	0.20	0.22
15	—	0.18	0.18	0.20

rupting alliance trade with ROW, and key to disrupting intra-alliance trade, whereas the United States was not.

In addition to ranking countries according to qualitative criteria of this kind in each network layer, we ranked them according to purely quantitative criteria. Because normalized network centrality scores ranging from 0 to 1 become vanishingly small when multiplied together, we first multiplied these numbers by 10,000 before multiplying the nonzero scores by each other. We called the resulting number a country's *network depth*. The results of the exer-

TABLE 6.2

Top Countries in the Global Military Alliance Network: Diplomatic Layer, 2017

Country	Degree Rank	Betweenness Rank	Big Change in Dependence	Key to Disruption		Diplomatic Layer Score
				China and Russia	United States	
1	0.0600	0.0600	—	—	0.0600	0.1800
China	—	—	0.0667	0.0667	—	0.1333
Russia	—	0.0533	—	0.0433	—	0.0967
2	—	—	0.0667	—	—	0.0667
3	—	—	—	—	0.0367	0.0367
4	—	—	—	0.0267	—	0.0267
United States	0.0667	0.0667	—	0.0067	0.0667	0.2067
5	—	—	—	—	0.0133	0.0133
6	—	—	—	—	0.0067	0.0067
7	—	—	—	—	0.0067	0.0067
8–14	—	—	—	—	—	—

TABLE 6.3
Top Countries in the Global Military Alliance Network: Military Layer, 2017

Country	JME			Arms			Military Layer Score
	Degree Rank	Betweenness Rank	Disruption	Degree Rank	Betweenness Rank	Disruption	
1	0.0600	0.0667	0.0667	0.0400	0.0600	0.0667	0.3600
2	0.0533	0.0467	0.0600	0.0467	0.0533	0.0600	0.3200
United States	0.0667	—	—	0.0667	0.0667	—	0.2000
3	0.0400	—	—	0.0600	0.0333	0.0533	0.1867
4	0.0467	—	0.0533	0.0267	0.0267	—	0.1533
Russia	—	—	0.0667	0.0200	—	0.0667	0.1533
5	0.0067	—	—	0.0533	0.0400	0.0467	0.1467
6	0.0333	—	—	0.0333	0.0200	—	0.0867
7	0.0267	0.0600	—	—	—	—	0.0867
China	—	—	0.0600	—	0.0067	—	0.0667
8	—	0.0133	—	—	—	—	0.0133
9	0.0133	—	—	—	—	—	0.0133
10–14	—	—	—	—	—	—	—

TABLE 6.4

Top Countries in the Global Military Alliance Network: Economic Layer, 2017

Country	Betweenness Rank	Key to			Economic Layer Score
		ROW Trade Disruption	Intra-Ally Trade Disruption	Minerals and Commodities	
1	—	0.0333	0.0133	0.7293	0.7760
2	0.0533	0.0667	0.0133	0.6167	0.7500
3	0.0333	0.0267	0.0400	0.5873	0.6873
4	0.0667	0.0600	0.0133	0.3540	0.4940
5	—	0.0400	0.0333	0.3220	0.3953
6	0.0133	—	—	0.3740	0.3873
United States	—	—	—	0.3500	0.3500
7	0.0600	0.0533	0.0600	0.1520	0.3253
8	—	—	—	0.3113	0.3113
9	—	0.0467	0.0333	0.2113	0.2913
10	—	—	0.0200	0.2220	0.2420
11	—	—	0.0533	0.1427	0.1960
12	—	—	0.0133	0.1707	0.1840
13	—	0.0133	—	0.1280	0.1413
14	—	—	—	0.1260	0.1260
China	—	—	0.0667	—	0.0667
Russia	—	—	0.0467	—	0.0467

cise are shown in Tables 6.5 through 6.7. Because we deliberately made them large, the network-depth numbers in these tables are relevant only because they help us to distinguish differences in countries' ordinal rankings.

Tables 6.5 through 6.7 reveal a large degree of congruence between the qualitative and quantitative ranking methods that we used. They show countries E, F, G, and H and the United States as the highest-ranking countries in terms of network depth in 2017. Countries E, F, and G experienced the greatest gains in network depth between 1989 and 2017, and country H, Russia, and the United States experienced the greatest losses.

Like in the case of changes in interdependence in Chapter 2, the calculations that led to these results can be run backward to reveal the underlying causes of a country's change in network depth. Between 1989 and 2017, country E suffered losses in network centrality in the diplomatic, trade, and arms sales networks (in descending order). However, these losses were more than offset by an increase in country E's centrality in the JME network, of two orders of magnitude. As country E increased the number of its exercise partners and of JMEs in the Sahel, North Africa, and elsewhere, country E's centrality to the JME network rose precipitously.

By contrast, the United States experienced no change to its centrality to the JME network between 1989 and 2017. Its centrality to the arms sale network increased by close to one-third (29 percent). However, as China rose to become an international trading power, displacing the United States, U.S. centrality to the economic network layer fell by more than two-thirds (69 percent). When combined with a loss of centrality of about one-tenth (12 percent) in the diplomatic (military alliance) network layer, this was enough to ensure that the United States placed as the greatest loser of network depth between 1989 and 2017.

We compared the rankings produced by the quantitative and qualitative methods just described. Any country that both methods placed in the top ten was designated a core ally or partner. Any country that only one method placed in the top ten was dubbed a semiperipheral ally or partner. We deemed all other countries to be peripheral. Figure 6.1 both lists and maps the eight countries that we identified as being core to the U.S. network of allies and partners; it does the same for the 13 semiperipheral countries. Countries bolded in the lists at the bottom of Figure 6.1 underwent large changes in interdependence between 1989 and 2017.

TABLE 6.5
Network Depth: Top Countries, 2017

Country	Network Depth			Change in Network Depth	
	2017	2000	1989	1989–2017	2000–2017
1	6,304,139,897	2,696,566,695	56,903,729	6,247,236,167	3,607,573,202
2	650,519,917	48,675,834	14,253,408	636,266,509	601,844,084
United States	96,692,185	61,750,525	253,168,323	–156,476,139	34,941,659
3	12,255,588	429,661	20	12,255,569	11,825,927
4	11,074,611	22,188,847	29,833	11,044,778	–11,114,237
5	9,351,572	9,783,121	766,627	8,584,945	–431,549
6	6,433,348	16,756	20	6,433,327	6,416,592
7	2,928,193	11,868	4,942,404	–2,014,211	2,916,324
8	2,786,289	106,629	12,545	2,773,743	2,679,659
Russia	608,148	181,553	16,512,145	–15,903,998	426,594
10	477,581	33,554	131,759	345,822	444,026

NOTE: The range of the network-depth score is between 0 and 1×10^{12} .

TABLE 6.6

Top Countries' Network Depths, 1989, 2000, and 2017: Greatest Gainers

Country	Network Depth			Change in Network Depth	
	2017	2000	1989	2000–2017	1989–2017
1	6,304,139,897	2,696,566,695	56,903,729	3,607,573,202	6,247,236,167
2	650,519,917	48,675,834	14,253,408	601,844,084	636,266,509
3	12,255,588	429,661	20	11,825,927	12,255,569
4	11,074,611	22,188,847	29,833	–11,114,237	11,044,778
5	9,351,572	9,783,121	766,627	–431,549	8,584,945
6	6,433,348	16,756	20	6,416,592	6,433,327
7	2,786,289	106,629	12,545	2,679,659	2,773,743
8	477,581	33,554	131,759	444,026	345,822
9	278,579	5,563,391	12	–5,284,812	278,566
10	176,191	22	0	176,169	176,191

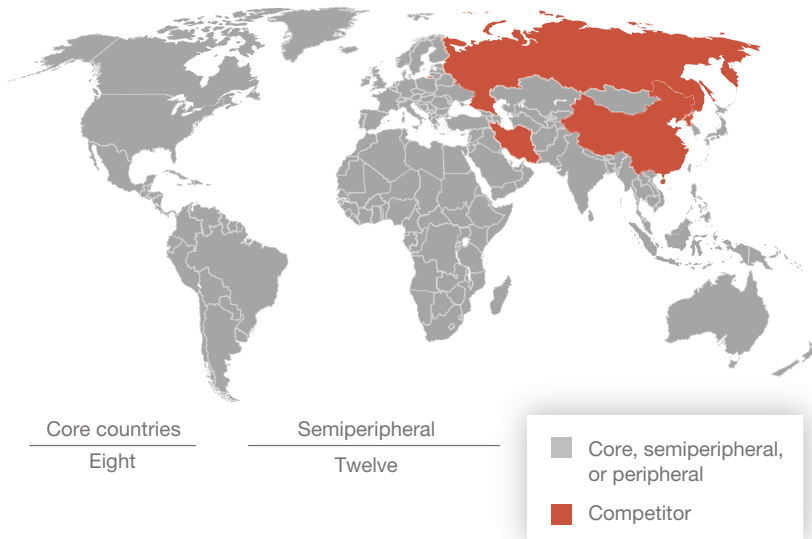
NOTE: The range of the network-depth score is between 0 and 1×10^{12} .

TABLE 6.7

Top Countries' Network Depths, 1989, 2000, and 2017: Greatest Losers

Country	Network Depth			Change in Network Depth	
	2017	2000	1989	2000–2017	1989–2000
United States	96,692,185	61,750,525	253,168,323	34,941,659	–156,476,139
Russia	608,148	181,553	16,512,145	426,594	–15,903,998
3	115,183	1,280	9,121,609	113,903	–9,006,426
4	266,400	371,143	5,019,091	–104,743	–4,752,691
5	2,928,193	11,868	4,942,404	2,916,324	–2,014,211
6	2,190	29	97,385	2,160	–95,195
7	13	0	20,808	13	–20,794
8	2,300	10	5,961	2,290	–3,661
9	391	1,134	2,732	–743	–2,342
10	14	1,030	1,821	–1,016	–1,807

NOTE: The range of the network-depth score is between 0 and 1×10^{12} .

FIGURE 6.1**Core, Peripheral, and Semiperipheral Countries**

NOTE: Three core countries and five semiperipheral ones underwent large changes in interdependence between 1989 and 2017.

Using an adapted form of a methodology developed in 2019, we compared the share of the burden of collective defense borne by 59 of the United States' 65 treaty allies whose burden shares we were able to measure with their share of total allied income.¹ Forty allies' share of the burden of allied collective defense was less than their share of total alliance income. However, in 2017, 32 of those 40 allies (those listed as underappreciated in Table 6.8) provided above-median access to network depth per dollar of total 2000–2017 assistance that the United States provided to them.² They contributed other elements of national power to the U.S.-led alliance system

¹ The methodology by which we calculated each country's burden share is taken from unpublished research we performed for OSD on allied burden-sharing. We did not collect burden-sharing data for nine countries and were therefore unable to calculate burden shares for these countries.

² Assistance includes economic aid, arms sales, and security assistance, as collated at Security Assistance Monitor, undated.

besides just the military spending, military equipment, and personnel considered when calculating burden share. By this broader measure, just eight of 68 allies (12 percent) might be considered undercontributors (listed as such in Table 6.8).

Table 6.8 is notable for its inclusion of country I as an undercontributor despite the massive increases in country I's defense spending and activity that have taken place. To assess the reasons for this, we used both approaches, qualitative and quantitative, that we used to calculate network depth and to identify core and noncore countries.

Auditing country I's results under the first (qualitative) approach to determining network depth, we found that, in 2017, country I figured as a key player in only the economic network layer; it did not place in either the diplomatic (military alliance) or military (JME and arms sales) network layer. Within the economic layer, country I placed as a key player only in trade in key commodities and strategic minerals. It did not place when it comes to centrality to general merchandise trade or to disrupting allied networks of trade with one another or ROW.

When we audited the calculation of country I's network depth using the second (quantitative) approach to calculating network depth, we found that country I's network depth more than halved (it fell by 54 percent) between 1989 and 2017. This caused country I to fall from 31st to 68th place in terms of network depth. Country I owed its relatively high rank in 1989 almost exclusively to its centrality in the economic network layer; it also enjoyed quite modest centrality in the arms trade network at that time. By 2000, as China grew to supplant country I as Asia's leading trading nation, country I's centrality to the economic network layer fell by 66 percent; its centrality to arms sales disappeared, but that was offset by a small increase in country I's centrality in the JME network. By 2017,

TABLE 6.8
Underappreciated and
Undercontributing Allies

Status	Number of Countries
Underappreciated	32
Undercontributing	8

country I's centrality to trade in the economic network layer had fallen by more than three-quarters (76 percent) from where it had been in 1989. Country I reestablished some modest centrality in the arms sales network by that time, while, in 2000, its centrality in the JME network fell to one-quarter of its previous modest level.

Conclusion

The picture that emerges from this report is one of continued U.S. diplomatic and military strength, lower U.S. economic influence, growing Chinese power, and declining Russian power. China owes its expanding power principally to the economic growth that it achieved in the past four decades. Although it is important to acknowledge the strategic advantages conveyed to China by its economic growth trajectory, it is also worth recognizing some of China's continuing economic limitations. Even though China was the leading trading partner by value in two-thirds of the world's bilateral trading relations in 2017, the United States' network of allies and partners was 1.8 times more central to the global trade network than China and its 66 BRI partners were. In the economic sphere, the U.S. network of allies and partners should—properly managed—be able to continue to play a leading role in shaping the overall environment. This is important because it is from this economic environment that the United States' leading competitor, China, draws much of its power.

Nine out of ten countries that were key to trade between ROW and the competing great powers and their allies and partners in 2017 were U.S. allies. More than two-thirds of the countries that were key players in trade in key commodities and strategic minerals were U.S. allies. And China's network of trade with its 66 BRI partners in 2017 was almost four times more vulnerable to deliberate disruption than the network of trade between the United States and its partners and allies.

That is not to say that the advantages that this network provided the United States in the military realm were inconsiderable. The universe of countries with military alliances remained 12 times more militarily dependent on the United States than on China in 2017. U.S. allies were, at that time, on average, significantly more dependent on the United States than

China's allies were on China. Moreover, military dependence on the United States had been growing since the end of the Cold War. That growth allowed the U.S. network of partners and allies to continue to remain most central to military dependence in all six regions of the world when it remained most central to trade in only half the regions of the world. Furthermore, in 2017, China and Russia's alliance networks were twice and 1.5 times, respectively, more vulnerable to deliberate disruption than that of the United States.

Military dependence on China rose significantly between 1989 and 2017. By 2017, China had reached a point at which it had supplanted Russia in second place as the country on which allies depended most militarily, on average, in all regions of the world. This surge in military dependence on China means that there are no grounds for complacency, despite the United States' apparent continuing ability to shape the global economic and military environments when working closely and cooperatively with its network of allies and partners.

Forty-three percent of countries with military alliances in 2017 experienced a 50-percent or greater change in their dependence on other countries between 1989 and 2017. These changes might have given many international decisionmakers on security issues cause to reconsider both their place in the post-World War II international security system and the continuing value of existing alliance ties to their countries. What was true of the global alliance system was all the truer for the U.S. network of allies and partners. Forty-six percent of them experienced similar-size changes in their interdependence. For decisionmakers in these countries, the international security landscape was in flux. Although many commentators speak about the U.S. alliance network as largely static and durable, these changes in dependence suggest that policymakers should pay careful attention to the strength of the network and their approach to individual countries where these shifts are significant.

Can the United States continue to rely on the advantages conferred to it by its network of partners and allies in formulating its grand strategy? The analyses described in this report suggest that, for the time being, the answer appears to be an emphatic "Yes!" However, they also show that there are no grounds for complacency. If the United States wishes to be able to continue to rely on these advantages, there is much work to be done.

Diplomatic Network Layer Calculations

This appendix documents step by step, in a manner that allows other researchers to replicate this relatively infrequently used procedure, how the methodology developed in Maoz's "The Effects of Strategic and Economic Interdependence on International Conflict Across Levels of Analysis" (Maoz, 2009) was corrected, adapted, and applied to the task of measuring interdependence within and across military alliances. It is important to note that Maoz did not rely solely on the adjacency matrix of diplomatic ties. Rather, he made use of known properties of this matrix to add elements related to national capabilities and potential future opponents that allow measures of dependence, important to IR theory but not to SNA, to be calculated.

We first describe the three input matrices:

- an alliance commitment matrix (**A**), identifying states' alliance partners
- a capability matrix (**C**), measuring the capabilities of states
- a global SRG matrix (**SRG**) that identifies which states have the opportunity and the will to threaten other states.

We next describe the intermediate matrices derived from the inputs:

- the sensitivity dependence matrix, $(\mathbf{D}_{SA}^1)$, capturing, for each state, the effect that a change in a state's allies' supplies of resources and capabilities has on that state

- the opportunity-cost matrix (**OC**), indicating how much security each state would lose if a given alliance commitment were violated or terminated.

Finally, we explain how these intermediate matrices can be combined to produce two final matrices and four measures of interdependence that are derived from these two matrices:

- the matrix of first-order strategic dependence between allies (**D_A^1**)
- the matrix including up to the m th- or final-order strategic dependence between allies (**D_A^F**)
- *outdependence*, the extent to which states in the alliance system depend on a focal state
- *ondependence*, a focal state's dependence on all other states in the alliance system
- *monadic interdependence*, the degree to which a state depends on other states, regardless of the direction of the dependencies
- *the monadic-interdependence balance*, the net dependence on or dependence of a state.

Although most of the methodology presented here is obtained from Maoz, 2009, and related works, there are a few errors contained in those publications, mostly related to notation. We have, to our knowledge, corrected these errors in the version presented here and have implemented those corrections in the corresponding computer code. Thus, this work is not intended to align perfectly with Maoz, 2009.

As is customary in linear algebra, matrices are represented in bold upper case, while their elements and indices are represented in italicized lower case. We use the index i to refer to an arbitrary row and j to refer to an arbitrary column. The symbol $\times$ denotes standard matrix multiplication, while the symbol $*$ denotes standard scalar multiplication. The symbol $\circ$ is used to denote elementwise multiplication. A series of three dots within a matrix (e.g., ...) is used to indicate that the matrix is of an unspecified size and continues in the pattern presented.

According to Maoz, we can characterize the direct dependencies of each state in a given system of alliances on every other state in the system using the first-order strategic dependence matrix, defined as

$$\mathbf{D}_A^1 = \mathbf{OCD} \circ (\mathbf{A} \times \mathbf{C}),$$

where

- $\mathbf{A}$ is an adjacency matrix of the commitments of states i to states j (i.e., alliance ties with an associated estimate of the probability of fulfillment of those commitments)
- $\mathbf{C}$ is a diagonal matrix consisting of a measure of the capabilities of individual states
- the matrix product $(\mathbf{A} \times \mathbf{C})$ is the sensitivity dependence matrix, a matrix measuring the extent to which a change in state j 's supply of military capabilities affects state i 's ability to defend against potential future opponents
- $\mathbf{OCD}$ is a square matrix providing the opportunity cost to state i of a disruption of its alliance relationships
- the entry in the i th column and j th row of $\mathbf{D}_A^1$ gives the direct dependence of state i on state j .

In the rest of this appendix, we describe the data and steps required to obtain and analyze this matrix, $\mathbf{D}_A^1$, and its higher-order derivatives.

Input Data

The Alliance Commitment Matrix

$\mathbf{A}$ is a square adjacency matrix representing the alliance network under consideration, where rows and columns represent nodes and matrix elements represent edges:

$$\mathbf{A} = \begin{bmatrix} a_{1,1} & \cdots & a_{1,j} \\ \vdots & \ddots & \vdots \\ a_{i,1} & \cdots & a_{i,j} \end{bmatrix}.$$

The diagonal elements (e.g., $a_{1,1}$) represent each state's self-reliance. Because a state is, by definition, fully committed to itself, the diagonal elements are strictly equal to 1. A nonzero off-diagonal element $a_{i,j}$ indicates the existence of an alliance between two states i and j .

Although alliance ties are often assumed to be of equal quality, they are not. Here, the term *quality* encapsulates deterrent value, credibility, and the posterior probability of an alliance commitment being observed. Alliance quality is captured in the values of the elements $a_{i,j}$, known as *edge weights*, and can be interpreted as the level of commitment of state i to state j . In our work, we estimated the quality of a given alliance commitment using a posterior probability estimate that the alliance would be observed. Importantly, matrix **A** is not necessarily symmetric; state i and state j can exhibit different levels of commitment toward one another, in which case $a_{i,j}$ differs from $a_{j,i}$. The edges, $a_{i,j}$, are unweighted, containing either a 0 or a 1, depending on the presence or absence of an alliance tie between the two countries.

The Capability Matrix

Pooling of resources gives rise to interdependence between allies. All else equal, alliances with highly capable or resource-rich states might be more valuable than alliances with resource-poor states. It is therefore important to account for the capabilities that each ally and potential opponent contributes, in addition to the credibility of the various alliance commitments, as described in the previous section. The capabilities of each state in the system are represented by a diagonal matrix, **C**, as follows:

$$\mathbf{C} = \begin{bmatrix} c_{1,1} & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & c_{i,j} \end{bmatrix}.$$

To quantify these capabilities, we use countries' International Futures GPI score (see Moyer and Markle, 2018). The GPI is composed of 15 measures grouped in five dimensions along which International Futures measured countries' power (Moyer and Markle, 2018):

- military
 - military spending
 - share of stock of nuclear weapons
- demography
 - population
- economy
 - foreign direct investment inflow
 - gross domestic product at purchasing-power parity
 - share of global trade
 - share of global energy production
 - per capita share of global gross domestic product at purchasing-power parity
- technology
 - research and development spending
 - share of global information and communication technology stock
- international interactions
 - share of global foreign aid donations
 - global share of the number of embassies held in other countries as a percentage of total possible embassies
 - global share of IGO memberships, weighted by importance
 - global share of treaty signings and ratifications, weighted by importance, as a percentage of total possible weighted participation
 - global share of diplomatic power times government revenue.

The Strategic Reference Group

As described in Maoz, 2009, a focal state's SRG is defined as the subset of neighboring countries and powers in the state's region and major powers with global reach that (1) had MIDs with the focal state within the past decade; (2) are strategic rivals of the focal state that do not meet the first

condition, or (3) are allies of states qualifying under the first two criteria (i.e., allies of the focal state's enemies) (Maoz, 2009, pp. 231–232).

SRG is thus a square, symmetric matrix consisting of a set of indicator variables (i.e., taking only the value 0 or 1) designating states that might have the opportunity and the will to threaten or attack the focal state:

$$\mathbf{SRG} = \begin{bmatrix} s_{1,1} & \cdots & s_{1,j} \\ \vdots & \ddots & \vdots \\ s_{i,1} & \cdots & s_{i,j} \end{bmatrix}.$$

Because $s_{i,j}$ takes on only the value 0 or 1, a dyad satisfying one of the stated conditions is given equal weight to a dyad satisfying multiple conditions.

We next describe the process of constructing the global **SRG** matrix for our analysis.

Regional Powers

We obtained the directed dyad–year–level¹ version of the master data of the Correlates of War Direct Contiguity dataset covering 1816–2016 (version 3.2) (Stinnett et al., 2002). The state labels and contiguity type for 2016 were analyzed to acquire contiguity data for all states in the system. The three-letter country labels were replaced with ISO 3166-1 alpha-2 two-letter country codes.

Global Powers

Data on global powers were processed as follows:

1. **MIDs:** We obtained the UCDP/Peace Research Institute Oslo Armed Conflict Dataset, version 19.1, covering the years 1946 through 2018 (Pettersson, Högbladh, and Öberg, 2019). We analyzed intrastate conflicts of the past 20 years (starting in 1998), not considering dis-

¹ *Level* refers to one of the five categories of contiguity defined in the dataset: land contiguity (sharing a land border or separated by a river), separation by water up to 12 miles, separation by water up to 24 miles, separation by water up to 150 miles, and separation by water up to 400 miles.

putes involving nonstate actors. All conflicts were given an equal weight of 1. Key disputes in this dataset include those between

- the United States and country A versus country B
 - the United States and countries A and C versus country D
 - country E versus country F
 - country G versus country H
 - country J versus country K.
2. **strategic rivals:** We next obtained Thompson's list of strategic rivalries and hand-coded them as dyads (Thompson, 2001). Examples of key rivalries in this dataset include those between
 - country L versus countries M, N, and O
 - China versus the European great powers, country P, and the United States
 - countries Q, R, S, and T versus Russia.
 3. **allies of enemies:** According to the methodology presented in Maoz, 2009, the final step would be to add, for each state, all allies of the states already accounted for in its SRG (i.e., the "allies of its enemies"). However, because this step renders the SRG extremely, if not excessively, dense, we opted to omit allies of enemies in the global SRG.

Row i of **SRG** gives the SRG for state i in the international alliance system. Each entry in that row, s_{ij} , represents a potential opponent country. If that entry $s_{ij} = 1$, state j is a potential opponent of state i and vice versa. If $s_{ij} = 0$, states i and j are not considered to be opponents, according to this exercise.

Taken together, the columns and rows of the global SRG matrix **SRG** represent a network of rivalries between potential future opponents.

Intermediate Calculations

The Sensitivity Dependence Matrix

Sensitivity dependence is a function of both the credibility of alliance commitments and the capabilities that other states bring to the common pool of allied resources. It captures, for each state, the realized impact of a change

in its allies' supplies of resources or overall capabilities. The direct sensitivity dependence matrix, which we call the first-order sensitivity dependence matrix ($\mathbf{D}_{SA}^1$), is obtained by multiplying matrix $\mathbf{A}$ by matrix $\mathbf{C}$:

$$\mathbf{D}_{SA}^1 = \mathbf{A} \times \mathbf{C}$$

$$\begin{bmatrix} d_{1,1|SA}^1 & \cdots & d_{1,j|SA}^1 \\ \vdots & \ddots & \vdots \\ d_{i,1|SA}^1 & \cdots & d_{i,j|SA}^1 \end{bmatrix} = \begin{bmatrix} a_{1,1} & \cdots & a_{1,j} \\ \vdots & \ddots & \vdots \\ a_{i,1} & \cdots & a_{i,j} \end{bmatrix} \times \begin{bmatrix} c_{1,1} & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & c_{i,j} \end{bmatrix}.$$

Thus $d_{i,j|SA}^1$ represents the extent of the effect that a change in state j 's capabilities has on state i . Note that, here, we use the symbol $\times$ to indicate traditional matrix multiplication, although the effect is the same as multiplying each element in $\mathbf{A}$ by the element in the corresponding column of $\mathbf{C}$, such that $d_{i,j|SA}^1 = a_{i,j} * c_{j,j}$. Matrix $\mathbf{D}_{SA}^1$ is, in general, not symmetric, even in the special case in which matrix $\mathbf{A}$ is symmetric.²

The Opportunity-Cost Matrix

An alliance's opportunity cost indicates how much security each state would lose if a given alliance commitment were violated or terminated. It is the product of the **SRG** and $\mathbf{C}$ matrices:

$$\mathbf{OC} = \mathbf{SRG} \times \mathbf{C}$$

$$\begin{bmatrix} oc_{1,1} & \cdots & oc_{1,j} \\ \vdots & \ddots & \vdots \\ oc_{i,1} & \cdots & oc_{i,j} \end{bmatrix} = \begin{bmatrix} s_{1,1} & \cdots & s_{1,j} \\ \vdots & \ddots & \vdots \\ s_{i,1} & \cdots & s_{i,j} \end{bmatrix} \times \begin{bmatrix} c_{1,1} & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & c_{i,j} \end{bmatrix}.$$

The elements in row i of $\mathbf{OC}$ provide the capabilities of the states in state i 's SRG. Again, we use the symbol $\times$ to indicate traditional matrix multiplication, although the effect is the same as multiplying each element in $\mathbf{SRG}$ by the element in the corresponding column of $\mathbf{C}$, such that $oc_{i,j} = s_{i,j} * c_{j,j}$. Note that the diagonal entries of $\mathbf{OC}$ are strictly 0 because no state is a member of its own SRG.

² $\mathbf{D}_{SA}^1$ can be symmetric only in the case in which $\mathbf{A}$ is symmetric and all states' capabilities are identical.

The Opportunity-Cost Vector

For each row state i , we next take the sum of the capabilities of its SRG:

$$\Sigma SRG = \sum_{j=1}^j oc_{ij}.$$

Using this vector of capability sums, we can compare a state's capability to its *security challenge*, or the total capability of the member states of its SRG. For each row state i , we define its opportunity cost as

$$oc'_i = \begin{cases} 1 - \left(\frac{c_{i,i}}{\Sigma SRG} \right) & \text{if } c_{i,i} < \Sigma SRG \\ 0 & \text{otherwise.} \end{cases} \quad \text{unless } c_{i,i} = 0.$$

This allows us to quantify the opportunity cost of forgoing alliances with other countries. A state with capabilities exceeding that of its SRG would, in theory, not need to rely on external resources to contend with its enemies, even in a worst-case scenario, and thus has an opportunity cost of 0. In contrast, a state with lesser capabilities than its SRG would not be well equipped to handle a conflict on its own, and thus has a higher opportunity cost of forgoing alliances.

The opportunity-cost vector (**OC'**) is then a column vector consisting of the opportunity-cost scores for each of the states i under consideration, oc'_1 through oc'_i :

$$\mathbf{OC}' = \begin{bmatrix} oc'_1 \\ \vdots \\ oc'_i \end{bmatrix}.$$

We convert this to a second opportunity-cost matrix, which we call matrix **OCD**, which translates opportunity costs into discount factors to be applied to the dependencies of nations on one another. This is a square matrix in which each column is composed of **OC'** but the diagonal is set to 1.³

$$\mathbf{OCD} = \begin{bmatrix} 1 & oc'_1 & \cdots & oc'_1 \\ oc'_2 & 1 & \cdots & oc'_2 \\ \vdots & \vdots & \ddots & \vdots \\ oc'_i & oc'_i & \cdots & 1 \end{bmatrix} = \begin{bmatrix} ocd_{1,1} & \cdots & ocd_{1,j} \\ \vdots & \ddots & \vdots \\ ocd_{i,1} & \cdots & ocd_{i,j} \end{bmatrix}.$$

A state with high capability relative to its SRG will have smaller values in the corresponding rows of **OCD** than states with relatively low capability. These smaller values ultimately discount the dependence of highly capable states on their allies.

Resulting Measures of Interdependence

The Strategic Dependence Matrices

Matrix $\mathbf{D}_A^1$ is the *elementwise* product of matrix **OCD** and the matrix $\mathbf{D}_{SA}^1$:

$$\mathbf{D}_A^1 = \mathbf{OCD} \circ \mathbf{D}_{SA}^1$$

$$\begin{bmatrix} d_{1,1|A}^1 & \cdots & d_{1,j|A}^1 \\ \vdots & \ddots & \vdots \\ d_{i,1|A}^1 & \cdots & d_{i,j|A}^1 \end{bmatrix} = \begin{bmatrix} ocd_{1,1} & \cdots & ocd_{1,j} \\ \vdots & \ddots & \vdots \\ ocd_{i,1} & \cdots & ocd_{i,j} \end{bmatrix} \circ \begin{bmatrix} d_{1,1|SA}^1 & \cdots & d_{1,j|SA}^1 \\ \vdots & \ddots & \vdots \\ d_{i,1|SA}^1 & \cdots & d_{i,j|SA}^1 \end{bmatrix}.$$

³ The diagonal of **OCD** is set to 1 because the concept of “forgoing an alliance with oneself” is not interpreted or considered as a possibility in this study. Note that 1 is not attainable from

$$oc'_i = \begin{cases} 1 - \left(\frac{c_{i,i}}{\Sigma SRG} \right) & \text{if } c_{i,i} < \Sigma SRG \\ 0 & \text{otherwise.} \end{cases} \quad \text{unless } c_{i,i} = 0.$$

Note that, here, we use the symbol $\circ$ to indicate elementwise multiplication, so we have $d_{ij|A}^1 = ocd_{ij} \star d_{ij|SA}^1$. Each off-diagonal entry $d_{ij|A}^1$ reflects state i 's strategic dependence on state j , given i 's sensitivity to changes in state j , as well as i 's opportunity cost of alliance disruption.

Higher-order dependencies can be obtained by multiplying $\mathbf{D}_A^1$ by itself. The m th-order strategic dependence matrix, $\mathbf{D}_A^m$, is calculated as $\mathbf{D}_A^m = (\mathbf{D}_A^1)^m$.

The maximum possible value of m is $n - 1$, where n is the number of states under consideration, equivalent to the number of rows or columns in $\mathbf{A}$. The off-diagonal elements in $\mathbf{D}_A^m$ give the direct and indirect dependence of one ally on another after a walk of m iterations across the ties of the alliance network. Allies that are not directly dependent on one another in the first order (i.e., the corresponding element of $\mathbf{D}_A^1$ equals 0) can be indirectly dependent on one another at higher orders of dependence, in which case the corresponding element in the $\mathbf{D}_A^m$ matrix will be nonzero. The literature is divided over whether indirect self-ties should be included in the calculation of $\mathbf{D}_A^m$. Omission of such ties while retaining direct self-ties would involve setting diagonal values of $\mathbf{D}_A^i$ to 0 for $i > 1$. In our work, we adopt this approach, which we believe to be that favored by Maoz.

Maoz's metrics of dependence and interdependence, as well as our adaptations of them, can be calculated based on any of $\mathbf{D}_A^1$ through $\mathbf{D}_A^F$, where $\mathbf{D}_A^F$ is the final-order dependence matrix, calculated as

$$\mathbf{D}_A^F = \sum_{i=1}^m \mathbf{D}_A^i, \text{ where } m \leq n - 1.$$

This matrix accounts for all direct and indirect dependencies between states in the system of interest.

Derivative Dependence Metrics

We consider the values of $\mathbf{D}_A^m$ to evaluate the dependencies on and of a given country of interest at order m . For a given state i , the entries in row i of $\mathbf{D}_A^m$ give all other states' dependence on state i at the m th order, and the entries in column i of $\mathbf{D}_A^m$ give state i 's dependence on all other states at the m th order. The metrics of dependence and interdependence that follow are intended

to be calculated for $\mathbf{D}_A^F$ incorporating direct and all indirect ties.⁴ However, these metrics rapidly approach 0 for reasonably sized systems of nations, so we choose to calculate them for $\mathbf{D}_A^1$ and a small number of higher-order dependence matrices. Further detail on the derivation of these metrics is given at the end of this appendix.

Ondependence and Outdependence

In addition to measuring each of the n allied states' direct and indirect dependence on other allied states, cumulative measurements of dependence can be made:

- Ondependence ($ONDEP_i$) reflects the extent and scope of state i 's dependence on other states in the system.
- Outdependence ($OUTDEP_j$) reflects the extent to which other states in the system depend on state j .

Ondependence and *outdependence* are defined as the actual levels of direct and indirect dependence divided by the maximum possible level of dependence in the system, given the maximum possible level of dependence between two states (k) and the order of indirectness (m):⁵

$$ONDEP_i = \frac{(\sum_{j=1}^n d_{ij} - d_{ii})(1 - k(n-1))}{k(n-1)(1 - (k(n-1))^m)}$$

$$OUTDEP_j = \frac{(\sum_{i=1}^n d_{ij} - d_{jj})(1 - k(n-1))}{k(n-1)(1 - (k(n-1))^m)}.$$

⁴ Any of three approaches is possible: (1) include all self-ties, direct or indirect; (2) omit indirect self-ties but retain direct; or (3) omit all self-ties, direct or indirect. After further inspection of Maoz's work, we believe that method 2 is the one that he adopts.

⁵ Typically, we define k as the largest value of the first-order dependence matrix, inclusive or exclusive of the diagonal entries, depending on whether we do or do not wish to include indirect self-ties. Parameter m takes on values $1 \leq m \leq n-1$. The elements d_{ij} correspond to $\mathbf{D}_A^m$.

Here, d_{ij} are elements of $\mathbf{D}_A^m$, and $d_{i,i}$ and $d_{j,j}$ are the i th row and j th column diagonal elements, respectively. Ondependence and outdependence are the sums of the row and column vectors, respectively, making up the strategic dependence matrix, standardized relative to the maximum dependence value in the matrix. Ondependence thus provides a cumulative summary of the rows of the matrix, while outdependence provides a cumulative summary of the columns:

$$\begin{array}{ccc}
 \left[\begin{array}{ccc} d_{1,1} & \cdots & d_{1,j} \\ \vdots & \ddots & \vdots \\ d_{i,1} & \cdots & d_{i,j} \end{array} \right] & \begin{array}{l} \rightarrow ONDEP_1 \\ \vdots \\ \rightarrow ONDEP_i \end{array} & \\
 \downarrow & & \downarrow \\
 OUTDEP_1 & \cdots & OUTDEP_j
 \end{array}$$

Monadic Interdependence

Monadic interdependence measures the degree of a country's overall interdependence with other countries. This measure does not take the direction of the dependencies into account. Its theoretical range is 0 to 1. Countries scoring 0 are militarily independent of other countries. Countries scoring 1 are totally militarily dependent on other countries. *Monadic interdependence* is defined as the sum of a country's ondependence and outdependence divided by the total of ondependence, outdependence, and self-reliance:

$$MONINT_i = \frac{OUTDEP_i + ONDEP_i}{OUTDEP_i + ONDEP_i + d_{i,i}}.$$

The Monadic-Interdependence Balance

The monadic-interdependence balance reflects the net dependence on or of a given state. A positive dependence balance indicates that a state's outdependence outweighs its ondependence and indicates a greater dependence of other actors on the state than dependence of the state on other actors. A negative dependence balance indicates the opposite and occurs when a state's ondependence outweighs its outdependence. The monadic-interdependence balance is defined as the difference between ondependence

and outdependence, divided by the total of ondependence, outdependence, and self-reliance:

$$MONINTBAL_i = \frac{OUTDEP_i - ONDEP_i}{OUTDEP_i + ONDEP_i + d_{i,i}}.$$

Derivation of Maximum Dependence for Ondependence and Outdependence

Proposition

Maoz standardizes ondependence and outdependence as the ratio of the actual ondependence and outdependence measures to the maximum possible value. Given n states and a maximum level of dependence between any two states of k , the maximum total dependence of a state on all other states in the system would be $k(n-1)$ at first order. At order m , the maximum level of dependence is given by the geometric series

$$\begin{aligned} d_{i(max)} &= k(n-1) + (k(n-1))^2 + \dots + (k(n-1))^m \\ &= \sum_{i=1}^m (k(n-1))^i \\ &= \frac{k(n-1)(1 - (k(n-1))^m)}{n(1 - k(n-1))}. \end{aligned}$$

Verification

To verify the above proposition, we use the following identity:

$$\sum_{i=0}^n a^i = a^0 + a^1 + \dots + a^n = \frac{1 - a^{n+1}}{1 - a}.$$

Thus,

$$\begin{aligned}
 \sum_{i=1}^m (k(n-1))^m &= \frac{1 - (k(n-1))^{m+1}}{1 - (k(n-1))} - (k(n-1))^0 \\
 &= \frac{1 - (k(n-1))^{m+1}}{1 - k(n-1)} - 1 \\
 &= \frac{1 - (k(n-1))^{m+1} - (1 - k(n-1))}{1 - k(n-1)} \\
 &= \frac{(k(n-1)) - (k(n-1))^{m+1}}{1 - k(n-1)} \\
 &= \frac{k(n-1)(1 - (k(n-1))^m)}{1 - k(n-1)}.
 \end{aligned}$$

Note that this result differs slightly from that of Maoz, which includes an additional factor of n in the denominator. Maoz does not specify the source of this factor, so we do not include it in our calculations.

Then, because

$$OUTDEP_j = \frac{outdep_j}{d_{j(max)}}$$

and

$$ONDEP_i = \frac{ondep_i}{d_{i(max)}},$$

we have

$$\begin{aligned}
 OUTDEP_j &= \frac{\sum_{i=1}^n d_{ij} - d_{jj}}{\frac{k(n-1)(1 - (k(n-1))^m)}{1 - k(n-1)}} \\
 &= \frac{(1 - k(n-1))(\sum_{i=1}^n d_{ij} - d_{jj})}{k(n-1)(1 - (k(n-1))^m)}
 \end{aligned}$$

and

$$\begin{aligned}
 ONDEP_i &= \frac{\sum_{j=1}^n d_{ij} - d_{ii}}{\frac{k(n-1)(1 - (k(n-1))^m)}{1 - k(n-1)}} \\
 &= \frac{(1 - k(n-1))(\sum_{j=1}^n d_{ij} - d_{ii})}{k(n-1)(1 - (k(n-1))^m)}.
 \end{aligned}$$

Supporting Data

This appendix provides tables with data supporting the figures in Chapter 2. Tables B.1 through B.7 list the U.S. allies, as defined above, for the years 1989, 2000, and 2017. Because these allies all have the United States as an ally in common, we treated these countries as belonging to a single U.S. alliance network, even though that system consists of several multi-lateral and bilateral alliances. For each network layer, we analyzed relations between the U.S. alliance system and the other alliance systems. We also examined the importance of individual members of the U.S. alliance system within each network layer.

TABLE B.1
U.S. Allies, 1989, 2000, and 2017:
Summary

Alliance Category	1989	2000	2017
NATO members	15	18	28
Bilateral U.S.–Asian allies	7	7	7
Rio Pact parties	22	21	17
SEATO members	6	6	6
De facto allies	3	8	8
MNNAs	5	8	17
Total	47	55	65

TABLE B.2**U.S. Allies, 1989, 2000, and 2017: NATO Members**

Country	1989	2000	2017	Country	1989	2000	2017
Albania			x	Lithuania			x
Belgium	x	x	x	Luxembourg	x	x	x
Bulgaria			x	Montenegro			x
Canada	x	x	x	Netherlands	x	x	x
Croatia			x	Norway	x	x	x
Czech Republic		x	x	Poland		x	x
Denmark	x	x	x	Portugal	x	x	x
Estonia			x	Romania			x
France	x	x	x	Slovenia			x
Germany	x	x	x	Slovakia			x
Greece	x	x	x	Spain	x	x	x
Hungary		x	x	Turkey	x	x	x
Iceland	x	x	x	UK	x	x	x
Italy	x	x	x	Total	15	18	28
Latvia			x	NOTE: x = ally.			

TABLE B.3
U.S. Allies, 1989, 2000, and
2017: Bilateral U.S.–Asia
Allies

Country	1989	2000	2017
Australia	x	x	x
Japan	x	x	x
New Zealand	x	x	x
Philippines	x	x	x
ROK	x	x	x
Taiwan	x	x	x
Thailand	x	x	x
Total	7	7	7

NOTE: ROK = Republic of Korea (South Korea). x = ally.

TABLE B.4
U.S. Allies, 1989, 2000, and
2017: Inter-American Treaty of
Reciprocal Assistance Parties

Country	1989	2000	2017
Argentina	x	x	x
Bahamas	x	x	x
Bolivia	x	x	
Brazil	x	x	x
Chile	x	x	x
Colombia	x	x	x
Costa Rica	x	x	x
Cuba	x	x	x
Dominican Republic	x	x	x
Ecuador	x	x	
El Salvador	x	x	x
Guatemala	x	x	x
Haiti	x	x	x
Honduras	x	x	x
Mexico	x	x	
Nicaragua	x	x	
Panama	x	x	x
Paraguay	x	x	x
Peru	x		x
Trinidad and Tobago	x	x	x
Uruguay	x	x	x
Venezuela	x	x	
Total	22	21	17

NOTE: x = ally.

TABLE B.5
U.S. Allies, 1989, 2000, and
2017: Southeast Asia Treaty
Organization Members

Country	1989	2000	2017
Australia	x	x	x
France	x	x	x
New Zealand	x	x	x
Philippines	x	x	x
Thailand	x	x	x
UK	x	x	x
Total	6	6	6

NOTE: x = ally. Although SEATO dissolved on June 30, 1977, after multiple members withdrew support, the U.S. Department of State considers the SEATO alliance to still be in force. See U.S. Department of State, undated.

TABLE B.6
U.S. Allies, 1989, 2000, and 2017:
De Facto Allies

Country	1989	2000	2017
Bahrain	x	x	x
Israel	x	x	x
Kuwait		x	x
Oman		x	x
Qatar		x	x
Saudi Arabia		x	x
Taiwan	x	x	x
United Arab Emirates		x	x
Total	3	8	8

NOTE: x = ally.

TABLE B.7
U.S. Allies, 1989, 2000, and
2017: Major Non-NATO
Allies

Country	1989	2000	2017
Afghanistan			x
Argentina		x	x
Australia	x	x	x
Bahrain			x
Egypt	x	x	x
Israel	x	x	x
Japan	x	x	x
Jordan		x	x
Kuwait			x
Morocco			x
New Zealand		x	x
Pakistan			x
Philippines			x
ROK	x	x	x
Taiwan			x
Thailand			x
Tunisia			x
Total	5	8	17

NOTE: x = ally.

Tables B.8 through B.13 list the allies of each of the four U.S. competitors identified in the 2018 NDS for the years 1989, 2000, and 2017 (China, the DPRK, Iran, and Russia). In this case, too, we treated each U.S. competitor's alliances as forming a single system, even though those systems consist of several multilateral and bilateral alliances. Here too, for each of the network layers, we analyzed relations between those alliance systems and the other

TABLE B.8
U.S. Competitors' Allies,
1989, 2000, and 2017:
Summary

Country	1989	2000	2017
China	1	1	8
DPRK	3	3	2
Iran	0	0	5
Russia	8	10	11
Total	11	13	17

TABLE B.9
U.S. Competitors' Allies,
1989, 2000, and 2017:
People's Republic of China

Country	1989	2000	2017
DPRK	x	x	x
India			x
Kazakhstan			x
Kyrgyzstan			x
Pakistan			x
Russia			x
Tajikistan			x
Uzbekistan			x
Total	1	1	8

NOTE: x = ally.

alliance systems in that layer. We examined the importance of individual members of each alliance system within each network layer. Finally, because of increased signs of cooperation and coordination between U.S. competitors, we also analyzed the relations between the *combined* competitors' alliance systems and other alliance systems and actors in each network layer.

TABLE B.10**China's 2017 Belt and Road Initiative Partners**

Afghanistan	Iran	Pakistan
Albania	Iraq	Philippines
Armenia	Israel	Poland
Azerbaijan	Jordan	Qatar
Bahrain	Kazakhstan	Romania
Bangladesh	Kenya	Russia
Belarus	Korea, South	Saudi Arabia
Bhutan	Kuwait	Serbia
Bosnia and Herzegovina	Kyrgyzstan	Singapore
Brunei Darussalam	Laos	Slovakia
Bulgaria	Latvia	Slovenia
Cambodia	Lebanon	Sri Lanka
Croatia	Lithuania	Syria
Czech Republic	Malaysia	Tajikistan
Djibouti	Maldives	Thailand
Egypt	Moldova	Timor-Leste
Estonia	Mongolia	Turkey
Ethiopia	Montenegro	Turkmenistan
Georgia	Myanmar	Ukraine
Hungary	Nepal	United Arab Emirates
India	North Macedonia	Uzbekistan
Indonesia	Oman	Vietnam
Iran		

TABLE B.11
U.S. Competitors' Allies,
1989, 2000, and 2017:
Democratic People's
Republic of Korea

Country	1989	2000	2017
China	x	x	x
Cuba	x	x	x
Russia	x	x	
Total	3	3	2

NOTE: x = ally.

TABLE B.12
U.S. Competitors' Allies,
1989, 2000, and 2017:
Islamic Republic of Iran

Country	1989	2000	2017
Iraq			x
Lebanon			x
Russia			x
Syria			x
Yemen			x
Total	0	0	5

NOTE: x = ally.

TABLE B.13**U.S. Competitors' Allies, 1989, 2000, and 2017:
Russian Federation**

Country	1989	2000	2017
Armenia		x	x
Azerbaijan		x	x
Belarus			x
Bosnia		x	
Bulgaria	x	x	
China			x
Czechoslovakia	x		
DPRK	x	x	
East Germany	x	Not applicable	Not applicable
Finland	x		
Hungary	x		
India			x
Kazakhstan		x	x
Kyrgyzstan		x	x
Pakistan			x
Poland	x		
Romania	x		
Syria			x
Tajikistan		x	x
Turkmenistan		x	
Uzbekistan		x	x
Total	8	10	11

NOTE: x = ally. East Germany was dissolved in 1990.

The development of allied levels of interdependence of U.S. competitors and their allies is summarized in Tables B.14 through B.19.

TABLE B.14

U.S. Allies' Dependence on the United States, 1989, 2000, and 2017: Summary

Alliance	Year			Percentage Change	
	1989	2000	2017	1989–2017	2000–2017
Rio Pact	0.2560	0.2616	0.2221	–3.40	–3.95
Asian allies	0.2565	0.2602	0.2133	–4.32	–4.69
MNNA	0.0833	0.0699	0.2128	12.95	14.29
NATO	0.2368	0.2438	0.2060	–3.08	–3.78
Mean	0.2477	0.2535	0.2008	–4.69	–5.26
Gulf Cooperation Council ^a	0.0000	0.0000	0.1252	12.52	12.52

SOURCE: Leeds, undated.

^a *Gulf Cooperation Council* is a short reference to the Cooperation Council for the Arab States of the Gulf. We include it in the table because of the 12.5-percent jump.

TABLE B.15

Average Interdependence of U.S. Competitors and Their Allies, 1989, 2000, 2017: Summary

Country	Year			Percentage Change	
	1989	2000	2017	1989–2017	2000–2017
China	0.0000	0.0000	0.1335	13.35	13.35
Mean	0.0280	0.0098	0.0470	1.89	3.72
Russia	0.1103	0.0385	0.0458	–6.46	0.73
Iran	0.0000	0.0000	0.0071	0.71	0.71
DPRK	0.0017	0.0006	0.0014	–0.04	0.08

SOURCE: Leeds, undated.

TABLE B.16**Interdependence of U.S. Competitors and Their Allies, 1989, 2000, 2017: China**

Country	Year			Percentage Change	
	1989	2000	2017	1989–2017	2000–2017
1	—	—	0.1445	14.45	—
2	—	—	0.1442	14.42	—
3	—	—	0.1425	14.25	—
DPRK	0.0412	0.0564	0.1389	9.77	8.26
4	—	—	0.1377	13.77	—
Mean	0.0412	0.0564	0.1335	9.23	7.72
Russia	—	—	0.1306	13.06	—
5	—	—	0.1159	11.59	—
6	—	—	0.1138	11.38	—

SOURCE: Leeds, undated.

TABLE B.17

**Interdependence of U.S. Competitors and Their Allies, 1989,
2000, 2017: Russia**

Country	Year			Percentage Change	
	1989	2000	2017	1989–2017	2000–2017
1	—	0.0439	0.0529	5.29	0.90
2	—	0.0435	0.0523	5.23	0.88
3	—	0.0411	0.0506	5.06	0.94
4	—	—	0.0491	4.91	—
5	—	0.0442	0.0463	4.63	0.21
6	—	0.0436	0.0463	4.63	0.27
Mean	0.1103	0.0385	0.0458	–6.46	0.73
7	—	—	0.0445	4.45	—
8	—	0.0305	0.0436	4.36	1.31
9	—	—	0.0434	4.34	—
10	—	—	0.0398	3.98	—
China	—	—	0.0349	3.49	—
11	0.1127	0.0483	—	–11.27	–4.83
12	—	0.0441	—	0.00	–4.41
13	—	0.0434	—	0.00	–4.34
DPRK	0.1115	0.0410	—	–11.15	–4.10
14	—	0.0000	—	0.00	–0.00
East Germany	0.1139	—	—	–11.39	—
15	0.1116	—	—	–11.16	—
16	0.1100	—	—	–11.00	—
17	0.1099	—	—	–10.99	—
18	0.1093	—	—	–10.93	—
Czechoslovakia	0.1038	—	—	–10.38	—

SOURCE: Leeds, undated.

TABLE B.18**Interdependence of U.S. Competitors and Their Allies, 1989, 2000, 2017: Iran**

Country	Year			Percentage Change	
	1989	2000	2017	1989–2017	2000–2017
1	—	—	0.0073	0.73	0.73
Mean	0.0000	0.0000	0.0071	0.71	0.71
2	—	—	0.0071	0.71	0.71
3	—	—	0.0070	0.70	0.70

SOURCE: Leeds, undated.

TABLE B.19**Interdependence of U.S. Competitors and Their Allies, 1989, 2000, 2017: Democratic People's Republic of Korea**

Country	Year			Percentage Change	
	1989	2000	2017	1989–2017	2000–2017
1	0.0018	0.0006	0.0012	–0.05	0.07
2	0.0019	0.0006	0.0015	–0.03	0.09
3	0.0016	0.0006	—	–0.16	–0.06
Mean	0.0017	0.0006	0.0014	–0.04	0.08

SOURCE: Leeds, undated.

Abbreviations

AFRICOM	U.S. Africa Command
AOR	area of responsibility
ATOP	Alliance Treaty Obligations and Provisions
BRI	Belt and Road Initiative
CENTCOM	U.S. Central Command
CSTO	Collective Security Treaty Organization
DME	diplomatic, military, or economic
DPRK	Democratic People's Republic of Korea
GPI	Global Power Index
IGO	intergovernmental organization
IISS	International Institute for Strategic Studies
IR	international relations
ISO	International Organization for Standardization
JME	joint military exercise
MID	militarized interstate dispute
MNNA	major non-North Atlantic Treaty Organization ally
NATO	North Atlantic Treaty Organization
NDS	National Defense Strategy
OSD	Office of the Secretary of Defense
ROK	Republic of Korea
ROW	rest of the world
SCO	Shanghai Cooperation Organisation
SEATO	Southeast Asia Treaty Organization
SIPRI	Stockholm International Peace Research Institute
SNA	social network analysis
SOUTHCOM	U.S. Southern Command
UCDP	Uppsala Conflict Data Program
UK	United Kingdom
UN	United Nations

USEUCOM	U.S. European Command
USINDOPACOM	U.S. Indo-Pacific Command
USNORTHCOM	U.S. Northern Command
USPACOM	U.S. Pacific Command
USSR	Union of Soviet Socialist Republics

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The Office of the Secretary of Defense asked the RAND Corporation to measure the strength and health of the United States' network of allies and partners. It did so with a view to determining how much the United States can continue to rely on that network in formulating and executing its defense strategy.

Using network analysis, interdependence analysis, combinatorial optimization, and simulation, the RAND team constructed global networks representing diplomatic, military, and economic elements of national power in 1989, 2000, and 2017. The team then conducted an exploratory analysis of these networks separately and in combination. The team members compared the connections, centrality, interdependence, vulnerability to disruption, risk of conflict contagion, network depth, and U.S. access to network depth per dollar of U.S. assistance provided to allies and partners of the United States. This analysis suggests that the U.S. network remains strong and robust enough that the United States can probably continue to rely on it for the formulation and execution of its grand strategy for the time being. However, the authors identified more than two-fifths of the U.S. network's member states that had experienced changes in their levels of interdependence between 1989 and 2017 that could give decisionmakers in those countries grounds to question the continuing value of their alliance ties. This suggests that policymakers should pay careful attention to the strength of the U.S. alliance network going forward and to their approach to individual countries where shifts in dependence have been significant.

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