Nuclear Stability and Conventional Conflict

Matthew Kroenig[†]
Robert F. Trager[††]

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What is the relationship between the stability of the nuclear balance among nuclear-armed states and the incidence of conventional warfare? The stability-instability paradox suggests that the more stable the strategic nuclear balance, the higher the likelihood of conventional conflict. We demonstrate the logic of this argument with a simple rationalist model of conflict and then test the argument using a new dataset of nuclear capabilities. We find strong evidence that several measures of nuclear stability are related to a substantial increase in the probability of conventional conflict. The evidence indicates these results are not driven by the possibility that nuclear stability is endogenous to expectations of conflict.

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[†] Assistant Professor, Georgetown University, mhk32@georgetown.edu.
[††] Assistant Professor, University of California, Los Angeles, rtrager@ucla.edu.

In its prototypical version, the "stability-instability paradox" considers rival states possessing both conventional and nuclear weapons. The first word, "stability," refers to the likelihood of a nuclear war between them, and the next, "instability" is the probability of conventional conflict. The "paradox" is that if they take steps to increase nuclear stability, such as developing secure, second-strike capabilities, they will feel safer to engage in conventional wars and these will become more frequent.

In 1956, Liddell Hart gave a clear statement of the idea, and the concept later became associated with Snyder (1965), who did not use the name but discussed the logic (Bleek 2007, Krepon 2005). During the Cold War, the argument prompted American strategists to worry that the Soviet Union would feel confident to invade Western Europe, and many called for steps to destabilize nuclear weapons (Jervis 1984). They avoided the word "destabilize," of course, talking instead about "coupling" a conventional war to a global nuclear war, or generating a "seamless web of deterrence" that crossed between the two levels of conflict.

Recent nuclear proliferation, threatened or actual, has generated more interest in the idea. Kapur and Ganguly (2008), for instance, debated whether the conflicts between India and Pakistan, such as the 1999 war in Kargil, were prompted by the nuclear tests in 1998, or whether they happened in spite of these. Analysts have also examined the implications of proliferation in other places such as the Korean peninsula and the Middle East.

In the first section of the article, we analyze a simple model to predict the conditions under which the paradox will hold. Past formal models of deterrence, crisis instability and escalation touched on the idea (e.g. O'Neill 1994, Powell 1989), and some have addressed it explicitly (e.g., Zagare and Kilgour 2000), but we are not aware of any that focus on the paradox or provide formal rationalist foundations for it. We construct a model in which the incentive to strike first is dependent on the second strike capability of the other side and each side's expectations about the incentives and behavior of the other side.[1] We show that instability, understood as the incentive of one side or the other to strike first with nuclear weapons, dramatically decreases the probability of conventional war.

In the second section, drawing on a new dataset of nuclear stability among nuclear-armed states, we examine the impact of nuclear stability on international conflict. Recent quantitative research examines the effect of nuclear weapon possession on conflict(Gartzke and Kroenig 2009; Rauchhaus 2009; Gartzke and Jo 2009), but these scholars examine differences in conflict behavior between nuclear and nonnuclear states. Unlike the stability-instability paradox as classically conceived, they do not examine how variation in nuclear stability affects conflict among the subset of states with nuclear arms. We find a powerful relationship between the stability of the nuclear balance and the likelihood of conflict between nuclear-armed states. Shifting from a position of nuclear instability to a position of nuclear stability is associated with a 950% increase in the probability that a dyad experiences a militarized interstate dispute (MID). This finding holds even after controlling for confounding factors and evidence indicates that it is not driven by strategic selection into a position of nuclear stability.

We conclude with the implications of our findings for theory and practice. This project contributes to scholarship by presenting the first formal theoretical model and the first systematic empirical test of the stability-instability paradox. While the article's primary contribution is to the scholarly literature on nuclear deterrence and international conflict, it also contains important implications for defense policy. Our findings suggest that as officials develop their nuclear force postures, they face an important dilemma. By striving for strategic stability vis-

[1]Other mechanisms that have been suggested to lead to instability in the sense of increasing the probability of a nuclear war resulting from a conventional conflict include accidents including misunderstood information that the other side is attacking, unauthorized use, or the emotions of tension and desperation.

a-vis nuclear-armed rivals, they may reduce the probability of nuclear war (although this is uncertain), but only by increasing the likelihood of conventional conflict.

A Model of the Stability-Instability Paradox

The standard version of the paradox relates the stability of nuclear weapons (rather than their simple possession) to the frequency of conventional wars. Related ideas have sometimes born the title. One is whether more conventional conflict springs from increasing existing nuclear arsenals; another is whether it follows from acquiring nuclear weapons for the first time, either alone or jointly with a rival; and another is whether nuclear instability not only permits conventional wars but foments them (Bleek 2007).

We shall focus on the logic of the standard version. The model described here provides rationalist foundations for the paradox. The analysis also demonstrates the conditions under which the level of nuclear stability will have profound effects on the likelihood of conventional war.

There are two states, State 1 and State 2, indexed by $i, j \in I \equiv \{1, 2\}$. In the first stage, nature draws costs of conventional conflict c_i for each player from commonly known, independent distribution functions f_i with supports $(0, \bar{c}_i]$. Nature's draws are observed by both players. State 1 then decides whether to initiate a conventional war. If it does not, State 2 decides whether to begin a conventional war. If either player initiates a conventional war, both players then simultaneously decide whether to initiate a nuclear war. We shall refer to this as the nuclear war decision subgame. If one state does and the other does not, then a nuclear war occurs in which the first state has initiated a first strike.

Players are bargaining over outcomes in the bargaining space $X \equiv [0, 1] \subset \mathbb{R}$ (with generic element x) and at the beginning of the game, the status quo is $q \in X$. Player utilities are increasing in their share of X. If neither player initiates a conventional war, players' payoffs are q and $1-q$ respectively.[2] If a conventional or nuclear war is fought, one state or the other wins the war, and the winning state achieves its most preferred outcome in the bargaining space. (The costs of fighting a nuclear war, discussed below, may be so high that achieving the most preferred bargaining outcome would be of little importance.) The probability that State 1 wins the conventional conflict is p and each player pays a cost of conventional conflict c_i. Without loss of generality, taking player utilities for their least and most preferred bargaining outcomes to be 0 and 1 respectively, player expected utilities for conventional conflict are $p - c_1$ and $1 - p - c_2$.

We let b_i be the probability that player i wins a nuclear war when that side strikes first. This probability must therefore account for the second strike capability of the other side and b_i can be interpreted as the nuclear balance immediately following the first strike. Costs of nuclear conflict depend heavily on these same factors. If a first strike would destroy the nuclear arsenal of the other side, for instance, b_i would approach 1 and costs of conflict to player i would be minimal.[3] We therefore take the costs of a nuclear conflict where State i strikes first to be $c_i^n(1-b_i)$ and $c_j^n b_i$ for $j \neq i$. $c_i^n > c_i$ for all i.

When both sides initiate a nuclear war, players' expected utilities are r_i. We assume that players would prefer to strike first to simultaneous strikes and simultaneous strikes to striking second and that both sides prefer the status quo to a nuclear war initiated simultaneously by the sides. Formally, $q > r_1 > 1 - b_2 - c_1^n b_2$, $1 - q > r_2 > 1 - b_1 - c_2^n b_1$, $b_1 - c_1^n(1-b_1) > r_1$

[2] We assume risk neutrality over outcomes in the bargaining space only for simplicity of exposition. This has no effect on the substantive conclusions of the model.

[3] The psychological and ethical costs of initiating a first strike will vary greatly across leaders and are not considered here.

and $b_2 - c_2^n(1 - b_2) > r_2$. A final piece of notation is η, which we shall use to denote the overall probability of conventional conflict in a particular subgame perfect equilibrium.

The model has an equilibrium in which the status quo is always the outcome because both sides are expected to launch a nuclear attack if the status quo is challenged. This clearly does not match the strategic expectations of states. The equilibrium also does not correspond to the facts of international history, which includes many instances of low level conventional conflicts between nuclear powers.

A more reasonable equilibrium also exists, however. In this equilibrium, players fight a conventional war when one side is sufficiently dissatisfied with the status quo and they each prefer a conventional war to initiating a first strike. When one side or the other has an incentive to launch a first strike, the players understand this and choose to maintain the status quo. We shall focus on this second pure strategy equilibrium.

The parameters b_1 and b_2 capture the most common understanding of instability related to the second strike capability of the sides. Proposition 1 demonstrates that the stability-instability paradox follows a rationalist logic in the more reasonable equilibrium. The proposition demonstrates that an equilibrium exists in which the probability of conflict is decreasing in b_1 and b_2.

Proposition 1 A subgame perfect equilibrium exists in which η is weakly decreasing in b_1 and b_2, and strictly decreasing in at least one over some range.

The impact of first-strike advantages can be seen graphically in Figure 1. Here, State 1 is "dissatisfied" with the status quo ($q < p$), but not necessarily so dissatisfied as to start a war. The costs of conventional war, a measure of state resolve, are assumed to follow a stochastic process. In this example, the costs of war of each state are uniformly and independently distributed between 0 and 1. As the figure illustrates, when either state has a sufficiently high first-strike incentive (b_i), the probability of conventional war is zero because both sides understand that a conventional war must result in a nuclear war. In this parameter range, this is true of any equilibrium of the model.

Figure 1 About Here.

In some parameter ranges, decreases in the first-strike incentives of both states increase the probability of conflict and decreases in the incentive of one increase the marginal effect on the probability of war of decreases in the incentive of the other. When State 1, the dissatisfied state, has a sufficiently low incentive to initiate a nuclear first strike, however, further decreases in State 1's first strike incentive have no effect on the probability of conventional war. The reason is that if State 1 has a small first-strike incentive, then if State 1's costs of conventional war, c_1, are sufficiently low such that State 1 would prefer to fight a conventional war rather than maintain the status quo, then State 1's costs are also sufficiently low such that it is certain to prefer a conventional war to a nuclear war. In such cases, further decreases in State 1's first-strike incentive have no effect on the probability of conventional war.

Discussion

The model provides a rationalist foundation for the stability-instability paradox. The greater the second strike capability of both sides, the greater the likelihood of conventional conflict. If the second strike capability of either side is questionable, then neither side will initiate a conventional conflict for fear of provoking a nuclear war.

These dynamics offer an explanation for why the first strike advantage of one side or both is destabilizing. Suppose State 1 has a strong incentive to initiate a first strike - it has the capability to destroy all or most of the State 2's nuclear capabilities in a first strike. In the event of a conventional conflict, therefore, State 1 would have an incentive to initiate a nuclear war. State 2 will understand this as well and, while State 2 would likely have a very strong preference to avoid nuclear war altogether, it reasons that if a nuclear war is coming because of State 1's incentive to strike first, then nuclear war where State 2 launches before its nuclear capabilities are destroyed appears preferable to a nuclear war where State 1 launches first. Thus, even though State 2 is disadvantaged in terms of nuclear capabilities, the advantage of State 1 and State 2's resulting expectations about State 1's behavior give State 2 an incentive to initiate a nuclear war. Of course, State 1 also prefers to initiate a nuclear war when it expects State 2 to do so. So, first-strike incentives on one side create a general instability. Since both sides understand and expect these dynamics, both sides have incentive to avoid escalating to the stage where State 1 is faced with the choice between conventional and nuclear war. Better, both reason, that State 1 be faced only with the choice between the status quo and an escalation that would lead to nuclear war. In the latter case, State 1 decides to live with things as they are and State 2 does as well.[4]

The model also suggests that if the conventional and nuclear balances are very different, the chances of conventional war will be reduced. If State 1 has the nuclear capability to destroy much of the arsenal of its adversary, then the weaker State 1 is in conventional terms, the more likely a conventional conflict would result in a nuclear war. In such cases, the probability of conventional conflict decreases in the conventional weakness of State 1.[5]

Certain other ways of conceptualizing the strategic context produce similar relationships between nuclear stability and conventional conflict. Suppose, for instance, that the satisfied state, State 2, has an opportunity to buy off State 1, but that public commitments made

[4]For related discussions of the relationship between first-strike advantages and stability, see Powell 1989, Snyder 1965, and Snyder and Diesing 1977.

[5]This point can be seen formally through an examination of equations (1) and (2) in the appendix.

previously and other factors imply that State 2 would rather fight a conventional war than do so. If a nuclear war were expected to be particularly costly to State 2, as it certainly would be if State 1 had a substantial advantage in the nuclear balance, however, then State 2 might prefer to buy off the dissatisfied state rather than face a nuclear conflict. In such a context, as in the model described previously, the likelihood of conventional conflict decreases in the first-strike incentive of State 1.

Some ways of understanding the strategic context do not produce a stability-instability paradox, however. In some bargaining models with incomplete information, for instance, the nuclear advantage of one side increases the probability of conventional and nuclear conflict by increasing the aggressiveness of the advantaged side (even though the behavior of the disadvantaged side is also moderated).[6] The equilibrium dynamics are also somewhat different in models where nuclear wars occur probabilistically, rather than as a result of the choices of the actors, and the likelihood of nuclear conflict increases in the severity of the conventional conflict. In such a framework, the expected utility of conventional war can increase in the probability of nuclear war resulting from a given level of aggression. Thus, contrary to the paradox, greater nuclear instability can produce more frequent conventional conflict. The reason for this dynamic is that nuclear instability can sometimes cause conventionally superior powers to refrain from pressing their advantage, which in turn can increase the attractiveness of conflict to weaker powers. While we think these dynamics are likely to be the exception rather than the rule for the reasons stated above, we believe additional theoretical inquiry in this area would

[6]See, for instance, Powell 2003. On the relationship between costs of war and willingness to risk one, see Banks 1990 and Slantchev 2010, 136-141. For an empirical demonstration that nuclear superiority increases bargaining leverage, see AUTHOR.

yield insight.[7]

Data

To analyze the effect of nuclear stability on international conflict, we created a new nuclear stability dataset that includes information on nuclear force size and delivery vehicles for every nuclear-armed state in the international system. We analyze our hypotheses in a standard statistical test of international conflict using a sample of all dyad years (1950-1992). This sample has been the subject of many prominent analyses of the determinants of international conflict (e.g., Russett and Oneal 1999; Gartzke 2007). We limit our analysis to dyads in which both states possess nuclear weapons because the stability-instability paradox is a theory about how variation in nuclear stability affects the behavior of nuclear-armed states and because scholars have previously studied the effect of nuclear weapon possession on conflict among all states (e.g., Rachchaus 2009; Gartzke and Jo 2009). Nevertheless, a robustness test including all states (nuclear and nonnuclear) produces similar results to those reported below.

Dependent Variable

The Correlates of War's construction of dyadic militarized interstate disputes (MID) is used as the dependent variable, with the standard dichotomous coding of "1" if a MID occurred in the dyad and "0" otherwise (Gochman and Maoz 1984; Jones, Bremer, and Singer 1996; Ghosn, Palmer, and Bremer 2004). MIDs include threats to use force, shows of force, uses of force, and war. A total of 46 MIDs occurred among nuclear-armed states between 1950 and 1992.

[7]For discussion of dynamics of this sort see Kapur 2008 and AUTHOR.

Key Independent Variables

To develop measures for nuclear stability, we began by collecting data on nuclear arsenal size and the numbers, types, and ranges of delivery vehicles for every nuclear-armed state in the international system from 1945 to the present. Appendix B provides information on the coding rules and sources used to calculate nuclear arsenal sizes. The size of nuclear arsenals ranges from a low of zero (France from 1960 to 1963) to a high of 40,723 (the Soviet Union in 1986).[8] Next, we coded dyadic information on whether a nuclear-armed state possessed nuclear-capable ballistic missiles, nuclear-capable bomber aircraft, and submarine launch ballistic missiles (SLBMs) capable of reaching the other state in the dyad. Information on the initial operational capability (IOC) of delivery vehicles and their ranges were taken from a variety of sources, including the The Bulletin of the Atomic Scientists, the Federation of American Scientists, the National Resources Defense Council, and the Nuclear Threat Initiative. A state was considered capable of delivering nuclear weapons to the other state in the dyad if the distance between capital cities was less than the maximum range of the state's ballistic missiles or bomber aircraft, or if the state possessed SLBMs, which, due to the ability of submarines to maneuver in open waters, have virtually unlimited ranges. Of course, states could always deliver nuclear weapons using unconventional means (e.g., on a cargo ship) or, if unable to deliver them against an adversary's homeland, use them against a target valued by the opponent, such as a regional state aligned with the opponent, but these three platforms are the most reliable means of delivering nuclear weapons. Appendix C provides a list of the nuclear-armed states, the nuclear-armed opponents against which these states are capable of delivering nuclear weapons, as well as the years in

[8] France became a nuclear power when it conducted its first nuclear test in 1960, but did not begin maintaining a nuclear stockpile until 1964.

which the states achieved that capability.[9]

In the theoretical section, we defined nuclear instability as prevailing when one or both states possess a nuclear first-strike capability against its opponent. This is consistent with the theoretical and policy literature, which also conceptualizes nuclear stability as resulting from the possession of secure, second-strike capabilities by nuclear-armed opponents (Glaser 1990). To measure nuclear stability, therefore, we assess whether at least one state within the dyad enjoys a possible first-strike advantage. We begin with a minimalist conceptualization of stability. Clearly, a state lacks a secure second-strike capability and might be vulnerable to a first strike if its opponent has the ability to target it with nuclear weapons, but it does not itself possess a reliable means of retaliation against its opponent. *Nuclear stability* is a dichotomous variable coded "0", for unstable, if one of the states in the dyad lacks a reliable means of delivering nuclear weapons to the homeland of an opponent. It is coded "1," for stable, if both nuclear-armed states in the dyad have the ability to deliver nuclear weapons against each other.

We also create alternate measures of nuclear stability. In addition to the possession of delivery vehicles, a state might be vulnerable to a first strike if its opponent possesses a preponderant share of the total nuclear warheads in the dyad. Nuclear strategists argue that nuclear superiority provides states with a counterforce advantage because it provides them more firepower with which to blunt the nuclear capabilities of their opponents (Glaser 1990, 133-165; Kaplan 1991, 201-219; Freedman 1989, 117-130). The possession of over 75% of the warheads within a dyad, for example, would give a state the ability to target at least three of its warheads on every one of its opponent's warheads, potentially causing leaders in one or both states to believe that that state possesses a first-strike advantage. If, on the other hand, both states have the ability to reliably deliver nuclear warheads to the homeland of its opponent and neither state

[9]This data is available here: AUTHOR WEBSITE.

possesses a stark nuclear advantage, neither state possesses a first-strike capability and the nuclear balance could be considered stable. Our next measure of nuclear stability, therefore, accounts for the effects of large numerical advantages in nuclear warhead counts. *Ratio stability* is a dichotomous variable coded “0”, for unstable, if one of the states in the dyad lacks a reliable means of delivering nuclear weapons to the homeland of an opponent, or if both states have a reliable means of delivery, but one state possesses at least 75% of the nuclear warheads within the dyad. Otherwise, it is coded “1” for stable.

While many nuclear strategists conceive of nuclear instability as resulting from the possession of a first-strike capability, many others conceive of stability as a continuum. They believe that as states make adjustments to their nuclear posture, such as increasing or decreasing the number of warheads or developing or retiring delivery vehicles, they can increase or decrease strategic stability among nuclear-armed states. While strategic stability depends on many factors, strategists generally assume that stability increases as the numbers of warheads and delivery vehicles on both sides increase, because the prospect for a first strike by one side or the other becomes less imaginable. For example, analysts often argue that the nuclear balance between the United States and the Soviet Union was more stable in the mid-1970s when both states had tens of thousands of warheads and all three major delivery platforms than in the early 1960s when both sides had fewer warheads and means of delivery. The *Stability index* is a five-point index that ranges from 0 (less stable) to 5 (more stable). It is coded: (0) if at least one of the states has fewer than one hundred nuclear weapons and/or lacks a reliable means of delivery against its opponent, (1) if both states have at least one hundred nuclear weapons and one means of reliable delivery, (2) if both states have at least two hundred nuclear weapons and two reliable means of delivery, (3) if both states have at least five hundred nuclear weapons and two reliable means of delivery (4) if both states have at least one thousand nuclear weapons and three reliable means of delivery, and (5) if both states have at least ten thousand nuclear weapons and three reliable means of delivery.

Control Variables

We include a standard set of control variables to account for other factors that might affect the onset of military conflict. All variables are from Oneal and Russett (1999) and extracted using EuGene (Bennett and Stam 2000) unless otherwise noted. For instance, states in close geographic proximity are more likely to fight one another. To account for the possible confounding effect of geography on conflict, therefore, we include *Distance*, a variable that gauges the great circle distance between national capitals.

Previous studies also control for the conventional military balance between states (e.g., Oneal and Russett 1997, Gartzke 2007). *Capabilities* assesses the ratio of the capabilities of the stronger state in the dyad to that of the total combined capabilities of both states in the dyad. Capabilities are measured using the Correlates of War (COW) composite capabilities index (CINC), which contains information on total population, urban population, energy consumption, iron and steel production, military manpower, and military expenditures.[10]

The democratic peace hypothesis suggests that democratic states are less likely to engage in conflict with one another (e.g., Doyle 1986; Oneal and Russett 1997). Following standard practice, we measure democracy using Polity scores, drawn from the Polity IV data set (Jaggers and Gurr 1995). Following previous research (Russett and Oneal 2001; Gartzke 2007), we employ a "weak link" measurement strategy. *Democracy(low)* reports the lower of the democracy

[10]Studies of conflict often control for whether at least one state in the dyad is a major power and for alliance ties between states. These variables are not included in this study because major power status is collinear with nuclear weapons possession and because the "no alliance" category perfectly predicts failure among nuclear-armed states.

scores in the dyad.

The commercial peace literature contends that trade dependence has a dampening effect on the onset of conflict. To capture this factor, we follow the Oneal and Russett operataionalization. Levels of trade dependence for each state are constructed using a ratio of bilateral trade as a percentage of each state's GDP to measure the importance of bilateral trade in relation to the state's total economy. *Trade(low)* denotes the lower trade dependence statistic in the dyad (Oneal and Russett 1997, 1999a, 1999b).

Empirical Analysis

We begin by analyzing simple cross tabulations of stability and international conflict. The results are presented in Table 1. As the table illustrates, nuclear-armed states are conflict prone. Militarized disputes are often considered rare events by international relations scholars, but the table reveals that nuclear-armed states experience conflict in 7% of all observations. This is consistent with past research (e.g., Rauchhaus 2009), which suggests that nuclear-armed states are more likely to experience conflict than nonnuclear states. The table also demonstrates that strategic stability is slightly less common than strategic instability. Of the 624 dyad years, 306 (49%) are characterized by nuclear stability. Turning now to the evidence for the theory presented above, we find that nuclear stable dyads are more likely to experience conflict than unstable dyads. Stable nuclear dyads experience a militarized interstate dispute in 10% of the observations. This is more than double the rate (4%) at which unstable nuclear dyads experience conflict. The chi-squared test reveals that the probability of observing this difference between stable and unstable nuclear dyads if strategic stability has no bearing on conflict behavior is 0.004. Simple cross tabulations provide support for the idea of a stability-instability paradox. Nuclear stable dyads are more likely to experience military disputes than nuclear unstable dyads.

Insert Table 1 About Here.

Next, we turn to the results of the regression analysis. We estimate coefficients using probit. [11] We employ cubic polynomials (Carter and Signorino 2010) to control for duration dependence. Robust standard errors are adjusted for clustering by dyad. The results are presented in Table 2. The table demonstrates that Nuclear stability is statistically significant and positively correlated with the occurrence of MIDs when measured using *Strike stability* (model 1), *Ratio stability* (model 2), or the *Stability index* (model 3). Nuclear stable dyads are more likely to experience conflict than unstable dyads. The analysis reveals strong support for the existence of a stability-instability paradox.

Insert Table 2 About Here.

Using Clarify, we assess the substantive effect of shifting from nuclear instability to nuclear stability on the probability of militarized conflict after accounting for possible confounding factors. We find that a shift from nuclear instability to nuclear stability is associated with a 952% increase in the probability of conflict. [12] The stability of the nuclear balance has a substantive, as well as a statistically, significant effect on conflict behavior.

[11]The results are not sensitive to the choice of statistical estimator. Using Logit and Rare-events Logit produced similar results

[12]Substantive interpretations are based on Table 2, model 1. All variables are set to their means. The expected probability of MID onset for a nuclear unstable dyad, holding all other variables constant at their mean, is 0.0005. The 95% confidence interval is 7.16e-10 to 0.004. A dyad characterized by nuclear stability, however, has an expected probability of conflict when holding the other variables at their mean of 0.005. The 95% confidence interval is 8.30e-07 to 0.034.

Next, we briefly comment on the control variables. We find support for the commercial peace hypothesis. The sign on the coefficient for *Trade(low)* is negative and statistically significant in every model in which it is included. Consistent with past research, therefore, we find that the more trade dependent the states in a dyad, the less likely they are to experience conflict. The other variables receive less support. *Capabilities* is statistically significant in model 1, but not in models 2 and 3. While the other variables, *Distance* and *Democracy(low)*, do not reach statistical significance in any of the models in which they are included. Although these variables have been shown to correlate with conflict in previous research, it is understandable that the conflict behavior of the nuclear-armed states analyzed in this study would exhibit different patterns of conflict. The conventional balance of power and distance are often correlated with conflict among states when analyzing the entire universe of cases because they are indicators of a state's opportunity to come into conflict with other states. The subset of nuclear-armed states, however, contain a disproportionate share of major powers with strong conventional militaries and the capability to project power great distances. It is intuitive, therefore, that these variables would be less salient predictors of conflict among a subset of nuclear-armed states. The finding that the democratic peace hypothesis might not hold among nuclear-armed states is intriguing, less intuitive than the other nonfindings, and could make an interesting subject for further research.

Robustness Tests

This section presents the results of a number of robustness tests to examine whether the observed relationship between nuclear stability and conflict is sensitive to model specification or is the result of a selection effect or endogeneity.

We first examine whether the results depend on model specification. To ensure that the results were not being driven by the inclusion of specific control variables, we reran dozens of models, omitting right-hand-side variables one at a time. The core results were unaffected.

Next, we analyzed whether the findings are the result of an endogenous relationship between the level of conflict in a dyad and investment in nuclear capabilities. It is possible that stable nuclear dyads experience greater levels of conflict, not due to the stability-instability paradox, but because dispute-prone dyads are more likely to invest in second-strike capabilities, causing their dyads to be characterized by nuclear stability. The standard means of exploring this possibility would be through instrumental variables techniques. We see no instruments that appear sufficiently correlated with nuclear acquisition decisions in dyads and uncorrelated with conflict decisions, however. Therefore, we conducted two separate tests, presented in Table 3.[13]

Insert Table 3 About Here.

First, we estimated a first-stage model of the correlates of *Nuclear stability*. We specified *Nuclear stability* as a function of the CINC score of State A and the CINC score of State B under the assumption that more capable states are more likely to develop secure second-strike capabilities. Next, we estimated the predicted probability that a dyad achieves nuclear stability to create a new variable *Pr(Nuclear stability)*. We then included this variable on the right-hand side of a Probit regression estimating MID onset alongside the full range of independent variables described above. We found that *Pr(Nuclear stability)* did not reach statistical signifigance.[14] There is no relationship between the probability that a dyad will acheive nuclear stability and the incidence of conflict. This casts doubt on the possibility that an endogenous relationship between stability and conflict explains the results. Moreover, the various measures of nuclear stability remained positive and statistically significant even after controlling for *Pr(Nuclear*

[13]This data is available here: AUTHOR WEBSITE.

[14]See Table 3, model 4.

stability). Indeed, a shift from nuclear instability to nuclear stability resulted in a roughly 400% increase on the probability of MID onset even after accounting for the probability that a dyad is characterized by nuclear stability.

Second, we reran the models after excluding each state's primary nuclear rival. Past studies have demonstrated that the acquisition of nuclear capabilities is not driven primarily by the need to balance against nuclear armed rivals (e.g., Sagan 1995/1996). It is unlikely, therefore, that the results described above are a product of an endogenous effect such that states that expect to experience disputes with specific states seek nuclear parity with those states. Nevertheless, as a second test of this possibility, we conduct the above analysis on a subset of the data that excludes primary nuclear rival dyads. We define primary nuclear rivals as dyads in which the nuclear force posture of both states in the dyad developed largely in response to the nuclear capabilities of the other. We define primary nuclear rivals as the United States and the Soviet Union during the Cold War and India and Pakistan. We then excluded all observations including primary nuclear rivals. Rerunning the above analysis on the remaining subset of data did not affect the key findings. *Nuclear stability* was statistically significant and positively correlated with MID onset.[15] This test demonstrates that the observed relationship between nuclear stability and conflict is not the result of a selection effect in which dyads select into nuclear stability based on their expectations of future conflict with a primary nuclear rival. This test also demonstrates that the results are not driven exclusively by the most prominent and dispute-prone nuclear dyads.

[15]See Table 3, Model 6.

Conclusion

This article examined the relationship between the stability of the strategic nuclear balance and the dispute behavior of nuclear-armed states. We formalized rationalist foundations for the stability-instability paradox and discussed the conditions under which such foundations exist. We hypothesized that dyads in which both states possess secure, second-strike capabilities (strategic stability), will be more likely to experience conventional disputes (tactical instability).

In our empirical analysis, we found that dyads characterized by nuclear stability were more likely to experience conventional conflict than those marked by nuclear instability. This finding held even after controlling for other determinants of conflict and for possible selection and endogeniety biases. The primary contributions of this article, therefore, are to present the first formal theory and the first systematic empirical test of the stability-instability paradox.

In testing for a stability-instability paradox, this article also provided an analysis of the determinants of conflict among nuclear-armed states. There is a vast scholarly literature on the causes of international conflict. Empirical studies often find that measures of capability are strongly correlated with the incidence of disputes. This is the first study to our knowledge, however, that explores the causes of conflict among nuclear-armed states. We found that common predictors of conflict, such as the conventional balance of power and geographic distance, do not explain the frequency of conflict among nuclear-armed states. This finding is understandable given that nuclear-armed states are among the most capable states in the international system and military capabilities and geographic distance impose less of a constraint on their ability to project power and, thus, to come into conflict with one another. This finding suggests that scholars should be careful about drawing inferences about the causes of conflict among nuclear-armed states from studies performed on a universe of all states in the international system.

By carefully measuring nuclear stability according to nuclear arsenal size and the ranges of a state's nuclear delivery vehicles, this article also contributes to a growing scholarly literature that takes nuclear force posture seriously (e.g., Narang 2009). Much of the previous scholarly literature on nuclear deterrence has examined differences in the conflict behavior of nuclear and nonnuclear states (e.g., Sagan and Waltz 1995; Rauchhaus 2009), but there has been less attention to how variation in the nuclear postures of nuclear-armed states affects international politics. Defense planners have long operated on the assumption that numbers of nuclear weapons and the capabilities of nuclear delivery vehicles have a strong bearing on deterrence outcomes, but scholars have largely ignored the effects of nuclear posture on conflict. The findings of this study suggest that scholars potentially overlook important determinants of conflict by ignoring variation in nuclear force posture and nuclear stability.

While the primary contribution of this article is to develop our scholarly understanding of the stability-instability paradox, it also contains important implications for U.S. national security policy. In the 2010 Nuclear Posture Review (NPR), the United States articulated five key objectives for U.S. nuclear weapons including "maintaining strategic deterrence and stability at reduced force levels" (DoD, iii). In the report, Washington vowed to pursue future nuclear reductions, but recognized that cuts to the size of the nuclear arsenal, combined with other developments, such as its continued pursuit of missile defense capabilities and conventionally-armed ballistic missiles, and nuclear modernization in Russia and China, could eventually combine to weaken strategic stability among the major nuclear powers. The logic underpinning our theoretical argument suggests that U.S. officials are correct to worry that future force reductions could undermine strategic stability, especially if the reductions proceed to the point at which one or more nuclear-armed states believes it has a first-strike capability. More fundamentally, however, the findings of this article suggest that U.S. foreign policy makers face an intractable dilemma. The logic and evidence of the stability-instability paradox suggests that the maintenance of strategic stability can actually foment lower-level violence among the great powers. U.S. officials, therefore, may have a choice between pursuing strategic stability at the risk of increased conflict at lower levels, or to deter lower-level conflict by increasing the risk of nuclear war. This is a tradeoff that is not explicitly recognized in the NPR, but both theory and evidence suggest that the paradox should be taken seriously by U.S. officials.

In navigating this dilemma, we believe that the United States should prioritize the reduction in the risk of a catastrophic nuclear war to the greatest extent possible. For this reason, the best course in our view is to pursue strategic stability among the major powers to deter nuclear war, while simultaneously taking other steps, such as investing in conventional military capabilities, to deal with lower-level conflicts that will likely result.

Appendix A: Proof of Proposition

Proof of Proposition 1 We will show that these strategies constitute a subgame perfect equilibrium with the required property. Let State 1's strategy be: choose war at the first decision node iff $p - c_1 > q$, $p - c_1 > b_1 - c_1^n(1 - b_1)$ and $1 - p - c_2 > b_2 - c_2^n(1 - b_2)$; choose conventional war in any nuclear war decision subgame iff $p - c_1 > b_1 - c_1^n(1 - b_1)$ and $1 - p - c_2 > b_2 - c_2^n(1 - b_2)$. Let State 2's strategy be: choose war at its first decision node iff $1-p-c_2 > 1-q$, $p-c_1 > b_1-c_1^n(1-b_1)$ and $1-p-c_2 > b_2-c_2^n(1-b_2)$; choose conventional war in any nuclear war decision subgame iff $p - c_1 > b_1 - c_1^n(1 - b_1)$ and $1 - p - c_2 > b_2 - c_2^n(1 - b_2)$.

In the nuclear war decision subgames, the players' strategies restricted to the subgames simply state the equilibrium condition. At State 2's initial decision nodes following Nature and State 1's choices, given the other components of the players' strategies, the State's payoff is $1 - p - c_2$ when the conditions for the conventional war choice are satisfied and $1 - q$ otherwise, so it has no incentive to deviate to choosing the status quo when the conditions are satisfied. If one of the conditions for the conventional war choice is not satisfied, then deviating to choosing war results in either $1 - p - c_2 < 1 - q$ or in $r_2 < 1 - q$, so this deviation also is not profitable. By similar argument, State 1 has no profitable deviation at it's initial choice nodes. Thus, these strategies constitute an equilibrium of the game.

In this equilibrium, war occurs when either $c_1 < p - q$ or $c_2 < q - p$ and

$$c_1 \leq p - b_1 + c_1^n(1 - b_1) \equiv \hat{c}_1$$

and

$$c_2 \leq 1 - p - b_2 + c_2^n(1 - b_2) \equiv \hat{c}_2$$

Thus, writing F_i for the cdf of f_i, if $q < p$, the equilibrium probability of war is

$$\begin{cases} F_1(p-q)F_2(\hat{c}_2) & p-q \leq \hat{c}_1 \\ F_1(p-q)\frac{F_1(\hat{c}_1)}{F_1(p-q)}F_2(\hat{c}_2) & p-q > \hat{c}_1 \end{cases} \tag{1}$$

while if $q \geq p$, the equilibrium probability of war is

$$\begin{cases} F_2(q-p)F_1(\hat{c}_1) & q-p \leq \hat{c}_2 \\ F_2(q-p)\frac{F_2(\hat{c}_2)}{F_2(q-p)}F_1(\hat{c}_1) & q-p > \hat{c}_2 \end{cases} \tag{2}$$

In each case of equations (1) and (2), the equilibrium probability of conventional war is weakly decreasing in either b_1, b_2 or both and strictly decreasing in one or the other over some range.■

Appendix B: Nuclear Arsenal Size

To assess a country's nuclear arsenal size, we measure all nuclear warheads in the state's arsenal, including both tactical and strategic weapons.[16] Data on nuclear arsenal size were drawn from a number of sources. Detailed annual information on the arsenals of the five countries recognized as nuclear weapon states by the Nuclear Nonproliferation Treaty (the United States, Russia, Great Britain, France, and China) is available from the National Resource Defense Council's online nuclear database.[17] After disabling its nuclear arsenal in 1990, the South African government released detailed information on the size of its nuclear arsenal. Data on the size of South Africa's nuclear arsenal from 1979 to 1990 were gathered from a variety of sources. There is less information available on the size of the nuclear arsenals in Israel, India, and Pakistan. Estimates of Israel's arsenal size from the mid 1980s until the present vary anywhere from seventy to four hundred weapons. I used data from the Federation of American Scientists that estimates the size of Israel's arsenal in every year from 1967 to the present based on the capacity of Israel's nuclear facilities to produce weapons-grade fissile material.[18] According to these estimates, Israel currently possesses roughly two hundred nuclear weapons. India and Pakistan are thought to maintain nuclear warheads de-mated from delivery systems. Estimates of the size of these countries' arsenals, therefore, are denominated in nuclear weapon equivalents (NWEs). Estimates of India and Pakistan's NWEs are available from a variety of sources and are based on the weapons-grade fissile material production capacity of the countries' nuclear facilities. When sources provide an estimated range for a given year, or when multiple

[16]Data distinguishing between tactical and strategic weapons, or between deployed and non-deployed weapons, are not available for each nuclear weapon state in each year.

[17]NRDC Nuclear Data.

[18]Federation of American Scientists.

sources provide different point estimates, I take the mean of these estimates as the size of the countries' arsenal in that year. For years in which no estimate is available, I assume that the arsenal changed at a steady rate between the years for which point estimates are available, calculating the difference in arsenal size, divided by the number of years between estimates. While these estimates may not be exact, they provide a more than adequate foundation for measuring whether a state possesses over 75% of the weapons in the dyad to code *Nuclear stability*.

Appendix C: Year of Delivery Vehicle Acquisition

Year Nuclear-Armed States Acquired Nuclear-Capable Delivery Vehicles Capable of Reaching Other Nuclear-Armed States

	Potential nuclear-armed targets								
Nuclear-Armed States	China	France	India	Israel	Pakistan	Russia	South Africa	United Kingdom	United States
China	X	1981	1974*	1975	1990*	1975	------	1981	1981
France	1974	X	1974	1967*	1990*	1964	1982*	1960	1974
India	------	------	X	------	1990*	------	------	------	------
Israel	------	------	------	X	------	------	------	------	------
Pakistan	------	------	1990	------	X	------	------	------	------
Russia	1964*	1960*	1974*	1967*	1990*	X	1982*	1956	1956
S. Africa	------	------	------	------	------	------	X	------	------
United Kingdom	1968	1960*	1974*	1967*	1990*	1955	1982*	X	1955
United States	1964*	1960*	1974*	1967*	1990*	1949*	1982*	1952*	X

Note: * denotes left-censoring due to target’s lack of nuclear weapons in prior years.

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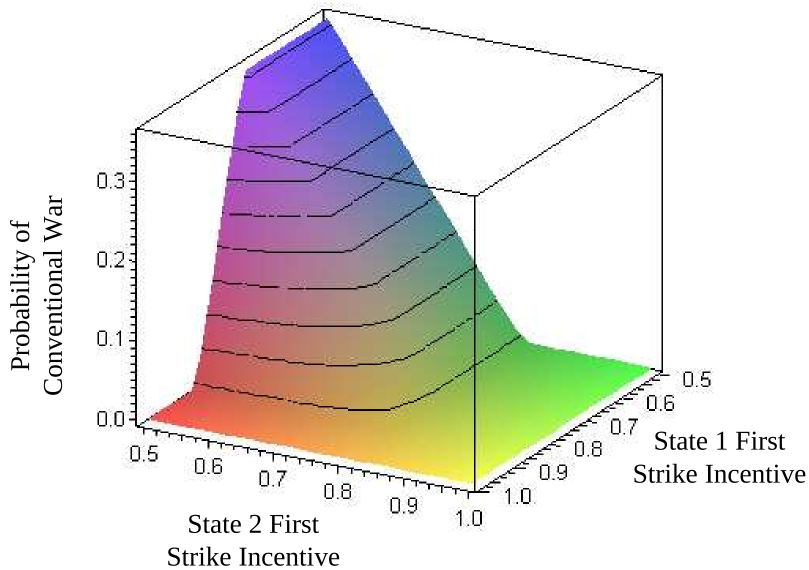

Figure 1. Probability of War When State 1 is Dissatisfied.

Table 1. Cross Tabulations of Nuclear Stability and Conflict, 1950-1992

		Militarized Interstate Dispute		
		Yes	No	Total
Nuclear Stability	Yes	32 (10%)	274 (90%)	306 (100%)
	No	14 (4%)	304 (96%)	318 (100%)
	Total	46 (07%)	578 (93%)	624 (100%)
	X^2 = 8.373 (p=0.004)			

Table 2. Probit Regression of Nuclear Stability on Militarized Interstate Disputes, 1950-1992			
Variables	Model 1 (Strike Stability)	Model 2 (Ratio Stability)	Model 3 (Stability Index)
Nuclear stability	1.053*** (0.321)	0.544*** (0.131)	0.297*** (0.034)
Capabilities	1.260* (0.503)	0.315 (0.428)	0.423 (0.394)
Distance	0.077 (0.041)	0.028 (0.062)	-0.013 (0.037)
Democracy (low)	-0.023 (0.021)	-0.009 (0.026)	-0.289 (0.029)
Trade (low)	-407.412*** (108.981)	-301.379** (111.431)	-418.229*** (136.995)
Constant	-1.720* (0.569)	-0.539 (0.514)	-0.764 (0.531)
N	624	624	624
Wald chi^2	109.78	128.82	713.20
Log pseudolikelihood	-89.376	-95.088	-87.250
Pseudo R^2	0.456	0.421	0.469
Note: Robust standard errors adjusted for clustering by dyad in parentheses. *significant at 5%, **significant at 1%, ***significant at 0.1% . All tests are two-tailed. Estimates for cubic polynomials suppressed.			

Table 3. Probit Regression of Nuclear Stability on Militarized Interstate Disputes, 1950-1992.[1]		
Variables	Model 4	Model 5
Nuclear stability	1.043*** (0.286)	0.317** (0.110)
Pr (Nuclear stability)	2.641 (1.844)	
Capabilities	2.719* (1.348)	0.753* (0.354)
Distance	0.088* (0.044)	-0.001 (0.038)
Democracy (low)	-0.036 (0.024)	-0.034* (0.016)
Trade (low)	-466.034*** (133.296)	-244.480 (133.489)
Constant	-3.853* (1.818)	-1.381** (0.472)
N	624	624
Wald chi^2	92.51	136.53
Log pseudolikelihood	-89.039	-65.274
Pseudo R^2	0.458	0.329
Note: Robust standard errors adjusted for clustering by dyad in parentheses. *significant at 5%, **significant at 1%, ***significant at 0.1% . All tests are two-tailed. Estimates for cubic polynomials suppressed. Model 5 excludes data from primary nuclear rivals.		

[1] Upon publication, this table will be posted online at the authors' professional websites.