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Short title: Complementarity in alliances

Keywords: international security, alliances, military capabilities

Author contact information:

J Andrés Gannon

[juan.gannon@vanderbilt.edu](mailto:juan.gannon@vanderbilt.edu)

Department of Political Science  
230 Appleton Place  
PMB 0505  
Nashville, TN 37203

The author is thankful to many who provided feedback on earlier and related drafts, especially Abhit Bhandari, Steven Brooks, Rosella Cappella Zielinski, Jonathan Caverley, Joshua Clinton, Andrew Coe, Benjamin Fordham, Erik Gartzke, Brenton Kenkel, Nadiya Kostyuk, Kendrick Kuo, David Lake, Nicole R. Letourneau, Jonathan Markowitz, Sara Plana, Abigail Post, Philip Roeder, Erik Sand, Kaija Schilde, Ryan Shandler, Branislav Slantchev, Jennifer Spindel, and Sanne Verschuren. Excellent research assistance was provided by the Vanderbilt University Research on Conflict and Collective Action (ROCCA) Lab and the UC San Diego Center for Peace and Security Studies (cPASS). This project benefited from financial support from the Smith Richardson Foundation, the Stand Together Trust, and the APSA Centennial Center.

## Complementarity in Alliances: How strategic compatibility and hierarchy promote efficient cooperation in international security

**Abstract** How can defense alliances reap the efficiency gains of working together when coordination and opportunism costs are high? Although specializing as part of a collective comes with economic and functional benefits, states must bargain over the distribution of those gains and ensure the costs of collective action are minimized. I argue that states can overcome these problems by forming alliances with high strategic compatibility and hierarchy. This approach minimizes opportunism and coordination costs by efficiently distributing defense capabilities, encouraging complementarity rather than redundancy. I demonstrate this by developing a novel network-level measure of division of labor and applying it to data on national military capabilities from 1970 to 2014. This research not only enhances understanding of the modern international system but also underscores the importance of these considerations for intra-alliance bargaining more broadly.

**Verification Materials:** The data and materials required to verify the computational reproducibility of the results, procedures and analyses in this article are available on the American Journal of Political Science Dataverse within the Harvard Dataverse Network, at: <https://doi.org/10.7910/DVN/VMXTRC>.

Word count: 9,893

A fundamental purpose of military alliances is to change members' defense spending. One way to do this is specializing in certain defense capabilities, taking advantage of economies of scale and operational efficiency to reduce the opportunity cost of the “regrettable necessity” of military spending.<sup>1</sup> Domestically, defense industries, constituencies, and bureaucracies create path dependence (Halperin, Clapp, and Kanter 1974; Whitten and Williams 2011), while internationally, specialization risks arise if allies fail to fulfill commitments (Snyder 1984; Palmer 1990b). To address this dilemma, states must engage in intra-alliance bargaining over the distribution of defense capabilities. Familiar problems arise when deciding what capabilities each partner should bring to the table, as actors have to consider the coordination costs and opportunism risk inherent in such collective decisions (Niou and Ordeshook 1994; Papayoanou 1997). What factors shape whether an alliances can reliable engage in collective defense, and how does that change the strategic composition of arms across allied states?

This study identifies the conditions under which alliances can overcome domestic and international obstacles to coordinate the specialization of their military capabilities to avoid duplication, and second, explains the characteristics of alliances that play a role in shaping the composition of defense portfolios. In this study, I argue that the composition of defense portfolios in military alliances provides evidence of how states manage this dilemma of complementary specialization. Rather than simply *aggregating* military capabilities, alliances vary in how they *divide* those capabilities among themselves.

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<sup>1</sup> On the societal costs of defense spending and international security, see Nordhaus and Tobin (1973, 515–17), Powell (1993), and Fearon (2018).

Building on organizational behavior research, this theory highlights how strategic compatibility and hierarchy create efficient and complementary joint warfighting forces. Strategic compatibility, or the degree to which states agree about the nature of the international threat environment, creates compatible payoff structures that increase joint warfighting efficiency. Hierarchical alliances, characterized by an asymmetric distribution of influence over security decisions, are better equipped to resolve information asymmetries and harmonize interoperability standards. By reducing opportunism and coordination costs, alliances with these two characteristics are more successful at efficiently allocating defense capabilities across actors through complementary portfolios.

To test this theory, I analyze military capabilities across alliance members from 1970 to 2014 (Leeds et al. 2002; Gannon 2023). Using these data, I develop a new index adapted from statistical ecology to measure division of labor as the complementarity of military capabilities across alliance members while also improving state of the art measures of strategic compatibility (Leeds, Mattes, and Vogel 2009; Poast 2019a) and hierarchy (Beardsley et al. 2020). The results show that alliances with high strategic compatibility and hierarchy exhibit a greater division of labor, suggesting these factors mitigate opportunism and coordination costs.

This study advances our understanding of several key issues in international politics. First, it clarifies how alliances and armaments interact (Morrow 1993; Diehl 1994), suggesting that the distribution of armaments within alliances is shaped by compatible security interests and centralized decision-making. The efficacy of military spending can only be understood in the context of what that money is spent on, and this is particularly true of allies whose spending

could be high but superfluous or low but effectual. Second, it addresses the debate over the efficacy of alliances in improving security and stability (Kimball 2010; Blankenship 2023), offering a novel mechanism – complementarity – by which allies can pool distinctly specialized capabilities to improve the efficiency of defense spending (Gannon 2024). Third, it challenges the foundational view that states behave as like-units due to the ability to use force and the absence of central authority (Stein 1982; Posen 1984), demonstrating instead that functional differentiation occurs when aligned states adopt different roles and responsibilities through cooperation (Bukovansky et al. 2012, 6–7).

The argument is organized as follows. Section 1 reviews existing explanations for how states improve their security through arming and allying. Section 2 details the theory of a shared production model of security, explaining how strategic compatibility and hierarchy can foster effective intra-alliance bargaining that promotes a division of labor in defense capabilities. Section 3 presents a quantitative empirical test of this theory using cross-national data on disaggregated military capabilities from 1970 to 2014. Section 4 concludes with a discussion of the implications of these findings for theories about intra-alliance bargaining and conflict and offers suggestions for future research.

## Existing explanations for cooperative security

A well-established literature has theorized that the two ways a state can develop a military response to foreign threats are internal balancing (arming) and external balancing (allying).<sup>2</sup> Both

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<sup>2</sup> See, for example, Altfeld (1984); Barnett and Levy (1991); Morrow (1991); Conybeare (1992); Morrow (1993); Diehl (1994); Sorokin (1994); Conybeare (1994b); Kimball (2010); DiGiuseppe and Poast (2016); Yarhi-Milo, Lanoszka, and Cooper (2016); Horowitz, Poast, and Stam (2017).

strategies share the same primary motivation: security. States develop arms as a military response to foreign threats (Conybeare 1994b; Goldman 2007; Nordhaus, Oneal, and Russett 2012) and at their core, military alliances are fundamentally an agreement about when and how to fight (Niou and Zeigler 2019; Poast 2019a). Other positive externalities can motivate both arming and allying, and these incentives may in some cases be more salient, but an expectation of improved security is a necessary condition.<sup>3</sup>

Neither arming nor allying is a strictly dominant strategy for improving security across all circumstances and contingencies. Arming (internal balancing) provides more reliable defense but is slower and costlier. (Powell 1993; Clark 2001; Poast 2019b). Allying (external balancing) provides faster access to defense but carries risks of relying on others for security (Snyder 1984; Walt 1987).

Whether arming and allying are substitutes or complements has long been debated, with a mixed empirical record (Thies 1987; Morrow 1991, 928–29; Conybeare, Murdoch, and Sandler 1994, 526). To take Europe as an example, while “one might expect a continent with both a long-established military alliance and highly integrated economies and policymaking machineries to also have a highly integrated defense economy” (Mawdsley 2018, 261), some have found that Europe’s defense market is actually quite fragmented and protectionist (Bitzinger 2009). The 27 states in the EU have a combined 25 armies, 21 air forces, and 18 navies most of which possess different weapons systems and that rarely coordinate force planning (Howorth 2007). This is not

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<sup>3</sup> Non-security reasons for alliance formation include, for example, trade and economic cooperation (Poast 2012; Haim 2016; Kinne and Bunte 2020), domestic policy concessions (Barnett and Levy 1991; Kim 2016), and influence over another state’s foreign and domestic policy (Morrow 1991; Lake 1999).

a new problem either; not long after the end of the Cold War, De Vestel (1995) noted that the redundancy of Europe's defense platforms was becoming increasingly costly. Similarly, research on extended nuclear deterrence continues to debate the relationship between the perceived reliability of a nuclear state's promise of protection and a protege's demand for nuclear and conventional arms (Bleek and Lorber 2014; Fuhrmann and Sechser 2014; Monteiro and Debs 2014; Reiter 2014; Lanoszka 2018; Narang and Mehta 2019).

This stands in stark contrast to models of international trade, where the established wisdom favors economic partnerships because the gains from each participant specializing produce an efficient and mutually interdependent division of labor. Those pessimistic about the efficacy of alliances make a more common assumption explicit; because the high politics of international security concern survival while the low politics of economics do not, true dependence on others for security is prohibitively risky and states avoid it whenever possible. When alliances do form, states join forces as "temporary marriages of convenience" (Mearsheimer 2001, 33) against today's common enemy, but they do so by aggregating capabilities rather than dividing responsibilities (Olson and Zeckhauser 1966). Proponents argue this feature distinguishes domestic and international politics (Waltz 1979, 97–99), since while there is "functional specialization - an intense division of labor" within states and other organizations, "the same is obviously not true of international politics. There, power is distributed more equally than in organizations. Moreover, it is distributed to protect no group purpose. There is no functional specialization among states." (Posen 1984, 36–37).

Conflicting empirical findings stem from inattention to the *composition* of arms aggregated across alliances. Most studies homogenize alliances (Becker et al. 2024; Gannon 2024) or aggregate defense spending (Alley 2021). As a result, the state of the art insufficiently explains why states facing a common threat vary in how they aggregate distinct capabilities against that threat. In arguing that countries in alliances specialize due to the economic and functional benefits of specialization, Gannon (2024) treats specialization as a state-level decision. But because different capabilities have distinct public and private benefits, states have to actively coordinate and bargain to ensure everyone does not specialize in the same capabilities. While extensive research has documented ways alliances themselves vary across time and space, a framework to understand when and why alliances can reliably engage in collective defense and how that changes the strategic composition of arms across allied states remains unexplored.<sup>4</sup>

Understanding this phenomenon is a worthwhile enterprise, as how each state contributes to collective security has long been (Olson and Zeckhauser 1966; Christensen and Snyder 1990; Palmer 1990a; Snyder 1997), and remains, a central question in international politics (Fuhrmann 2020; Blankenship 2023; Kinne and Kang 2023). Although the focus of this article is on the causes of a division of labor across allies rather than its consequences, the enduring political significance of this phenomenon motivates its study. Systematic empirical evidence linking alliance specialization to military effectiveness is sparse, yet several scholars propose mechanisms through which it could improve conflict outcomes. In alliances with complementary

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<sup>4</sup> On alliance reliability more generally, see Morrow (1994b); A. Smith (1995); Fearon (1997); Leeds, Long, and Mitchell (2000); Leeds (2003a); Leeds (2003b); Leeds and Savun (2007); B. V. Benson (2012); Crescenzi et al. (2012); Mattes (2012a); Mattes (2012b); B. V. Benson, Meirowitz, and Ramsay (2014); Blankenship (2020); Henry (2020); B. C. Smith (2021); B. V. Benson and Smith (2023).



military portfolios each member can focus on a smaller set of competencies, making them more successful at task execution (Bensahel 2007). Similarly, through specialization, an ally can “fill important niches in the coalition force structure, thereby magnifying the real effect of its contribution” (Lake 1999, 223–25).

The Allied invasion of Normandy in June 1944 serves as an illustrative account, as the US and the UK showcased a carefully coordinated use of resources that overcame significant logistical and operational challenges. Developing capabilities for an amphibious assault of mainland Europe had not been a priority for the United States. US shipyards were focused on rebuilding major fleet combat elements following the attack on Pearl Harbor (Greenwood 1993, 4) as well as producing escort vessels to counter German U-boats (Leighton and Coakley 1955, 17–20). And whatever amphibious capabilities the US was building were primarily dedicated to the Pacific front (Lawson 2020, 13). Instead, the task of developing large amphibious craft – like LSTs (Landing Ship, Tank) capable of crossing the English Channel (Greenwood 1993, 6) and “Hobart’s Funnies” armored fighting vehicles specialized for beach landings (Hart 1997, 165, 177) – was left to the British, who were well-suited for the task given their geographic location and experience with the tank during World War I (Larrabee 1988, 444–45; Harrison 1993, 61). Churchill emphasized the strategic importance of these craft, famously lamenting their scarcity and linking their production to the success of the Allied war effort (Lawson 2020, 13). By integrating British amphibious expertise and U.S. personnel and major combat fleet capabilities, the specialized Allies achieved the largest and most complex amphibious operation in history (Larrabee 1988, 440; Weiss 1996, 46–47).

Because such a division of labor reduces costs via economies of scale, it also serves an important domestic political purpose. President Ronald Reagan's Secretary of Defense Caspar Weinberger (1981) noted that the alternative to working side by side with NATO allies for naval responsibilities risked the US "marching alone", which would mean the United States "could lose at home the critical public support for which we have labored long and hard." Notably, such a division of labor can also be a political liability precisely because it involves working side by side. Canadian reliance on United Kingdom logistics and transport vehicles during the 2001 Afghanistan war is exemplary of this phenomenon (Auerswald and Saideman 2014, 232), as were European concerns that dependence on the United States for advanced munitions and radar during the Kosovo War exposed one-sided reliance, prompting the former German ambassador to the US von Kyaw (1999) to note "if we are not careful, we Europeans will become the Hessians of the Americans...we never have a guarantee against neoisolationist developments. Nobody knows how Congress will decide. Nobody knows what sort of U.S. president we might have."

While this study does not empirically test the link between alliance specialization and combat outcomes or political bargaining, it underscores the strategic logic of a division of labor, with potential implications for international and domestic politics. These logics and historical accounts suggest that complementary military capabilities can align with an alliance's broader military needs and intervene in domestic political processes, even if robust empirical evidence remains an area for future research.

# A shared production model of security

Under what conditions can allies ensure successful military cooperation? Alliances are a promise to cooperate with another actor under a given set of contingencies (Morrow 2000, 63–65). That cooperation requires the actors to provide something that makes the other actor better off than if they acted alone. Much research on bargaining within alliances starts with the Ricardo (1817) model of comparative advantage in trading goods based on differences in production costs (Snyder and Diesing 1977; Snyder 1984, 1997; Palmer 1990a; Morrow 1993). Who provides what matters because contributions to an alliance differ in their private benefits (economies of scale), public benefits (contribution to aggregated defense), and asset specificity. Because the efficiency of a complementary division of labor over these capabilities produces individual and collective gains, the distribution of these gains requires intra-alliance bargaining over the terms of that cooperation (Papayoanou 1997).

While Gannon (2024) establishes the foundational link between alliances and specialization, this manuscript introduces strategic compatibility and hierarchy as the mechanisms of complementary specialization. Complementarity is not merely the presence of specialization but the deliberate differentiation of roles and responsibilities among allies to create an integrated and interdependent defense posture. The central argument is that intra-alliance bargaining reduces opportunism and coordination costs when (1) strategic compatibility is high, meaning members have similar security interests (Papayoanou 1997; Poast 2019a) and (2) the alliance is hierarchic, allowing a small number of participants to dictate the terms of the bargain (Krasner 1991; Lake 2001). Under these conditions, states are able to produce complementary militaries in ways that

garner the efficiency gains of specialized production while maintaining the security gains of a diversified defense portfolio. If intra-alliance bargaining fails because strategic incompatibility has widened the bargaining range and/or because one actor cannot sufficiently dictate the terms of the bargain, there will not be a shared division of labor over the production of security. In this way, a division of labor serves as evidence of confidence in the durability of an alliance since “[s]pecialization of forces may leave both allies exposed to other threats” (Morrow 1994b, 272). States will design defense portfolios that rely less on the capabilities of others and are thus more redundant and self-reliant. After outlining the broader problem of security cooperation in Section 2.1, Section 2.2 and Section 2.3 detail the effectiveness of strategic compatibility and hierarchy, respectively, as solutions.

## Barriers to cooperation under anarchy

A state’s decision about whether to cooperate with other states over the ownership and use of security assets is a function of three factors - the gains from cooperation, the expected cost of opportunism, and the expected cost of coordination (Axelrod and Keohane 1985; Oye 1985; Lake 1997).<sup>5</sup> While these features are a hallmark of the collective action problem more generally, they are particularly pronounced in the context of international security cooperation since that requires resolving integrated command and control, intelligence sharing, and interoperability of

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<sup>5</sup> While I here focus on defense pacts as the primary institution through which states coordinate strategies to jointly produce security (Sandler and Forbes 1980; Murdoch and Sandler 1982), there is an extensive body of research concerning different forms of defense cooperation and security alignments (Lake 1996; Weber 1997, 2000; Adler and Barnett 1998; Haftendorn, Keohane, and Wallender 1999; Leeds et al. 2002; B. V. Benson 2012; Wilkins 2012; Kinne 2018; Edgerton 2024). The theory may generalize to other less formal forms of defense cooperation, but I only analyze defense pacts as the clearest and easiest case of an arrangement where states may have agreement about the use and division of force.

complex and constantly evolving systems (Bensahel 2007). The gains from cooperation include economic benefits from economies of scale (Cappella Zielinski and Poast 2021), political benefits from the efficiency gains of focusing on core competencies (Hoffmann 2005, 129–31), and security benefits from improved performance at particular security needs (Gannon 2024). After all, one of the expected payoffs from developing relationships with strategically compatible states is the expectation that some aspect of your ally's military resources are available during war (Olson and Zeckhauser 1966; Conybeare 1992).

The expected cost of opportunism is a function of the severity and likelihood of abandonment, entrapment, and exploitation (Snyder 1984; Christensen and Snyder 1990). Relying on another state that may renege when asked to contribute to your defense could seriously jeopardize a state's security (Dekker 2004). If this risk is seen as high, states should instead opt to produce security on their own. Opportunism via abandonment (shirking or buck-passing), entrapment (chain ganging), or exploitation can prove fatal to a state that depends on another for defense, especially if that dependence took the form of omitting necessary defense assets. Avoiding this requires avenues for communication and routines for interaction that mitigate concerns about opportunism and the cost of war sufficient to encourage coordinated military strategies (Ikenberry 2001, 65–69; Wolford 2014). Relying on partners risks losing autonomy over the conduct of combat, creating uncertainty over cooperation's net impact on security goals (Morrow 1991). As Auerwald and Saideman (2014, 232) put it, “in alliance warfare, allies sometimes do not always show up when needed or they show up but are not able to do what is needed.”

While opportunism costs concern *partner* uncertainty, coordination costs involve *task* uncertainty (Oxley 1997). Coordination costs reflect the effort required to ensure the relationship achieves the expected benefits, including communication and making adjustments in response to your partners' actions (Gulati and Singh 1998; White 2005, 1385). Even with identical interests, actors must still designate roles and contributions. This is fundamentally an issue of information asymmetry (Bearce, Flanagan, and Floros 2006), so creating a "common knowledge assumption" can induce and stabilize cooperation by reducing uncertainty about the other actor's payoffs structure and conveying one's own payoff structure to your partner (Gulati and Nohria 1992, 19).<sup>6</sup> Theories of international cooperation inspired by Williamson (1985) and the accompanying transaction cost framework have been less concerned with coordination costs, instead arguing opportunism costs drive most of the variation in security relationships (Lake 1996). Coordination costs may not be particularly salient in contexts where resources are simply pooled, but that is not the case in the security context (Overhage 2013). It is quite difficult to fight a war with another state's tools. In defense, "duplication of facilities, differences in requirements, coordination problems, lack of clear control and delays due to different budgetary systems all tend to increase the costs of collaborative projects" (R. Smith 1996, 69–70).

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<sup>6</sup> I make a weak common knowledge assumption in the intra-alliance bargaining process whereby alliance partners have a reasonable amount of certainty about each other's threat environment and military capabilities. While not strictly true in all cases, allies do generally have an incentive both to believe their partner and be honest with them since lying to your partner about those things creates costs from false compatibility or unnecessary duplication.

## Cooperative benefits of strategic compatibility

I define strategic compatibility as the consistency of states' security interests and degree to which they agree on the nature of the possible international threat environment (Poast 2019a, 5). This involves two dimensions: consistency about who constitutes a security threat and the salience of those shared threats.<sup>7</sup> When security interests among states are consistent, an adversary that poses a threat to one state's security interests also poses a threat to the other states' security interests (Yarhi-Milo, Lanoszka, and Cooper 2016; Markowitz and Fariss 2018). Salience of those shared threats means that the threat is a high priority for the states in question due to the military power of the adversary. During the Cold War, for example, not all Warsaw Pact states got equal military attention from NATO strategic planners. Bulgaria, in particular, was noted as militarily weak and thus little was done to coordinate Western defense portfolios regarding that specific threat (Nelson 1989). Naturally, the more diverse the threat environment the harder it will be to achieve an efficient division of labor. In a singular threat environment, where all alliance members focus on a single adversary, a division of labor is easier to achieve. By contrast, a diverse threat environment complicates coordination, as members must balance multiple security concerns. Even where there is strong alignment on both the nature and salience of the threats, more possible scenarios for future conflict opponents makes complementarity harder to achieve.

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<sup>7</sup> Poast (2019a) separates his concept of ideal war plan compatibility into strategic compatibility and operational compatibility. My definition is consistent with how he thinks about strategic compatibility, while operational compatibility – defined as similarity in military doctrine concerning agreement on how to meet the threat – is most similar to my dependent variable. One reading of my argument is that successful operational compatibility – agreement about how to *jointly* meet a threat – is a function of strategic compatibility.

Strategic compatibility is conducive to a division of defense labor because it increases the gains of cooperation and reduce opportunism and coordination costs.<sup>8</sup> In cases of high strategic compatibility, states are more likely to have compatible payoff structures regarding behavior conducive to the creation or maintenance of the ideal international environment (Axelrod and Keohane 1985; A. Smith 1995; Johnson, Leeds, and Wu 2015).<sup>9</sup> In the event of a potential military contest with an adversary, this creates an incentive to make more effective coalition contributions (Snyder 1984; Stueck 1997; Kreps 2011; McInnis 2019; Cappella Zielinski and Grauer 2020). This also reduces the risk of opportunism because the presence of a common objective that both actors seek produces higher payoffs to conscious policy coordination (Oye 1985; Thies 2003; Wolford 2014).

Intra-alliance bargaining becomes easier when similarity of interest expands the bargaining range; participants want to ensure that each actors' participation is augmenting the efforts of the others (Wolford 2015). Snyder (1997, 166) writes that "among the most prominent issues in intra-alliance bargaining are the coordination of military plans, the stance to be adopted toward the opponent in a diplomatic crisis, and the sharing of preparedness burdens in peacetime." The gains from a division of labor can now be realized if the accompanying costs have been sufficiently reduced. High strategic compatibility increases willingness to adopt shared security production by reducing the expected costs of opportunism and coordination. By increasing the

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<sup>8</sup> Some degree of strategic compatibility is necessary for security-motivated defense cooperation, but it is not a sufficient condition for cooperation (Gibler and Rider 2004).

<sup>9</sup> I assume homogeneity in what alliance members are willing to fight for. But whether alliance partners agree that the expected costs of war are preferable to the demands they would otherwise concede could create different reservation points across allies (Wolford 2015).



expected gains of cooperation and overcoming the expected costs of opportunism and coordination, high strategic compatibility can increase states' willingness to embrace a shared production model of military capabilities.

Under complementarity, the gains from economies of scale mean that each state is better off than if they simply added their redundant military capabilities together. Each state can specialize in distinct capabilities that take advantage of their relative economic and geographic advantages in a way that allows them to jointly focus resources and innovations efficiently (Gannon 2024).

*Hypothesis 1: Defense alliances with high strategic compatibility should have a higher division of labor than alliances without high strategic compatibility.*

## Cooperative benefits of hierarchy

I define hierarchy as a security community with an asymmetric distribution of influence where a small number of dominant actors authoritatively control the behavior and characteristics of a larger number of subordinate actors (Zaheer and Venkatraman 1995; Donnelly 2006).<sup>10</sup> In contrast to its early conceptualizations, hierarchy here is a structural attribute of a community defined by its relations; a network of actors has some observable degree of hierarchy defined by the nature of their relationships (MacDonald 2018; Beardsley et al. 2020).<sup>11</sup> Influence within the

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<sup>10</sup> I scope my analysis to security hierarchies and think about them narrowly as a contract-functionalist arrangement deliberately constructed by purposive agents to advance their interests. See Zarakol (2017, 4–10) for an overview of different ways to conceptualize hierarchies. Similar theories have been developed on hierarchies concerning, for example, economics (Manger, Pickup, and Snijders 2012) and social status (Hobson and Sharman 2005; Larson and Shevchenko 2014; Musgrave and Nexon 2018).

<sup>11</sup> Especially concerning empirical identification and measurement, only recently has work on hierarchies in international politics shifted its level of analysis from dyads (Lake 2009; Jung and

network is asymmetric in that decisions about self-enforcement are controlled by one or a few dominant actors which contrasts with non-hierarchical communities where arrangements about defense efforts are more uniformly self-enforcing (Jung and Lake 2011).<sup>12</sup> Authoritative control means that the dominant state(s) exerts influence over the decisions of other states with varying degrees of consent and/or coercion, although the means used do not determine if a community is hierarchical (Beardsley 2024).<sup>13</sup>

Hierarchy reduces opportunism and coordination costs by structuring task division (Pondy 1977; Oye 1985) and creating mutual interdependence (Gulati, Wohlgezogen, and Zhelyazkov 2012, 533). Task division represents a coordination problem because even if they both prefer cooperation to non-cooperation, actors may disagree on the form cooperation should take and how to share its surplus gains. In a simplified context where we consider a division over the military domains of land, air, and sea, two actors may agree that they should each retain whatever ground forces are needed to defend their own territory, but they may disagree about who should provide air and naval forces that involved in collective defense. Both actors may prefer to provide the naval forces due to domestic political considerations or expected production

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Lake 2011; Nieman 2016) to networks (Beardsley et al. 2020; Kinne and Kang 2023).

<sup>12</sup> While hierarchy involves power imbalances and structures of control and decision-making, it is not strictly synonymous with either of these concepts (Lake 1997). Although some hierarchical relationships have an unequal distribution of material military power such that “a more powerful state has the material capability to intervene in and provide security for the weaker one” the presence of such a capability is not synonymous with hierarchy nor is its absence indicative of a more symmetrical relationship (Wendt and Friedheim 1995, 696).

<sup>13</sup> For contrasting views on the role of consent and coercion in hierarchy, see Holsti, Hopmann, and Sullivan (1985), Lake (1996), Hobson and Sharman (2005), Lake (2007), Lanoszka (2013), Mattern and Zarakol (2016, 632), MacDonald (2018), Mcconaughey, Musgrave, and Nexon (2018), and Nicholls (2020).

costs, but as in a coordination game their strongest preference is to coordinate their actions and complement the other party's decision.

Hierarchy means there is someone who is expected to be the leader (Galbraith 1977; Morrow 1994a, 408), and that leader can solve the coordination problem benevolently by just shouldering the burden of creating an ordering regime knowing that all alliance members will benefit (Kindleberger 1986, 288–305) or it could do so in a self-interested way because hierarchy allows that actor to establish the regime that it prefers (Krasner 1976). Because such coordination involves high transaction costs, weaker states in particular benefit from joining a hierarchical as opposed to non-hierarchical alliance regime because another actor shoulders the coordination costs that a weaker state is unable to overcome even if doing so reaps the benefits of coordinated defense efforts (Weber 1997, 329; Gulati and Singh 1998, 304).

The dominant state delegates nodes of responsibility to the subordinate state either because those tasks are less important niche capabilities or because the subordinate state can perform those tasks at a lower cost given comparative advantage offered by geography or industrial capacity (Sugiyama and Sugawara 2017). By transferring a purely exchange relationship into a power relationship, hierarchy ensures unified command and standard operating procedures that create the type of task coordination needed for a division of responsibility (March and Simon 1958; Galbraith 1977; Gulati and Singh 1998; Koremenos, Lipson, and Snidal 2001). Under either mechanism, hierarchy serves as a regime that makes coordination easier by centralizing the flow of authoritative communication which ensures that “information can spread among the entire group via a minimum number of connections” (Zafeiris and Vicsek 2018, 55) and by minimizing

information failures through “strong and clear rules government behavior...between networks of states linked under a common leader” (Lake 2009, 101).<sup>14</sup>

While the dominant state takes the leading role in structure task division, hierarchy can also reduce opportunism through mutual interdependence.<sup>15</sup> Because it is easier to catch flies with honey than vinegar, states in hierarchical alliances can collectively agree upon differentiated obligations to manage collective problems given the inequality of their material capabilities (Ikenberry 2001, 35–77; Beardsley 2024). Even where the strong state is determining the terms of the agreement, in hierarchical alliances both the dominant and subordinate states are able to leverage the power of their allies to achieve international outcomes that are in their favor (Davidson 2011). Smaller states may desire institutionalizing their relationship with more dominant states precisely because that increases their bargaining leverage and creates mutual interdependence (Bosse and Alvarez 2010; Schneider 2011). The dominant state benefits from such an arrangement, as it resolves credible commitment problems at a lower cost since – like mutual hostage-taking – a division of labor can reduce incentives to free ride by making some degree of dependence mutual (Williamson 1983). This provides a way for both actors to value the alliance independent of the degree of control they exercise in determining the structure and terms of that alliance (Schroeder 2004; Weitsman 2004; Bearce, Flanagan, and Floros 2006). By

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<sup>14</sup> This “authoritative communication” mechanism is consistent with experimental evidence suggesting stag’s hunt coordination games result in efficient equilibrium under one-way communication more often than two-way communication regardless of whether payoffs are symmetrical or asymmetrical (Agranov 2024).

<sup>15</sup> I here will not attempt to empirically identify which mechanism is at play, but that presents an important avenue for future research.

reducing the costs of opportunism, institutionalization makes that interdependence of tasks easier which, in turn, facilitates a division of labor (Ikenberry 2001, 75–77).

*Hypothesis 2: More hierarchical defense alliances should have a higher division of labor than less hierarchical defense alliances.*

In sum, I predict a high division of labor in alliances that have high strategic compatibility and that are hierarchical because the expected gains of cooperation exceed the expected costs of opportunism and coordination. In this situation, purposeful functionally differentiation across militaries is possible and desirable despite a division of labor creating potentially costly dependence on other states. Otherwise, allies will be composed of redundant militaries with overlapping capabilities that rarely coordinate with one another.

Importantly, both strategic compatibility and hierarchy could influence alliance formation itself, potentially impacting the observed relationship of these factors on division of labor (Poast 2019a, 67–70). Like theories skeptical about compliance with international institutions (Mearsheimer 1994; Downs, Rocke, and Barsoom 1996), alliances may form among states with high strategic compatibility and when hierarchical structures are accepted because they find it easier to coordinate when they already have much to gain, thus attenuating the observed relationship between strategic compatibility and hierarchy on the division of labor. Alternatively, alliances may form in cases of low compatibility or the absence of hierarchy because those conditions make informal ad-hoc cooperation uncertain or abandonment likely, which could overestimate the relationship of these variables with a division of labor (Snyder 1984; Gannon and Kent 2021). While difficult to entangle both theoretically and with observational panel data, these

dynamics suggest that alliance formation and internal cooperation are intertwined, which future research could explore further.

## Characterizing alliances

I differentiate alliances over time and space by operationalizing the two variables described earlier – strategic compatibility and hierarchy – to identify their association with division of labor within an alliance. Despite the well-recognized challenges of empirically measuring these variables (MacDonald and Lake 2008; Häge 2011), recent methodological innovations concerning similar concepts provide means to improve existing measures (Poast 2019a; Beardsley et al. 2020).

## Measuring the division of defense labor

I conceptualize security as an output that requires a number of distinct *tasks* (observed as military capabilities) that can be distributed among some number of members of an alliance (Gorelick et al. 2004).<sup>16</sup> The division of labor over the production of this security output can be quantified as the degree to which members of the alliance specialize in one task versus performing all tasks and whether a task is performed by one alliance member or many of them (Gorelick and Bertram 2007). When multiple allies possess the same military capabilities and omit the same military capabilities, their division of labor is low and can be described as

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<sup>16</sup> I assume that these technologies could at least in theory be allocated to the defense of other allied states. Some capabilities are harder to transport far away and states are members of multiple alliances (Gibler and Wolford 2006, 137–38; Adler and Greve 2009; Kinne 2013a; Li et al. 2017), complicating inferences about whether a state's possession of a particular military capability is associated with one alliance as opposed to another. This will be discussed in the empirical model.

redundant – neither is making a substantial unique contribution to their “pooled” defense capabilities. By comparison, when multiple allies possess different military capabilities from one another, they each fill in the gaps such that the combination of their capabilities is distinct from that of any individual state.

The unit of analysis is an alliance-year defined as a network of states that share a defensive alliance pact. Alliance membership is measured annually using the Alliance Treaty and Provisions (ATOP) data set version 5.1 (Leeds et al. 2002). The division of labor among states in an alliance is calculated annually as their ‘niche overlap’ – the weighted mean similarity of military portfolios (Araújo et al. 2008; Dormann et al. 2009). This is measured using the Distribution of Military Capabilities (rDMC) dataset providing country-year counts of military capabilities across roughly 70 categories (Gannon 2023).

For each alliance-year  $t$ , consider a bipartite network as an  $n \times m$  matrix with a row for each alliance member  $N$  and column for each technology  $M$ .  $\theta_{ij} = \sum_m m \in (p_{\mathfrak{z}} p_{jm})$  describes the mean similarity measure for state  $i$  and every state  $j \neq i$  where  $p_{\mathfrak{z}}$  and  $p_{jm}$  represent the relative proportions of technology  $m$  within each state  $i$  and  $j$ , respectively, as well as the relative proportion of technology  $m$  across all states (Hurlbert 1978; Zaccarelli, Bolnick, and Mancinelli 2013). A division of labor can thus be observed as the complementarity associated with high dissimilarity since it means your partners possesses capabilities you do not and visa versa.

The distribution of this index across the entire universe of alliance-years is shown in Figure 1. To contextualize the variation, the figure shows that in 2002 the Australia, New Zealand, and United States Security Treaty (ANZUS) had a higher division of labor than the population average,

while the Collective Security Treaty Organization (CSTO) had a lower division of labor than average in the same year. The high division of labor for ANZUS reflects the alliance's ability to coordinate military capabilities across its members, with the Australia and the United States developing a strong expectation of mutual support and military commitments through Australia's development of expeditionary forces and naval surveillance capabilities while the United States contributes nuclear extended deterrent capabilities (Von Hlatky 2013, 113–37). Contrastly, the CSTO's inability to even establish a functioning rapid reaction force is emblematic of a “propensity to defect from cooperation” where each states prefers to “establish separate regional armed groups designated to meet the defense needs of specific members of CSTO” (Davidzon 2022, 172).

[FIGURE 1 ABOUT HERE]

This measure has a few unique properties that make it well-suited to the task at hand. Unlike other measures of portfolio similarity, this measure can account for actors with very sparse military portfolios, was developed to account for wide differences in the availability of technologies across a sample, and is scale-invariant which allows for comparisons of relative complementarity across alliances of different sizes and years with different technologies (Hurlbert 1978; Manthey and Fridley 2009). Additionally, the measure includes the simultaneous weighting of capability distribution within and across actors, as it quantifies the interdependence between state nodes and technology nodes as mutual entropy (Bolnick et al. 2002; Gorelick and Bertram 2007). The index consequently measures the redundancy of military portfolios across countries relative to a baseline prior expectation informed by the distribution of capabilities



within each state and the distribution of each capability across states. For example, in a bilateral alliance in 2000 where each partner possesses 150 main battle tanks, that capability similarity does not contribute very much to their overall similarity because main battle tanks are generally quite common and those two states possess the modal value in that year. By contrast, a bilateral alliance where each partner possessed 150 ICBMs would, as a result, have more similarity given the rarity of that capability globally makes two states possessing that capability in similar and unusual quantities unlikely.

## Measuring strategic compatibility

Strategic compatibility describes the consistency of states' security interests and agreement on the nature of the international threat environment. I create a new index of strategic compatibility across alliance members in a given year by first creating an annual measure of each state's geopolitical threat environment, defined as the actors within a state's geopolitical environment with whom competition could involve coercive bargaining intended to degrade that state's perceived security (Maoz 1996; Powell 1999; Markowitz and Fariss 2018; Beardsley 2024).

Scholars have long moved past the view that anarchy means every state is a threat to every other state (Powell 1993); instead, whether a state constitutes a geopolitical threat is a function of foreign policy orientation and power (Leeds and Savun 2007; Poast 2019a). This is coded as any state B that meets at least one of the following criteria:<sup>17</sup> (1) strategic rivals, meaning both states perceive each other as enemies and resource competitors (Bremer 1992; Thompson 2001;

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<sup>17</sup> The appendix (p. 4-6) contains a more thorough description of the three criteria – including definitions from the primary sources – as well as a comparison of their coverage. This measure relies heavily on the extensive efforts of all of the scholars mentioned, but particularly Leeds and Savun (2007) and Poast (2019a), as I largely combine and slightly modify their measures.

Colaresi, Rasler, and Thompson 2008) using data from Thompson, Sakuwa, and Suhas (2021, 34–46); (2) peace scale rivals, coded as a “severe rivalry” or a non-allied “lesser rivalry”, meaning both states have war plans, unresolved issues, and “see the use of military force as a legitimate means for resolving disputes” (Goertz, Diehl, and Balas 2016, 34; Diehl, Goertz, and Gallegos 2021); or (3) politically relevant threat environment, meaning state B is contiguous or a great power (Maoz 1996, 168; Lemke and Reed 2001; M. A. Benson 2005; Bennett 2006) *and* it is non-allied with a kappa chance-corrected alliance similarity score below the population median (Cohen 1960; Häge 2011; Chiba, Johnson, and Leeds 2015). This includes politically relevant dyads with inconsistent foreign policy orientations (Leeds and Savun 2007; Leeds, Mattes, and Vogel 2009).

These criteria identify states with whom one is likely to engage in coercive bargaining based on willingness (foreign policy orientation) and capability (power); its strategic rivals, its negative peace rivals, and its politically relevant threat environment.<sup>18</sup> Following Poast (2019a, 55), I then identify the threats that all states in an alliance have in common each year and sum their Composite Index of National Capability (CINC) scores.<sup>19</sup> So if State A and State B had a bilateral alliance and State A’s threat environment was composed of State X and State Y while State B’s threat environment was composed of State Y and State Z, that bilateral alliance’s

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<sup>18</sup> Dangerous dyads have been used to identify threats based on dispute density and conflict history (Bremer 1992; Klein, Goertz, and Diehl 2006), but they are inapplicable here as they are endogenous with alliance military capabilities (Leeds 2003b). Dangerous dyads also assumes that states one has fought constitute threats and that those one hasn’t fought aren’t, despite much historical evidence to the contrary (Thompson 2001, 574; Poast 2019a, 53–55).

<sup>19</sup> This differs from Poast (2019a, 55–56) in that his measure of strategic compatibility is binary, not continuous, and is a ratio of the count of shared versus non-shared threats, rather than shared threats weighted by CINC score.

shared threat environment would be the CINC score of State Y, since it is the only state in both alliance members' threat environment. The measure is continuous and scaled between 0 and 1 where higher values represent an alliance where all members share a highly salient common threat environment. While formal alliance membership itself may not change rapidly or substantially, this measure allows more variation within and across alliances as threats to alliance members change. Figure 2 shows the evolution of US-Japan strategic compatibility as existing shared threats like the Soviet Union became less powerful (Wallander 2000) and as changes in states' foreign policy orientation altered when China and North Korea were considered shared adversaries by the US and Japan (Lind 2004).

[FIGURE 2 ABOUT HERE]

## Measuring hierarchy

Alliances are joint-production security communities. Defined as the distribution of authoritative control of security decisions across actors in a community, hierarchy is thus a community-level measure based on the relative influence of actors within that community.<sup>20</sup> An alliance is more hierarchical if its members have differing levels of influence on security-production decisions. Arms sales dependence has been used by many recent works to measure asymmetry in the relative influence of each state on its security community (Kinne 2012; Beardsley et al. 2020; Chou, Teng, and Tung 2023). This appropriately measures my conception of hierarchy because a dominant state is not simply one that possesses a high concentration of defense capabilities, but

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<sup>20</sup> Measurements of hierarchy have evolved beyond dyadic measures due to methodological advancements in network analysis (Hoff and Ward 2004; Maoz 2010, 2012; Poast 2010, 2016; Warren 2010; Dorff and Ward 2013; Kinne 2013b; Cranmer, Menninga, and Mucha 2015; Cranmer and Desmarais 2016; Fordham and Poast 2016; Galambos 2024).

because it “reside[s] in central positions in networks of exchange” (MacDonald 2018, 131).

Armaments are vital war input materials (Cappella Zielinski and Poast 2021), and the ability to determine what arms allies possess constitutes an important degree of authority over decisions about the joint-production of security in a community (Turner et al. 2019; Beardsley et al. 2020, 735–36). An alliance where all states are equally central in arms exchange is non-hierarchical. But if one or a few states produce and distribute many of the capabilities that its partners possess, the alliance is relatively more hierarchic because that network has a structural power imbalance that comes from a few states influencing the production of security (Morrow 1991; Kahler 2009).

To measure this, I create an annual global network with weighted directed edges accounting for arms sales between each pair of states using the “SIPRI Arms Transfers Database” (2024) Trend Indicator Values (TIV). Within each alliance, I identify the importance of each state to the overall structure of the network by measuring the consequence of that actor’s removal from the network on that alliance’s stock and flow of arms. This is quantified as the network’s ability to respond to the loss of that node; the more change that is required to stabilize the network after a given node has been removed, the more important that node was to the structure of the network (Qi et al. 2012). Computationally, this is a measure of each state’s Laplacian entropy

$$C_L(v_i, G) = \frac{(\Delta E)_i}{E_L(G)} = \frac{E_L(G) - E_L(G_i)}{E_L(G)} \text{ where } G \text{ is a weighted network with vertices}$$

$V(G) = (v_1, v_2, \dots, v_n)$  and directed edges  $w_{ij}$  with non-negative integer weights (Gutman and

Zhou 2006; Guerrero 2022).<sup>21</sup>  $G$  and  $G_i$  refer to the original network and the network with node  $i$  removed, respectively, such that  $E_L(G)$  is the Laplacian entropy of the entire network.  $C_L(v_i, G)$  thus measures the amount of “effort” required to create a most-similar distribution of arms exchange across an alliance network if each actor  $i$  were removed.

For each alliance year, I then calculate  $E_L(G) = \frac{\sum_i^n \max(C_L) - C_{Li}}{n}$  as the mean of the difference

between the highest state’s value and every other value. This represents the network-level measure of hierarchy with measurable distinctions between networks with a single dominant state, those with multiple dominant states, and those where all states occupy equally central positions as security-producers in the network (Savage 2021). Figure 3 demonstrates the construction of this measure for NATO in 1975. In Figure 3a, the alliance’s joint-production of security is measured as the flow of arms throughout the network from each member to the others. Figure 3b quantifies the consequence of each member of the alliance being theoretically removed from the alliance with higher values indicating a larger “shock” to the network if that node were removed. The results are consistent with the historical record in identifying the most central security-producing NATO members as the United States followed by France and the United Kingdom.

This measure is similar to, and positively correlated with, other measures of network centrality.<sup>22</sup> It differs in accounting for weighted and directed edges and being invariant to network size

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<sup>21</sup> As states are represented in the network as vertices, this is quantified as the sum of squares of the eigenvalues in the matrix of arms sales (Boley, Buendia, and Golnari 2018; Cordeiro et al. 2018). The notation provided is taken from the formal proofs in Qi et al. (2012).

which allows across-alliance comparisons. Additionally, because this measure accounts for the overall flow of armaments in the whole network, the dependence of each state on others accounts for the relative amount of arms they receive from that actor as well as the other states who in turn depend on that state. In other words, if State A is the sole arms provider to State B who then provides a majority of the arms for States C, D, E, and F, that downstream dependence makes State A important despite being a degree removed from the majority of arms recipients.

[FIGURE 3 ABOUT HERE]

## Empirical models and results

With these new measures, I can now quantitatively identify the association between an alliance's ability to engage in intra-alliance bargaining and that alliance's division of defense labor. The dependent variable is the division of labor, with higher values representing more complementarity and less redundancy.<sup>23</sup> As the dependent variable is continuous, the models are estimated using a series of simplified and fully specified ordinary least squares (OLS) regressions, as the best unbiased linear estimator should be optimal under common assumptions (Portnoy 2022). I account for the panel nature of the data with various time trend and standard errors clustering specifications given the non-independence of repeated alliance observations and

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<sup>22</sup> This measure has been previously used to identify the relative importance of central actors in terrorist networks (Qi et al. 2013) and cyber operations (Aksoy, Purvine, and Young 2021).

<sup>23</sup> Since the theory is about variation in the institutional characteristics of alliances, limiting the scope to observed alliances is not selecting on the dependent variable since there is no comparison being drawn between alliances and non-alliances (Vance and Ritter 2014). This is consistent with prior research on the design of security institutions (Leeds and Anac 2005; Leeds and Savun 2007; Chiba, Johnson, and Leeds 2015).

since the evolution of technologies over time may impact the observed division of labor and the error structure of the model. The first pair of models accounts for time trends using cubic year polynomials (Carter and Signorino 2010), the second pair instead include year fixed effects (Bell and Jones 2015; Plümper and Troeger 2019), and the final pair are hierarchical multilevel models nesting observations within year (Hazlett and Wainstein 2022).<sup>24</sup>

For each model specification, I first include only the explanatory variables to avoid post-treatment bias and over-adjustment, especially given the panel data has unspecified temporal dynamics (Montgomery, Nyhan, and Torres 2018; Clarke, Kenkel, and Rueda 2018; Dworschak 2023). I add control variables existing research suggests could influence military portfolio similarity or security cooperation.<sup>25</sup> To account for other features of alliance design, the models control for peacetime military coordination indicating the presence of peacetime integrated military command and a common defense policy (Leeds and Anac 2005). Democratic allies may differ in trust and expectations of cooperation so, I control for the proportion of alliance members with a Polity score greater or equal to 6 (Chiba, Johnson, and Leeds 2015; DiGiuseppe and Poast 2016; Warren 2016; Fjellstul and Reiter 2019). Because geographic proximity may better enable allied states to cooperate (Bak 2018) and increases the chance two states fight alongside each other (Gartzke and Gleditsch 2022), the models control for the proportion of alliances members that are contiguous and the maximum capital to capital distance across

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<sup>24</sup> Unit fixed effects are omitted because they assume exogeneity between past treatment and current outcome as well as past outcome and current treatment which is not true for these data and is hard to measure given the unknown and heterogeneous temporal lag in anticipated treatment effect (Imai and Kim 2019).

<sup>25</sup> Many variables were compiled using peacesciencer (Miller 2022).

members (Fordham and Poast 2016). As discussed in Section 2.2, more diverse threat environments make it harder to coordinate a division of labor, so the models account for the logged number of total threats faced by all alliance members. A control for the logged number of states in each alliance year accounts for the fact that more partners increases the potential for capability overlap (Chiba, Johnson, and Leeds 2015) and because the benefits of hierarchy decline with group size (Beek et al. 2024). Established alliances with deeper roots have an easier time cooperating, so I include the average number of years each member has been in the alliance (Palmer 1990a; B. V. Benson and Clinton 2016).

[TABLE 1 ABOUT HERE]

These primary results are presented in Table 1. Across all model specifications, strategic compatibility and hierarchy both have a positive and statistically significant association ( $p < 0.05$ ) with the division of labor in a military alliance. This provides suggestive evidence that alliances with high strategic compatibility and hierarchy are more likely to have a high division of labor in the military capabilities that their members possess, even factoring in other explanations for why states might have redundant or complementary armaments. I do not interpret the model coefficients for any of the control variables due to the absence of confounders for those variables (Keele, Stevenson, and Elwert 2020; Dworschak 2023) and also do not compare the coefficients of the fixed effects models with the cross-sectional models because they only explain across-unit variation (Mummolo and Peterson 2018; Hill et al. 2020).

The results are also substantively significant. Figure 4 illustrates the conditional effects of the two explanatory variables using an ordered beta regression, which appropriately accounts for the



bounded nature of the dependent variable (Kubinec 2022).<sup>26</sup> For strategic compatibility (Figure 4a), a one standard deviation increase centered around the mean value is associated with a 0.039 unit increase in the division of labor. Put concretely, this was how much strategic compatibility in the US-Philippine alliance increased from 1992 to 2008. The end of the Cold War reduced the salience of many of the threats that the US and Philippines jointly faced, and by 1992 the US withdrew all troops because of failure to negotiate terms justifying a continued US presence. But soon after, Chinese aggression in the South China Sea caught the Philippines' attention when they occupied Mischief Reef in 1995, prompting tension between the two states (de Castro 2009). This marked the beginning of a revival in US-Philippine defense cooperation, including the creation of a Joint Defence Assessment (JDA) mechanism in 1999 as a precursor to being designated a major non-NATO ally for the War on Terror in 2003 (Medeiros et al. 2008, 114–15). As a part of this, the US helped the Philippines specialize in counter-terrorism naval capabilities it did not itself possess while also trying to ensure it remained an effective hedge against China (Green, Hicks, and Cancian 2016, 73–78). By 2011, the US-Philippine division of labor had increased one average expected contrast given the average conditional expectations of the other covariates in the model.

For hierarchy (Figure 4b), a one standard deviation increase centered around the mean value is associated with a 0.083 unit increase in the division of labor. This is what we observe in NATO from 1975 to 2000. A decade after the end of the Cold War, NATO was more hierarchical than it had been when facing the Soviet Union. Part of this can be attributed to the increasingly

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<sup>26</sup> A table of the full ordered beta regression results is provided in the appendix (p. 3) rather than [Table 1](#) as the coefficients are on a log odds scale and not comparable to the coefficients from the other models.

dominant role of the United States in the provision of alliance security (Burton 2018) and part of it can also be attributed to NATO expansion, as the Czech Republic, Hungary, and Poland had smaller than average militaries that developed capabilities for search and rescue and air defense in an explicit attempt demonstrate their value to the alliance through the provision of niche capabilities (Herspring 1994; Danov 2001).

[FIGURE 4 ABOUT HERE]

A series of additional models in the appendix (p. 4-19) provide further evidence of a robust positive association consistent with theoretical expectations. To ensure the results are not just an artifact of new explanatory variable measurements, I estimate strategic compatibility and hierarchy using well established indices of most-similar concepts like alliance portfolio similarity, alliance institutionalization, and military power asymmetry (e.g. B. V. Benson and Clinton (2016) and Alley (2021)). I find no statistically significant results for an interaction term for strategic compatibility and hierarchy, despite research suggesting they may serve as substitutes if lower strategic compatibility requires more hierarchy or a more coercive form of hierarchy (Beardsley 2024). I also find consistent results using alternate control variables for democracy and geography as well as with the addition of control variables for NATO (Gibler and Sewell 2006), alliances with US participation (DiGiuseppe and Poast 2016), and the Cold War (Leeds and Mattes 2007; Fuhrmann 2020). Consistent results are also found with different corrections for the panel structure of the data like two-way alliance-year clustered standard errors (Chiang and Sasaki 2023). The results of a Bayesian multilevel model also produces posterior means for the expected division of labor conditional on strategic compatibility and hierarchy that

are consistent with theoretical expectations (Shor et al. 2007; Bürkner 2017), and a double/de-biased machine learning model (described in detail in the appendix (p. 19)) produces similar predictions that are robust to omitted variable bias and overfitting by using a cross-fitting split for out of sample validation (Chernozhukov et al. 2018; Bach et al. 2024).

Despite the robustness of the results across a wide variety of model specifications, the limitations of quantitative models using observational panel data warrant caution in interpreting this as evidence of a causal relationship. There is a plausibly endogenous relationship that the models cannot account for – a state’s relationship with other states influences the capabilities each state produces but the capabilities each state has at their disposal also impacts the decision to ally with another state (DiGiuseppe and Poast 2016). Furthermore, threat environments could be endogenous to alliance formation if alliances create threats rather than protect against them. And, as discussed in Section 2.3, strategic compatibility and hierarchy could influence selection into alliances itself.

Some of these endogeneity concerns are addressed with the double/de-biased machine learning model outlined in the appendix (p. 19) which mitigates bias through post-selection inference both into the sample and by separating the independent variables from the controls in a two-stage residual model, though challenges related to unobserved non-alliances remain. But even with that, these problems cannot be fully overcome with the data and methods used here. However, the goal of this study is to identify a robust empirical pattern consistent with the novel conception of alliances I have outlined with the hope that the theory and results presented here provide a justification for more causally-oriented studies. Future research could explore this

issue further by, for example, examining the conditions under which alliances form and how these conditions influence the division of labor within alliances.

## Implications and conclusion

This study advances our understanding of three foundational debates in international politics; cooperation under anarchy, burden-sharing, and allies versus armaments. First, traditional debates assume alliances and armaments are zero-sum, but since the military capabilities a state needs is a function of the military capabilities their allies possess, external balancing influences how a state internally balances. States differ in the military capabilities they choose for their security because the composition of their force structure is conditioned by those of their allies *and* the nature of their relationship with those allies. What those allies spend defense dollars on matters as much, if not more, than how much they spend. This mechanism allows states to save resources by sharing security production, freeing more for non-security purposes (Conybeare 1994a; DiGiuseppe and Poast 2016). Efficiency gains observed in alliances stem from strategic compatibility and hierarchy enabling a division of labor (Pamp, Dendorfer, and Thurner 2018; Alley and Fuhrmann 2021; Kinne and Kang 2023).

Second, the public goods theory of alliances concludes that although it would be ideal if every alliance participant contributed to collective defense, the incentive to free ride renders such a situation unlikely, even for actors behaving in their own self-interest. One conclusion from this is pessimism and distrust of alliances as a security mechanism. But competing strategies for augmenting security – internally arming or externally allying – have been treated as fungible assets compared based on their relative size. But by looking at *what* states are contributing to the

common defense, rather than how much they are spending, new perspectives on burden-sharing and the value of the alliance may emerge (Thies 1987; Blankenship 2023). What is commonly observed as free riding may actually be efficient specialization by actors participating in a division of labor (Conybeare and Sandler 1990). Actors with common security interests recognize that, if coordinated, their defense capabilities can focus on “special responsibilities” in ways that are more than the sum of their parts (Bukovansky et al. 2012, 5–17).

Third, pessimism about cooperation under anarchy is challenged not, as others have argued, by the existence of alliances, but rather by evidence that those alliances produce functional differentiation. When it comes to defense, states are not like-units (Sørensen 1998). Security cooperation goes beyond simply aggregating similar capabilities and involves mutually interdependent states adopting functionally differentiated defense roles.

This study introduces the first quantitative measure of military capability distribution, addressing an overlooked gap in understanding how states arm. Independent of the validity of the theory, the measurement produced here describes the observable world in a way that can advance the study of important topics like arms racing, military innovation, and scientific R&D cultures. The improvement in existing measures of strategic compatibility and hierarchy is also of note, given the centrality of those concepts to the contemporary study of international politics is matched only by the difficulty of their measurement.

There are important policy implications of thinking about how alliances should be configured. While alliances enhance security, coordination is costly, and defection risks must be mitigated. Divisions of responsibility over defense capabilities are evidence that strategically compatible

security interests and hierarchical security networks can accomplish this. Alliances help each participant focus on their strengths while others compensate for their weaknesses, generating more bang for the buck in more efficiently generating military force than having to go it alone. While the US possesses only 2 Arctic-capable icebreakers (as opposed to Russia's 40), 7 of the 8 Arctic nations are US allies via NATO or NATO-partners (Markowitz 2020, 76–78). This is not simply a case of the US delegating a low-priority security task to untrustworthy partners, as the Thule Air Base housing the US Ballistic Missile Early Warning System (BMEWS) can only be accessed by sea in the winter because of Canada's icebreaker fleet (Cross 2019). This US omission is rendered less costly because of its allies' strengths. By operating icebreakers in the Arctic, "allies and partners can free up U.S. time and resources to focus elsewhere" (Avey 2019). The composition of militaries, not just the amount spent, is what truly matters for dealing with future threats. As a result, what military capabilities potential or actual partners can bring to the table should be the focus of contemporary policy debates.

Successful defense cooperation involves an intra-alliance bargaining process that distributes the gains of coordinating complementary military capabilities (Snidal 1985; Fearon 1998). This study offers new insights into the conditions under which alliances overcome domestic and international obstacles to coordinate their defense portfolios. States can specialize their military capabilities in coordination with like-minded states, but they have to negotiate the terms of that cooperation which shapes who specializes in what capabilities. Building on previous work establishing the link between alliances and military specialization (Gannon 2024), this manuscript identifies strategic compatibility and hierarchy as characteristics of alliances that help achieve complementarity. In doing so, it explains why some alliances can achieve a division of

labor, while others remain trapped in redundancy. Alliances that exhibit high levels of strategic compatibility are more likely to coordinate effectively. Additionally, alliances with hierarchical decision-making structures are better equipped to manage information asymmetries and the risk of defection.

Far from being the final word, this study advances our understanding of the relationship between alliances and how states arm in a way that motivates multiple avenues for future research.

Division of labor could be systematically studied as an independent variable that explains variation in conflict outcomes and the effectiveness of coalition warfare. Also, this study assumes homogeneity in what alliance members are willing to fight for. But whether alliance partners agree that the expected costs of war are preferable to the demands they would otherwise concede could create different reservation points across allies (Wolford 2015). Additionally, I here take the alliance as the unit of analysis. While the network-based nature of this measure is an advancement beyond traditionally dyadic theories, it does not theoretically or empirically identify who within the alliance specializes and what they specialize in. Future research could examine this descriptively based on the new measure produced, and in doing so develop a novel theory about how one's degree and type of specialization is impacted by where a state is located in the alliance network. In sum, the nature of international cooperation influences *how* states arm.

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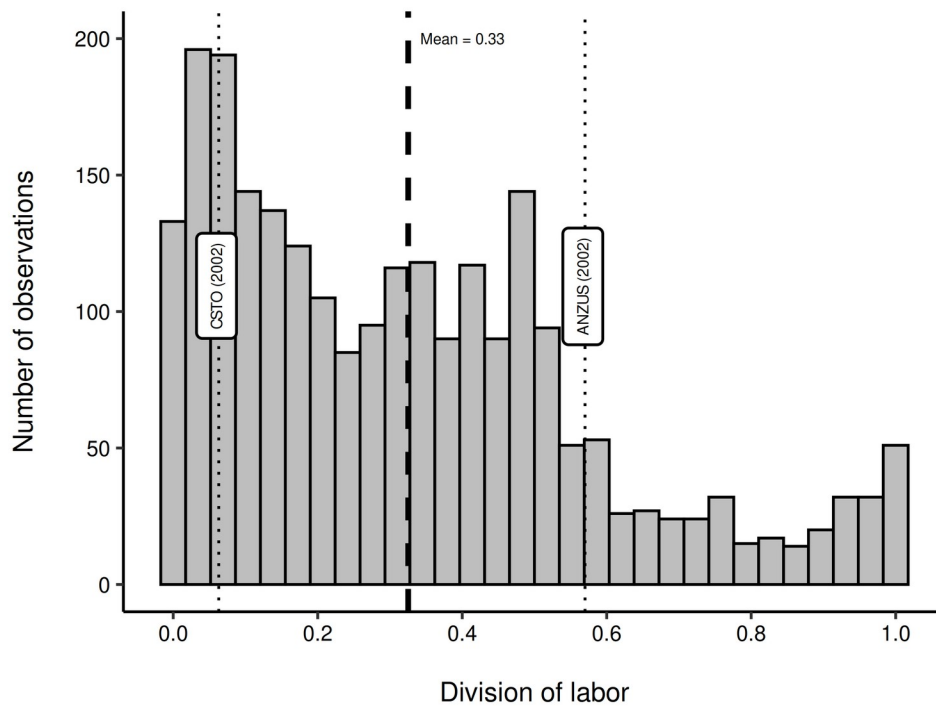


Figure 1: Division of labor index across alliance-years (1970-2014). Note: The measure is bounded between 0 and 1, with 1 representing the highest level of division of labor. Illustrative values for Collective Security Treaty Organization (CSTO) and Australia, New Zealand, and United States Security Treaty (ANZUS) shown.



Figure 2: US-Japan alliance strategic compatibility (1970-2014). Note: Y-axis shows raw non-normalized values. Higher y-axis values indicate higher aggregated Composite Index of National Capability (CINC) scores for countries in the shared US and Japan threat environment.

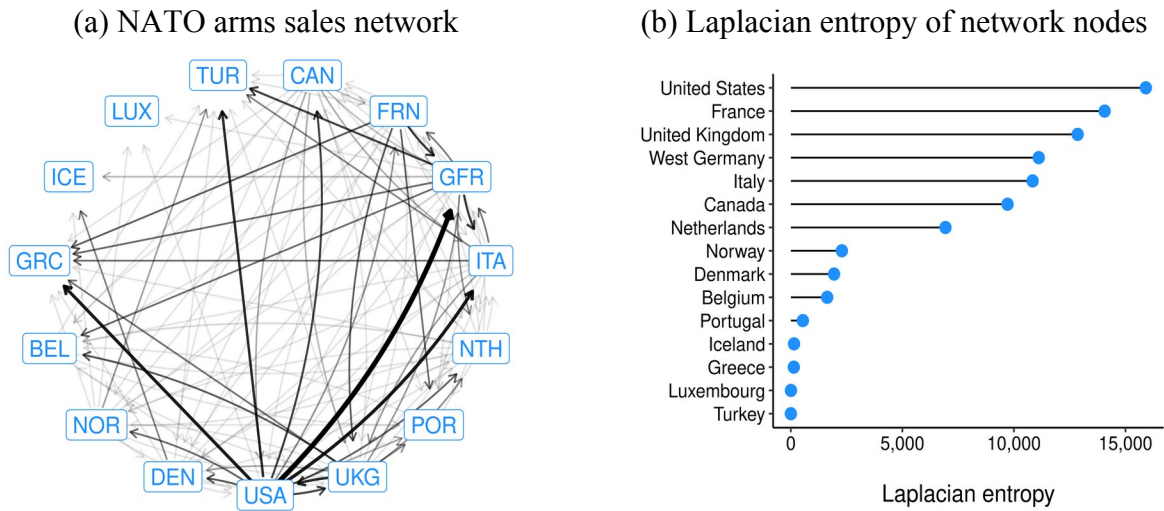


Figure 3: Hierarchy measure of security production among North Atlantic Treaty Organization (NATO) alliance members (1975). Note: Darker and thicker edges indicate higher arms sales and higher Laplacian entropy values indicate higher node importance in the network.

Table 1: Coefficient estimates for regression models.

	Year polynomials		Year fixed effects		Multilevel model	
Strategic compatibility	0.186** (0.046)	0.153* (0.061)	0.192** (0.048)	0.165* (0.064)	0.197** (0.019)	0.168** (0.024)
Hierarchy	0.403** (0.067)	0.320** (0.119)	0.397** (0.067)	0.313* (0.121)	0.396** (0.021)	0.327** (0.039)
Alliance institutionalization		0.039* (0.017)		0.039* (0.017)		0.035** (0.006)
Democracy ratio		0.118* (0.046)		0.116* (0.047)		0.116** (0.017)
Contiguity ratio		-0.127 (0.106)		-0.140 (0.106)		-0.142** (0.045)
Maximum distance (log)		-0.025 <sup>†</sup> (0.015)		-0.026 <sup>†</sup> (0.015)		-0.026** (0.006)
Number of rivals (log)		0.064* (0.027)		0.060* (0.027)		0.066** (0.009)
Number of members (log)		-0.029 (0.019)		-0.027 (0.019)		-0.031** (0.008)
Alliance age (average)		0.000 (0.001)		0.000 (0.001)		0.000 (0.000)
Number of Observations	2398	2280	2398	2280	2398	2280
R2	0.206	0.284	0.232	0.307		
R2 Adj.	0.204	0.281	0.217	0.290		
R2 Marg.					0.127	0.201
R2 Cond.					0.217	0.289
AIC	-226.4	-482.2	-226.2	-472.2	-158.4	-341.9
BIC	-191.8	-407.7	45.5	-162.7	-129.4	-273.1
RMSE	0.23	0.22	0.23	0.21	0.23	0.21

<sup>†</sup> p < .10, \* p < .05, \*\* p < .01

Note: The unit of analysis is the alliance-year and the dependent variable is the division of labor.



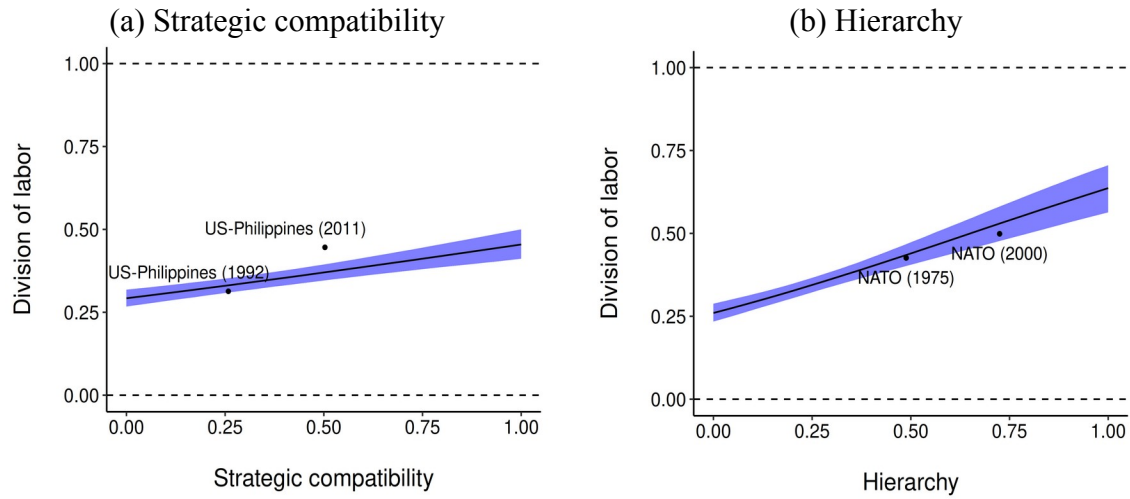


Figure 4: Predicted values of division of labor for each explanatory variable. Note: Predictions based on an ordered beta regression with year fixed effects and all control variables described above held at their mean value. Highlight points represent the observed values on each dimension for those observations. The difference between the points on the x-axis is one standard deviation and the difference between the points on the y-axis is the estimated conditional expectation.