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Innovation and Alliances

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Abstract

Explanations for national success in science and technology typically focus on domestic institutions and policies. However, that line of research has yet to identify any particular set of institutions or policies that explain variation in national innovation rates across cases or over time. This article offers new evidence that the problem with domestic institutions approaches stems from their failure to consider international security factors. Specifically, this article finds a positive effect for U.S. security alliances on innovation. This finding is robust across different specifications and periods of analysis. While countries that ally militarily with the United States are found to realize benefits in economy-wide, indigenous innovation, such an effect is not *observed in military technologies. This suggests that alliances may substitute for being on the frontier in military technologies. Therefore, this article contributes not just to debates over S&T competitiveness, but also to alliance formation.*

KEY WORDS: innovation, intellectual property, alliances, military technology

Introduction: How Do States Innovate?

The majority of social scientists argue that technological innovation is strongly determined by a nation's *domestic* institutions and policies. However, recent findings (Chang & Chang, 2013; Taylor, 2009, 2016) suggest that domestic-focused approaches may omit important *international* determinants of innovation. This article picks up on anomalies in the long-run national innovation data that point toward a new international determinant of innovation: strategic military alliances. Specifically, this article shows that when strategic military alliances with the United States are included in the analysis, they reveal a consistent and robust correlation with national innovation rates.

The article's general logical sequence is as follows. First, we review the lack of evidence for the causal effect of domestic institutions on technological innovation. We argue that institutions matter, they are a means to an end; but we point out that there is little empirical support for a general causal relationship between domestic institutions (or policies) and innovation. Then, we identify anomalies that do suggest a potential causal relationship: strategic military alliances. We investigate whether these anomalies are robust across different measures and cases or whether they are just random or spurious observations that cannot be corroborated. After we provide evidence that this correlation is robust, we discuss potential theoretical

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explanations. Hence, this article does not test existing hypotheses, it generates new ones.

Our findings are consistent with research that suggests that being within the American economic network (i.e., flows of trade, finance, and human capital) correlates strongly with national innovation rates, even after controlling for domestic institutions. Yet the two types of relationships (economic vs. military) appear to have independent effects. In other words, military relationships may matter as much as, if not more than, strictly economic linkages. Indeed, it may be that states can use military relationships as a substitute for risky, expensive economic investments at home or even for major domestic institutional or policy change.

We also find that while alliances aid overall innovation, they do *not* necessarily increase innovation in military technologies. In fact, alliances may correlate *negatively* with military innovation, but *positively* with civilian innovation. In other words, strategic alliances may provide a substitute for creating one's own path to the military technological frontier.

Together, these findings imply that all nations may face a security-innovation trilemma. All nations want simultaneously: independent defense policy, inexpensive technology, and advanced technology. But states can, at most, achieve only two of these. Building an indigenous world-class military or a competitive indigenous S&T sector each come with high costs and risks. Therefore, some nations may be willing to sacrifice military autonomy (i.e., enter into strategic military alliances) in order to defray the costs of indigenous military innovation, while simultaneously gaining access to American innovation capabilities *without* the expense, risk, or conflicts involved in the purely domestic development of these capabilities. Therefore, this article contributes not just to debates over national innovation competitiveness, but also to theories of alliance formation and economic development. It implies that these, often separate, literatures might benefit from synthesis.

Problem: The Incompleteness of Explanations Based on Domestic Institutions and Policies

The majority of social scientists argue that innovation is determined by domestic forces. These innovation scholars tend to fall into three categories. Some view innovation as benefiting society as a whole. The question for these scholars is: why do some nations fail to innovate when innovation is so clearly valuable to all? They therefore focus on the market failures and collective action problems associated with investing in, and then executing, technological change (Greenhalgh & Rogers, 2010; Scotchmer, 2006). Other scholars recognize that innovation is distributive. They therefore focus on the battles between the winners and losers created by innovation, emphasizing the obstructive role of *status quo* interest groups who fight against innovation (Balalaeva, 2015; Bauer, 1997; Mokyr, 1994). Still other scholars argue that culture determines national innovation rates (Harrison & Huntington, 2000; Landes, 1999). They argue that different cultural priorities on, and definitions of, risk, reward, change, and prestige affect society-wide incentives and allowances for the pursuit of innovation, as opposed to, say, religion, sports, the arts, military, or organized crime.

Almost uniformly, each of these sets of scholars posits that domestic institutions and policies are the primary determinants of national innovation performance.

When properly designed and implemented, domestic institutions and policies bring down the costs and risks associated with innovation. They solve the market failures and collective action problems that slow innovation, or prevent it from happening altogether. They can compensate, coerce, or block *status quo* interest groups that seek to obstruct innovation. They can even overcome cultural impediments to innovation. At the micro level, these domestic solutions include intellectual property rights, R&D expenditures, education spending, antitrust regimes, and dozens of other policies (Arrow, 1962; Greenhalgh & Rogers, 2010; B. H. Hall & Harhoff, 2012; Hart, 2001; Varsakelis, 2006). At the macro level, theorists have alternately posited that domestic institutions such as democracy, political decentralization, and different varieties of capitalism are essential for national innovation performance (Acemoglu & Robinson, 2013; P. Hall & Soskice, 2001; North, 1990; Rosenberg & Birdzell, 1985).

That national policies and domestic institutions operate jointly to determine national rates of innovation is the principal idea underlying the national innovation system (NIS) approach developed largely by Freeman (1982), Lundvall (1992), and Nelson (1993). The NIS approach has been remarkably successful in thoroughly documenting the myriad country-specific actors, policies, institutions, and their interactions that determine a country's innovativeness. However, despite several decades of empirical investigations, NIS scholars have failed to identify any particular domestic institution or policy, or combination thereof, that consistently explains variation in national innovation performance across time and space (Taylor, 2016). This is not to say that institutions do not matter for innovation. They surely do. But rather that an empirically validated *general* theory of national innovation has yet to emerge from the NIS approach.

Indeed, individual studies have since chipped away at the causal importance of many of these variables. That is, many domestic institutions or policies that have been theorized to foster innovation have been subsequently shown to cut both ways with the empirical data. For example, innovation researchers have examined the effects of education (Varsakelis, 2006), universities (Cole, 2009; Stephan & Ehrenberg, 2010; Vest, 2007), antitrust policy (Hart, 2001; Schumpeter, 1942), trade regimes (Baldwin & Gu, 2004; Breznitz, 2007) even capitalism itself (Amable, 2000; Breznitz, 2007; P. Hall & Soskice, 2001). In some cases, the institutions and policies seem to correlate with innovation, in others there is no correlation at all, in still others these same institutions and policies appear to harm innovation (Taylor, 2016).

The Solution?—Data Anomalies and Omitted Variable Bias

Scientifically speaking, when a theory is strong, but the empirical data fail to consistently support it, then it makes sense to ask whether scholars are missing an important causal variable. In the course of testing the varieties of capitalism model of technological innovation, Taylor (2004) identified an anomaly in the innovation data that suggests just such an omitted variable: *international strategic military alliances*. Specifically, that article observed that states with strategic military and economic ties with the United States, the lead innovator, also enjoyed high levels of national innovation performance. In particular, the article suggested Japan, Canada, the United Kingdom, Israel, and Taiwan as exemplars. Since then, researchers have confirmed that these states' strategic *economic* linkages with the United States have played important roles in determining their national innovation performance (Breznitz, 2007; Taylor, 2009). However, despite their relevance, economic linkages still fail to provide a complete explanation; there remains a significant amount of unexplained variation in national innovation performance even after controlling for domestic institutions and economic linkages.

Military linkages may therefore be a key explanatory variable, yet they remain little studied. In fact, the effects of military linkages may be quite powerful because a country's security concerns can, at least partly, determine its strategic economic linkages. For example, the economic relationships established during the Cold War between the United States and numerous states (e.g., Germany, Japan, Taiwan, Korea, and Israel) were in part a function of security concerns about an expansionist Soviet Union or People's Republic of China.

Yet no one has yet directly tested whether there exists a robust correlation between strategic *military* alliances and national innovation rates. This article therefore investigates whether the military component of strategic alliances has predictive power in explaining differences in national innovation rates. Certainly, the investigation of anomalies is essential for scientific progress. Kuhn (1962) underscored the role of anomalies as harbingers of the proximate decline of an incumbent theoretical framework. While our proposed contribution to innovation scholarship is by no means revolutionary in a Kuhnian sense, it does follow his basic logic that accumulated anomalies precede the articulation of novel positive claims. In other words, we do not purport to develop a fully specified positive theory of how alliances effect innovation. Rather, the data and methods used here seek to investigate whether the anomalies observed in Taylor (2004) are merely anecdotal or are indicative of a general relationship that needs explaining. The regression results therefore serve to provide a basis upon which to generate new theory and causal mechanisms, not to test existing ones.

The regressions performed below seek to confirm whether strategic military alliances with the United States increase national innovation output. If they represent a general phenomenon, then we would expect large-N analysis to reveal the following three correlations, even when controlling for important economic and institutional variables:

1 *The presence of a formal security alliance with the United States should correlate with an increase in national innovative rates.*

2 *As the strength of a security alliance with the United States increases, national innovative rates should also increase.*

Similarly, if strategic military alliances increase innovation in military technology, then we would expect the following correlation to hold, even when controlling for important economic and institutional variables:

3 *As the strength of a security alliance with the United States increases, innovation in military technologies should also increase.*

Definitions, Methods, and Data

This article uses regression analysis to investigate the effect of security alliances on two outcomes: overall national innovative rates and innovation in military technologies. To investigate the effect of security alliances on national innovation rates, we

Table 1. Descriptive Statistics

Variable	Obs.	Mean	SD	Min.	Max	Source
Dependent Variables						
Patents*	139	94,032	538,532	0	5,954,399	USPTO
Military patents*	136	20	23	0	3,135	Derwent
Capacity for innovation**	117	3.18	0.93	1.72	5.88	Sala-I-Martin et al. (2011)
PCT patents*	115	158,532	964,694	0	10,066,989	WIPO
Independent Variables						
Joint military exercises	135	16.93	28.17	0	171	Vito D'Orazio
U.S. military visits	135	2.30	4.99	0	35	Vito D'Orazio
Control Variables						
Development (1974)***	107	6.59	1.36	4.08	10.15	UN
Democratic institutions (1974)	109	−0.22	1.2	−2.39	1.10	Coppedge et al. (2008)
Institutional stability (1974)	108	20.03	23.39	0	126	Polity IV
Globalization (1974)	96	37.81	16.87	9.03	89.74	Dreher

*Citations weighted, period counts (1975–2010).
**2010 data.
***Logged GDP per capita (2016 prices in U.S. dollars).

gathered data on security, innovation, economic, and political variables for 193 countries. We excluded states with populations under two million because such states (e.g., Liechtenstein, Monaco, and Barbados) are, to a disproportionate degree, characterized by little indigenous innovation yet high nominal innovative output due to being tax or tariff havens.[1] Countries with incomplete data were also omitted. Nevertheless, no highly innovative countries fail to appear in the final dataset. An examination of our data reveals that it presents a representative sample of countries, with diverse technological, security, political, and economic characteristics.[2] A full list of the countries included can be found in the Appendix.

To facilitate discussion, our primary specifications are done using ordinary least squares (OLS) regression with Huber–White standard errors to control for heteroscedasticity. We do this for two reasons. First, and most importantly, the data and research question best fit basic OLS analysis. Second, OLS is the perhaps the most transparent statistical approach. Here, we acknowledge that many scholars involved in the innovation or security debates specialize in qualitative research. To some of them, regressions are either opaque or artifice or both. Although we are practitioners of quantitative methods, we cannot help but sympathize somewhat with this critique. There is simply much quantitative research which takes low quality data and puts it through a "taffy-machine" of statistical analysis. Often only specialists can judge the end product, if at all, while the rest of the scientific community are left out of the debate, skeptical, and unconvinced. Therefore, in an attempt to facilitate greater scrutiny, this article will attempt to offer clear claims, backed by transparent data and methods. We do this with confidence because we have found that applying the statistical "taffy-machine" only strengthens the findings below. We use datasets that are entirely publicly accessible; hence the sophisticated statistical reader is encouraged to confirm this for herself. Finally, we adhere to the advice offered by Achen (2005) and Schrodt (2013) and limit the number of covariates included in our models in an effort to mitigate the effect of collinearity.

Table 1 provides descriptive statistics and the data sources for the variables used herein.[3] Table 2 provides the pairwise correlations of our primary variables of interest.[4] Note that we use logged values of joint military exercises, official U.S. military visits, GDP per capita, and all three innovation measures. The estimates are

Table 2. Correlation Matrix

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Patents	1								
(2) Military patents	0.85***	1							
(3) PCT patents	0.76***	0.79***	1						
(4) Joint military exercises	0.56***	0.41**	0.50***	1					
(5) U.S. military visits	0.37***	0.32*	0.33**	0.54***	1				
(6) Development (1974)	0.81***	0.67***	0.75***	0.48***	0.20*	1			
(7) Democratic institutions (1974)	0.28**	0.25	0.41**	0.21*	−0.07	0.26**	1		
(8) Institutional stability (1974)	0.46***	0.37*	0.45***	0.26**	0.12	0.42***	0.26**	1	
(9) Globalization (1974)	0.70***	0.55***	0.63***	0.31**	0.18†	0.75***	0.22*	0.40***	1

Notes: Patent data are the natural log of citations-weighted, per capita figure; joint military exercise and U.S. military visits are natural log.
†$p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$ (two-tailed).

therefore less sensitive to outliers and can be interpreted in terms of elasticities; log–log models are also consistent with much of the prior work in this type of research (Furman, Porter, & Stern, 2002; Jones & Vollrath, 2013). The basic regression model is along the following lines:

$$(\text{Innovation}_{t=0 \text{ thru } 1}) = B_0 + B_1 * (\text{Military Alliance}_{t=0 \text{ thru } 1}) + B_2 * \left(\text{Level of Econ. Development}_{t=0}\right) + B_3 * (\text{Institution Controls}_{t=0}) + B_5 * (\text{Globalization}_{t=0})$$

where innovative output in period $t = 0$ through $t = 1$ is a function of the independent variables at time $t = 0$.

Dependent Variables: Innovation and Military Technology Innovation

Innovation Definitions—For the purposes of this article, *innovation* is defined as the discovery, introduction, or development of new technology, or the adaptation of established technology to a new use or to a new physical or social environment.[5] Innovation occurs throughout the technical evolution of an invention. It includes the technological changes introduced from first prototype to the establishment of a globally competitive industry. *Technology* is defined as a physical product or a process for physically altering materials that is used as an aid in problem solving. More precisely, technology is a product or process that allows social actors to perform entirely new activities or to perform established activities with increased efficiency (Taylor, 2012). Note that since technology is defined as a product or process, innovation can refer to advances in either. The term "national innovation rate" refers to a country's indigenously produced technological change over a given period of time. It is a measure of output or performance (Taylor, 2012).

Cheung (2014) defines three dimensions of military innovation: doctrine, organization, and technology. In what follows, we confine our focus to innovation in military technology. Certainly, these phenomena sometimes enjoy considerable overlap, in that changes in doctrine and so forth sometimes have causal interactions with technological innovation. However, we concentrate here on the technological aspects of military innovation.

Nor do we include creativity in food, fashion, entertainment, or cultural products. These are not the types of innovation we wish to capture here. Rather, we are specifically interested in technological innovation because it brings with it the increasing returns upon which endogenous growth, military and industrial competitiveness, and considerable national wealth are based (Taylor, 2012).

It is also important to emphasize that the dependent variables considered by this article are innovation, not diffusion. These two phenomena are sometimes so interdependent that they are difficult to separate out. This article does not claim to have solved this perennial problem. But where possible, we focus on why some countries are better at inventing new technologies, or developing them from prototype to mass production, or improving them, or adapting them to new uses. We are less concerned with the spread of new technology throughout society.

Innovation Measures—The construct validity of innovation is critical to the strength of our claims. Therefore, we triangulate on innovation using multiple, independent datasets to measure the same underlying phenomena. Specifically, we measure innovation in three different ways (described below): citations-weighted patents, Patent Cooperation Treaty (PCT) patents, and Sala-I-Martin, Blanke, Hanouz, Geiger, and Mia's (2011) Capacity for Innovation. The idea here is that, if multiple, independent measures each produce similar results, then we should be more confident than when relying on only a single dataset. Certainly, patents have their weaknesses. However, we should recall that *all* data have errors, noise, and perhaps bias. We should not let the quest for "perfect" innovation or alliance data prevent us from using much "good" data that we have available.

U.S. Patent and Trademark Office Patents—For our primary measure of innovation, we use a country's accumulated citations-weighted patents (per capita) from 1975 to 2010 (inclusive). This metric is calculated using U.S. Patent and Trademark Office (USPTO) data on roughly four million utility patents and their over 12.6 million citations (Sampat, 2011). The debate over the strengths and weaknesses of patents as a measure of innovation is described in depth elsewhere (Archibugi & Planta, 1996; Eaton & Kortum, 1999; Griliches, 1991; B. H. Hall, Jaffe, & Trajtenberg, 2001; Harhoff, Narin, Scherer, & Vopel, 1999; Jaffe & Trajtenberg, 2002; Jaffe, Trajtenberg, & Fogarty, 2000; Trajtenberg, 1990). In brief, the current consensus among innovation scholars is that patent data best measure innovation when used in large aggregates and over long periods of time (e.g., nations over decades), but are less accurate when estimating micro level innovation (e.g., to compare individual firms or universities from year to year).

Of single-jurisdiction patent data sources, the USPTO data series is considered to contain the least bias in coverage (Ma & Lee, 2008). Research has shown that even foreign innovators *not* intending to market their products in the United States still acquire USPTO patents to protect themselves from imitation in the world's largest market for new innovation. Also, foreign applicants who seek access to the lucrative U.S. market are more common in the USPTO data than in other patent jurisdictions such as the European Patent Office (EPO) (Guellec & van Pottelsberghe de la Potterie, 2001). Over the period of analysis (1975–2010), foreign inventors were awarded 46% of all USPTO patents, which then accumulated 34% of all forward citations.

Weighting patents by their forward citations further improves their accuracy as an innovation measure. Forward citations are derived from the "prior art" section of subsequent patent documents, which describes the existing technologies that a patent's applicants deemed as critical inputs to their innovation. Weighting patents by forward citations roughly captures the importance of each innovation, based on the frequency with which a patent is used in subsequent innovations. The intuition that highly cited patents represent innovations that are more innovative than those with few citations is confirmed by research which has shown that forward citation counts are strongly associated with the opinions of knowledgeable peers regarding the technical impact of a given patent (Albert, Avery, Narin, & McAllister, 1991). Still other research has shown that citation-weighted patents correlate strongly with market value of the corporate patent holder, the likelihood of patent renewal and litigation, inventor perception of value, and other measures of innovation outputs (B. H. Hall, Jaffe, & Trajtenberg, 2000, 2005; Jaffe et al., 2000; Lanjouw & Schankerman, 1997, 1999; Odasso, Scellato, & Ughetto, 2015; Trajtenberg, 1990).

International Patents—For researchers concerned about the potential for home-bias in USPTO patents, we triangulate using patents filed under the PCT between 1975 and 2010. Because patents successfully filed with the PCT give assignees protection in each of the Treaty's 145 signatory states, using PCT data have been found to negate the problem of home-bias found in patent data sourced from a single jurisdiction (de Rassenfosse et al., 2013). PCT data are provided by the World Bank via the World Intellectual Property Organization (WIPO).[6]

Capacity for Innovation—Whereas weighting patents by forward citations may account for variation in the quality of individual patents and using international patents may mitigate the effects of home-bias, patent-based measures of innovation are imperfect. For example, sector-specific variation in the propensity to patent skews patent-based measures in favor of countries whose innovation activity is focused in sectors such as pharmaceuticals that have a high patent propensity (Arundel & Kabla, 1998).[7] Our third measure of innovation does not rely on patent tallies, but rather the opinions of experts. In particular, we use the 2010 Capacity for Innovation metric issued by the Global Competitiveness Report (Sala-I-Martin et al., 2011). These data are based on the World Economic Forum's annual Executive Opinion Survey, which in 2010 was based on the responses of over 13,000 business executives from 142 countries. We use the report's primary innovation metric: the Capacity for Innovation, which measures the average national score in response to survey questions regarding how companies within a given country obtain technology (1 = exclusively from licensing or imitating foreign companies; 7 = by conducting formal research and pioneering their own new products and processes).

Military Patents—As our proxy measure of innovation in military technology, we use military patents (citations-weighted, per capita) granted between 1975 and 2008. During this period, 36,919 military patents were granted to assignees from 75 countries and these patents accumulated 53,767 forward citations.[8] We obtain the patent data from the Derwent Innovation Index (DII) and the citation data come from the EPO Worldwide Patent Statistical Database (PATSTAT). Appendix A, and the associated tables, provide a more thorough explanation and justification of the use of military patents as a gauge of military technology innovation.

In operationalizing military technology innovation, we seek to conform to the definition provided in Rosen (1991). Rosen defines military technology innovation as “the process by which new weapons and military systems are created” and contends that it “is the business of military research and development (R&D) communities” (p. 185). Thus, operationalization of Rosen’s definition requires that the data conform to two principal criteria. First, the data should measure “instances” of new weapons and military systems. The patents used here have been hand-curated by subject-matter experts at Derwent and classified as military technologies. To confirm the accuracy of this classification, we randomly examined a subset of these patents and confirmed that they were granted for improvements in military technologies (e.g., armored vehicle protection, drone munitions, short take-off technologies for strike fighters). Table A1 in Appendix A provides the patent names for the most recent 20 military patents used in this analysis.

Second, in order to conform to Rosen’s definition, the innovations in question should be granted to members of the military R&D community. Again, a closer look at the data reveals this to be the case. That is, these patents have been granted to well-known producers of military technology (e.g., Raytheon, Lockheed Martin, Honeywell, Thales, and the U.S. Secretary of Navy). Tables A2–A4 in Appendix A break down patent output by country and by assignee.

We do not claim that these patents are an exact proxy for variable national military technology output. The protection of intellectual property by means of secrecy (rather than patenting) is likely to be particularly common for military technologies. Thus, patent-based measures of military innovation likely omit many military technology innovations.[9] Nevertheless, we argue that the measures utilized here provide good proxies for, or rough estimates of, relative performance across countries. Further, other scholars have used similar measures to trace the diffusion of military technologies (Acosta, Coronado, & Marín, 2011; Acosta, Coronado, Marin, & Prats, 2013; Schmid, 2017).

Independent Variable: Security Alliances

Alliance Definition—In operationalizing security alliances, we conform to Walt’s (1990) broad definition of alliances as agreements (both formal and informal) between two or more states to cooperate in regards to national security. Walt correctly observes that limiting the definition of alliances to those relationships involving formal agreements would result in omitting important cases such as the historically close bilateral security relationship between the United States and Israel. Therefore, in measuring a state’s alliance status with the United States, we employ measures based on both formal alliances and observable, nontreaty measures of the closeness of bilateral security relationships. Also, in practice, alliances are heterogeneous in their strength and their substantive characteristics (Moul, 1988; Singer & Small, 1966). Our use of alternative and nonbinary measures of “alliedness” allows us to capture just such variance in the strength of alliances.

Alliance Measures—Again, the construct validity of alliances is critical to the strength of our claims. Therefore, we triangulate on these variables using multiple, independent datasets to measure the same underlying phenomena. Specifically, we measure alliances in three different ways (described below): joint military exercises, official military visits, and formal alliances.

Joint Military Exercises with the United States—Our primary measure of security alliances is period counts of joint military exercises with the United States. By integrating national defense capabilities, practicing coordinated military responses, and signaling the capability to implement combined operations, joint military exercise conform neatly to our definition of alliance as a commitment to coordinate in regard to national security. The data on joint military exercises were compiled by Vito D'Orazio (University of Texas, Dallas), who used automated document classification to code the data.[10] During the primary period of analysis (1975–2010), there were a total of 3,321 country observations split between 1,478 discrete joint military exercises (giving an average exercise size of 2.25 countries). In our sample, the average number of exercises in which a country participated was 16.4. Besides the United States (834 exercises), the top participants were the United Kingdom (171), Germany (134), Canada (110), and the Netherlands (106).

Official U.S. Military Visits—Our second measure of alliance is counts of official high-ranking U.S. military visits. The reasoning behind the use of U.S. military visits mirrors that of joint military exercises. Namely, a visit by a high-ranking military official constitutes an observable measure of security coordination and commitment *vis-à-vis* an ally. The official U.S. military visits data contain 377 observations on foreign visits by high-ranking official U.S. military personnel spanning the period 1990–2010.[11] Once again, these data come from Vito D'Orazio who submitted eleven Freedom of Information Act requests to various government agencies in gathering the data. It is likely that the official U.S. military visits data are incomplete and may contain biases. However, we think the uniqueness of this data and our utilization of alterative and independent datasets to triangulate its effect warrants its inclusion here. The top hosting countries were Germany (35 visits), Afghanistan (23), Japan (20), South Korea (19), and Iraq (18).

Formal Security Alliances with the United States—The most direct measure of security alignment with the United States is the presence of a formal written agreement. Using this criterion, states are coded as allied with the United States when at the period's end a formal alliance with the United States is present. Using the period's end as the relevant demarcation point (as opposed to the more inclusive criteria of the one-time presence of an alliance during the period in question), serves to exclude short-lived pacts from the analysis. The alliance data come from v4.1 of the formal interstate alliances Correlates of War dataset (Gibler, 2009).

U.S. Bias

Our methodological approach has a U.S. bias in both the alliance and innovation data. Therefore, we should interpret the results reported below as those of a "most-likely case" design. That is, the United States is by far the most innovative and militarily powerful nation during the period studied. Also, throughout the time period covered by the data, American foreign relations were explicitly loaded with strategic security concerns. Strategic allies are arguably likely to patent in the United States more than are nonallies. Therefore, if there does exist a general relationship between alliances and innovation, then it should be most evident in this U.S.-biased analysis.[12]

Control Variables

Development—Our control for economic development is GDP per capita (in constant U.S. Dollars).[13] Controlling for economic development seeks to insulate our argument from three potential objections to the relevance of the correlations observed in Table 2. First, controlling for development seeks to address concerns regarding development-based selection effects in alliance formation. Second, including level of development as a control mitigates a major potential source of omitted variable bias. That is, if development were not included, it could be argued that positive and significant alliance coefficients merely reflect a country's ability to pay for expensive military exercises. Finally, economic development provides a well-documented advantage for innovation because more developed economies tend to have greater resources and infrastructure for the creation of new innovation.[14]

Democratic Institutions—We control for democratic institutions using a composite measure created by Coppedge, Alvarez, and Maldonado (2008). This control allows us to account for two alternative interpretations of a correlation between alliances and innovation. First, the United States may have a higher propensity to formally ally, engage in combined exercises, or send/receive high-level military envoys with other democracies. Second, democratic institutions are often theorized as a requirement for high innovation output at the national level (Varsakelis, 2006).

Institutional Stability—Besides controlling for the character of a country's democratic institutions, we control for their stability with respect to time. To control for institutional stability, we use the Polity IV measure of "regime durability," which measures the number of years that have passed since a regime has changed (i.e., experienced a three-point change or more in its polity score; Marshall, Jaggers, & Gurr, 2011). We control for institutional stability because it has been hypothesized to drive innovation (Johnson, 1992).

Globalization—Some argue that the degree to which a country is "globalized" or knitted into the world's economic networks explains its innovation rate (Dreher, 2006). This may occur through technology transfer, foreign direct investment (FDI), the incentives to innovate coming from trade competition, or socialization into more technology-oriented communities. Globalization is measured as the economic globalization component of the KOF globalization index.[15] The variable is constructed using data on trade flows, FDI, impediments to international capital, and goods flows.

Results

In the regression tables that follow, we present the standardized (beta) and unstandardized coefficients for each of the alliance variables; for the control variables, we present only the standardized (beta) coefficients. Recall that standardized (beta) coefficients are interpreted in terms of standard deviations. This allows for apples-to-apples comparisons of the magnitude of the effects of different independent variables.

Table 3. Joint Military Exercises, Dependent Variable = Logged Weighted Per Capita Patent Production

	(1)	(2)	(3)	(4)
Joint military exercises	0.582	0.579	0.650	0.601
	0.249	*0.248*	*0.278*	*0.248*
	[3.60]**	[3.60]**	[4.17]***	[3.62]**
Development (1974)	*0.695*	*0.669*	*0.602*	*0.501*
	[7.68]***	[7.77]***	[6.55]***	[4.86]***
Democratic institutions (1974)		*0.158*		*0.175*
		[3.02]**		[3.20]**
Institutional stability (1974)			*0.192*	
			[3.72]***	
Globalization (1974)				*0.233*
				[3.10]**
Constant	–24.488	–23.936	–23.418	–22.568
	[–15.43]***	[–15.548]***	[–15.24]***	[13.84]***
No. Obs.	89	89	89	83
R^2	0.710	0.734	0.740	0.771

Notes: Analysis is by OLS using Huber–White standard errors, t-statistics in brackets, standardized beta coefficients in italics. Analysis limited to countries with average population > 2,000,000. Joint military exercises = # of joint military exercises, 1975–2010; Development (1974) = per capita GDP, 1974; Democratic institutions (1974) = democratic inclusivity composite score (Coppedge et al., 2008), 1974; Institutional stability (1974) = Polity IV regime durability, 1974; Globalization (1974) = KOF Economic Globalization Index Score, 1974.
$^{**}p < .01$; $^{***}p < .001$.

Overall, the data support our expectations 1 and 2 (above), where the results are strong and unambiguous. Using three separate measures of alliances, and after controlling for other widely hypothesized determinants of innovation, being allied with the United States is consistently associated with significantly higher national rates of innovation. Tables 3–5 and those provided in the Appendix (Tables C1 and C2) contain the evidence in support of this finding. Comparing the alliance beta coefficients to those of the institutions variables suggests that the effect of alliances on innovation is larger than that of institutions.

In regards to expectation 3, our results suggest that alliances with the United States are *not* a robust predictor of *military* technology innovation. Indeed, the sign of the alliance coefficient for the formal alliance dummy turns negative when the dependent variable is changed to military patents (Table 6). This implies that countries may be substituting military alliances for military innovation.

Alliances and National Innovation

In regard to overall innovation, the major takeaway from the regressions is that the alliance variables remain positive and significant. For example, in the simple bivariate regressions (not shown), each of the alliance variables is strong and significant, accounting for a fairly large amount of change. After adding a control for level of economic development, a formal alliance with the United States is associated with a 137% increase in the national innovation rate over the period 1975–2010 (Table 4, column 1).[16] A 1% increase in joint military exercises brings with it an increase of roughly 0.6% in innovation (Table 3, column 1). A 1% increase in official U.S. military visits correlates with around 0.6% increased innovation (Table 5, column 1).

These results are quite rigorous to changes in the model or variables used. Perhaps the strongest downward effect on the alliance coefficients is seen when level of

Table 4. Official U.S. Military Visits, Dependent Variable = Logged Weighted Per Capita Patent Production

	(1)	(2)	(3)	(4)
Official U.S. military visits	0.576	0.570	0.567	0.684
	0.177	*0.210*	*0.173*	*0.204*
	[2.73]**	[3.60]**	[2.56]*	[3.23]**
Development (1974)	*0.760*	*0.718*	*0.700*	*0.566*
	[9.12]***	[8.83]***	[7.73]***	[5.63]***
Democratic institutions (1974)		*0.193*		*0.176*
		[3.22]**		[2.76]**
Institutional stability (1974)			*0.148*	
			[2.62]*	
Globalization (1974)				*0.217*
				[2.93]**
Constant	–24.741	–23.897	–24.028	–22.579
	[–15.56]***	[–15.20]***	[–14.83]***	[13.42]***
No. Obs.	89	89	89	83
R^2	0.690	0.725	0.708	0.762

Notes: Analysis is by OLS using Huber–White standard errors, t-statistics in brackets, standardized beta coefficients in italics. Analysis limited to countries with average population > 2,000,000. U.S. military visits = # of official U.S. military visits, 1990–2010; Development (1974) = per capita GDP, 1974; Democratic Institutions (1974) = democratic inclusivity composite score (Coppedge et al., 2008), 1974; Institutional stability (1974) = Polity IV regime durability, 1974; Globalization (1974) = KOF Economic Globalization Index Score, 1974.
*$p < .05$; **$p < .01$; ***$p < .001$.

Table 5. Alliance with United States, Dependent Variable = Logged Weighted Per Capita Patent Production

	(1)	(2)	(3)	(4)
Alliance with United States (Dummy)	1.387	1.371	1.503	0.390
	0.192	*0.190*	*0.208*	*0.191*
	[2.86]**	[3.03]**	[3.17]**	[3.04]**
Development (1974)	*0.767*	*0.741*	*0.691*	*0.576*
	[9.36]***	[9.63]***	[7.86]***	[5.59]***
Democratic institutions (1974)		*0.156*		0.164
		[3.10]**		[3.03]**
Institutional stability (1974)			*0.174*	
			[3.09]**	
Globalization (1974)				*0.233*
				[3.03]**
Constant	–25.325	–24.777	–24.453	–23.362
	[–17.43]***	[–17.49]***	[–16.80]***	[–14.94]***
No. Obs	89	89	89	83
R^2	0.696	0.712	0.721	0.756

Notes: Analysis is by OLS using Huber-White standard errors, t-statistics in brackets, standardized beta coefficients in italics. Analysis limited to countries with average population > 2,000,000. Alliance with United States = Dummy indicating alliance with United States (alliance = 1); Development (1974) = per capita GDP, 1974; Democratic institutions (1974) = democratic inclusivity composite score (Coppedge et al., 2008), 1974; Institutional stability (1974) = Polity IV regime durability, 1974; Globalization (1974) = KOF Economic Globalization Index Score, 1974.
**$p < .01$; ***$p < .001$.

economic development is added to the model: clearly wealthy, developed countries have an advantage in creating new technology. Nevertheless, the alliance variables remain strong, positive, and significant in each of these models. Also, the addition of controls for democratic institutions and institutional stability does not significantly affect the alliance coefficients. For the overall innovation regressions (Tables 3–5), the alliance variables are statistically significant in 15 out of 15

Table 6. Alliance with United States, Dependent Variable = Logged Weighted Per Capita Military Patent Production

	(1)	(2)	(3)	(4)
Alliance with United States (Dummy)	–0.056	–0.090	0.046	–0.206
	–0.013	*–0.021*	*0.011*	*–0.047*
	[–0.15]	[–0.26]	[0.13]	[–0.54]
Development (1974)	*0.656*	*0.627*	*0.533*	*0.469*
	[6.60]***	[6.45]***	[5.27]***	[3.49]**
Democratic institutions (1974)		*0.122*		0.084
		[1.66]†		[1.05]
Institutional stability (1974)			*0.272*	
			[4.16]***	
Globalization (1974)				*0.275*
				[3.20]**
Constant	–22.447	–22.094	–21.730	–21.881
	[–24.89]***	[–24.22]***	[–24.87]***	[–20.24]***
No. Obs	106	106	106	96
R^2	0.424	0.438	0.485	0.509

Notes: Analysis is by OLS using Huber–White standard errors, t-statistics in brackets, standardized beta coefficients in italics. Analysis limited to countries with average population > 2,000,000. Alliance with United States = Dummy indicating alliance with United States (alliance = 1); Development (1974) = per capita GDP, 1974; Democratic institutions (1974) = democratic inclusivity composite score (Coppedge et al., 2008), 1974; Institutional Stability (1974) = Polity IV regime durability, 1974; Globalization (1974) = KOF Economic Globalization Index Score, 1974.
†$p < .10$; **$p < .01$; ***$p < .001$.

models, and often with p-values of .01 or better.[17] Even the addition of the KOF Globalization index (to control for economic linkages) does not weaken the alliance variables.

Still more encouraging, the coefficients on the alliance variables triangulate strongly with each other. That is, similar models produce coefficients of similar magnitude, even when using different measures of alliances. For example, in the simple bivariate regressions: an "Alliance with the United States" has a 0.400 standard deviation effect on innovation rates; while a "U.S. military visit" has a 0.395 standard deviation effect; and a "joint military exercise" has a 0.540 standard deviation effect. Even after control variables are added, these similarities across alliance measures are maintained.

A critical reader might object that differences in innovation between U.S.-allied and non-U.S.-allied states could be due to a propensity by the United States to ally with states possessing the characteristics that drive innovation. That is, it is possible (indeed, it is likely) that the United States and its potential allies form alliances in a way that is nonrandom. For example, it is possible that alliances will form more readily between countries of matched economic development, political institutions, economic institutions, or international openness. However, we observe that even after controlling for each of these potential sources of selection bias (Tables 3–5, column 4), the alliance coefficients remains significant, positive, and large.

Alliances and Innovation in Military Technology

The effect of alliances on military innovation is less clear yet still intriguing. Whereas all three alliance measures have statistically significant and large effects on *overall* innovation, none of the alliance measures are statistically significant predictors of *military* innovation. Indeed, in the case of the formal alliance dummy, the sign of the alliance effect in most models turn negative; suggesting the possibility that alliances may substitute for military innovation. Given the robust relationship observed between alliances and overall innovation, the failure to observe such a relationship within this category is intriguing. Table 6 presents the results of a set of models in which we regress weapons innovation on the alliance dummy variable and the controls.

Implications and Speculation

The regression results have implications for both innovation theory and security studies. First, the observed correlations raise questions regarding the mechanism in operation. Second, the results appear to indicate that the anomaly observed in Taylor (2004) is a general phenomenon. In large cross-national, long-run datasets, strategic military alliances with the United States do appear to increase national innovation output. Third, to the extent that alliances reflect external threats, the results refocus attention on the importance of security concerns in driving innovation throughout the entire economy, although not military innovation. Finally, these findings suggest that nations may face an alliances-innovation trilemma. We expound on each of these implications below.

On Potential Mechanisms

Perhaps the least controversial speculation to draw from the evidence above is that being within the U.S. security network strongly influences national performance in innovation. The more interesting question that remains is one of causal mechanisms; for we have only shown here a robust, statistical correlation. Space constraints limit us to the provision of hypotheses about possible explanations for this correlation.

While we are aware of no previous studies empirically linking security alliances to innovation, scholars have found alliances to have positive effects on other economic outcomes. These studies can be used to shed light on the potential causal mechanisms underlying our findings. Specifically, scholars have proposed that alliances affect economic variables by means of signaling information about interstate relations or by producing security externalities.

As much of interstate relations are unobservable to economic actors, the signaling dimension of alliances may explain their apparent role in affecting economic outcomes. Several studies finding a positive association between alliances and FDI evoke signaling as the underlying mechanism. For example, Biglaiser and DeRouen (2007) find that among a sample of 126 developing countries, the stationing of U.S. troops within a country is associated with increased U.S. FDI inflows. The authors hypothesize that investors interpret the military presence as a signal of the existence of a security alliance with the United States, which, in turn, increases investors' confidence that they will be able to realize returns on their investments. Similarly, in a study of 58 countries, Li and Vashchilko (2010) find that among high-income/low-income country dyads, the presence of a security alliance is associated with greater bilateral FDI flows. The authors attribute this relationship to the role of security alliances in signaling information to investors regarding the status of interstate political relations.

A plausible case can be made for the operation of signaling in the observed correlation between alliances and innovation. For example, innovation requires investors to have a reasonable degree of confidence that they will be able to realize returns on their investments. The existence of close security ties with the United States may serve to transmit information regarding the likelihood that a given investment environment is sufficiently stable to make R&D investment profitable.

It has also been found that international trade flows are higher among allied states (Gowa, 1995; Mansfield & Bronson, 1997). However, rather than focusing on signaling, the prevailing explanation for this effect is that trade produces security externalities. That is, a state may forgo trade with a nonally due to concerns that the associated gains of trade will be used in a way that increases the threat posed by the nonally.

Indeed, there is evidence that such a dynamic characterizes the relationship between alliances and innovation. The United States explicitly limits skill or technology transfer with nonallies due to concerns about how the transferred capabilities that would effect its security position. Specifically, exports control of defense-relevant technologies—implemented largely through International Traffic in Arms Regulations (ITAR) under the authority of the Arms Export Control Act—expressly limit the transfer of technologies to certain countries based on national security considerations. MacDonald examines the effect of U.S.-imposed export controls during the Cold War and finds that such restrictions hindered "the delicate process of innovation" (1990, p. 5). More recently, Mineiro (2011) observes that U.S.-imposed export controls have severely obstructed the development of the Chinese commercial satellite industry.[18]

Conversely, the United States may encourage the transfer of innovation capabilities to allies in an effort to increase the aggregate strength of the alliance. Indeed, the North Atlantic Treaty (the document that establishes NATO) is explicit in extending the agreement's scope into the economic sphere, stating that members "will seek to eliminate conflict in their international economic policies and will encourage economic collaboration between any or all of them" (The North Atlantic Treaty, Article 2).

Implications for the International Political Economy of Innovation

Our findings substantiate a critique of the NIS approach to explaining national rates of innovation. The NIS approach depends (as do all systems of innovation approaches) on whether the borders of the system under scrutiny are appropriately defined (Edquist, 2005). Our findings suggest that defining an innovation system using national borders may prevent the consideration of important international determinants of innovation.

From its inception, the NIS approach has exhibited variation in regard to what factors are considered within the system under consideration. Definitions of system boundaries vary from those focusing narrowly on the organizations directly engaged in R&D (Nelson & Rosenberg, 1993), to those cognizant of the societies and cultures in which these organizations are embedded (Lundvall, 1992), to those encompassing "all important economic, social, political, organizational, and other factors that influence the development, diffusion, and use of innovations" (Edquist, 1997, p. 14). Later, Lundvall gives a similarly encompassing definition, defining NIS so as to "include [. . .] all parts and aspects of the economic structure and the institutional set-up affecting learning as well as searching and exploring" (Lundvall, 2009, p. 12).

However, while the theoretical boundaries of the NIS framework are somewhat inconsistent, empirical treatment is less so. That is, in investigating any particular NIS, scholars tend to focus on a particular subset of actor types, institutions, and linkages. In terms of actors, empirical studies tend to focus on universities, firms, and government research institutions (Edquist, 2005; Schmid & Wang, 2017). While empirical treatment of domestic institutions is more varied than that of actor types, a review of the literature reveals a consistent list of "usual suspect" institutions. This list includes market regulation, financial institutions, intellectual property rights, and political institutions. Regarding linkages, research tends to focus on strong and weak ties (Granovetter, 1973), formal and informal ties (Powell & Grodal, 2005), tacit and explicit knowledge flows (Nonaka, 1994; Polanyi, 1958), and linkages between epistemic communities (Crane, 1972; Rosenkopf & Tushman, 1998). However, regardless of the particular actors, institutions, and linkages that are included in a given study, within the NIS approach, system constituents are, by definition, located *within* the borders of the nation-state under scrutiny.[19]

Our results suggest that the NIS approach, by focusing exclusively on domestic variables, may be omitting an important determinant: states' international security context. We argue that military alliances matter for innovation. The weak form of our argument is that alliances should be included among the determinants in standard models of innovation. That is, in addition to domestic institutions and policies, material inputs to innovation, and linkages, a state's security context must also be considered.

A strong form of our argument might speculate that security is a "master variable" that drives not only innovation but also domestic institutions and international economic linkages. In this form, institutions still matter for determining innovative output. They are the essential machinery that states use to improve innovation performance in response to security threats. But they have little or no causal power of their own accord. Small sample, qualitative investigations into whether and how national security concerns influence domestic institutions and international economic linkages would be an important next step here.

Regardless of whether the weak or strong form proves more apt, our results have consequences for how labor is divided between political scientists and economists in the future study of innovation. Thus far, attempts to study innovation have been dominated by economists and business scholars who often omit international security and politics from their analysis. Such scholars, nevertheless, possess critical insight into the manner in which domestic institutions affect innovation within specific countries and sectors. Conversely, international relations scholars have developed a sophisticated understanding (and means of operationalization) of national security variables such as alliances and external threats. Thus, we contend that cross-disciplinary collaboration is possibly the most effective way to contribute to innovation scholarship going forward.

Implications for Military Innovation

To the extent that strategic military alliances are formed in response to external threats, the evidence above brings security threats back to the causal forefront of studies of military innovation. A prominent line of theory within security studies once held that military innovation is best explained as a function of a state's external security environment. Specifically, Posen's (1986) *Sources of Military Doctrine* argued that, when a state faces heightened external threats, its civilian leadership will direct increased attention toward military affairs. Increased civilian scrutiny, in turn, leads to innovation on the part of the military. This will result in innovation in military doctrine, and also implicitly, in military technology.

However, in the 30 years since the publication Posen's book, numerous scholars have demoted the role of external threats to that of a secondary, even tangential, causal factor in explaining military innovation. The dominant opposing view is found in Stephen Peter Rosen's (1991) *Winning the Next War*, which proposes a model of military innovation based on factors internal to the military itself. External threats are treated as secondary to the organizational conditions of the military. Harvey Sapolsky (1972) and Owen R. Coté (1996) each offer a third approach to explaining military innovation, one based on interservice competition. In a related argument, Dombrowski and Gholz (2006) emphasize the importance of the political relationships between private contractors, defense bureaucrats, and military and political leaders to defense innovation. In these approaches, external threats are treated as second-order concerns.[20] In other recent research, external threats do not fare much better. Stulberg (2005) argues that specific management practices and norms are "the key to nurturing successful military transformation" (p. 491). External threats here are at best a necessary, but insufficient, condition. Mukunda (2010) has argued that external threats can even impede innovations that are disruptive. Still other scholars identify the primary causal factor driving military innovation as culture (Kier, 1997), bureaucratic politics (Kaufman, 1994), or the structure of civilian institutions (Avant, 1993). None of these explanations emphasize military alliances or realist security threats. Hence, within security studies, the role of external competitive threats or pressures in prompting innovation has all but disappeared.

If we believe that strategic military alliances are formed in response to external threats, then the research reported in this article presents an interesting twist. It offers evidence for the continued relevance of external threats for explaining general civilian innovation, but not military innovation. What then is going on?

A Security-Innovation Trilemma?

We speculate that nations may face a security-innovation trilemma, and that this occurs simultaneously on both the civilian and military fronts. Why? The data analyzed above suggest that strategic military alliances strongly aid overall innovation, but have far weaker (and perhaps negative) effects on purely military innovation. Therefore, it could be that nations use strategic military alliances with technological great powers as a substitute for domestic military innovation.[21] These alliances may also reduce the unusually high costs and risks of domestic civilian innovation. Put these opportunities and constraints together with the classic security concerns faced by nation-states, and there results a trilemma.

All nations want simultaneously: independent defense policy, inexpensive technology, and advanced technology. But states can, at most, achieve only two of these. The trilemma exists, in part, because innovation is expensive and even politically risky. Cutting-edge innovation requires massive investments in R&D, STEM training, universities, patent regimes, infant industry protectionism, and so forth. However, these investments drain money and political capital away other pursuits. Every dollar spent on innovation is a dollar not spent on welfare programs, infrastructure, tax rebates, less risky low-tech, or the lining of elite pockets. If investments in innovation lead to failure, then political careers and party power can be lost. Therefore, governments should tend to shy away from investing heavily in innovation at the technological frontier.

Of course, a military that is both competitive and independent (i.e., able to function without depending heavily upon allies) can also be expensive and politically risky. A competitive military requires investment in developing effective weapons systems, a domestic manufacturing base capable of producing them, and highly trained troops and technicians capable of using and maintaining them. These investments similarly drain money and political capital away from the civilian sector. Therefore, governments should prefer to spend their money on other pursuits. Even military governments may prefer to use their funds to purchase domestic political support rather than to develop advanced indigenous weapons systems.

The most obvious means by which to reduce the costs and risks of innovation, especially in military technology, is to rely on a technological great power for defense, or at least for imports of advanced defense technologies. Therefore, some nations will sacrifice military autonomy (i.e., enter into strategic military alliances) in order to win access to advanced military technology. In other words, strategic alliances provide substitutes for being on the technological frontier for the partner state, especially in military technologies.[22]

Finally, we posit that this creates *two* trilemmas because some important technologies can either be military or civilian but not both (e.g., fighters/bombers vs. passenger planes, warships vs. container ships, missiles vs. space exploration, and so forth). There may be some fundamental overlap between specific military and civilian technologies. However, developing and producing technology X for the military market rarely solves these same problems for the civilian market. Therefore, nations should fall into six different categories depending on which two out of three they select to pursue in the civilian and military spheres. Figure 1 illustrates the security-innovation trilemma.

What should we expect to find empirically? We speculate that countries might fall into categories along the lines shown in Figure 2.

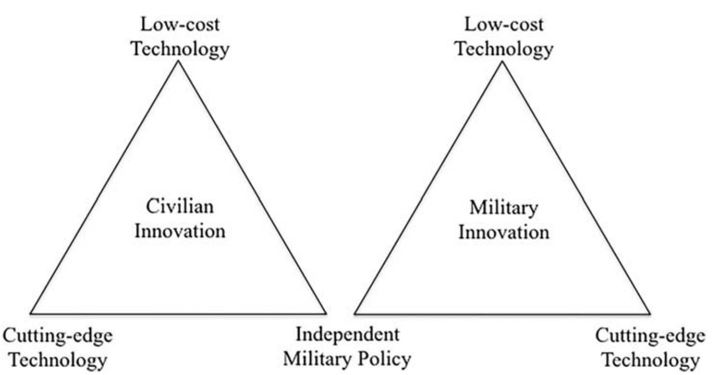

Figure 1. The Security-Innovation Trilemma

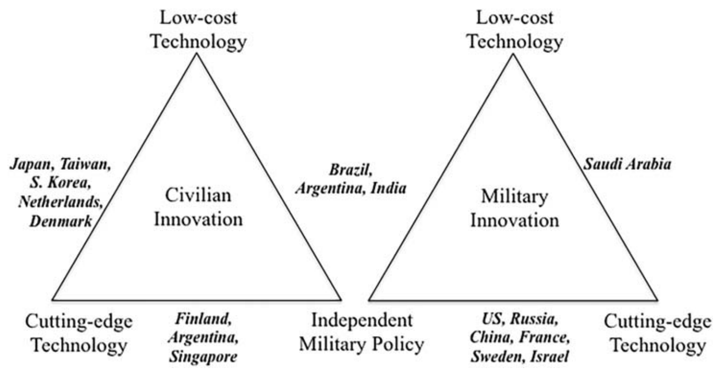

Figure 2. The Security-Innovation Trilemma, Suggestive Evidence

However, even if this trilemma is confirmed, considerable questions remain. Why and how do nations use military alliances to improve civilian innovation capabilities? And why emphasize overall innovation at the expense of military innovation? This article has found that the alliance-innovation anomaly is real, robust, and occurs widely. New research needs to explain why.

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Notes

1 Excluding small states leaves us with 99.93% of all non-U.S. patenting from 1975 to 2010.

2 Appendix B provides a comprehensive list of countries contained in the analysis.

3 In all cases in which variables have been calculated on a per capita basis, population is calculated as the mean annual population during the period of analysis. With the exception of Taiwan, population data are from the World Bank. Taiwan population data are from National Statistics, National Statistical Bureau, Republic of China (Taiwan), http://eng.stat.gov.tw/.

4 Capacity for Innovation (Sala-I-Martin et al., 2011) not shown in the correlation matrix because we use the 2010 data (and thus 2009 controls) in the regressions (Table A2).

5 Definitions here taken from Taylor (2012, 2016).

6 World Bank Development Indicators, Patent Applications, Residents, 1975–2010, http://data.worldbank.org/indicator/IP.PAT.RESD.

7 We are grateful to an anonymous referee for underscoring this flaw concerning patent-based measures.

8 As of December 31, 2008. Because we use a five-year rolling window to search for each patent's forward citations and we use the 2013 version of PATSTAT, the cutoff date of December 31, 2008 is the final date for which a full five-year window is available. Using data from after this date would not allow more recent patents a full five-year window during which to accumulate forward citations and may result in bias.

9 As military technology is increasingly developed by commercial, rather than government, entities, the importance of protecting intellectual property by means of secrecy rather than patenting is likely to fall (Stowsky, 2004).

10 http://vitodorazio.weebly.com/data.html.
11 On the data hosting website (http://vitodorazio.weebly.com/data.html), D'Orazio describes the positions as follows, "Positions we are seeking information on include the Secretary of Defense, the Deputy Secretary of Defense, the Chairman of the JCS, the Vice Chairman of the JCS, the Army, Navy, Air Force, and Marine Corps Chief of Staff, the commanders of the nine Unified Combatant Commands, and the Secretaries of the Army, Navy, and Air Force."
12 Admittedly, the U.S. bias here is not extreme. The PCT patents are awarded by the World Intellectual Property Organization, based in Switzerland, an organization within the United Nations. Also, innovators in nonallied states will often obtain U.S. patents, even if they have no immediate intent to sell there, so as to prevent imitation in the lucrative American market. This is especially true of large high-tech firms in nonallied states (e.g., Baidu, Embraer, and Nokia) who do not want adaptations of their own technologies coming back as U.S. exports to compete with them, or to preclude future sales in the United States.
13 Lagged (usually 1974).
14 While the precise nature of the relationships between technological change and economic development is beyond the scope of the present analysis, it suffices to say that causality is bidirectional.
15 Lagged (usually 1974). When 2010 capacity for innovation is used as the dependent variable, we use controls from 2009.
16 Recall that the dependent variable is the logged weighted per capita production of technology patents. Therefore, the coefficients can be interpreted as percentage changes in national innovation rate.
17 This includes the simple bivariate regressions, which have not been included due to consideration of space.
18 It should be noted, however, that the technology transfer limiting effect of ITAR is not limited to nonallies. NATO members have successfully marketed "ITAR-free" satellites that do not require users to navigate the costly and burdensome U.S. regulation (Sundahl, 2010, p. 3). Similarly, the regulatory burden of ITAR nearly led Britain to leave the F-35 program. Nevertheless, because the ITAR-imposed regulatory burden and its outright restrictions are higher for nonallies than for allies (p. 15), the net effect of ITAR on technology and knowledge transfer with the United States may help explain our findings.
19 Illustrative of the prevailing approach of innovation scholars is the seminal article by Furman and others (2002). In search of the determinants of a country's ability to innovate technologically, the authors synthesize the NIS approach with two additional theoretical frames: ideas-driven growth and Porter's cluster-based approach. However, despite their substantial efforts at theoretical widening, the authors are left with twelve primary determinants of national innovative capacity, of which none are international in nature.
20 Although in other work, both Sapolsky and Gholz have linked threat level to investment in the defense industries. See Gholz (2000) and Gholz and Sapolsky (1999).
21 The notion that alliances may substitute for military technology innovation and free up scarce R&D resources for civilian ends is not original to us. Mowery and Rosenberg (1991) recognized the potential for such an effect during the Cold War alliance structure; observing that military spending in Japan and West Germany following World War II was low while their ratio of civilian fR&D to total output had "been substantially higher than in the United States for many years" (p. 160).
22 Other authors have proposed that alliances may be substitutes for other means of attaining national defense (Altfeld, 1984; Diehl, 1994). The potential trade-off between alliance formation and armaments is formally defined in Altfeld (1984), where alliance formation is modeled as a function of a utility maximizing state's choosing between the two, security-enhancing, goods: weapons purchases and alliances.

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Appendix A: Patents as a Measure of Military Weapons Innovation

We utilize two complementary datasets to construct a novel dataset of all military technology patenting and forward citations for the period in question. We begin by obtaining the full sample of military technology patents from the DII. For each patent, these patent numbers are used to query the country of residence information and the forward citation data (using a sliding five-year window) from the EPO Worldwide Patent Statistical Database (PATSTAT 2013).

Central to the validity of the research design employed here is the construct validity of our military technology variable. At least three arguments can be made in support of operationalizing military technology innovation using military patents. First, the primary data in question are hand curated by subject matter experts at Derwent as military technology patents. In this regard, the Derwent Class Code W07 (Electrical Military Equipment and Weapons) is preferable to broader classification such as Cooperative Patent Classification System codes F41 (Weapons) and F42 (Ammunition; Blasting), which do not disaggregate military and civilian technologies.

Table A1. Twenty Most Recent Derwent Weapons Patents (Class W07—2008)

1. Anticipated event, e.g., acoustic noise, monitoring apparatus for military application, has control circuitry coupled to early event detection circuitry, and providing control signals in response to intermediate signal.
2. Antimicrobial card, e.g., identification card for employees in service jobs such as government, includes card made from antimicrobial polymeric material comprising polymer and antimicrobial agent, and identifier.
3. Archery bow sight for electronically assessing and indicating position of a sight relative to a bow includes an ocular that is adjusted relative to the bow-engaging body and that encloses an area into which a fiber-optic filament extends.
4. Defensive aids suite for light armored vehicle, has search and track radar elements and high-speed grenade launchers on main turret of vehicle, and threat sensing subsystem including wide field of view sensors on main turret.
5. Detecting odor, e.g., biogas odor in a gas sample involves reducing an amount of water present in the gas sample using a membrane; and detecting and measuring odor in the sample using a gas sensor.
6. Detecting presence of compound, e.g., explosive chemical compound in air sample, comprises collecting air sample, increasing concentration of compound, and detecting presence of compound in concentrated air sample with spectrometer.
7. Electromagnetic actuator for actuator system used in, e.g., flight surface control systems for aircraft, has rotor which produces first magnetic field that translates along shaft axis and second magnetic field that rotates around shaft axis.
8. Integrated circuit device, e.g., TV set, has video decoder circuitry coupled to baseband demodulator circuitry to generate and output formatted video signal matched to selected channel of broadcast spectrum using video signal.
9. Method for operating hybrid propulsion system of marine vessel, particularly navy vessel, involves driving individually or jointly propulsion unit for example propeller of marine vessel.
10. Mobile robot for performing reconnaissance task in hostile environment, controls robot drive system to move robot in direction aligned with strongest line among detected linear patterns in occupancy grid map.
11. Monolithic nuclear event detector for military electronic systems, includes diode and signal processing circuitry integrated within single semiconductor chip using silicon-on-insulator processing.
12. Multifunction peripheral for common access card security system, has access card and information based on characteristics associated with user bearing card added to be replicated such that characteristics are not indicated in document.
13. Multispectral target apparatus for training, e.g., firefighter, has target equipped with thermal emitting layer, controller module communicated with remote user, and brightness controller including input.
14. Night vision system has four locating features, the first interacting with the third to align input optical axis of image intensifier tube with lens and the second interacting with fourth to align output optical axis with optical component.
15. Object's, i.e., wireless device, range, i.e., time of arrival, estimating method, e.g., radar, involves determining range based on number of clock pulses between transmitting and receiving ultrawide band signal and phase of fractional signal.
16. Recognitive hydrogel, e.g., for use in biosensor, intelligent drug delivery devices, and systems for immunoassays, comprises imprinted polymer having binding cavity specific for triggering molecule, and conductive polymer.
17. Self-contained axle module for, e.g., military vehicle, has wheel end and independent suspension assemblies, housing and electric motor, which are removable from vehicle as unit by detaching housing from support structure.
18. Sensor element carrier useful in mass-sensitive chemical sensor instrument, comprises a base component and a lid component, a compressible sealing member surrounding a recessed area of the base or lid component, and two carrier electrodes.
19. Solid-state neutron detector for use by, e.g., military service personnel, has thin film of boron nitride deposited onto semiconductor substrate and being responsive to energetic neutrons incident to produce charged reaction particles.
20. Two-dimensional/three-dimensional display apparatus for use in, e.g., medical imaging, has display panel for displaying input image and illuminated by light being transmitted through lenticular array.

Source: Thomson Reuters Derwent World Patents Innovation Index, Accessed online February 23, 2016.

Second, the data in question clear the hurdle of face validity. That is, the patents considered are exactly the type of innovations that scholars refer to when they study military technology change. The innovations represented in these patents represent a broad array of offensive and defensive technologies used on variety of military platforms. For example, these innovations include: a system for protecting a bunker or armored vehicle from an airborne missile by means of detecting an incoming airborne missile and deploying a fragmentation projectile (DE4426014); kits for affixing mortar munitions to Predator and Raptor drones (US8237096); technologies used to assist in the take-off of the Short Take-off Vertical Landing Joint Strike Fighter (US2004050056); a night vision helmet for fighter jet pilots (FR2742636); a remote-

Table A2. Military Patent Productivity by State, 1975–2008

Country	% of Total Military Patenting	Per Capita Ranking
United States	64.31%	1
Germany	8.93%	5
Russia	6.55%	17
France	2.63%	6
United Kingdom	1.77%	7
Taiwan	1.21%	10
Israel	1.10%	2
Canada	1.07%	9
Sweden	0.71%	3
Switzerland	0.63%	4
Korea, South	0.45%	19
Australia	0.20%	14
Netherlands	0.16%	15
Belgium	0.14%	20
Norway	0.09%	12
Singapore	0.09%	8
Austria	0.08%	13
Finland	0.08%	11
Denmark	0.03%	16
New Zealand	0.01%	18

Source: Thomson Reuters Derwent World Patents Innovation Index, Accessed online February 23, 2016.

Table A3. Military Patent Productivity by Assignee

Patent Assignee	Patents	% of Total	Entity Type	Country of Origin
U.S. Sec of Navy	965	4.00%	Government	USA
U.S. Sec of Army	705	2.92%	Government	USA
Mitsubishi	689	2.86%	Corporate	South Korea
Raytheon	635	2.63%	Corporate	USA
Boeicho Gijutsu Kenkyu Honbuch	446	1.85%	Corporate	Japan
Boeing	446	1.85%	Corporate	USA
Thales	406	1.68%	Corporate	France
BAE Systems	395	1.64%	Corporate	UK
Messerschmitt-Boelkow-Blohm	393	1.63%	Corporate	Germany
Hughes Aircraft	389	1.61%	Corporate	USA
Diehl Bgt Defence	368	1.53%	Corporate	Germany
Honeywell	337	1.40%	Corporate	USA
Lockheed Martin Corp	315	1.31%	Corporate	USA
Rheinmetall	219	0.91%	Corporate	Germany
Instrument-Making Des Bur Unitary Enterp	201	0.83%	Corporate	Russia
U.S. Sec of Air Force	195	0.81%	Government	USA
Toshiba	177	0.73%	Corporate	Japan
Northrop Grumman	156	0.65%	Corporate	USA
Deutsche Aerospace	126	0.52%	Corporate	Germany
ITT Corp	116	0.48%	Corporate	USA

Source: Thomson Reuters Derwent World Patents Innovation Index, Accessed online February 23, 2016.

controlled mine detector (GB2321882); a weapons diagnostic device used in the F-15 and F-16 fighter aircraft (US2005081733); and a system for launching various type of munitions (e.g., smart bomb or precision-guided munition) from various military platforms such as fighter jets helicopters, aircraft carrier, and submarines (US2012055322). Table A1 provides the most recent 20 patent titles of the primary dataset used here. Table A2 provides a listing of the top military patent producing states.

Finally, besides "looking like" military innovation, these patents are also granted to precisely those actors that we would expect given current understandings of the military innovation system. Table A3 provides the top patent producers (by assignee) during the period of concern.

Table A4. Military Patent Productivity by Assignee (Government Agencies)

Patent Assignee	Patents	% of Total	Country of Origin
U.S. Sec. of Navy	965	4.00%	USA
U.S. Sec. of Army	705	2.92%	USA
U.S. Sec. of Air Force	195	0.81%	USA
U.K. Sec. for Defence	108	0.45%	U.K.
Soc. Nat. Ind. Aerospatiale	85	0.35%	France
U.S. Dept. Energy	58	0.24%	USA
Inst. Franco Allemand Rech. Saint Louis	50	0.21%	Germany/France
Canada Min Nat Defence	46	0.19%	Canada
Armed Forces General Military Acad	45	0.19%	Russia
U.S. Dept. of The Navy	38	0.16%	USA

Source: Thomson Reuters Derwent World Patents Innovation Index, Accessed online February 23, 2016.

The table demonstrates that our dataset is dominated by the actors that make up the military R&D community. Government military research agencies are also represented in the sample, Table A4 provides the top government contributors to our military innovation dataset.

Appendix B: Countries Included in the Analyses

After removing countries with populations less than two million, the United States, and countries with that filed no USPTO patents during the period (1975–2010), the dataset contained the following list of 112 countries:

Albania, Algeria, Argentina, Armenia, Australia, Austria, Azerbaijan, Bangladesh, Belarus, Belgium, Benin, Bolivia, Bosnia and Herzegovina, Brazil, Bulgaria, Burkina Faso, Cameroon, Canada, Chad, Chile, China, Colombia, Congo, Democratic Republic, Costa Rica, Cote d'Ivoire, Croatia, Cuba, Czech Republic, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Ethiopia, Finland, France, Georgia, Germany, Ghana, Greece, Guatemala, Guinea, Haiti, Honduras, Hungary, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Korea (North), Korea (South), Kyrgyzstan, Latvia, Lebanon, Liberia, Lithuania, Madagascar, Malawi, Malaysia, Mauritania, Mexico, Moldova, Morocco, Myanmar, Netherlands, New Zealand, Nicaragua, Nigeria, Norway, Pakistan, Panama, Paraguay, Peru, Philippines, Poland, Portugal, Romania, Russia, Saudi Arabia, Senegal, Serbia, Singapore, Slovakia, South Africa, Spain, Sri Lanka, Sweden, Switzerland, Syria, Taiwan, Tanzania, Thailand, Tunisia, Turkey, Uganda, Ukraine, United Arab Emirates, United Kingdom, Uruguay, Uzbekistan, Venezuela, Vietnam, Yemen, Zimbabwe

After controlling for economic development (1974), the dataset contained 90 countries: Albania, Algeria, Argentina, Australia, Austria, Belgium, Benin, Bolivia, Brazil, Bulgaria, Cameroon, Canada, Chile, China, Colombia, Congo (Democratic Republic), Costa Rica, Cote d'Ivoire, Cuba, Czech Republic, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Ethiopia, Finland, France, Germany, Ghana, Greece, Guatemala, Haiti, Honduras, Hungary, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kenya, Korea (North), Korea (South), Lebanon, Malaysia, Mexico, Morocco, Myanmar, Netherlands, New Zealand, Nicaragua, Nigeria, Norway, Pakistan, Panama, Paraguay, Peru, Philippines, Poland, Portugal, Romania, Russia, Saudi Arabia, Senegal, Singapore, Slovakia, South Africa, Spain, Sri Lanka, Sweden, Switzerland, Syria, Taiwan, Tanzania, Thailand, Tunisia, Turkey, United Arab Emirates, United Kingdom, Uruguay, Venezuela, Vietnam, Yemen, Zimbabwe

Appendix C: Base Regression Models Using Alternative Innovation Measures

Table C1. Joint Military Exercises, Dependent Variable = PCT Patents

	(1)	(2)	(3)	(4)
Joint military exercises	0.324	0.287	0.372	0.426
	0.192	0.170	0.220	0.232
	[2.15]*	[2.03]*	[2.47]*	[2.63]*
Development (1974)	0.621	0.620	0.574	0.494
	[8.18]***	[7.74]***	[6.49]***	[3.85]***
Democratic institutions (1974)		0.208		0.197
		[2.89]**		[2.83]**
Institutional stability (1974)			0.193	
			[3.41]**	
Globalization (1974)				0.155
				[1.61]
Constant	–21.346	–20.533	–20.604	–20.26
	[–22.29]***	[–19.87]***	[–20.96]	[16.12]***
No. Obs.	87	87	87	79
R^2	0.596	0.636	0.626	0.693

Notes: Analysis is by OLS using Huber–White standard errors, t-statistics in brackets, standardized beta coefficients in italics. Analysis limited to countries with average population > 2,000,000. Joint military exercises = # of joint military exercises, 1975–2010; Development (1974) = per capita GDP, 1974; Democratic institutions (1974) = democratic inclusivity composite score (Coppedge et al., 2008), 1974; Institutional stability (1974) = Polity IV regime durability, 1974; Globalization (1974) = KOF Economic Globalization Index Score, 1974. The Coppedge et al. (2008) measure of "Democratic Institutions" is not available for 2009. We thus use only one measure for domestic institutions: institutional stability.
$^*p < .05$, $^{**}p < .01$, $^{***}p < .001$.

Table C2. Joint Military Exercises, Dependent Variable = Capacity for Innovation (2010)

	(1)	(2)	(3)
Joint Military Exercises	0.123	0.138	0.116
	0.184	*0.206*	*0.174*
	[2.20]*	[2.71]**	[2.15]*
Development (2009)	*0.608*	*0.395*	*0.199*
	[7.14]***	[4.87]*	[1.10]
Institutional Stability (2009)		*0.334*	*0.327*
		[3.91]***	[3.92]***
Globalization (2009)			*0.242*
			[1.35]
Constant	–0.296	0.499	0.677
	[–0.30]	[1.38]	[1.62]
No. Obs.	115	114	114
R^2	0.526	0.595	0.606

Notes: Analysis is by OLS using Huber–White standard errors, t-statistics in brackets, standardized beta coefficients in italics. Analysis limited to countries with average population > 2,000,000. Joint military exercises = # of joint military exercises, 1975-2010; Development (2009) = per capita GDP, 2009; Institutional stability (2009) = Polity IV regime durability, 2009; Globalization (2009) = KOF Economic Globalization Index Score, 2009.
$^*p < .05$; $^{**}p < .01$; $^{***}p < .001$.