Structural Vulnerabilities and Deterrence Failure: A Game Theory Analysis of Potential North Korean Invasion

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Abstract

Deterrence has long served as the foundation of stability on the Korean Peninsula, despite North Korea's persistent military provocations. Yet, structural vulnerabilities amidst the changing global order—most notably South Korea's demographic decline, uncertainties in the U.S.–ROK relationship and deepening North Korea–Russia alliance—raise serious concerns about future conflicts. This paper addresses these concerns by extending a three-player extensive game-theoretic framework to model strategic interactions between North Korea, South Korea, and the United States. By integrating variables for military capability, alliance credibility, and nuclear retaliation risks, the research aims to quantify shifting payoffs and derive Subgame Perfect Equilibria to understand how deterrence capabilities evolve. Analysis shows that the likelihood of military escalation increases as South Korea's military manpower diminishes and U.S. commitment wavers, depicting the erosion of deterrence that is not merely theoretical. These findings underscore the need for South Korea to further invest in military technology, reassess U.S.–ROK dependency, and address long-term structural weaknesses for the future.

Keywords

Deterrence; Korean Peninsula; Game theory; Subgame Perfect Equilibrium; Nuclear Strategy

Introduction

Deterrence in the context of defense has long been applied to explain strategic interactions between nations during and after the Cold War, especially in nuclear contexts. It posits that deterring aggression from sovereign states can mainly be achieved when they perceive unacceptable costs that outweigh their utility. In other words, deterrence can fail when the international community fails to understand a shift in such calculations—whether through misjudged resolve, changing alliances, or evolving military balances—epitomized by the Russia-Ukraine war. Today, South Korea faces analogous concerns, growing increasingly volatile due to its dwindling demographics, troubled relations with the United States, and deepening North Korea–Russia cooperation that are altering the long-held ceasefire. In order to prevent a breakout of another military conflict, understanding these changes is crucial. Specifically, the three aforementioned factors are defined as structural vulnerabilities faced by South Korea. By depicting these structural

vulnerabilities in a formal game-theoretic model, this paper answers the question: under what structural and strategic conditions will deterrence on the Korean Peninsula fail?

Post-Cold War, the Korean Peninsula remains one of the most geopolitically tense regions, with consistent North Korean provocation, failure of diplomatic agreements, and nuclear threats. At the same time, with the superior South Korean military, backed by 25,000 United States Forces Korea (USFK) troops, the chances of a military conflict between the two adjacent nations were deemed implausible. A large bulk of literature suggests that Kim Jong-eun's primary goal is regime survival; hence, their decision-making is shaped around rent extraction, elite survival, and international bargaining position rather than a military advantage (Scobell, 2005; Sin, 2013; Bennet et al, 2020; Garlauskas & Gilbert, 2023). While Kim values the doctrine of unification under Pyongyang, it remains a penultimate goal for its regime, and a full-scale invasion is one of the least plausible scenarios (Garlauskas & Gilbert, 2023).

That deterrence is crumbling, however. Starting with the North's projected success of the Intercontinental Ballistic Missile (ICBM) development in 2017, its advancing arsenal makes North Korea an increasingly dangerous and unpredictable actor. Mazarr et al. estimate in 2018 that within five to eight years, North Korea would have sufficient survival nuclear capability to make any moves into the North prohibitively costly, which suggests U.S. reluctance to join in a breakout of war. Furthermore, North Korea's alliance with Russia in June 2024 presents new threats in the changing global order. To support Russia's war efforts in Ukraine, Kim Jong-eun deployed 11,000 troops and arms support; Russia, in exchange, openly expressed support for North Korea and its nuclear program and possibly aided North Korea's outdated military technology and structure (Byun, 2025).

The growing external threat is becoming increasingly concerning as South Korea currently faces structural problems both internally and externally that could dwindle its deterrence capabilities. First is the world's lowest fertility rate in South Korea, expected to decrease the number of South Korean troops from 600,000 in the early 2000s to less than 400,000 within the next 15 years (KIDA, 2023). Even as technology dominates the course of warfare, the Russian-Ukrainian war of attrition showcases the importance of manpower and conscription (Sharma and Roy, 2024). South Korea's superior military technology does not change the fact that the country faces the vast North Korean army of 1.2 million (Council of Foreign Relations, 2022). Second is the increasing uncertainty of the United States' support under President Donald Trump's conservative domestic policy, alongside the rise of China. Roberts et al. (2023) delineate the erosion of the alliance between the two parties under divergence in perceived threat. The United States views strategic competition with China as its greatest priority, while for South Korea, it is security concerns with the North (Roberts et al., 2023). Furthermore, the recently elected South Korean president Lee Jae-myong's leftist agenda is starkly contradictory to the stance of U.S. President Donald Trump, who is threatening to pull the USFK out of the South. The stability provided by the U.S. presence might be slowly ceasing. Understanding how these payoffs evolve is pivotal to assessing the future outlook of the

Korean Peninsula. Hence, to analyze this dynamic, this paper utilizes game theory to model strategic interactions of an extensive game with changing payoffs.

Game theory has been widely applied to understand deterrence, with Schelling (1960) making a significant contribution to the field. Game theory provides valuable insights into how and why certain decisions are made in this context. The Prisoner's Dilemma, for example, explains why the United States and the Soviet Union both nuclearized when the world was clearly safer without them. Snyder (1961) establishes two primary branches of deterrence: deterrence by denial, which convinces the aggressors that they will fail, and deterrence by punishment, which communicates the severity of retaliation. In doing so, he establishes that deterrence as a game between perfectly rational players depends on perceptions of strength, credibility, and willingness.

However, such a framework, known as Classical Deterrence Theory, was criticized for being a rigid one-shot framework that is unable to specify interactions between evolving preferences. Most importantly, as Zagare (1987) contends, the likes of Scheiling (1960,1966) and Snyder (1961,1972) were "unable to specify, unambiguously, what constitutes rational behavior." As an alternative, Zagare and Quackenbush (2006) developed the Theory of Moves (TOM), the foundational framework of a more formal game-theoretical analysis we see today. In TOM, players can reconsider and change their course of action, motivated not only by payoffs but also by the other player's moves, taking each player's preferences into account, while allowing empirical flexibility. By emphasizing the dynamics of decision-making, TOM offers a more realistic framework with greater empirical accountability, serving as a baseline in understanding Korean Peninsula deterrence.

This paper examines how structural vulnerabilities can undermine deterrence through a game-theoretical approach. Understanding these conditions is crucial for policymakers seeking to prevent future conflict on the Peninsula. Specifically extending upon McGarvey et al. (2017)'s qualitative model into a quantified game, the research captures whether deterrence remains stable as structural vulnerabilities evolve. By performing numerical analysis through a series of supported assumptions, the paper induces Subgame Perfect Equilibria. Section two reviews the paper's methodology and describes specific payoff calculations. Section three finds the game's Subgame Perfect Equilibrium and presents its implications. Section four tests the conclusions derived in Section three and interprets the significance of the result. Section five summarizes findings and suggests courses of action to the Korean government.

Methods

Model Overview

The mathematical model shown in Figure 1 utilizes the extensive three-player framework introduced by McGarvey et al. (2017) with North Korea, South Korea, and the United States as players. The game unfolds in four sequential stages: initial aggression by the North, response by the South, intervention decision by the US, and final escalation or retreat by the North. Each stage corresponds to a unique conflict scenario, represented in Figure 1.

- Status Quo. North Korea is successfully deterred at stage 1,
- Bilateral War. South Korea resists North Korean aggression with the U.S. abstaining,
- South Concede. South Korea concedes to North Korean aggression, with the U.S. abstaining,
- North Korea's retreat. North Korea decides to retreat following the United States' intervention,
- Multilateral War. North Korea chooses to continue the war following the United States' intervention.

In this model, each player is assumed to be rational, seeking to maximize their utility with complete information. To calculate expected payoffs of each player's corresponding moves, the model incorporates the following parameters.

- p_1 represents the probability of South Korean victory against North Korea
- p_2 represents the probability of South Korea–U.S. alliance victory against the North.
- θ represents the probability of successful defense against North Korea's ICBM.
- R represents the alternative reward for the U.S. outside of the Korean Peninsula

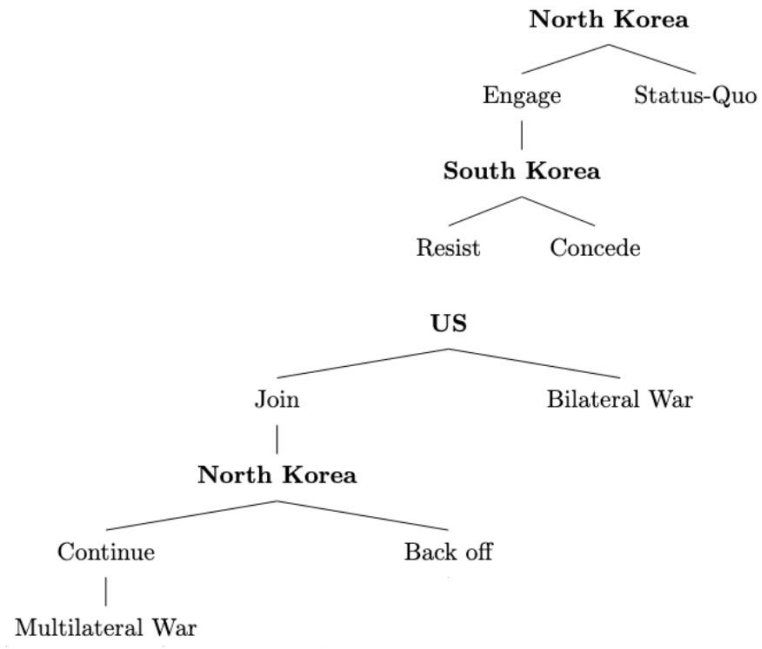

Figure 1: Game tree structure

Payoff Structure

Stage 1: North Korea's initial strategic choice: Invades or maintains the status quo
North Korea makes strategic decisions between two mutually exclusive moves: maintaining the status quo or choosing to invade the South. The Status Quo is represented as the baseline outcome with the respective payoffs normalized to (0, 0, 0) for North Korea, South Korea, and the United States, respectively. All future payoff triples follow this structure.

Status Quo Payoffs: (0, 0, 0) for (North Korea, South Korea, United States)

Stage 2: South Korea resists North's aggression or concedes
Conditional on North Korea's decision to initiate an invasion, South Korea either resists or concedes to North Korea.

- Losing the war results in a payoff of -100 for both countries.
- North Korea's victory results in a payoff of 90, high but less significant than the regime's survival.
- South Korea's loss would yield a payoff of -40 for the U.S. South Korea occupies a crucial position in the U.S. strategic containment of China's expanding military influence as "a fundamental building block of allied maritime security strategies in the Indo-Pacific" (Kim, 2021).

Hence, if South Korea concedes to North Korea's invasion, it leads to the following payoff of (90, -100, -40).

Concession Payoffs: (90, -100, -40)

Stage 3: The United States joins an ally or stays out.

If South Korea resists, the United States either joins the war or stays out, and several factors influence this decision, including alliance credibility and alternative rewards. If the United States stays out, a Bilateral War results.

- North Korea, analogous to stage 2, receives 90 for victory, plus an additional -40 for war costs.
- South Korea receives a payoff of only 40 for victory and -150 for a loss. Half of South Korea's population and over 70% of its economic activities are focused in Seoul. North Korea's threat of turning Seoul into a "sea of fire" suggests a catastrophic outcome for the South in both human and economic costs (Mazarr et al., 2018). Even if North Korea does not use its nuclear arsenal close to home, the Pentagon cautiously estimates that a war would cause 20,000 South Korean civilian deaths daily, with more common forecasts estimating 100,000 deaths within 48 hours (Demick, 2017; Feffer, 2017). As a country heavily dependent on exports, South Korea will suffer significant damage to its GDP and lose its position in global supply chains in any event of conflict. If South Korea wins, there are indeed substantial long-term benefits, including security relief, market growth, the development of underground resources, expedited transportation to China, and the regulation of housing prices. However, the prospects of restoring the damaged South and integrating the underdeveloped North would be nebulous.
- The U.S. receives a payoff of -20 if it stays out. Supporting South Korea is a way to showcase Washington's reliability to its allies, bolstering alliance confidence and commitment to the region's security network (Lowther, 2023). Neglecting alliance harms the U.S. defense credibility.
- The U.S. also receives a payoff of R if they stay out, an alternative reward outside of the Korean Peninsula. This includes other potential areas of conflict or domestic issues.

Additional factors, including payoffs for victory and defeat, remain unchanged from previous stages. We summarize and calculate the expected payoffs as follows, with p_1 representing the probability of South Korean victory in a Bilateral War:

Bilateral War Payoffs:

p_1(-100, 40, -20+R) + 1-p_1(50, -150, -60+R) = (50-150p_1, -150+190p_1, -60+R+40p_1)

Stage 4: North Korea decides to continue its attack or retreat.

If the United States joins and North Korea decides to continue its aggression, conflict results in a Multilateral war.

- The North would face a tougher fight with U.S. involvement, with the war cost increasing from
  -40 → -50 compared to a Bilateral War.
- Hence, the North cannot compete against the superior U.S. military and would likely lead to regime collapse, resulting in -100.
- With U.S. support, the South will find it easier to push the war into the North and suffer fewer casualties, receiving 50 for victory.
- A multilateral war is highly likely to result in a nuclear exchange. The U.S. will showcase its alliance credibility, +20, and preserve South Korea, but would suffer -100 of a nuclear attack under probability 1-θ and moderate war costs of -20. As Mazarr et al. and retired U.S. Air Force General Sam Gardiner suggested, locating all of North Korea's nuclear weapons and eliminating their risks from conventional weaponry are highly unlikely, and attempts to do so will trigger nuclear strikes (Feffer, 2017). But as the Center for Arms Control and Non-Proliferation suggests, there remains no reliable anti-missile system to counter an already launched ICBM for the United States (Center for Arms Control and Non-Proliferation). If defense mechanisms fail, millions of civilian deaths will also occur on U.S. soil, resulting in a payoff of -100 for the U.S. The current defense mechanism for the ICBM, Ground-based Midcourse Defense (GMD) program, has an approximately 50% success rate (θ = 50%).
- If the alliance loses, the United States will lose additional credibility, resulting in -50.

Additional factors, including payoffs for victory and defeat, remain identical to previous stages. Combining all aspects, the Multilateral War payoff calculation is as follows.
Multilateral War Payoffs:
p_2(-100, 50, 20-20-100(1-θ) -R) + 1-p_2(40, -150, 20-20-50-100(1-θ) -R) =
(40-140p_1, -150+200p_1, 50p_2+100θ-R-150)

If North Korea retreats after observing U.S. intervention:

- South Korea receives -50 and North Korea receives 50. South Korea would already have suffered immense damage following the initial attack, giving North Korea a strategic advantage. Furthermore, even if the U.S. joins and pushes North Korean troops out of South Korea, further escalation into the North would embody significant risks of nuclear retaliation. In fact, the U.S. strategic considerations will also affect the North's decision-making; North Korea may not be compelled to retreat after the initial attack when the possibility of retaliation is low. Hence, unless θ is high enough to guarantee safety against the ICBM, the alliance will not be able

to punish the North. We will also represent the probability of alliance punitive retaliation as θ; as the credibility of the defense mechanism increases, the possibility of alliance retaliation increases. Without reasonable punishment, North Korea's retreat would appear as a strategic fallback rather than a successful deterrence.

- With retaliation, the North Korean regime will likely collapse, but with another threat of nuclear exchanges, resulting in a payoff analogous to stage 4.1. South Korea will face a minimum damage of -40 and a reward of 60 for unification.

Hence, the payoff for calculation for North Korea's retreat is dependent on the probability of retaliation, summarized as follows.

North Korea Retreating Payoffs:

θ(-100, -40+60, 20-20-100(1-θ) -R) + 1-θ(50, -50, 20-20-R) = (50-150θ, -50+70θ, -100θ+100θ^2-R)

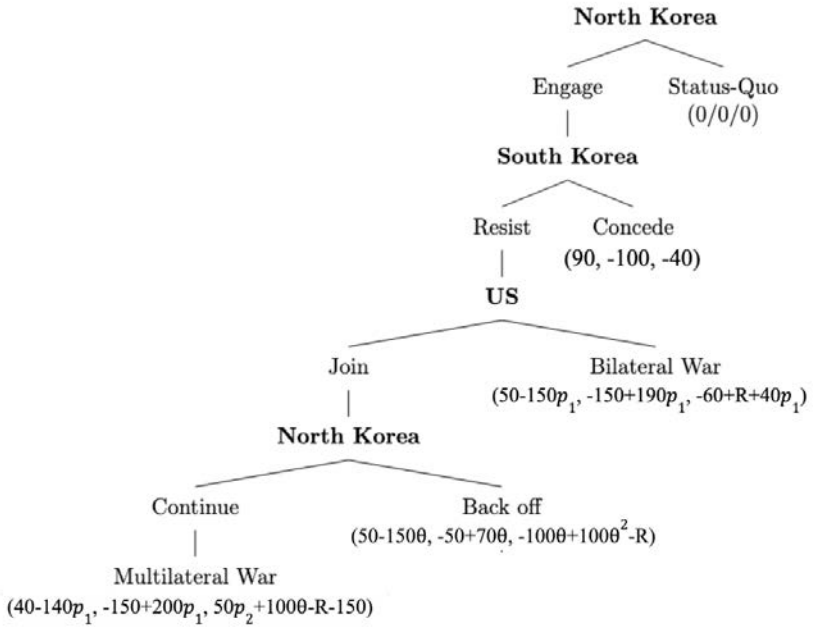

Figure 2: Game tree with complete information

Results

Subgame Perfect Equilibrium

The solution concept for this extensive-form game is the Subgame Perfect Equilibrium (SPE). A subgame is a portion of the game tree that begins with a single decision node, and the SPE is a strategy profile where every player responds with their optimal choice in every subgame. SPE can be derived using backward induction, which starts at the final

decision node of the game and moves upwards with each player's optimal decision. Applying backward induction and arranging parameters reveals the following conclusions:

Proposition 1

If 50-150p_1 < 0, 40-140p_2 < 0, and 50θ-150 < 0, there exists a unique SPE at Status Quo. Under the following conditions, North Korea is successfully deterred, as an invasion of the North on stage 1 cannot produce a positive payoff, regardless of the subsequent actions.

$$p_1 > 1/3,\ p_2 > 2/7,\ \theta > 1/3 \quad (1)$$

Proposition 2

North Korea will retreat at Stage 4 if 40-140p_2 < 50-150θ; The p_2 threshold for North Korea retreating is

$$p_2 > \frac{150\theta-10}{140} \quad (2)$$

If the North retreats, through backward induction, the U.S. joins at Stage 3 when

$$-100\theta + 100\theta\text{^}2 - R > -60+R+40p_1$$

$$-50\theta\ (1-\theta) + 30 - 20p_1 > R \quad (3)$$

South Korea at Stage 2 will strictly prefer to resist since -50+70θ is always greater than -100.

Under these conditions, North Korea will likely choose to invade at Stage 1 when

$$50-150\theta > 0$$

$$1/3 > \theta \quad (4)$$

If all given conditions are met, a unique SPE exists with North Korea retreating in Stage 4

Proposition 3

Similar to (2), North Korea does not retreat at Stage 4 if $p_2 < \frac{150\theta-10}{140}$. Then, the U.S. joins when

$$60p_2 + 100\theta - R - 170 > -60+R+40p_1$$

$$30p_2 + 50\theta\text{-}55\text{-}20p_1 > R \quad (5)$$

South Korea will resist at Stage 2 when

$$-150+200p_2 > -100$$
$$p_2 > 1/4$$

However, North Korea will choose to invade at Stage 1 under the condition

$$40\text{-}140p_2 > 0$$
$$2/7 > p_2$$

Hence, a Multilateral War is a SPE if

$$30p_2 + 50\theta\text{-}55\text{-}20p_1 > R \quad (5)$$

$$1/4 < p_2 < \frac{150\theta-10}{140}, 2/7 \quad (6)$$

Proposition 4

If boundaries for R in (3) and (5) are not met—and the United States stays out—South Korea will resist as long as $-100 < -150+190p_1$. North Korea will choose to invade if $50\text{-}150p_1 > 0$. Hence, there exists a unique SPE at Bilateral War if R value does not satisfy the conditions given in (3) and (5), and

$$5/19 < p_1 < 1/3 \quad (7)$$

Proposition 5

If $p_1 < 5/19$, and conditions for R in (3) and (5) are not met, and the United States stays out, South Korea's conceding to the North is a unique SPE of this game.

Implications

The above model finds five distinct equilibrium outcomes, each contingent on parameter conditions.

1. Successful Deterrence

Proposition 1 suggests that a deterrence mechanism functions when both thresholds ensure South Korea's defensive success probability is high enough to make aggression unprofitable regardless of subsequent U.S. choices. While imperfect, quantified thresholds suggest that North Korea invades only when the chance of its victory is high, as shown in (1). Section 5 will show that the current military equilibrium satisfies the deterrence threshold and how changing military structures amid structural vulnerabilities affect this dynamic.

2. Likelihood of an all-out attack

(2), (3), and (4) suggest that North Korea will choose to invade at Stage 1 if θ is less than 1/3. However, recalling that the US GMD program has an approximate success rate of 50%, North Korea invading and then consequently retreating is an unlikely outcome. This suggests that North Korea's invasion would likely be an all-out attack rather than a temporary escalation for military and diplomatic advantages.

3. United States Incentives

Conditions driven by propositions 2 and 3 suggest that U.S. incentives to join are dependent on all three variables to the game: p_1, p_2, and θ. Higher reliability of the U.S. defense system, represented by a higher θ value, results in the United States' support. Given that North Korea engages in a multilateral war, higher chances of alliance victory prompt the United States to join the war. However, paradoxically, higher odds of South Korea's victory, represented by a higher p_1 value, the incentive for the United States to join decreases.

Given that p_1, p_2, $\theta \in [0,1]$, we find that the alternative reward for the U.S. outside of the Korean Peninsula, R, must be minimal for the U.S. to join. Conservatively estimating by letting $p_1 = 0$ and p_2, $\theta = 1$, (3) and (5) suggest that the alternative reward that the U.S. needs to stay away from conflict is still smaller than the strategic value of South Korea to the U.S, represented by a payoff of -40. This suggests that in the presence of other disputes and conflicts, conflict in the Korean Peninsula is not likely to be a U.S. priority. This is likely motivated by concerns regarding North Korean nuclear capabilities, represented by the strong influence of θ on the U.S. payoff structure.

4. Limited likelihood of Multilateral War

Multilateral war is a possible outcome, but highly unlikely. Given (6), $p_2 < \frac{150\theta - 10}{140}$ and 2/7, the magnitude of the alternative reward for the U.S. to stay away, even under the most optimistic conditions for the U.S. intervention, is $\frac{60}{7} + 50 \times (\theta = 1) - 55 - 20 \times (p_1 = 0)$ $\approx$ 3.71, which supports the conclusion that the U.S. will not prioritize the Korean Peninsula when it comes to direct military conflict. Especially since North Korea is likely to instigate an all-out attack in the face of conflict, as stated in Implication 2, the U.S. finds little incentive to join. Furthermore, the range of p_2 required for the North to commit to an invasion in stage 1 is very slim, between 1/4 and 2/7, a range of 0.03. Sections 5 and 6 will also show, by estimating the possible range of p_2, that a multilateral war is not a likely equilibrium.

5. Prospects of Bilateral Conflict

Propositions 4 and 5 suggest that a bilateral conflict is the most viable outcome of North Korea's invasion. With the absence of the U.S, strategies are solely dependent on p_1. Sections 5 and 6 will estimate the range of the p_1 value depending on the relative military strength of North and South, affected by fertility rates and technology levels, to show how bilateral tensions evolve.

The Subgame Perfect Equilibrium provides insights into how the conflict will evolve. Despite the volatile and interconnected nature of East Asian geopolitical tensions, the SPE has evinced that South Korea will likely stand on its own in the time of war. In interpreting this result, it is crucial to note that China has consistently expressed a desire to seize Taiwan by force if necessary; North Korea's invasion is likely part of a sequential attack of the China–North Korea alliance. The U.S. is expected to mobilize support for both Taiwan and South Korea; however, given Taiwan's strategic importance in the United States' superior goal of containing China and maintaining control of the regional defense, combined with the lack of incentives suggested by the SPE, South Korea is not likely to be a U.S. priority.

Such a scenario is merely a speculation, and the U.S. will not easily give up on South Korea. Continuous diplomatic efforts are no less crucial than alternative measures. However, the conclusions emphasize that the degree to which successful deterrence depends heavily on South Korea's independent ability to ward off North Korea, sending a strong signal to deter any intentions of military escalation. This would mean that government response to declining military personnel, investment in technology, and strategic planning is imperative. The following sections aim to delineate these factors further.

Discussions

To interpret the significance of the conclusions drawn, this section of the paper intends to specify parameters p_1 and p_2, the win probabilities of the South, based on changing military capability of players over time due to structural vulnerabilities. Even though the numbers and models are vastly simplified, it aims to serve as a baseline tool for understanding how the dynamics in the Korean Peninsula change.

We map win probability P using a Contest Success Function, letting MP_{SK} and MP_{NK} represent the military power of each player.

$$P = \frac{{MP_{SK}}^r}{{MP_{SK}}^r + {MP_{NK}}^r}$$

* r adjust for the sensitivity of change relative to MP

While r cannot be specified, the model for P helps understand how tensions will evolve

In our analysis, we assume that military capability depends primarily on two factors: manpower and technology, represented by the following equation.

$$\text{MP(t)} = M(t)^{0.3} \text{ x } T(t)^{0.7}$$

South Korea has approximately 500,000 available military personnel, but the Korean National Statistical Office estimates that the male population available for conscription, above age 20, to decline 40% until 2040 (KOSTAT, 2024). A significant reduction in the standing and reserve forces is inevitable (Han, 2023). We estimate an annual decline rate of 2.5% in the South Korean military.

The Korea Research Institute for Defense Technology planning and advancement (KDIT) contends that the development of various guided weapons has continually complemented the country's technology level, reaching among the top 8 globally (KDIT, 2024): KDIT rates that of South Korea as 82, between Russia and France of 89, and Italy of 79, given the U.S. rating as 100. According to the KDIT, South Korea's technology level has fluctuated around 80 in the past few years: 80 in 2018, 79 in 2021, and 82 in 2024. Given South Korea's military is almost fully developed, it is likely to stay within this range (KDIT, 2024). We consider the two factors and represent the military power of South Korea as follows,

$$MP_{SK}\text{(t)} = (A * 500{,}000\ (1 - 0.025)^{t-2025})^{0.3} * (82\ (1 + 0.005)^{t-2025})^{0.7}$$

*A = 0.001 for scalar adjustments

North Korea has approximately 1,200,000 available military personnel, and unlike South Korea, it retains a population growth of 0.4%, expected to peak between 2030 and 2035 (Han, 2023). North's weapons systems hold an overwhelming quantitative advantage in the number of joint combat ships, landing ships, and mine warfare vessels (Han, 2023). However, the overall quality and technological advantages still fall short of those in South Korea. The specific level of North Korea's technology is largely nebulous, and KDIT does not quantify North Korea in its research; we estimate its technology level as 41, half of South Korea's. Considering such factors, we represent the military power of North Korea as follows,

$$MP_{SK}\text{(t)} = (A * 1{,}200{,}000\ (1 + 0.004)^{t-2025})^{0.3} * (41\ (1 + 0.010)^{t-2025})^{0.7}$$

We can also model the military power of the United States the same way. 28,500 USFK are residing in South Korea, and KDIT rates the United States military as 100. We

conservatively disregard additional US soldiers or technological growth, as they won't affect the conclusion. We will use these two values to quantify $MP_{U.S}$ in South Korea as

$$MP_{U.S} = 28500^{0.3} * 100^{0.7}$$

Interpretations

According to this model,

$$MP_{SK}(2025) = 70.69,\ MP_{NK}(2025) = 56.59,\ MP_{U.S}(2025) = 68.62$$

Which results in the following p_1 and p_2 values using r = 1.

$$p_1 = \frac{MP_{SK}}{MP_{SK} + MP_{NK}} = 55.54\%$$

$$p_2 = \frac{MP_{SK}+MP_{UK}}{MP_{SK} + MP_{NK}+MP_{US}} = 71.11\%$$

Recalling that the U.S. GMD program has an approximately 50% success rate ($\theta \approx 1/2$), North Korea currently is successfully deterred as the status quo aligns with (1) from Section 3: p_1= 55.54 > 1/3, p_2= 71.11 > 2/7, $\theta \approx 0.5 > 1/3$.

However, over time, South Korea's declining population weakens the South Korean military, which converges with that of North Korea, as shown in Figure 3. Despite conservative estimation using r =1, we can also use these quantities to represent p_1 and p_2, which are shown to decrease over time, as illustrated in Figure 4. These graphs ultimately depict how military dynamics on the Korean Peninsula could change over time, emphasizing the conclusions drawn in Section 4. Specifically, with the limited likelihood of a Multilateral conflict, condition (1) is the most significant threshold for deterrence. With the decline of South Korea's military manpower, p_1 also decreases. Furthermore, despite their unlikeliness, condition (6) to deter North Korea's continued aggression at Stage 4 is dependent on maintaining p_2 above the given threshold. Given that the ultimate goal of the South Korean government is not to win the war but to prevent any source of military conflict in the first place, any signs of change in the preserved military balance, demonstrated by figures 3 and 4 below, should not be taken lightly.

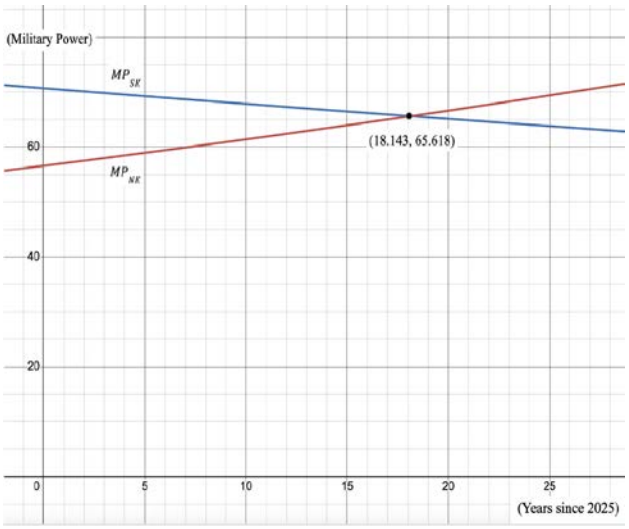

Figure 3: Change in Military Power over time

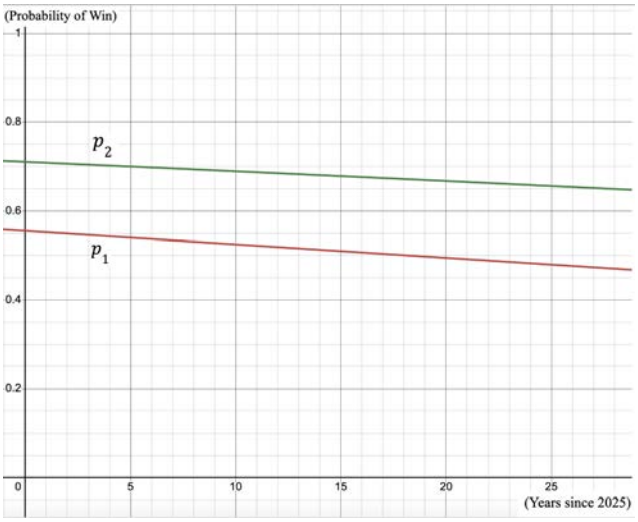

Figure 4: Change in Win probability for South Korea
* Conservative estimate using r =1

Conclusion

The three-party extended game has revealed that under specific conditions, deterrence on the Korean Peninsula fails. By formalizing strategic interactions and incorporating parameters for shifting military capabilities, alliance credibility, and nuclear escalation risks, the analysis highlights the fragility of deterrence when underlying payoffs evolve. The game specifically employed variables of win probability based on military power in order to demonstrate this dynamic.

Analysis of Subgame Perfect Equilibrium and parameterization of variables reveal that failure of deterrence is impending, in fact eroding this very moment. Taken together, the model suggests several key factors that should be addressed for a successful deterrence. First, the South Korean government should mitigate the demographic gap in the military by investing further in weapons production, technology development, or incentives to encourage enlistment, to address the nation's quantitative disadvantages. South Korea's fertility rate will continue to dwindle the nation's capability for immediate response to a threat, while North Korea enlarges its conventional weaponry without pertinent sanctions. It is more than a possibility that the South and North will be on equal footing or that North Korea will have the upper hand within the next few decades, even though this future seems far-reaching for many South Koreans (Han, 2023). Second, meticulous revision of the U.S.–ROK relationship, while also preparing contingencies for isolation. Results suggest that U.S. incentives to intervene are not guaranteed, but rather conditional on credibility costs, alternative strategic priorities, and nuclear risk tolerance. To ensure U.S. commitment, South Korea must deepen defense-industrial cooperation. At the same time, South Korea should diversify its security partnerships. Diplomatic affiliation with Japan, NATO members, and emerging regional coalitions could become increasingly important. Third, South Korea's security planning must adopt a long-term strategic outline. Analysis shows that deterrence slowly erodes until conditions meet a certain threshold. Military

modernization, alliance management, and demographic resilience should be viewed as intergenerational tasks.

It should be noted that the quantities presented in this research should not be holistically trusted and viewed with the understanding that they represent a simplified narrative. Payoffs are assumptions based on available information, not an accurate reflection of each country's interest. In times of war, players are likely to act based on what is right rather than what is rational. Accurately assessing military strength is a much complex process that requires a far extensive and rigorous methodology just to come close. Military strength alone cannot predict the outcome of a war. The game tree itself does not fully capture decisions of external players, including NATO, Russia, or China, or take North Korea's use of nuclear weapons fully into consideration. Addressing these limitations could bolster the accuracy of the conclusion and provide a more comprehensive evaluation of the situation. Ultimately, the significance of this research lies in its attempt to portray strategic interactions through numbers, not in its definitive accuracy.

Given that national defense isn't entirely concerned with what happens in the next few years, but rather look 20-30 years into the future, the ability to understand structural vulnerabilities and prevent what is ahead is a tool of utmost importance in the face of a changing global order. Ultimately, South Korea's goal is to prevent a war from escalating in the first place, not to win the war. With that said, this paper aims to address such vulnerabilities to depict under what conditions international governance can avoid a future that isn't merely theoretical.

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References

Byun, S. (2025) Russia and North Korea's Official Acknowledgment of North Korean Troop Deployment: Background and Implications. [online] Institute for National Security Strategy (INSS). Available at: https://www.inss.re.kr/upload/bbs/BBSA05/202505/F20250521101017484.pdf [Accessed 15 October 2025].

Demick, B. (2017) 'Escalating tension has experts simulating a new Korean War, and the scenarios are sobering', Los Angeles Times, 25 September. Available at: https://www.latimes.com/world/la-fg-korean-war-20170925-story.html [Accessed 15 October 2025].

Feffer, J. (2017) North Korea: The Costs of War, Calculated. Foreign Policy in Focus, 13 December. Available at: https://fpif.org/north-korea-costs-war-calculated/ [Accessed 15 October 2025].

Gilbert, L. and Garlauskas, M. (2023) Deterrence is Crumbling in Korea: How We Can Fix It. Atlantic Council, 9 November. Available at: https://www.atlanticcouncil.org/in-depth-research-reports/report/deterrence-is-crumbling-in-korea-how-we-can-fix-it/ [Accessed 15 October 2025].

Han, J.-G. (2023) Analysis of the Balance of Military Power on the Korean Peninsula Using a Comprehensive Assessment Methodology. [online] Korea Science. Available at: https://koreascience.kr/article/JAKO202307267794003.pdf [Accessed 15 October 2025].

Ice, L., Scouras, J., Rooker, K., Leonhard, R. and McGarvey, D. (2017) Nuclear Stability in Northeast Asia: Workshop Proceedings — Game Theory and Stability. [online] Johns Hopkins University Applied Physics Laboratory. Available at: https://www.jhuapl.edu/sites/default/files/2022-12/GameTheoryWorkshop.pdf [Accessed 15 October 2025].

Jun, K. (2025) US Shifts Priority to Indo-Pacific's "Second Island Chain"—What Does It Mean for Taiwan? Central European Institute of Asian Studies (CEIAS), April. Available at: https://ceias.eu/us-shifts-priority-to-indo-pacifics-second-island-chain-what-does-it-mean-for-taiwan/ [Accessed 15 October 2025].

Kim, G. (2025) South Korea Is an Island, Entire of Itself: The Missing Island in Allied First Island Chain Strategies. Center for a New American Security (CNAS). Available at: https://www.cnas.org/publications/commentary/south-korea-is-an-island-entire-of-itself-the-missing-island-in-allied-first-island-chain-strategies [Accessed 15 October 2025].

Lowther, A. (2023) Kim's Nukes, Yoon's Qualms: Strengthening the US Nuclear Umbrella over South Korea. Air University (AU), 15 November. Available at: https://www.airuniversity.af.edu/JIPA/Display/Article/3588559/kims-nukes-yoons-qualms-strengthening-the-us-nuclear-umbrella-over-south-korea/ [Accessed 15 October 2025].

Mazarr, M.J., Gentile, G., Madden, D., Pettyjohn, S.L. and Crane, Y.K. (2018) The Korean Peninsula: Three Dangerous Scenarios. RAND Corporation. Available at: https://www.rand.org/pubs/perspectives/PE262.html [Accessed 15 October 2025].

Missile Defense (n.d.) Center for Arms Control and Non-Proliferation. Available at: https://armscontrolcenter.org/issues/missile-defense/ [Accessed 15 October 2025].

Roberts, B. (2023) China's Emergence as a Second Nuclear Peer: Implications for U.S. Nuclear Deterrence Strategy. [online] Center for Global Security Research (CGSR). Available at: https://cgsr.llnl.gov/content/assets/docs/CGSR_Two_Peer_%20230314.pdf [Accessed 15 October 2025].

Schelling, T. (2023) The Strategy of Conflict. Cambridge, MA: Harvard University Press. Available at: https://www.hup.harvard.edu/books/9780674840317 [Accessed 15 October 2025].

Scobell, A. (2005) North Korea’s Strategic Intentions. Carlisle, PA: United States Army War College Press. Available at: https://press.armywarcollege.edu/monographs/739/ [Accessed 15 October 2025].

Sharma, A. and Roy, T. (2024) South Korea’s Declining Demographics: A National Security Issue. Observer Research Foundation (ORF), 11 November. Available at: https://www.orfonline.org/expert-speak/south-korea-s-declining-demographics-a-national-security-issue [Accessed 15 October 2025].

Son, J.H. (2025) Defense Science & Technology Level Assessment by Country. Korea Research Institute for Defense Technology Planning and Advancement (KRIT), 22 January. Available at: https://www.krit.re.kr/krit/bbs/gbgh_list.do# [Accessed 15 October 2025].

Statistics Korea (2023) 2023 Birth Statistics. KOSTAT. Available at: https://kostat.go.kr/board.es?mid=a10301010000&bid=204&act=view&list_no=432388 [Accessed 15 October 2025].

Zagare, F. (2025) The Dynamics of Deterrence. [online] Google Books. Available at: https://books.google.co.kr/books?id=FhqL-Uh1X_8C [Accessed 15 October 2025].