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Nuclear balance and the initiation of nuclear crises: Does superiority matter?

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Abstract

The nuclear competition school, an emerging theoretical perspective on the political effect of nuclear weapons, argues that a favorable nuclear balance can significantly reduce one's expected costs of nuclear war and therefore affect the interaction between nuclear-armed states, such as deterrence and crisis outcomes. This new perspective also presents a wide array of empirical evidence demonstrating the significant effect of the nuclear balance of power on political outcomes, thereby challenging the theory of the nuclear revolution, which argues that the nuclear balance of power produces no meaningful effects on political outcomes because no state can escape costly nuclear destruction. Little attention, however, has been paid to systematically exploring the effect of the nuclear balance on the initiation of nuclear crises. This is surprising, given that observable factors, such as the nuclear balance, should have a powerful effect at the crisis initiation stage because countries can observe military balance and assess the costs and benefits of entering a crisis. This article tests a core argument of the nuclear competition school regarding the effect of the nuclear balance on the initiation of nuclear crises. With original data on strategic nuclear balance, my statistical analysis shows that having a superior nuclear arsenal than another nuclear-armed opponent does not lead to a reduced likelihood of nuclear crisis initiated by the opponent. These core findings hold after conducting a series of robustness tests with various measures of the balance of nuclear forces. They encourage us to reconsider the persuasiveness of the nuclear competition school and offer implications for US nuclear policy and force size.

Keywords

deterrence, nuclear crisis, nuclear revolution, nuclear superiority, nuclear weapons

Introduction

Does the balance of nuclear forces produce significant effects on international politics? For decades, a dominant scholarly answer to this question has been no. According to the *theory of the nuclear revolution*, a theory that has shaped our thinking about the effect of nuclear weapons on world politics, the nuclear balance of power has no meaningful impact on the outcomes of interaction between nuclear-armed states. This is because achieving nuclear superiority does not allow a state to escape a devastating nuclear exchange (Jervis, 1984, 1989; Waltz, 1990). As a result, the nuclear balance of power does not matter for important political outcomes such as deterrence, and rational states would have no incentive to pay attention to whether the balance of nuclear forces favors their opponents.

Recent studies on nuclear weapons, however, have argued that this core prediction of the theory of nuclear revolution is inaccurate. According to them, states have constantly attempted to cancel out a military nuclear advantage their rivals possess and have sought to undermine the survivability of adversaries' nuclear forces (Long & Green, 2015; Green & Long, 2017; Green, 2020; Lieber & Press, 2006, 2017, 2020). Some research also found that strategic nuclear superiority leads to better bargaining outcomes (Kroenig, 2013, 2018). The common argument of these studies is that winning a nuclear competition produces significant benefits because a favorable nuclear balance could substantially reduce the expected costs of nuclear war. Thus, the balance of strategic nuclear forces is an important factor determining several political outcomes, such as the

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prevention of conflict among nuclear states, the credibility of extended nuclear deterrence, and the outcomes of nuclear crises. These advocates of what might be called the *nuclear competition school* have questioned the validity of the theory of the nuclear revolution.

Surprisingly little effort, however, has been devoted to testing one of the most straightforward predictions of the nuclear competition school: strategic nuclear superiority would reduce the likelihood of crisis between nuclear states. This is a key implication of the nuclear competition school. If a favorable nuclear balance produces tangible political benefits, as claimed by the nuclear competition school, nuclear supremacy should also deter the initiation of nuclear crises by opponents. Indeed, the most straightforward way in which the nuclear balance of power affects deterrence is arguably its effect on crisis initiation, rather than crisis outcomes. Because the nuclear balance of power is an observable condition, it is likely to influence a potential challenger's pre-crisis assessment of the costs and benefits of its decision to initiate a nuclear crisis, and what shapes crisis outcomes is states' intra-crisis signals by conveying new information on actors' resolve and capability (Fearon, 1994, 2002). Therefore, if the balance of nuclear forces has any impacts, then we should be able to see the significant effect of possessing a superior nuclear capability at the crisis initiation stage. Specifically, we should observe that the state possessing a superior nuclear arsenal is significantly less likely to be challenged by its adversary with a weaker nuclear force.

An adequate assessment of this prediction also has significant implications for US nuclear policy. Pundits on nuclear strategy have claimed, based on the theory of the nuclear revolution, that military competition between nuclear-armed states is merely a waste of valuable financial resources and would only raise the risk of nuclear crisis, which could lead to a catastrophic nuclear exchange. If predictions of the nuclear competition school are correct, however, then the substantial costs of expanding and modernizing nuclear force might be justifiable, as far as there are considerable benefits that states can gain from having a military nuclear advantage over potential adversaries. Indeed, preventing a nuclear crisis from occurring would be a significant benefit, given that any nuclear crisis could potentially be escalated to a full-scale nuclear war. Thus, testing the effect of the nuclear balance on nuclear crisis initiation is directly related to an informed evaluation of various types of nuclear policy and doctrine suggested by nuclear experts.

Past studies on nuclear weapons, however, do not offer systematic and generalizable findings regarding the relationship between the balance of nuclear forces and nuclear crisis initiation. Early qualitative studies provide useful insights into how the nuclear balance may influence deterrence outcomes, but they tend to focus on well-known Cold War-era crises (e.g. Trachtenberg, 1985; Betts, 1987). Thus, their findings are less generalizable. On the other hand, recent quantitative studies on nuclear weapons tend to focus on how the possession of nuclear weapons affects political outcomes, thereby leaving unanswered the question of whether the balance of nuclear forces, rather than the mere possession of nuclear weapons, influences the interactions between nuclear-armed states (Asal & Beardsley, 2007; Beardsley & Asal, 2009a,b; Gartzke & Jo, 2009; Bell & Miller, 2015).

Although a handful of studies explore the effect of the balance of nuclear forces (Kroenig, 2013; Sechser & Fuhrmann, 2013, 2017), they have two notable limitations. First, most of them have analyzed whether nuclear superiority helps states prevail in the crises that have already taken place. As a result, they tell us little about whether possessing a military nuclear advantage affects the *initiation* of nuclear crises, not the *outcome* of those crises. Second, they have used suboptimal measures of the nuclear balance of power, which could threaten the validity of their conclusions. Specifically, the total nuclear warhead measure, which has been widely used by previous studies, ignores the role of strategic nuclear delivery platforms in shaping the expected outcomes of nuclear escalation. Kroenig (2018: ch. 5) is a notable exception in that he explores the impact of the nuclear balance of power on the initiation of militarized compellent threats (MCTs). Using all state dyad observations, including both nuclear-armed states and non-nuclear states, he found that possessing nuclear superiority, measured by the total warhead count, is negatively associated with the chance of being a target in an MCT. His finding constitutes an important step toward the evaluation of claims regarding how possessing a military nuclear advantage affects the onset of conflicts.

Building on those studies on the effect of the nuclear balance of power, this article offers a more direct test of competing claims regarding how nuclear superiority influences the initiation of nuclear crises by solely focusing on nuclear state dyad observations. Unlike previous research which used observations including both nuclear states and non-nuclear states (Sechser & Fuhrmann, 2017; Kroenig, 2018: ch. 5), therefore, my analysis can yield a more focused evaluation of the effect of the nuclear balance on the interaction between nuclear states.

Using original data on strategic nuclear balance, my statistical analysis finds no support for the argument that a favorable nuclear balance of power reduces the risk of nuclear crisis initiation: the variables measuring the nuclear balance of power fail to produce a statistically discernible effect on the likelihood of the initiation of nuclear crises. These core findings hold after conducting a series of robustness tests. At a minimum, my findings suggest that we cannot definitively claim that achieving nuclear superiority does create a more credible deterrent against other nuclear states, at least at the crisis initiation stage. These findings challenge the nuclear competition school's claim that strategic nuclear superiority could be a powerful deterrent against other nuclear-armed adversaries. They also have critical implications for assessing various proposals on US nuclear strategy and force size.

This article proceeds as follows. In the second section, I discuss the competing claims on the impact of the nuclear balance of power on deterrence against nuclear rivals. The third section lays out my strategy for measuring the nuclear balance of power. The fourth section describes my research design. The fifth section shows the results of my analyses. The sixth section discusses the validity of the results. The concluding section summarizes and discusses the findings and explores policy implications.

The nuclear revolution and its critics: Does the nuclear balance matter for deterrence?

Scholarly thinking about the effect of nuclear weapons has been arguably dominated by the theory of the nuclear revolution – which focuses on the revolutionary effect of nuclear weapons on competitions among nuclear-armed states. Works by Jervis (1979/80, 1984, 1989), Waltz (1990), and Glaser (1990) lay the logical foundation for the theory. While there are several implications that can be drawn from the theory, one of its core propositions is its refutation of the benefits of maintaining a favorable nuclear balance of power.

The nuclear revolution makes the balance obsolete

Proponents of the nuclear revolution theory argue that mutual possession of second-strike forces creates a situation in which no one can escape the prospect of mutual destruction (e.g. Jervis, 1989; Waltz, 1990; Glaser, 1990). Because mutual vulnerability makes achieving a military victory impossible, any form of military advantage that a favorable nuclear balance of power creates becomes obsolete. Jervis (1979/80: 618) argues, '[i]t does not matter which side has more nuclear weapons', adding, '[d]eterrence comes from having enough weapons to destroy the other's cities; this capability is an absolute, not a relative, one'. Waltz (1990: 738) also agrees: '[f]or deterrence one asks how much is enough, and enough is defined as "having a second-strike capability" [. . .] two countries with second-strike forces have the same amount of strategic power [. . .] adding more weapons does not change the effective military balance'.

The theory assumes that once a nuclear exchange occurs, the costs of a nuclear war are equally unacceptable to states. The horrendous costs of a nuclear war outweigh the value of almost any political objective, regardless of the balance of nuclear forces (Jervis, 1989: 19). This is the core assumption of the theory: because any nuclear force cannot substantially affect the relative costs of nuclear confrontation once both sides acquire second-strike forces, any military nuclear advantage cannot create any deterrent advantage.

This assumption leads the theory of the nuclear revolution to expect that there is no systematic relationship between the nuclear balance of power and the prevention of nuclear crises. Even a superior nuclear arsenal does not allow the possessor to escape the situation of mutual destruction, as the target could quickly launch a catastrophic retaliatory attack at any moment. Because it creates no additional deterrent advantage, nuclear superiority does not successfully prevent the initiation of nuclear crises.

The logic of nuclear competition: Why supremacy matters for deterrence

Scholars in the nuclear competition school strongly challenge the theory of the nuclear revolution. They argue that if the theory of the nuclear revolution is correct, then we should observe states' indifference to the shifting balance of nuclear forces; there should be no intense nuclear arms race between nuclear states; the nuclear balance should play no significant part in determining the outcome of interactions among nuclear states. But historically, the argument goes, states have not taken assured nuclear retaliation for granted and have put continued effort in gaining a meaningful military nuclear advantage over their rivals (Green & Long, 2017; Green, 2020; Lieber & Press, 2020). These efforts have been quite successful so that some states manage to obtain meaningfully superior nuclear capabilities (Lieber & Press, 2006, 2017). Lastly, nuclear superiority often provides states with meaningful political benefits, such as gaining political objectives in crisis bargaining (Kroenig, 2013, 2018).

Underlying this body of new empirical evidence challenging the core tenet of the theory of the nuclear revolution is a theoretical argument that the distribution of nuclear capabilities has important implications for deterrence. Gaining nuclear superiority, supporters of the nuclear competition school argue, makes deterrence more effective because a superior nuclear force allows its possessor to achieve a favorable outcome in a nuclear war, defined as having a better state of postwar conditions after an all-out nuclear conflict (Nitze, 1956: 189–191). With a superior nuclear arsenal, a state can launch an effective nuclear strike targeting the adversary's nuclear forces. If it can conduct such an effective counterforce strike, then it can also substantially reduce the expected costs of war because the adversary has to retaliate with a significantly impaired nuclear force (Kroenig, 2013: 149). As a result, those who possess superior nuclear arsenals would expect to suffer less from a potential all-out nuclear war, while those who have inferior nuclear arsenals would expect a more devastating war outcome. Jervis (1984: 69) summarizes this logic in the context of US–Russian nuclear confrontation: 'if the Russians believed that they could destroy many American missiles while maintaining a large force of their own, they might be tempted to strike [. . .] in the belief that they could prevail in a protracted nuclear war'. In other words, the theory posits that 'the outcome of the war would be governed in part by shifting strategic balance resulting from the counterforce campaign [. . .] a nuclear war would not necessarily be tantamount to national suicide' (Trachtenberg, 1991: 31–32).

This difference in the expected outcome of nuclear war influences the effectiveness of deterrence. If the outcome of a nuclear war is expected to be unequal, then a state having an inferior nuclear force is likely to be forced to retreat because it expects that if war occurred due to bargaining failure, it would face the substantially higher costs of an all-out nuclear war. Consequently, backing down becomes a preferred choice (Kroenig, 2013: 150). The higher costs of nuclear conflict also reduce the maximum level of the risk that one is willing to endure to push its adversary because the threshold at which the costs of employing risky bargaining tactics exceed its benefits gets lower (Kroenig, 2018: 25). On the other hand, a state armed with a superior nuclear force can push harder because it understands that it is better placed to reduce its expected damage in the event of further escalation. Hence, the maximum level of risk it is ready to endure to win the bargaining increases and its effort to compel its adversary to back down is more likely to be successful.

Implications of nuclear superiority for nuclear crisis initiation

While there are several testable implications of the nuclear competition school, one of the most straightforward propositions is that a state maintaining an inferior nuclear force is less likely to initiate a crisis against an adversary armed with a superior nuclear force. Because states 'select themselves' into crisis according to their prior beliefs, which are shaped by observable factors such as the balance of power and interests, a potential challenger would be dissuaded from initiating a crisis-triggering challenge in the first place when the observable factors led her to expect that the outcome of the crisis would be costly (Fearon, 1994, 2002). Consequently, if the balance of military power or interests is favorable for the target, the challenger would not initiate a crisis, as the costs of crisis initiation would outweigh its benefits.

Therefore, the nuclear balance of power should play an important role in explaining why nuclear crises occur in the first place, if the nuclear competition school is correct. Gavin (2014: 25) puts it nicely: 'to truly understand how important military balances or resolve are, you would not just analyze crisis *outcomes*; you would also need to include *the crises that never happened* [. . .] studying nuclear crises does not reveal the full story of whether and how military power plays affect world politics' (emphasis in original). Because nuclear-armed states can assess each other's nuclear capability before a crisis begins, states with inferior nuclear arsenals should restrain themselves from initiating a challenge in the first place because there is little incentive for them to initiate a crisis in which they are likely to submit later. As Green (2020: 50) notes, 'peacetime competition could bolster general deterrence – the deterrence, not just of war, but of crisis initiation – by dissuading the enemy from "selecting into" a crisis'. The central hypothesis of the nuclear competition school is drawn from the above discussion.

> *Hypothesis:* A challenger is less likely to initiate a crisis against a target if the target has a military nuclear advantage over the challenger.

Measuring nuclear superiority

A key task to test any hypotheses on the nuclear balance of power is defining and measuring the relative advantage a state's nuclear force possesses over its adversary. While they sharply disagree with the effect of nuclear superiority, scholars appear to agree that nuclear superiority can be defined as 'a military nuclear advantage over an opponent', an advantage that reduces one's relative costs of nuclear conflict (Kroenig, 2018: 16).[1]

Measuring nuclear superiority, however, is not an easy task. Ideally, one should calculate the relative balance of nuclear forces by evaluating how well a state's nuclear force is expected to execute relevant military missions, defined by its strategic aims, compared to its adversary (Salman, Sullivan & Van Evera, 1989: 176). To do so, one should determine not only the type of missions and nuclear strategy that a state assumes, but also factors such as command-and-control vulnerability and the rate of alerted nuclear forces must be taken into consideration. However, such an ideal measure of the nuclear balance is almost impossible to construct, as information on those factors remains strictly classified in most cases.

Past studies have attempted to overcome this problem by constructing simpler measures of the nuclear balance, such as counting the number of nuclear warheads (Kroenig, 2013, 2018; Sechser & Fuhrmann, 2013, 2017). Using the warhead measure has its own merits: not only is there available and reliable information on nuclear warheads, but it can also capture some aspects of nuclear capability, such as the total firepower of one's nuclear arsenal.

A simple warhead count, however, has several weaknesses. First, it does not differentiate warheads delivered by strategic nuclear platforms from non-strategic nuclear warheads (Sagan, 2014: 8). Since strategic nuclear warheads are more relevant weapons than tactical nuclear warheads in an all-out nuclear war, including non-strategic warheads may inflate the relative strength of a state's nuclear arsenal if it deploys a vast number of tactical nuclear warheads. Second, the warhead measure does not consider nuclear delivery platforms that a state deploys, a critical military asset for executing a nuclear strike against a given adversary. Without proper delivery platforms, nuclear warheads are of little military use. Depending on the range of delivery platforms and their ability to carry nuclear weapons, the level of nuclear destruction that the state can impose on its adversary may vary significantly. For example, if the state deploys a small number of nuclear platforms, it can strike only a handful of targets within the adversary. Similarly, a state possessing advanced nuclear platforms carrying multiple nuclear warheads can destroy many more targets than those that deploy delivery platforms carrying a single nuclear payload.

To address these weaknesses, I present three alternative measures: the total deliverable strategic warhead count, the total equivalent megatonnage (EMT) index, and the total counter military potential (CMP) index. These alternative indicators are better than the total warhead measure because they capture important dimensions of nuclear forces that are critical for shaping one's expectation of the costs of nuclear escalation, such as the yield of nuclear weapons, the range of nuclear delivery platforms, and their accuracy. The total warhead indicator cannot capture these aspects of nuclear capability. Yet these alternative measures, while improved, are not perfect measures of the nuclear balance, as they are still not able to reflect other factors determining the likely outcome of a nuclear exchange, such as alert rate, the quality of target intelligence, and command-and-control vulnerability. In addition, systematic information on these factors is simply not available.

Having those limitations in mind, my strategy is to employ all available indicators on nuclear capability and see whether the results from empirical analysis differ significantly. If all results based on different indicators show similar statistical patterns, then our confidence in the inferred relationship between nuclear superiority and crisis initiation would be greater than if we rely on a specific indicator. If the different measures of the nuclear balance of power demonstrate different statistical results, then these findings per se raise the need for additional research, which requires further discussion. By using various measures of states' nuclear arsenal, my strategy attempts to avoid the risk of relying on a particular measure of military nuclear capability and increase our confidence in empirical findings, given the imperfect nature of available indicators of the nuclear balance.

Now let me explain three alternative indicators of nuclear capability. First, I count the total number of nuclear warheads deliverable by a state's strategic nuclear platforms against a given adversary. Because it explicitly considers the number and the range of strategic nuclear platforms the state deploys, this deliverable strategic warhead count is better able to capture the total firepower of the state's nuclear strike against its adversary.[2]

[1] Similar definitions have been suggested. For instance, Glaser (1990: 136) argues that 'superiority is measured in terms of the superpowers' ability to inflict damage'.

[2] I only count the strategic nuclear platform whose range is greater than the inter-capital distance between the state and its adversary. See the Online appendix for a detailed justification for this choice.

Furthermore, it also takes into account that some delivery platforms carry multiple nuclear payloads, such as missiles with multiple independently targetable re-entry vehicles (MIRVs) and advanced strategic bombers. Thus, this measure also more accurately captures how many targets the state's nuclear strike can cover than merely counting the number of all deployed nuclear warheads. The wider the coverage of a state's nuclear arsenal is, the greater the level of damage it can impose against the adversary, including major cities, command-and-control centers, and nuclear delivery platforms. By considering each platform's warhead delivery capacity and their range, this indicator can measure the capability of a state's nuclear arsenal and its potential advantage over the adversary in a more accurate and realistic way.

Second, I calculate the EMT of a state's nuclear strike. This indicator reflects the fact that not all nuclear warheads have equal destructive power. Some nuclear payloads have more than ten megatons, while others may create a yield of a few kilotons. As high-yield weapons can impose greater damage on both civilian and military targets, the total EMT of a state's nuclear arsenal is a more direct measure of the total destructive power of a state's first nuclear strike.[3] In other words, the EMT indicator measures what the total warhead count intends to measure in a more direct and accurate way.

The procedure of calculating the total EMT of a state's nuclear attack is as follows. First, I identify a state's strategic nuclear platforms whose reach is greater than the inter-capital distance between the state and its dyad-specific adversary. Next, I gather information on the yield of the nuclear ordnance delivered by each distinct nuclear platform and the number of warheads that the platform can deliver. Finally, I use the following formulas to calculate the total EMT of a state's first nuclear salvo.

$$EMT_{total} = \sum_{i=1}^{M} N_i Y_i^{\frac{2}{3}} \; if \; \mathrm{Y}_i \leq 1MT \qquad (1)$$

and

$$EMT_{total} = \sum_{i=1}^{M} N_i Y_i^{\frac{1}{2}} \; if \; \mathrm{Y}_i > 1MT \qquad (2)$$

where M represents the total number of distinct delivery platforms, N_i is the total number of nuclear weapons that the ith delivery platform carries, Y_i is the destructive power (measured by megatonnage) of the weapon.[4]

The last indicator I use to measure the relative military advantage of a state's nuclear arsenal is the total CMP of a state's nuclear force. Contrary to the EMT index, which mainly evaluates the capability of a nuclear strike against countervalue targets such as major cities, the total CMP represents the effectiveness of a nuclear strike against hard targets, mostly the adversary's nuclear forces (Richelson, 1980: 785–786). Since the key to a successful counterforce nuclear strike is to possess accurate delivery platforms, this measure takes into account not only the destructiveness of nuclear payloads but also the accuracy of the platforms carrying out an attack. As counterforce capabilities of states' arsenals play a key role in the nuclear competition school's arguments, the relative advantage of states' nuclear forces could be well captured by assessing the total CMP of a state's military nuclear capability.

The total CMP of a state's nuclear strike is calculated in a similar way to how the total EMP of a state's nuclear salvo is measured, except that information on each strategic nuclear platform's accuracy is additionally taken into consideration. The following formulas are used.

$$CMP_{total} = \sum_{i=1}^{M} N_i \frac{Y_i^{\frac{2}{3}}}{\mathrm{CEP}_i} \; if \; \mathrm{Y}_i \geq 0.2MT \qquad (3)$$

and

$$CMP_{total} = \sum_{i=1}^{M} N_i \frac{Y_i^{\frac{4}{5}}}{\mathrm{CEP}_i} \; if \; \mathrm{Y}_i < 0.2MT \qquad (4)$$

where M represents the total number of distinct delivery platforms, N_i is the total number of nuclear weapons that the ith delivery platform carries, Y_i is the destructive power (measured by megatonnage) of the weapon, CEP_i is the accuracy, measured by circular error probable (CEP), of the ith delivery platform.[5]

[3] These three indicators are constructed based on an original dataset on strategic nuclear forces. See the Online appendix for a detailed explanation for how the dataset is constructed.

[4] For discussion of the formulas, see Richelson (1980: 783–784), Salman, Sullivan & Van Evera (1989: 209), and Przemieniecki (2000: 177).

[5] For discussion on the formulas, see Richelson (1980: 785–787) and Przemieniecki (2000: 179). I exclude strategic bombers carrying nuclear gravity bombs from the list of delivery platforms when calculating the total CMP of a state's nuclear arsenal because information on the accuracy of gravity bombs is extremely difficult to obtain. This exclusion would not be a significant issue, however, because gravity bombs are rarely used for counterforce nuclear strikes. Bombers armed with gravity bombs are included in the calculation of total EMT of a state's nuclear strike.

Research design: Data and methods

In this section, I test the nuclear competition school's primary hypothesis on the effect of a superior nuclear force on nuclear crisis initiation. As the hypothesis only deals with deterrence encounters between nuclear-armed states, I only use nuclear-states-dyads observations. The list of nuclear-armed states is obtained from Gartzke & Kroenig (2009: 154).

In order to test any hypotheses on conflict initiation, one should delineate a proper scope of one's sample, which is always a challenging task for any studies on dispute initiation. The heart of the problem is that including false-positive cases in which there is no realistic possibility of conflict into the sample could threaten our empirical inference (Huth & Russett, 1993: 62–63; Mahoney & Goertz, 2004: 655–657). The solution adopted here is to use the presence of a rivalry relationship between two states as identifying an opportunity for conflict. The literature on international rivalry suggests that conflict is highly likely when two states are in a rivalry relationship (Diehl & Goertz, 2001). Indeed, *all* crises between nuclear states in my dataset occur only between the nuclear states who share a rivalry relationship. Therefore, using the presence of interstate rivalry as an identifier of relevant cases seems to be a reasonable choice. My unit of analysis is a directed-nuclear rivalry dyad year from 1949 to 2000. The final sample includes total 381 directed-nuclear rivalry dyad years. Data on interstate rivalry are drawn from Klein, Goertz & Diehl (2006).[6]

Dependent variable

My dependent variable is the initiation of a crisis by a nuclear-armed state against another nuclear-armed state. I identify all episodes of nuclear crisis initiation by using Hewitt's (2003) dyadic international crisis data.[7] The dataset defines a foreign policy crisis as a situation in which the state perceives a threat to its basic values under the severe time pressure to respond, along with the high probability of armed hostilities (Brecher & Wilkenfeld, 1997: 3). Based on this dataset, *Crisis initiation* is coded 1 if a nuclear state A (a challenger) initiates a crisis-triggering action against another nuclear state B (a target), and 0 otherwise. There are a total of 25 cases of nuclear crisis in the final sample.[8]

Independent variables

The balance of nuclear forces. As explained above, I use four indicators of a state's military nuclear capability to measure the relative balance of nuclear forces: the warhead count, the deliverable strategic warhead count, the EMT score, and the CMP score. For each indicator, I construct two independent variables. First, *Superiority* is a binary variable, which is coded 1 if a challenger's nuclear capability is greater than a target's and 0 otherwise. Although this dichotomous variable has been widely used by previous studies (Kroenig, 2013, 2018; Sechser & Fuhrmann, 2013, 2017), it problematically considers different sizes of military nuclear advantage as equal, thus failing to capture the degree of the relative advantage of one's nuclear arsenal.[9] Therefore, I also include *Arsenal ratio*, a variable measuring the ratio of a target's nuclear capability to the sum of both a challenger's and target's nuclear capabilities.[10] The range of this variable is from 0 (the challenger's perfect superiority) to 1 (the target's perfect superiority).

To illustrate the relationship between these different indicators of nuclear capability, Figure 1 visualizes the variation in the value of *Arsenal ratio* of the most well-known nuclear dyad, the United States–the Soviet Union/Russia dyad, measured by the four indicators. The nuclear balance between the two states is measured by the ratio of US nuclear capability to the sum of both states' nuclear capabilities. From Figure 1, it becomes clear that significant variations exist across different nuclear arsenal indicators, although there are some correlations between the indicators. For example, the nuclear arsenal of the United States was inferior to that of the Soviet Union from the mid-1970s to 2000 in terms of the total number of nuclear warheads. However, Washington possessed a significant

[6] All directed-nuclear rivalry dyad years are identified by EUGene version 3.204 (Bennett & Stam, 2000). 1949 is when the first nuclear dyad emerged (the United States v. the Soviet Union).

[7] This dataset is constructed based on the International Crisis Behavior (ICB) dataset (Brecher & Wilkenfeld, 1997).

[8] The list of nuclear crises can be found in the Online appendix. The War in Angola crisis is excluded from the main analysis because of uncertainty about identifying initiator and target. Later I show that its inclusion does not affect the main results.

[9] It is also possible that the challenger would refrain from initiating a crisis only when the size of the target's military nuclear advantage is considerably large so that the cost of nuclear escalation is remarkably unfavorable for itself. In my robustness checks, I create a set of other dichotomous variables based on different threshold of a 'meaningful' nuclear superiority.

[10] If both states' nuclear capabilities are coded 0 (e.g., if both states deploy no nuclear delivery platforms although they completed their nuclear weapons program), the ratio is coded 0.5, as neither side possesses any military advantage over the other.

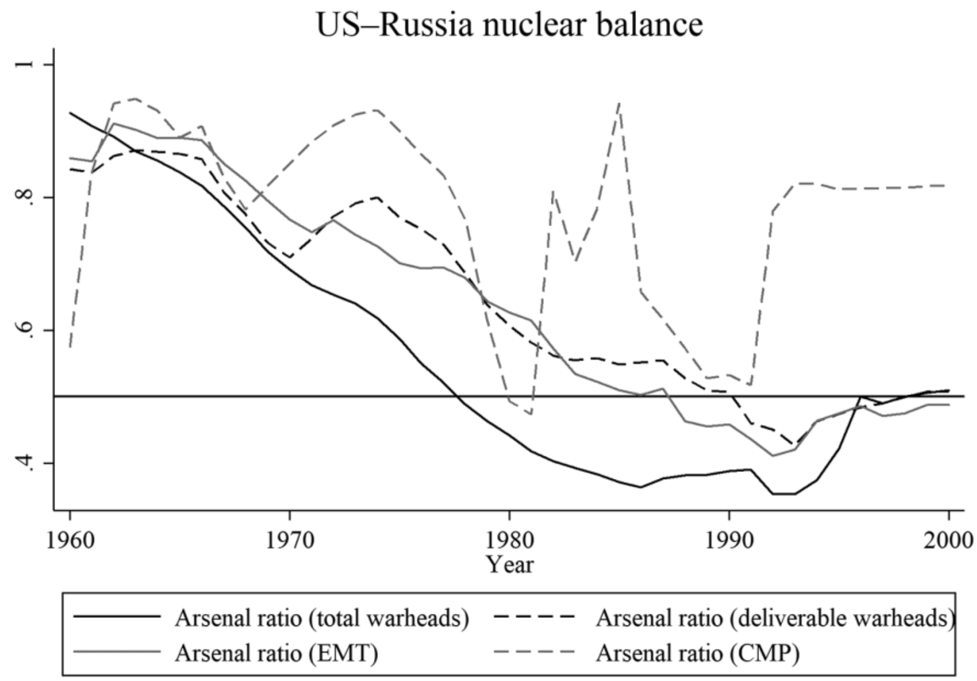

Figure 1. USA–Russia nuclear balance, 1960–2000

The ratio of US nuclear capability to the total sum of both states' nuclear capabilities. The black horizontal line represents 0.5, a parity between the two states.

advantage over Moscow in terms of hard target kill capabilities, measured by the CMP ratio, over almost all the period covered by my dataset. In terms of deliverable strategic weapons, the United States lost its advantage over the Soviet Union only after 1990. These trends also well reflect the introduction of novel nuclear delivery systems. For example, after witnessing a relative decline of the balance of deliverable strategic warheads, the United States again started to gain an upper hand from 1970, when it started to introduce MIRVed nuclear platforms. Moscow, however, again turned the tide in 1975, when its own MIRVed land-based ICBM forces started to be deployed. Such a variation, however, is not captured by the total warhead count, which describes a nuclear balance that is continuously unfavorable for the United States until the early 1990s. As policymakers in both states aptly responded to each other's acquisition of new nuclear delivery platforms, which resulted in the frequent shift in the nuclear balance, or the perception thereof (Green & Long, 2017; Green, 2020), this figure shows us that not only do my alternative measures capture important aspects of states' nuclear forces, but they are also able to reflect significant and qualitative changes in those nuclear capabilities, a substantial improvement over a simple warhead count.

Control variables

I also control for several variables that are believed to affect the probability of nuclear crisis initiation.

- *Joint democracy* accounts for the pacifying effect of democratic dyads. The variable is coded 1 if both states' Polity2 score is higher than 6 and 0 otherwise (Marshall, Gurr & Jaggers, 2015).
- *Distance* controls for the effect of geographic proximity on crisis initiation. The variable is the natural logarithm of the inter-capital distance between a challenger and a target.[11]
- *Foreign policy similarity* controls for the effect of foreign policy similarity. Drawing on Signorino & Ritter's (1999) S-score dataset, this variable varies from –1, which indicates the complete divergence of foreign policy interests, to 1, which means the complete similarity of foreign policy interests.
- *Conventional military balance* accounts for the effect of the conventional military balance on crisis initiation. The variable indicates the ratio of the target's Composite Index of National Capability (CINC) score, developed by the Correlates of War Project's National Material Capabilities

[11] *Distance* is calculated by EUGene version 3.204.

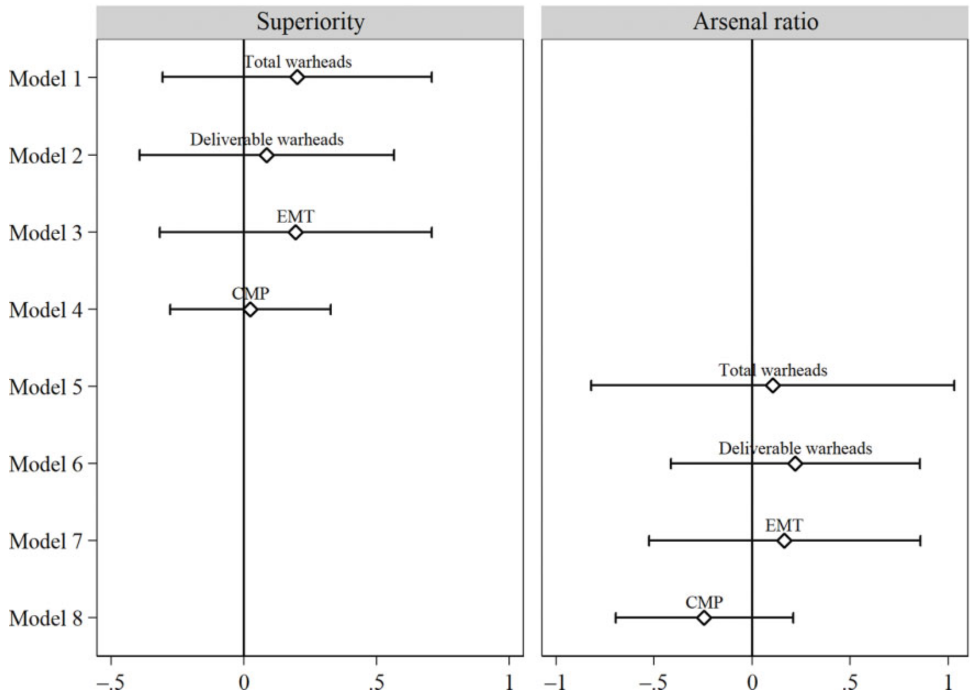

Figure 2. The effect of the nuclear balance on nuclear crisis initiation
All control variables are omitted from the figure. Confidence intervals are calculated at the 5% significance level.

dataset (Singer, Bremer & Stuckey, 1972), to the total sum of the target's and the challenger's CINC score.

- *Trade dependence* controls for the effect of economic interdependence on crisis initiation. Following Russett & Oneal's (2001: 142–143) 'weak link' approach, the degree of trade dependence of the dyad is determined by the state that has a lower trade dependence score. Trade dependence is calculated by dividing a state's total trade (exports plus imports) with its counterpart by its gross domestic product (GDP) (Gleditsch, 2002).
- *Superpower dyad* controls for the effect of dispute-proneness of the United States–Soviet Union/Russia dyad on crisis initiation. According to my data, more than half of the nuclear crises (13/25) occurred in the superpower dyad. This dichotomous variable is coded 1 if the two states in a dyad are the United States and the Soviet Union/Russia and 0 otherwise.

Data analysis

I estimate probit models because *Crisis initiation* is a dichotomous variable. I include a variable which counts the number of years since the last time a target faced a crisis-triggering action from a challenger and the variable's squared and cubed terms to correct for temporal dependence (Carter & Signorino, 2010). I estimate robust standard errors clustered by each directed-nuclear rivalry dyad.

Figure 2 demonstrates the estimated coefficients of the nuclear balance variables on the probability of nuclear crisis initiation. Models 1–4 estimate the coefficient of the *Superiority* variable, measured by the four different indicators. Models 5–8 estimate the coefficient of the *Arsenal ratio* variable, again calculated by four different measures. If a horizontal line, which displays the estimated confidence interval of the coefficient of a nuclear balance variable, crosses the black vertical line, this suggests that the coefficient of the variable is statistically indistinguishable from zero at the widely used 5% significance level.[12]

As shown above, the nuclear balance of power, no matter how it is measured, is *not* significantly associated with *Crisis initiation*. Put it differently, a favorable nuclear balance produces no discernible impact on the likelihood of nuclear crisis initiation, regardless of the type of military advantage a state's nuclear force possesses, including the total firepower, target coverage, or

[12] Full regression results of the entire analysis can be found in the Online appendix.

hard target kill capacity. Furthermore, all but one of the nuclear balance variables are *positively*, but insignificantly, correlated to our dependent variable, which is at odds with the prediction of the nuclear competition school. This finding strongly challenges the argument that those armed with superior nuclear arsenals are significantly *less* likely to be challenged against the adversary with a weaker nuclear force.

Note that there could be multiple explanations for the lack of empirical association between the balance of nuclear forces and the initiation of nuclear crises. A simple explanation is that the nuclear balance of power plays no role in shaping states' decision to initiate a crisis against their nuclear-armed opponents. The costs of nuclear escalation are considered as equally unbearable by both states, regardless of who possesses a military nuclear advantage, which renders the nuclear balance of power unimportant. This is consistent with what the theory of the nuclear revolution expects (Jervis, 1989; Waltz, 1990).

Another explanation posits that the lack of an empirical relationship between nuclear superiority and the initiation of nuclear crises is due to the cross-cutting effects of the nuclear balance. Specifically, the argument builds upon the insight that facing a strong counterforce threat, a state possessing a small, inferior nuclear arsenal may face the 'use-them-or-lose-them' pressure, which forces it to use nuclear weapons before its nuclear capabilities are destroyed or significantly crippled by its opponent's nuclear strike (Schelling, 1960: 207–229; Feaver, 1992/93: 164–165; Bell & MacDonald, 2019: 44–45). Such pressure may exist even if the opponent only uses conventional forces, as conventional military operations could be perceived by the state armed with an inferior nuclear arsenal as a significant threat to its nuclear assets (Talmadge, 2017a,b; Posen, 1991). If initiating a crisis against a nuclear-armed opponent with an inferior nuclear arsenal is perceived to carry a significant risk of nuclear escalation, then a state possessing a superior nuclear arsenal may hesitate to initiate the crisis in the first place: it may believe that the risk of nuclear escalation limits the range of bargaining and escalatory tactics it can use and outweighs the expected benefits of crisis initiation. On the other hand, an inferior nuclear state may exploit such a perceived risk of nuclear war and pursue its foreign policy goals, especially when the superior side's interests at stake are expected to be marginal.

In those explanations, the deterrent effect of nuclear superiority is considered as negligible. Either nuclear superiority does not play an important role in most nuclear dyads, or its effect may be important in some nuclear dyads but offset by the counteracting mechanisms operating in other nuclear dyads, thereby rendering the overall effect of possessing a superior nuclear arsenal insignificant. In other words, the benefits of maintaining a favorable nuclear balance are not strong enough to produce a discernible effect across different nuclear dyads.

Validity of the results

The above analysis shows that the nuclear competition school's primary observable implication regarding the initiation of nuclear crises does not find empirical support: the nuclear balance has no significant impact on a nuclear-armed state's decision to initiate a crisis against another nuclear-armed state. Here I examine the validity of my results.[13]

I first expand the scope of my sample to include all nuclear dyad observations and re-estimate the models. Second, I estimate rare events logistic regression models with the same covariates, given that nuclear crises rarely occur (King & Zeng, 2001).[14] Third, I include the War in Angola crisis in the sample, as it was excluded from the above analysis because of uncertainty about identifying initiator and target. Fourth, among 25 cases of nuclear crises, the Soviet Union acted as a crisis initiator in 15 cases. To control for the potential impact of the assertiveness of Soviet foreign policy during the Cold War, I add a dichotomous variable, which is coded 1 if a challenger is the Soviet Union/Russia and 0 otherwise, to the models. Fifth, to guard against the possibility that our null findings are driven by unmodeled unit-level heterogeneity, which is an important issue when analyzing any time-series–cross-sectional dataset, I use a penalized maximum likelihood fixed effects estimator, following Cook, Hays & Franzese's (2020) recommendation. Lastly, it is possible that the target's superior nuclear force has a strong deterrent effect only if the size of its nuclear advantage is substantially large. I test three different thresholds constituting what a meaningful nuclear superiority is and construct three sets of dichotomous variables: if the target's share of the total sum of nuclear capabilities in a dyad is equal to or greater than 75%, 80%, and 90%, it is coded as possessing a meaningful nuclear superiority, and 0 otherwise. I then rerun my

[13] The results of all robustness checks are reported in the Online appendix.

[14] Only 6.5% of all nuclear rivalry dyad observations (383) and 1.56% of all nuclear dyad observations (1,603) experience nuclear crisis (25).

analyses using these alternative variables of nuclear superiority.

In all additional analyses, my core findings substantively remain identical: the nuclear balance of power variables fail to have a significant impact on nuclear crisis initiation. That the nuclear competition school's hypothesis on the initiation of nuclear crises fails to find empirical support is not an artifact of a particular choice of model specification.

I further explore the possibility that more subtle, conditional claims regarding the deterrent effect of nuclear superiority may find empirical support. From the central hypothesis of the nuclear competition school, I draw two conditional hypotheses. They are based on an intuitive idea that the effect of a superior nuclear force may be negligible if nuclear escalation is deemed unlikely, but it may be strong when there are factors that increase the perceived risk of nuclear escalation.

First, the effect of the nuclear balance could differ depending on the target's nuclear posture. Narang's (2013, 2014) pathbreaking works demonstrate that not all nuclear postures are equally effective for manipulating the perceived risk of a nuclear war, a key source of the deterrent power of nuclear weapons. Specifically, those adopting an asymmetric escalation posture, a nuclear posture designed for the rapid use of nuclear weapons, are more capable of creating the genuine risk of a nuclear confrontation than other types of posture (Narang, 2013: 486). If this were the case, achieving nuclear superiority would decrease the chance of being challenged in a nuclear crisis only if a target adopted an asymmetric nuclear posture, as a potential challenger would believe that a confrontation with the target could risk a serious chance of nuclear escalation.

Second, the balance of conventional military force is another factor that could significantly moderate the effect of the target's nuclear advantage. If the balance of conventional force favors the challenger and it is expected to achieve its aims with its strong conventional force, the target may resort to nuclear options to avoid military defeat (Kapur, 2005, 2007; Lieber & Press, 2013, 2015; Talmadge, 2017a: 202; Castillo, 2018: 302). While such a deliberate escalation may not be attractive if nuclear escalation is equally costly for both sides, the target may prefer nuclear escalation to military defeat if the target's nuclear superiority significantly reduces the damage of a mutual nuclear exchange. Even if the initial scale of nuclear escalation might be limited, any limited use of nuclear weapons could vastly increase the perceived chance of a full-scale nuclear war, in which states use their nuclear forces on a massive scale.

As a result, the advantage of nuclear superiority might only be important when the conventional balance favors the challenger because the target's willingness to rely on nuclear forces could increase. Expecting the increased risk of nuclear escalation by the target, the challenger would assess that its anticipated cost of crisis initiation could be unbearably high. Therefore, all else being equal, a conventionally weaker target is perceived as more likely to resort to nuclear options, and a conventional force balance favoring the challenger would strengthen the effect of the target's military nuclear advantage.

I test these hypotheses by estimating a set of multiplicative interaction models. The results, however, demonstrate that the nuclear balance variables have no statistically discernible effects even if there are the conditions that are expected to strengthen the hypothesized effect of nuclear superiority.[15] My conclusion, therefore, remains valid: theoretical expectations of the nuclear competition school regarding nuclear crisis initiation find no statistical support.

Discussion and conclusion

Does achieving nuclear superiority lead to a reduced risk of nuclear crisis? This article finds that there is no statistical evidence for this proposition: a favorable balance of nuclear forces fails to produce the predicted effect on the probability of the initiation of nuclear crises. These null results are not artifacts of using a particular measure of the nuclear balance and a specific model specification; even after using alternative model specifications and new indicators of nuclear superiority that capture important dimensions of nuclear capabilities that the total warhead count cannot capture, those results remain unaltered. Furthermore, more qualified hypotheses that posit the conditional effects of nuclear superiority also do not find empirical support. By directly testing a key prediction of the nuclear competition school in a new empirical context, this article attempts to shed new light on the theoretical debate over the political benefits of a superior nuclear arsenal. Although my article does not conclusively disconfirm the validity of the nuclear competition school as a whole, it encourages researchers to reconsider the benefit of maintaining a favorable nuclear balance of power, which has been argued by the nuclear competition school.

This article also engages with a broader discussion on quantitative studies on nuclear weapons by

[15] A detailed discussion of testing the hypotheses and the estimated results can be found in the Online appendix.

acknowledging the importance of improving empirical measures of important variables. While previous quantitative studies substantially advanced our knowledge on nuclear weapons, they are not free from criticisms. For instance, several authors note that statistical analysis on nuclear weapons must carefully code theoretically important variables and take into account important issues such as heterogeneity among cases and the small-N problem (Montgomery & Sagan, 2009; Gavin, 2014). Others also point out that several findings of quantitative research on nuclear weapons are not as reliable as originally believed, demonstrating the significant methodological challenges scholars on nuclear security are facing (Bell, 2016; Winter & Lenine, 2020). Improving our measures of key variables using various open-source data on nuclear weapons is one way of addressing those challenges. By employing multiple measures of the nuclear balance of power, this article attempts to minimize the effect of the imperfect nature of those measures on the validity of statistical inference.

With mixed evidence regarding the political impact of the nuclear balance, one of the potentially important questions that future study can explore is to find conditions under which the balance of nuclear forces meaningfully shapes the outcomes of the interaction between nuclear-armed states. Instead of simply asking whether the nuclear balance matters at all, we could enrich our knowledge about the dynamics of crises between nuclear-armed states by examining what factors could potentially influence the effect of military nuclear advantage on political outcomes.

Another area for future research is to develop a coherent theoretical explanation for how the nuclear balance of power affects different stages of nuclear crises. I have demonstrated that nuclear superiority does not significantly reduce the risk of nuclear crisis initiation. However, Kroenig (2013; 2018: 119) finds that nuclear superiority contributes to favorable settlement of nuclear crises, and that states possessing nuclear superiority have never been targets of MCTs by nuclear inferior opponents, while several MCTs have been issued against states having inferior nuclear capabilities. These empirical patterns raise the need for further research on theoretical mechanisms through which the nuclear balance influences state behavior at different stages of nuclear crises. When and how does the nuclear balance of power have an impact on states' decisions to initiate a crisis, send escalatory threats, and make concessions against other nuclear-armed opponents? Answers to these questions would advance the literature on the merits of effective nuclear competition.

Does the United States need to maintain nuclear supremacy over its nuclear rivals, including Russia and China? Since 1945, US policymakers have continuously pursued meaningful military nuclear advantages over nuclear-armed competitors. Recently, the Trump administration made several decisions to pursue a more competitive nuclear policy. For instance, it announced the 2018 Nuclear Posture Review, in which it strongly argued for modernizing and adding new forms of delivery systems to the United States' already massive nuclear arsenals to cope with the nuclear force modernization of Russia and China (US Department of Defense, 2018). It also declared a withdrawal from the INF Treaty. The Biden administration extended the New START Treaty for another five years, but at the time of writing it is too early to know which nuclear modernization programs from the Trump administration will be continued under Biden. From the perspective of the nuclear competition school, the Trump administration's approach to nuclear issues reflects the continuous emphasis on maintaining US nuclear primacy and strengthening the deterrent power of US nuclear arsenal. Indeed, a leading advocate of the school claims that 'the goal of US nuclear strategy should be to reduce US vulnerability to nuclear war to the greatest extent possible, while simultaneously maximizing adversary vulnerability' (Kroenig, 2018: 199).

This article shows that empirical support for this claim is not as strong as argued by the nuclear competition school: the history of nuclear crises demonstrates that there is no strong evidence indicating a link between a favorable nuclear balance of power and the likelihood of nuclear crisis. Accordingly, the United States may not necessarily need to devote valuable resources to a nuclear arms race with other nuclear-armed major powers in order to deter potential challenges from them. Although the deterrent power of the superior US nuclear forces is not as strong as it is often expected to be, potential adversaries would not be emboldened even if their nuclear arsenals became superior to the US nuclear forces – putting aside the question of whether it is a realistic scenario that potential nuclear-armed rivals would gain nuclear supremacy over the United States. The nuclear balance of power between the United States and a potential aggressor would not play a significant role in determining whether Washington would be able to dissuade the aggressor from challenging its security interests. Unless a potential adversary can launch a successful nuclear disarming strike, which is almost impossible in the foreseeable future given the survivability and sheer size of the US strategic arsenal, the United States can have strong confidence in its ability to deter nuclear-armed adversaries regardless of the nuclear balance of power. In the equation of deterrence between nuclear states, the balance of nuclear forces may play a far smaller role than many believe.

Replication data

The dataset, codebook, and do-files for the empirical analysis in this article, along with the Online appendix, are available at https://www.prio.org/jpr/datasets/. All analyses were conducted using Stata 14.

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