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SENSITIVITY OF STABILITY INDICES TO FORCE UNCERTAINTIES

Gregory H. Canavan

Additional or hidden weapons in the possession of the side with the largest fraction of vulnerable weapons can improve stability. Vulnerable weapons contribute primarily at the end of force reduction; survivable weapons contribute throughout the transition.

A companion paper studies first strike stability below START II force levels. This paper studies sensitivity of those results to uncertainties in force levels or hidden weapons. It studies the impact of additional weapons on attack allocations, first and second strikes, first and second strike costs, and stability indices. The sensitivity of first strike stability to variations in forces below START II levels can be studied parametrically by studying the changes in attack allocations, first and second strikes, strike costs, and stability indices caused by real or possible variations in forces.

Additional vulnerable weapons in the inventory of the side with the greater fraction of vulnerable forces produces a shift to value in his second strike and a larger shift to missiles in the first strike of his opponent. Their first strikes change accordingly, increasing second strike costs more than first, which is generally destabilizing. The possession of additional weapons by the side with largely vulnerable forces would increase stability indices because it would partially compensate for his inferior initial position.

Additional survivable weapons would again produce a shift to value in his second strike but no shift in the first strike of his opponent. He simply uses them on value in his first or second strike. In contrast to vulnerable missiles, the additional survivable weapons cause the opponents first strike costs to increase faster than his second strike costs, and his second strike costs to decrease faster than his second strike costs, both of which reduce the perception of advantage to preemption, increasing stability.

When one side has more vulnerable forces, his possession of additional weapons appears to be stabilizing. However, for additional vulnerable weapons, stabilization is largely a compensation for his inferiority in the base configuration, is sensitive to model parameters, and obtains only when both sides approach single weapon missiles. For survivable weapons, stabilization is again a compensation for inferiority in the base configuration, but is less sensitive to model parameters, and provides useful increments to stability indices at intermediate steps in force reduction, where they would otherwise decline to bothersome levels.

The model used is described in the "Effect of Unsymmetric Force Reductions,"¹ which is extended to proportional force reductions from START I levels in "First Strike Stability at Low

Weapon Levels"² using the models for force exchanges, damage, costs, and stability indices derived in earlier notes.^{3,4} Attack allocations are determined analytically. Numerical calculations having shown that at these force levels, the impact of non linearity on attack allocation is 10-20% and on costs and stability indices is a few percent.

The effect of additional weapons is studied by taking the results of the previous calculations from proportional force reductions in "First Strike Stability at Low Weapon Levels;" adding a given number of vulnerable or survivable missiles at each stage; calculating the new attack allocations, first and second strikes, first and second strike costs, and stability indices; and subtracting those from "First Strike Stability at Low Weapon Levels" to produce the differences in or survivable missiles at each stage; calculating the new attack allocations, first and second strikes, first and second strike costs, and stability indices, which are discussed. Weapons that exist but are unsuspected would not impact allocations or stability indices. The assumption here is that the existence of the weapons is revealed or inferred and the analysis is used to discuss the impact that step would have on estimates of first strike stability.

Forces. The two sides are denoted as in the earlier notes by "unprime" and "prime," corresponding to the symbols used to denote their forces and parameters. The forces are reduced proportionally and shifted towards greater proportions of survivable forces. However, unprime starts with a large fraction of survivable forces, while prime starts with a preponderance of vulnerable forces, so it is assumed that prime's shift is only partial.

Figure 1 shows the forces used in the evaluation, which roughly start from START I missile force levels and compositions. The forces are assumed to be reduced proportionally, so unprime's weapons per vulnerable missile, m , can be used to index the reduction of all parameters. Unprime's non-survivable missiles M starts at 500 and falls to 20, i.e., it falls by 60 missiles each time m falls by 0.4. Unprime's survivable missiles N starts at 400 and falls to 40, i.e., it falls 45 missiles each time m falls by 0.4. The number of weapons on each remains at $n = 10$, as it is only the total number nN that impacts the stability analysis. By the time m falls to 1, the number of unprime weapons is $W = 1 \times 20 + 10 \times 40 = 20 + 400 = 420$.

Prime's non-survivable missiles M' starts at 500 and falls to 100, i.e., by 50 each time m falls by 0.4. The number of weapons per prime missiles falls 2.5 times faster than m . Prime's survivable missiles N' starts at 100 and falls to 20, i.e., it falls 10 missiles each time m falls by 0.4. The number of weapons on each missile remains at $n' = 10$. When m falls to 1, the number of prime weapons is $W' = 2 \times 100 + 10 \times 20 = 200 + 200 = 400$. This gives a rough parity in total weapons, although prime's force is 50% vulnerable, while unprime's force is only 5% vulnerable. The effects of this asymmetry are discussed below.

The effect of uncertainty or hidden weapons is treated by adding $\Delta M' = 50$ vulnerable or $\Delta N' = 10$ survivable missiles to these totals at each stage. This addition is a small perturbation for m close to 4, but a large increment for m close to 1.

Attack allocation. The two sides are assumed to have equal attack preferences $L = L' = 0.5$, kill probabilities of 0.6, and equal value target sets. Figure 2 shows the changes in the two sides' allocations of their first strikes as functions of m when M' is changed by $\Delta M' = 10$. The changes are small for m large. For $m = 4$, $df = 0.02$, which is a change of $0.02 / 0.26 = 7.7\%$ from the allocation of Fig. 2 of "First Strike Stability at Low Weapon Levels." Prime's $df \approx -0.02$ is a change of $-0.02 / 0.18 = -10\%$ from the allocation of "First Strike Stability." Those allocations are relatively stable until m reaches ≈ 2 . Then prime's df drops rapidly with f' because $f' \sim M \sim 0$, insensitive to $\Delta M'$. Conversely, unprime's allocation increases because $\Delta f \sim \Delta M'/W$. By $m = 1$, $df \approx 0.18$, which would increase the f of "First Strike Stability" by $0.18 / 0.34 \approx 50\%$. The revelation of hidden weapons would thus cause little shift in the possessor's (prime's) allocation but would almost double unprime's allocation to prime's $100 + 50$ (hidden) = 150 missiles to attempt to offset the 50 hidden missiles and maintain damage limitation.

Strikes. Figure 3 shows the resulting changes in each sides' first and second strikes. The top curve is the change in prime's first strike, which is augmented at $m = 4$ ($m' = 10$) by $10 \times 50 = 500$ weapons. The bottom line is the change in unprime's first strike due to the reallocation of $df \times W = 0.027 \times 6000 \approx 160$ weapons from the first strike on value to that on prime's missiles. Unprime's second strike does not change because the optimal allocation of prime's additional weapons is to value, so that unprime's second strike is unchanged. Prime's second strike increases by about 30 weapons for all m because while a larger fraction of the 50 missiles survive at small m , each carries a smaller number of weapons.

Costs. Figure 4 shows the changes in each sides' first and second strikes as functions of m . All are small in magnitude at large m , increase as m decreases, and saturate at $m = 1$. The top curve is unprime's second strike cost C_2 , which increases as m decreases because the dS' from Fig. 3. becomes 20% of S by $m = 1.5$. Unprime's first strike cost C_1 increases about half as fast because his first strike falls due to reallocation and prime's increases due to the hidden weapons. Prime's cost are much the mirror image. His first strike costs fall because of his increased inventory and his second strike costs fall because of his increased number of surviving hidden weapons. Note that C_1 and C_2 approach, cross, diverge, and approach again at $m = 1$. C_1' and C_2' are roughly equidistant at large m and diverge for small m .

Stability indices. Figure 5 shows the stability indices as functions of m . The bottom curve $dI = d(C_1/C_2)$ for unprime first falls as m decreases, passes through the axis at $m \approx 2.6$, where C_1 and C_2 cross in Fig. 4, has a minimum of about -0.02 at $m \approx 1.2$, and increases slightly by $m = 1$. Overall, the hidden weapons have a slight negative effect on stability as seen by

unprime. However, the effect is not large; this amounts to a $-0.02 / 0.82 \approx 2.5\%$ decrease in stability at the minimum. The top curve $dI' = d(C_1'/C_2')$ for prime is flat as m decreases to $m \approx 2$, then increases sharply to about 0.07 at $m = 1$. The hidden weapons have a stronger positive effect on stability as seen by prime. However, this only amounts to about a 7% increase in stability at $m = 1$. The composite curve for $d(I \times I')$ is roughly intermediate. It is increased slightly at large m where both dI and dI' are positive, falls at intermediate m due to the decrease in dI' , and increases sharply as m approaches $m = 1$ due to the increase in dI' . The increase at $m = 1$ is about 5%.

Survivable missiles. The same formalism can be used to study the effect of additional or hidden survivable weapons by varying N' rather than M' . The analysis below uses $\Delta N' = 10$, which gives an additional $10 \times 10 = 100$ weapons—comparable to the $2 \times 50 = 100$ weapons added at low m in the analysis of vulnerable weapons above. However, this amounts to adding a fixed number of weapons rather than just a fixed number of missiles, so the results are only approximately comparable.

Figure 6 shows the changes in optimal allocations. Unprime's does not change because the added weapons are not targetable. Unprime uses the additional weapons to shift his allocation from missiles to value. By $m = 1$ -1.5 the shift is comparable to that for vulnerable weapons in Fig. 2. Figure 7 shows that because of this unprime's first and second strikes and do not change and prime's first and second strikes simply increase by the added survivable weapons.

Figure 8 shows the changes in first and second strike costs. In contrast to the vulnerable missiles of Fig. 4, additional survivable weapons cause unprime's first strike costs to increase faster than his second strike costs, which reduces his perception of advantage to preemption and increases stability. Prime's second strike costs decrease faster than his second strike costs, which also reduces his perception of advantage to preemption and increases stability.

Figure 9 shows the stability indices as functions of m . The bottom curve dI' is relatively constant. The middle curve for dI increases to about 0.04 and then falls as C_1 and C_2 approach each other in the upper half of Fig. 8. The composite curve for $d(I \times I')$ is at the top. It rises and falls with I . The maximum $d(I \times I') \approx 0.045$ is not great, but it does represent a $0.045 / 0.6 \approx 7.5\%$ increase in the composite index in the range of m where it would otherwise decrease to a bothersome minimum.

Summary and conclusions. The sensitivity of first strike stability to variations in forces below START II levels can be studied parametrically by studying the changes in attack allocations, first and second strikes, strike costs, and stability indices caused by real or possible variations in forces. Additional vulnerable weapons in the inventory of the side with the greater fraction of vulnerable forces produces a shift to value in his second strike and a larger shift to missiles in the first strike of his opponent. Their first strikes change accordingly, increasing second strike costs more than first, which is generally destabilizing. The side with the greater

fraction of vulnerable forces generally sees stability as increasing; his opponent sees it as decreasing; and their composite is decreasing until both approach single weapon missiles. Overall, when one side has largely survivable forces and the other has largely vulnerable forces, the possession of additional weapons by the latter would increase stability indices because it would partially compensate for his inferior initial position.

Additional survivable weapons in the inventory of the side with the greater fraction of vulnerable forces again produces a shift to value in his second strike but no shift in the first strike of his opponent. The side with more vulnerable forces and additional survivable weapons simply uses them on value in his first or second strike. In contrast to vulnerable missiles, the additional survivable weapons cause the opponents first strike costs to increase faster than his second strike costs, and his second strike costs to decrease faster than his second strike costs, both of which reduce the perception of advantage to preemption, increasing stability.

For the situation in which one side has more vulnerable forces, his possession of additional weapons appears to be stabilizing. However, for additional vulnerable weapons, stabilization is largely a compensation for his inferiority in the base configuration, is sensitive to model parameters, and obtains only when both sides approach single weapon missiles. For survivable weapons, stabilization is again a compensation for inferiority in the base configuration, but is less sensitive to model parameters, and provides useful increments to stability indices at intermediate steps in force reduction, where they would otherwise decline to bothersome levels.

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2. G. Canavan, "First Strike Stability at Low Weapon Levels," Los Alamos National Laboratory report LA-UR-97-, July 1997.
3. G. Canavan, "Stability of Unsymmetric Forces," Los Alamos National Laboratory report LA-UR-97-1133, March 1997.
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forces vs m

Fig. 1. Prime and unprime forces.

df vs m

Fig. 2. df & df' versus m.

df & dS vs m

Fig. 3. change in strikes vs m .

dc vs m

Fig. 4. Change in costs versus m .

indices vs m; hidden

Fig. 5. Stability indices versus m.

Fig. 6. df & df' versus m; delta N' = 10.

dF & dS vs m

Fig. 7. change in strikes vs m; $dN' = 10$.

dC vs m

Fig. 8. Change in costs versus m; $dN' = 10$.

m

indices vs m; hidden

Fig. 9. Stability indices versus m; $dN' = 10$.