The Right Tool for the Job

Effectively Combatting Nuclear Proliferation

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Abstract

The international community has worked for decades to combat the spread of nuclear weapons, but while some efforts succeeded in halting or even rolling back that spread, many others have backfired with dangerous consequences. Weapons proliferators like Iran and North Korea have proven highly resistant to international engagement efforts, thwarting many international treaties and assuming considerable financial burden in their pursuit. Concerned states hoping to combat ongoing proliferation thus face a difficult policy choice, but research has yet to systematically evaluate the effectiveness of available engagement options. Counterproliferation policies can range from inducements like defense or nuclear cooperation to coercive policies like sanctions or threats of force, but no policy is guaranteed to succeed and some might even inadvertently incite greater proliferation instead. This paper therefore evaluates common counterproliferation strategies from 1945-2012, testing both the possibility of inducing nuclear roll back and the risk of perversely accelerating proliferation instead. It finds that policies that offer enduring commitments to cooperation most effectively encourage nuclear roll-back in proliferating states, while coercive strategies have the greatest risks of counterproductive consequences. It concludes by offering policy implications drawn from this analysis, and suggesting avenues for further examination of policy effectiveness.

Introduction

Nuclear proliferation – or the spread of new nuclear weapons – is an increasingly prominent concern in international statecraft. While most states have ratified the Nuclear Nonproliferation Treaty foreswearing these weapons of mass destruction, some resistant proliferators have persisted despite the international community's best efforts. North Korea, the world's newest and poorest nuclear-armed state, continues to thwart decades of international sanctions and negotiation efforts as it tests a burgeoning arsenal and increasingly powerful delivery systems. But these resistant proliferators are not entirely impervious to international engagement efforts, and in October 2015 the Islamic Republic of Iran finally concluded a multilateral nonproliferation agreement with six of the worlds powers after years of negotiations and decades of international pressure.

These recent cases are just the newest in a long history of international efforts to reverse ongoing nuclear proliferation, but they are unlikely to be the last. Understanding when and why some counterproliferation efforts succeed in rolling back weapons proliferation while others fail has become an increasingly prominent focus in both policy and research.

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Nuclear reversal tactics can range from negative coercion like economic sanctions or military force, to positive inducements like cooperation agreements and foreign aid, all aimed at encouraging the proliferating state to roll back its nuclear weapons program. However, these policies are often complex, costly, and time-consuming, with at best imperfect records of success. Research on coercive sticks like military intervention[1], threats of force[2], and economic sanctions[3] in general show that these policies are expensive and fail more often than not, though they may offer some important deterrence benefits, preventing future proliferation in outside observers mulling new programs of their own.[4] Unfortunately, research on policy carrots like foreign aid and cooperation agreements suggest these are not perfect either, arguing they are too weak to extract meaningful concessions or even worse that they risk spreading sensitive knowledge into the wrong hands.[5]

As a result, concerned states hoping to combat ongoing proliferation are left asking: Of all these imperfect options, which policies work best, which fail, and which should be avoided entirely? We seek to address these issues by asking: which foreign policies most effectively encourage nuclear reversal[6] and which risk inciting greater proliferation instead? We argue that cooperative overtures that offer enduring peacetime commitments are most effective, increasing the likelihood of roll back with minimal risk of perverse consequences. Coercive policies on the other hand are less effective strategies, sometimes leading to roll back, but often inadvertently increasing the risk of greater proliferation instead.

To test these hypotheses, we generate a cross-national dataset from 1945-2012 covering patterns of proliferation behavior in weapons-seeking states and the common foreign policies they face. We evaluate the risks and rewards of each policy, finding that some of the most prominent coercive policies actually present the greatest risk of counterproductive consequences, while offers of enduring cooperation present the greatest prospects for success. However, policy carrots are not universally effective nor sticks universally risky, and past research that has evaluated dovish or hawkish stances in aggregate have missed the unique promise of some policies as well as the individual dangers of others. These results are robust across time and space, even when accounting for other variables thought to influence state proliferation and roll-back.

By addressing ongoing dilemmas in counterproliferation, this article contributed to a broad literature on the effects of foreign policies. In particular, it offers new insights on how we define and test the effectiveness of counterproliferation policies. While past work on foreign policies effectiveness has focused on whether or not the policies succeed, this binary success-failure definition of effectiveness overlooks the possibility for perverse and potentially dangerous reactions. We address this gap by considering not only the possibility for success but also to inadvertent risks fo

[1]Braut-Hegghammer, M. (2011) "Revisiting Osirak: preventive attacks and nuclear proliferation risks" *International Security* 36(1), 101-132

[2]Sechser, T (2011) "Militarized Compellent Threats, 1918-2001" *Conflict Management and Peace Science* 28(4)

[3]For discussion of sanction effectiveness, see Pape, R. (1997) "Why Economic Sanctions Do Not Work" *International Security,* 22(2), 90-136; T. Clifton Morgan, Navin A. Bapat, and Valentin Krustev. (2009) "The Threat and Imposition of Sanctions 1971-2000" *Conflict Management and Peace Science* 26(1)

[4]Miller, N. L. (2014). "The secret success of nonproliferation sanctions" *International Organization*, 68(4), 913-944

[5]Fuhrmann, M. (2009). "Spreading temptation: proliferation and peaceful nuclear cooperation agreements." *International Security,* 34(1), 7-41.

[6]We use the terms reversal and roll-back to mean the reduction in a weapons-seeking state's nuclear weapons program, even when this 'roll-back' does not take the program all the way to zero. Reversal or the roll-back of ongoing nuclear proliferation includes even small steps away from a nuclear weapon, or more comprehensive measures to eliminate the entire weapons program.

doing more harm than good. In addition, research on foreign policies and counterproliferation policies usually examine the final outcome of a single policy in isolation. But foreign engagement is a long process, during which time the target state can face many different policies simultaneously. We therefore evaluate proliferators' behavior in response to the many different policies each faces – disentangling the effects of sanctions, for example, from military threats, diplomatic overtures, and security agreements.

The article proceeds by first offering an overview of the existing literature on the determinants of nuclear proliferation and the policies used to combat it. The subsequent section lays out our hypotheses, describing how different foreign policies can influence proliferators' decisions to accelerate or reverse their programs. We then turn to the empirical data needed to evaluate our hypotheses, and the statistical tests used to assess the risks and rewards of counterproliferation foreign policies. We describe the results of these tests and then applying the findings to recent counterproliferation efforts. We conclude by offering some policy lessons drawn from this study and suggesting avenues future work on counterproliferation and the effectiveness of foreign policies more broadly.

Effective Strategies for Nuclear Reversal

Research has made significant progress in explaining why states choose to weaponize, and why they may choose nuclear abstinence, finding that in the past, a prospective proliferator's technical capabilities, as well as its security and domestic political environment are all strong determinants of its decision to pursue a weapon. Early work focused on how states' technological capabilities facilitated or hindered nuclear ambitions, suggesting that the supply of necessary material, machinery, and know-how determined whether a state would seek and develop nuclear weapons.[7] As nuclear knowledge and materials have spread, however, research has increasingly turned to *why* proliferators' pursue nuclear weapons – the demand-side determinants of proliferation – rather than whether these states are capable of doing so.[8] Recognizing the potential spread of nuclear capabilities, the international community has worked to counteract the appeal of such weapons by imposing political and economic costs for proliferating and offering energy deals for those that abstain.

Despite longstanding non-proliferation norms and safeguards, some states persist in their pursuit, assuming considerable financial burden and contravening important international agreements in the process. This decision to proliferate is not taken lightly, and modern proliferators like Iran and North Korea have proven highly resistant to existing non-proliferation safeguards. [9] In the

[7]Epstein, W. (1976) *The Last Chance: Proliferation and Arms Control.* New York: Free Press; Sagan, S.D. (1996/7) "Why do States Build Nuclear Weapons? Three Models in Search of a Bomb," *International Security* (21) (3), 54–86; Sagan, S.D. (2000) "Rethinking the Causes of Nuclear Proliferation: Three Models in Search of a Bomb" In V.A. Utgoff (ed.) *The Coming Crisis: Nuclear Proliferation, US Interests, and World Order. Cambridge*, MA: MIT Press, pp. 17–50; Solingen, E. (1994) "The Political Economy of Restraint," *International Security* 19(2), 126–69

[8]For example, Sagan (2011) argues for "addressing the sources of the political *demand* for nuclear weapons, rather than focusing primarily on efforts to safeguard existing stockpiles of nuclear materials and to restrict the *supply* of specific weapons technology from the 'haves' to the 'have-nots'." (Emphasis in original. Sagan, S. (2011) "The Causes of Nuclear Weapons Proliferation," *Annual Review of Political Science* 14(1) 225-244)

[9]Meyer, S.M. (1984) *The Dynamics of Nuclear Proliferation.* Cambridge, MA: MIT Press; Levite, A.E. (2002/03) "Never Say Never Again: Revisited," *International Security* 27(3), 59–88; Rublee, M.R. (2009) *Nonproliferation Norms: Why States Choose Nuclear Restraint.* Athens, GA: University of Georgia Press

face of this resistance to preventative or *non*-proliferation efforts, research has increasingly turned to *counter*-proliferation policies that can combat ongoing weapons pursuits. Literature on reversing this process is early, but initial work is still divided. Policy has largely emphasized restricting the transfer or sensitive material or technology to would-be proliferators, implementing economic sanctions and trade restrictions as a way to handicap proliferators and force them to give up their nuclear ambitions. However, existing research on these supply-side restrictions suggest that they are often costly to the senders who impose them and yet still fail to roll back ongoing proliferation.[10] As Kemp (2014) explains, nuclear materials and technology are increasingly accessible even to the weakest states – technology that a half-century ago was "exotic is now pedestrian" – and as a result determined proliferators can often find ways to buy or develop restricted technologies despite international restrictions.[11] When trade restrictions fail, some research has argued in favor of preventive military strikes to forcibly end proliferators' nascent programs before they can breakout into a full-blown nuclear arsenal.[12] But others argue that military force can be costly for senders and risks sparing secret elements of the weapons program intact to quickly fill in the gaps.[13]

Given the ineffectiveness of common coercive counterproliferation strategies, another branch has argued that policy carrots or inducements might serve as a viable alternative. This work argues that offers of foreign aid or security assurances can entice proliferators to the negotiating table, rewarding nuclear reversal with inducements like "policy concessions and economic favors". [14] But like their coercive counterparts, positive inducement are highly contested, and some literature argues they may risk inadvertently arming proliferators with greater nuclear capabilities or resources.[15] Taken together, the growing literature on nuclear counterproliferation efforts provides a pessimistic but inconclusive assessment of available strategies. But concerned states facing ongoing proliferation will still choose from these imperfect options. As such, policymakers are still left asking: Of all the imperfect policies available, which are most effective and which should be avoided?

What we do know is that no foreign policy or strategy is guaranteed to succeed[16] and that each can be costly for their senders to impose. When the issue at stake is nuclear proliferation, choosing the most effective foreign policy has important implications for international security and the welfare of the states that impose them. Senders recognize the importance of their counterproliferation

[10]Solingen, E. (2007) *Logics: Contrasting Paths in East Asia and the Middle East*. Princeton: Princeton University Press

[11]Kemp, R.S. "The Nonproliferation Emperor has No Clothes: The Gas Centrifuge, Supply-Side Controls, and the Future of Nuclear Proliferation" *International Security* 38(4), 39-78

[12]Feldman, S. (1982) "The Bombing of Osiraq—Revisited," *International Security* 7(2), 114–142; Kroenig, M. (2014) *A Time to Attack: The Looming Iranian Nuclear Threat*, St. Martins Press.

[13]Braut-Hegghammer, M. (2011) "Revisiting Osirak: preventive attacks and nuclear proliferation risks" *International Security* 36(1), 101-132; Raas, W. and A. Long, (2007) "Osirak Redux? Assessing Israeli Capabilities to Destroy Iranian Nuclear Facilities," *International Security* 31(4), 7–33

[14]Nincic, M. (2010) "Getting What You Want: Positive Inducements in International Relations", *International Security* 35(1), 138-183

[15]Fuhrmann, M. (2009). "Spreading temptation: proliferation and peaceful nuclear cooperation agreements." *International security,* 34(1), 7-41; Kroenig, M. (2010) *Exporting the Bomb: Technology Transfer and the Spread of Nuclear Weapons* Cornell University Press: Ithica, NY

[16]Palmer, G. And A. Bhandari (2000) "The Investigation of Substitutability in Foreign Policy", *Journal of Conflict Resolution*, 44:1-10; Clark, D.H. and W. Reed (2005) "The strategic sources of foreign policy substitutability", *American Journal of Political Science* 49(3) 609-624

policy choices and carefully select the policies they believe will maximize their chances of success but at minimum cost to themselves. However, this choice may be more complicated than existing literature tends to assume.

Choosing the most effective foreign policy is not just about maximizing chances of success. Though existing work tends to use an oversimplified measure of policy success – considering only whether a policy succeeds to achieve its stated goals or not – the consequences of failure can be far worse than simply not succeeding. Foreign policies that fail to reverse ongoing nuclear pursuits weaken the international nonproliferation system, and even worse, some policies actually risk backfiring by inadvertently accelerating the very proliferation they sought to combat. Despite these risks, senders facing ongoing nuclear proliferation still choose from the limited and imperfect options available, so understanding the risks as well as potential rewards of any policy has important implications for international security and policymaking.

Foreign Policies: Punishments, Rewards, and Signals

To understand the effects of foreign policies on proliferator's nuclear responses, we turn now to describe how the components of a foreign engagement interact with the proliferator's demand for a nuclear weapon. Sending states can select from a variety of engagement tools in pursuit of their goals. Because many different policies can be employed to the same end, the choice of one policy type over another[17] gives the targets of these policies insight into the character and intentions of its adversary. Not only does a sender's choice of engagement impose costs or offer rewards, but it also sends the proliferator an implicit message about the character or intent of the sender themselves, and therefore about the proliferator's security environment more broadly.

And these signals about the proliferator's security environment are intrinsically tied to the proliferator's decision to acquire the bomb. Recent research suggests that proliferators' nuclear pursuits are especially influenced by their beliefs about their international security environment,[18] and that those beliefs are informed by their interactions with other states.[19] A proliferator's motivation for pursuing a nuclear weapon is therefore determined in part by the foreign policies they face – but not necessarily in the way that the sending state intends – leading to important differences in the proliferator's response to engagement.

Scholars and policymakers recognize that different foreign policies can offer different explicit rewards or punishments as a way to overtly change the target's cost-benefit calculus for complying. For example, cooperative offers like a nuclear energy agreement provide the proliferator with the explicit reward of energy aid in exchange for giving up the weapons dimension of the program. However, this focus on *explicit* rewards and punishments overlooks the less overt but equally im-

[17] See the foreign policy substitutability literature for more discussion. Though not usually apploed to the nuclear reversal, it provides insight into when and why policymakers choose one foreign policy over another. For example: Palmer, G. And A. Bhandari (2000) "The Investigation of Substitutability in Foreign Policy," *Journal of Conflict Resolution,* 44:1-10;

[18] Singh, S., and Way, C. (2004) "The Correlates of Proliferation: A Quantitative Test," *Journal of Conflict Resolution,* 48(6), 859–85; Jo, D.-J., and Gartzke, E. (2007) "Determinants of Nuclear Weapons Proliferation," *Journal of Conflict Resolution,* 51(1), 167–94; Kaplow, J. (2017) "The Changing Face of Nuclear Proliferation" Working paper presented at APSA: San Francisco, CA

[19] Kydd, A. (2005) *Trust and Mistrust in International Relations,* Princeton, NJ: Princeton University Press; Nincic, M. (2011) *The Logic of Positive Engagement,* Ithica, NY: Cornell University Press

portant *implicit* signals associated with any foreign policy choice. That same sender's choice to offer nuclear cooperation not only provides tangible energy benefits, it can also implicitly signal the sender's friendly intent. These implicit signals can serve to reassure the proliferator that its security environment is in fact more friendly than it had assumed and thereby reduce its security motivates for pursuing a nuclear deterrent. Cooperative overtures therefore reassure the proliferator about its security environment, provide explicit rewards and implicit peaceful signals, both of which can help convince the proliferator that nuclear roll back and accepting international safeguards are viable paths forward.

Conversely, coercive policies impose explicit punishments for proliferating intended to make the pursuit of nuclear weapons even more costly. However, like cooperation, a sender's choice to employ coercive instruments also conveys an implicit signal to the proliferator about its security environment. While cooperation can signals reassurance, coercion can signal that the sender is actually a potential threatening willing to use pain to extract concessions. As a result, though senders may choose coercion for the explicit costs they inflict for proliferating, the result may be to inadvertently increase the proliferator's security motivations for acquiring a powerful deterrent against future coercion. The implicit signals conveyed by selecting a coercive policy can thereby counteract the explicit costs they impose, inadvertently discouraging the vulnerability of nuclear roll back and even encouraging the very proliferation the sender sought to combat.

It should be clear by now that policy choices are complicated, as each can provide potential benefits and risks. Indeed, the same policies that can sometimes force proliferators to roll back their programs could also simultaneously increase the risk of further proliferation instead. Military intervention, for example, offers the ultimate trump card by forcibly eliminating the target's means of proliferation without the need for a negotiated middle ground. Senders desperate to combat ongoing proliferation might find this tempting – override a proliferator's resistance even if they refuse to comply with international nonproliferation agreements. Proponents point to examples like Israel's attack on Iraq's Osirak reactor in 1979, or on Syria's clandestine reactor in 2007 to argue that decisive military action can override target resistance and force nuclear roll-back.[20] But coercive strategies like military intervention are risky – not to mention potentially costly endeavors – and proliferators like Iraq and Syria who did indeed face a foreign attack each responded by doubling down on their weapons program rather than cowing to foreign pressure.[21] When a military intervention fails to entirely eliminate all capabilities and even technical knowledge, the target may pick up the shreds with even more determination, rearming with increased vigor in order to deter future attack.

As a result, strategies like military intervention that sometimes succeed, can other times backfire with dangerous consequences. This logic is not new[22] but its implications for nuclear negotiations are particularly serious and are not limited to military interventions. Indeed, nonkinetic forms of coercion can incentivize the same perverse calculation in their targets – sometimes succeeding in rolling back the program under duress, but other times incentivizing the proliferator to double down in pursuit of a powerful deterrent against future aggression despite the costs of such

[20] Sadot, U. (2016) "Osirak and the Counter-Proliferation Puzzle," *Security Studies,* 25(4), 646-676

[21] Braut-Hegghammer, M. (2011) "Revisiting Osirak: preventive attacks and nuclear proliferation risks" *International Security* 36(1), 101-132

[22] Kydd, A. (2005) *Trust and Mistrust in International Relations.* Princeton, NJ: Princeton University Press; Hultman, L. and D. Peksen (2015) "Successful or Counterproductive Coercion? The Effect of International Sanctions on Conflict Intensity" *Journal of Conflict Resolution* 61(6) 1315-1339

resistance.

For a foreign policy to be an effective nuclear reversal engagement option, it must therefore address two related goals. First, effective policies seek to increase the likelihood of achieving nuclear roll-back in the proliferating state. This is the explicit goal of senders who choose to combat ongoing proliferation. But there is related though implicit goal of at minimum doing no harm. So the second and often overlooked element of effective policies is they do not risk inadvertently inciting greater proliferation instead. Considering both the promise and possible risks of foreign policies thus moves beyond past debates for a more policy-relevant evaluation of foreign policy effectiveness.

THEORY AND TESTABLE HYPOTHESES

Building on the logic outlined above, we argue that when sending states choose to employ coercive tactics, they risk increasing the proliferator's perception of international threat and thereby its desire for a nuclear deterrent. When these sending states choose positive inducements instead – especially those entailing enduring commitments to future cooperation – they signal a non-threatening intent, thereby reducing the proliferator's fears and its motivation for investing in further proliferation. This means that cooperative inducements should be more effective than coercive strategies, leading to nuclear reversal more consistently and with lower risks of inciting perverse proliferation instead, giving the following testable hypotheses.

> COOPERATIVE REVERSAL HYPOTHESIS: Cooperative policies are more likely than coercive policies to lead to nuclear reversal in proliferating states.
>
> PERVERSE PROLIFERATION HYPOTHESIS: Coercive policies are more likely than cooperative policies to lead to increased proliferation.

To test these hypotheses, we must evaluate each strategy's likelihood for both successful roll back as well as its risks of perversely increasing proliferation instead. For our hypotheses to be correct, we should find that cooperative strategies like nuclear cooperation agreements or defense pacts are more likely to achieve nuclear roll-back in proliferating states and are less likely to result in increased proliferation than are the more coercive strategies like military force, threats, or sanctions. This does not imply either that coercive strategies never work or that all positive inducements are bound to succeed. Indeed, we expect that even the less effective strategies can sometimes succeed and the more effective though still imperfect alternatives can sometimes backfire, making it all the more important for any complete analysis to all these possibilities. We therefore do not dispute past research that finds coercion like sanctions or military threats may sometimes achieve negotiated settlements, or that inducement like defense pacts sometimes fail at counterproliferation. Rather, we argue for a more holistic approach to conceptualizing and testing policy effectiveness.

In line with the difficult choices that senders face, we argue for a more policy-relevant definition fo effectiveness that accounts for both potential risks as well as rewards, and for a testing strategy that compares this effectiveness for all available strategies. In the following section we outline the research methods and data we use to evaluate ten of the most common foreign policies. We begin by discussing what nuclear roll back and proliferation look like in practice and comparing our measure to traditional alternatives. We then outline the data and methods we use to test the cross-national trends in policy effects on nuclear proliferation and roll back.

Research Methods and Data: Evaluating Policy Effectiveness

Traction on the problem of counterproliferation policy effectiveness has been illusive: nuclear proliferation is thankfully relatively rare, but unfortunately it is also often done in secret.[23] This makes it difficult for researchers to measure when and why states proliferate or roll back their nuclear weapons programs. In addition, nuclear weapons take many years to develop, during which time the proliferator can face many different forms of foreign engagement, hampering past attempts to identify which policies succeeded and which failed. Over the course of a weapons program, proliferators can sometimes face coercion in the form of sanctions or military threats, and at others receive more cooperative offers like defense agreements or diplomatic overtures.

To understand which of these policies were most effective, we therefore cannot simply consider the final outcome that could come many years later and after many interceding or competing policies. Some policies can offer initial success, only to be replaced with other strategies when senders get impatient. This variation in engagement coupled with poor measures of proliferation has muddled the ability of past work to match the ultimate goal of total denuclearization with the responsible policies.

This means that while existing research has tended to focus on whether a proliferator eventually agreed to dismantle its weapons program (like South Africa did in 1989 or Brazil did 1990), considering only the final outcome overlooks the role of interim strategies that slowed a proliferator's march to the bomb and glosses over the risks of other strategies that inadvertently derailed this progress. A foreign policy can show promise in effectively reversing an existing nuclear weapons program without immediately achieving total denuclearization. Likewise, a different policy may present risks beyond simple failure even when the proliferator does not promptly test a nuclear devise. Examining the effects of policies on proliferator's nuclear behavior thus requires accounting for multiple competing policies and identifying even small successes short of complete denuclearization, as well as small risks even short of nuclear breakout.

We therefore employ a population averaged binomial logistic regression[24] to consider multiple policies all occurring simultaneously, and disaggregates the effects of different policies on the proliferators they target. We estimate the relative odds that a weapon-seeker will either roll back its existing program and the odds that it instead doubles down on its program in response to the policies it faced. To do so, We offer a new measure of proliferation to more closely match policies with proliferator responses, and use this to compare the effectiveness of multiple policies simultaneously. We develop a dataset which catalogs when proliferators faced different foreign policies, and when these proliferators increased, maintained, or rolled back their nuclear capabilities.[25]

[23] Kitano, M. (2016) "Opaque Nuclear Proliferation Revisited: Determinants, Dynamism, and Policy Implications" *The Nonproliferation Review* 23(3/4) 459-479

[24] Population averaged models estimate the effect of the regressors (the foreign policies here) on the average individual (here weapons-seeking state) by specifying a marginal distribution for the population. This model allows us to evaluate the behavior of proliferators in general without over-specifying population distribution (as in cluster-specific models like fixed or random effects models). FE and RA models are have similar point estimates, and are included in the appendix. For further discussion of the 'Dirty Pool' debate, see Neuhaus, J. M., J. D. Kalbfleisch, and W. W. Hauck. (1991) "A comparison of cluster-specific and population-averaged approaches for analyzing correlated binary data." *International Statistical Review* 59: 25-35.

[25] Aggregated data from 14 existing datasets, listed here by the variables each provided.

DEPENDENT VARIABLE: NUCLEAR ROLL-BACK VS. TOTAL DISARMAMENT

Proliferators take many years to either achieve nuclear breakout or eventually dismantle a weapons program, during which time their dedication to the program can vary in response the the international engagement they face. Some early research on nuclear reversal has evaluated whether a proliferator eventually achieved a nuclear weapon or dismantled its program, but using these course measures overlooks the temporary roll-back or acceleration that can occur in the interim.[26] For example, Iran temporarily rolled back its nuclear program in 2003 as part of nuclear negotiations with the EU3, but revitalize the program in 2005 when negotiations broke down and the UN imposed sanctions against Iran's nuclear program.[27] Iran faced both cooperative and coercive policies over the course of its nuclear program, but which of these succeeded in roll-back – even temporary and incomplete reversal – which had no effect, and which even led to greater proliferation instead?

To account for this variation throughout a weapons-seekers pursuit, we measure changes in the size of each proliferator's nuclear program by recording increases and decreases in the states nuclear enrichment and reprocessing (ENR) facilities. Enrichment and reprocessing facilities are responsible for the production of the nuclear fissile material used in nuclear weapons as well as nuclear energy reactors. They are expensive to construct and dismantle, making them a harder test of a weapons-seeker's dedication to roll-back or proliferation.

While they can be used for both weapons or civilian purposes, weapons-seeking states can and do hide their clandestine weapons programs under the guise of civilian nuclear facilities – siphoning materials and knowledge from even civilian nuclear facilities for use in their parallel military programs. We therefore assume that any increase in a known weapons-seeker's program may constitute nuclear weapons proliferation, and any reduction likely reduces the weapons-seeker's ability to develop new nuclear weapons. To measure these changes in proliferators' nuclear programs, we use the Nuclear Latency Dataset v1.2.[28] Using this information, we can therefore determine the response of weapons-seekers to the foreign policies they faced from year to year.

How does this data then compare to past measures of proliferation? Existing work on proliferation behavior has generally relied on course data that records only when a state either began exploring a nuclear weapons program, began actively pursuing a nuclear weapon, and when they finally acquired nuclear weapons.[29] The advantage of this data is that provides insight into proliferators' rare systemic nuclear decisions, but the disadvantage is it gives little insight into the interim changes and provides no traction on the proliferator's response to foreign policies.

Figure 1 compares our measure of proliferation behavior to the traditional alternative in one well-known example: engagement with the islamic Republic of Iran. While the traditional data tells us when Iran began its nuclear program – the dashed line on the right axis – it provides no additional indight since Iran began actively pursuing a weapon in 1989. We know, however, that

[26] Past work has largely relied on Singh and Way"s (2004) measures of large program changes (Singh, S., and Way, C. (2004) ("The Correlates of Proliferation: A Quantitative Test," Journal of Conflict Resolution 48(6), 859–85). For a good example of past work using this data, see Mattiacci, E. and B. Jones (2016) "(Nuclear) Change of Plans: What Explains Nuclear Reversals?" *International Interactions* 42(3) 530-558.

[27] Bahgat, G. (2006) "Nuclear proliferation: The Islamic Republic of Iran" *Iranian Studies* 39(3) 307-327

[28] Fuhrmann, M. and Tkach, B. (2015) Almost Nuclear: Introducing the Nuclear Latency Dataset. *Conflict Management and Peace Science* 32(4). This data covers 254 nuclear facilities in over 30 countries from 1939-2012, recording the start and end dates for construction and operation of each facility, as well as their respective operational size measured as an ordinal scale of laboratory (1), pilot (2), or commercial/industrial (3) scale.

[29] This data was originally developed by Singh, S. and C. Way, (2004) "Correlates of Nuclear Proliferation: A Quantitative Test" *Journal of Conflict Resolution* 48: 859-885, but updated as of 2012 by Way.

in the decades following the start of its program, Iran at some times doubled down on developing a nuclear weapon, and at others scaled back its program. We show these changes in the nuclear latency measure shown in the solid line (left axis), which records when Iran doubled down on a clandestine weapons program in the early 2000s, rapidly increasing its facilities.[30] This is followed by a sharp decrease in Iran's operational facilities when Tehran agreed to freeze its fledgling program as part of nuclear negotiations with the EU in 2003, and finally a rapid return to nuclear activity in 2005 when negotiations broke down and the UN imposed sanction. Measuring changes in a proliferator's nuclear facilities thus maps closely to what we know about proliferation activity and provides the nuance necessary to evaluate their response to foreign engagement.

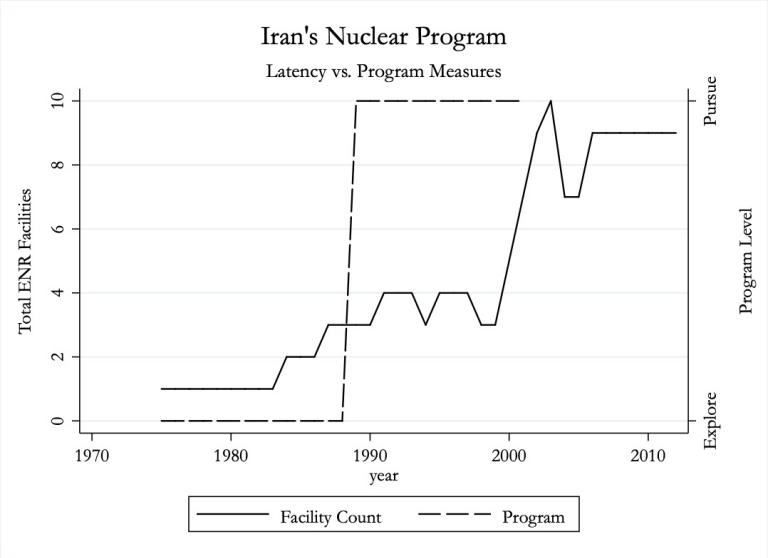

Figure 1: Comparing measures of nuclear proliferation

A proliferator like Iran can roll back its program by temporary or permanently closure existing facilities, as Iran did in 2003, or by downgrading the scale of an existing facilities operation. These proliferators can also increase their program by reopening a closed facility as Iran did in 2005, increasing the size of existing facilities, or even building new ones. All of these changes are costly endeavors, and are thus strong signals of the state's dedication to either proliferate further or roll back their existing program.[31] Because the goal of counterproliferation is to combat nuclear weapons proliferation and not legitimate peaceful energy programs, we test their effects only on proliferating states with active weapons programs,[32] and lag the outcome variable of roll-back or proliferation to account for the potential of reverse causality.[33]

[30] Arnold, A. et al, (2019) *The Iran Nuclear Archive: Impressions and implications* Harvard Kennedy School: Belfer Center for Science and International Affairs

[31] We measure changes in a weapon-seeker's program by recording whether the state rolled back – (1) for a latency reduction from the previous year, or (0) for no change or increase in total latency – or if it instead doubled down instead – again (1) if a weapons-seeker increased its total latency such as through the construction of a new ENR facility, and a (0) for no change or decrease in latency.

[32] From Singh and Way (2004), updated as of 2016 by Way

[33] See a discussion of lagging in Allison, Paul D. (2009) *Fixed Effects Regression Models.* London: Sage; Bellemare,

EXPLANATORY VARIABLES: FOREIGN ENGAGEMENT

We match proliferators' nuclear behavior to the foreign policies they face, comparing the effects of these policies across time and space. While much of the research on policy effectiveness has examined individual policies in isolation, ignoring how different policies can interact with and compare to other overlapping policies,[34] we instead evaluate ten key counterproliferation policies. This approach allows us to evaluate different strategies against common alternatives, and to account for the potential effects of other concurrent policies – effects that can be inappropriately attributed if we examined only one policy at a time. Other work has instead compared general approaches like positive inducements or negative coercion,[35] but some carrots or sticks can be more effective or more risky than others so comparing only general approaches clouds the effect of each policy with the competing effects of others. We therefore shed light on which specific policies present the best prospects for success, and which risks counterproductive consequences instead, comparing the response of proliferating states to the counterproliferation policies they face over the course of their weapons program.

Coercive policies as those that impose some costs for proliferating, including when the proliferator faced the threat and imposition of economic sanctions,[36] was the target of militarized interstate disputes,[37] militarized compellent threats,[38] and diplomatic sanctions.[39] Conversely, we define positive inducements as those policies that offer a benefit in exchange for nuclear reversal. These include nuclear cooperation agreements,[40] new or increased diplomatic exchanges,[41] defense cooperation agreements,[42] and finally foreign aid.[43] Each policy is a unique lever that

Marc F., Thomas B. Pepinsky, and Takaaki Masaki. (2017) "Lagged Explanatory Variables and the Estimation of Causal Effects." *Journal of Politics* 79(3):949–963

[34]See for example Fuhrmann, M (2009) "Spreading Temptation" *International Security* 34(1), 7-41; Sechser, T. S. (2011) "Militarized Compellent Threats, 1918–2001" *Conflict Management and Peace Science*, 28(4), 377–401; Gibbons, R. (2019) "Supply to Deny: The Benefits of Nuclear Assistance for Nuclear Nonproliferation" Journal of Global Security Studies 0(0) 1-17

[35]For example: Reardon, R. (2010) *Nuclear Bargaining: Using carrots and sticks in nuclear counterproliferation.* Boston: Massachusetts Institute of Technology Press; Mehta, R. (2014) *Deproliferation Dynamics: Why states give up nuclear weapons,* San Diego, CA: University of California, San Diego

[36]Measured from 1945-2006 (updated through 2009) using the Threat or Imposition of Economic Sanctions (TIES) v4.13 dataset. (Morgan, T.C., Bapat, N. and Kobayashi Y. (2014) The Threat and Imposition of Sanctions: Updating the TIES dataset. *Conflict Management and Peace Science* 31(5))

[37]Measured using the Correlates fo War (COW) Dyadic Militarized Interstate Dispute (MID) dataset from 1945-2010 when the proliferator was the target of an attack (Palmer, G, V. D'Orazio, M. Kenwick, and M. Lane. (2015) The MID4 Data Set: Procedures, Coding Rules, and Description. *Conflict Management and Peace Science.* 32(2), 222-242.)

[38]Using the Militarized Compellent Threat (MCT) dataset (Sechser, T. S. (2011). Militarized compellent threats, 1918-2001. *Conflict Management and Peace Science,* 28(4), 377-401)

[39]Including a reduction in diplomatic presence, including embassy closure of ambassador recalls from 1960-2012 (Moyer, J., D, Bohl, and S. Turner, (2015) "Diplomatic Representation Data Codebook" Diplometrics, Denver, CO: Frederick S. Pardee Center for International Futures, Josef Korbel School of International Studies, University of Denver, https://pardee.du.edu/diplomatic-representation-data-set)

[40]Using the Nuclear Cooperation Agreements Dataset (NCA) v2.0 from 1945-2003. (Fuhrmann, M. (2009). Spreading temptation: proliferation and peaceful nuclear cooperation agreements. *International security*, 34(1), 7-41)

[41]Such as opening an embassy or interest office, measured using the Diplomatic Representation Dataset from 1960-2012. (Moyer, and S. Turner. 2015)

[42]Using the Defense Cooperation Agreements dataset from 1980-2010. (Kinne, B. J. (2018) Defense Cooperation Agreements and the Emergence of a Global Security Network. *International Organization*, 72(4), 799-837)

[43]Using the Net Aid Transfers Data from 1960-2012 (Roodman, D. (2015) "Net Aid Trasnfers data set (1960-2015),"

senders can turn on and off independent of other policies, meaning that a proliferator like North Korea might face UN sanctions in the same year that they simultaneously receive foreign aid from China and the United States in exchange for nuclear roll-back.

CONTROLS VARIABLES

Finally, we control for alternative explanations like global trends in nuclear proliferation over time. Proliferation and senders' attempts to change it have been ongoing since the first bombs dropped in 1945. We therefore account for global changes in state access to nuclear material and expertise, as well as changes in the norms and regulations governing the pursuit of nuclear weapons[44] using time period controls: 1945-1969 for the nuclear era before the Non-Proliferation Treaty, 1970-89 for Cold War period following the signing of the NPT, and finally 1990-2012 for the nuclear world after the fall of the Iron Curtain.[45] Finally, because those who proliferate or roll-back their programs may be more likely to continue doing so in the future, we include auto-regressive controls to account for patterns of proliferation within each state.[46] The final dataset is structured as country-year units of observation with separate variables recording whether the country faced each policy in a given year, and pairs these independent policies to the likelihood of proliferation changes in these weapons-seekers' nuclear programs the following year. In this way, the nuclear behavior of proliferators is the consequence (and not the cause) of the foreign policies these targets faced.

Results and Discussion

We begin by comparing general trends in proliferators' nuclear response to different counterproliferation strategies using simple frequencies of proliferation, roll-back, or even no change following each policy. These frequencies (shown in Table 1) highlight trends in policy effects, showing first that both nuclear proliferation and roll back are both relatively rare events. This is to be expected as both building and dismantling nuclear capabilities are costly, whereas simply maintaining existing capabilities requires little in the way of economic or political capitol. However, when we compare proliferators that faced each foreign policy ('Yes') to those that did not ('No'), we see that almost every foreign policy actually reduces the frequency of 'no change'. This suggests that foreign policies indeed cause proliferators' to change their nuclear programs, but not always in the way the senders intended.

First, coercive policies like nuclear sanctions, militarized compellent threats (MCT), and use of force (MID) all counterproductively increases proliferation. Indeed, 23% of military threats perversely increased proliferation, up from only 14% of cases free from such threats. Even military engagement (MID) – intended to overwhelm a proliferators resistance through military force – perversely increased proliferation from 10% to over 16% of cases. Nonviolent alternatives did not fare much better, and nuclear sanctions – economic barriers intended to prevent proliferation – similarly increased proliferation while simultaneously *reducing* the intended outcome of roll-back. Of all negative policies, only a reduction in formal diplomatic ties increased nuclear roll-back

Working paper (accessed March 2018) https://davidroodman.com/data/)

[44]Simpson, J. (1994). "Nuclear non-proliferation in the post-cold war era." *International Affairs,* 70(1), 17-39.; Paul, T. V. (2009). *The tradition of non-use of nuclear weapons* Stanford University Press.

[45]See the appendix for robustness checks using alternative temporal controls.

[46]We also include cubic polynomials and splines in the appendix for robustness.

without risking perverse proliferation as well. Cooperative inducements, on the other hand, fared much better. Formal diplomatic ties, civilian nuclear cooperation agreements, and limited defense agreements all helped increase nuclear roll-back without also risking perverse proliferation as well. For example, nuclear cooperation agreements (NCA) increased roll-back from just 5% of cases to over 12%, and defense agreements (limited DCA) increased roll-back from just 6% to over 13%, meaning both forms of cooperation successfully doubled the rate of nuclear roll-back. But not all inducements are equally effective, and simple pay-offs foreign aid actually *reduced* roll-back, again suggesting that the success of inducements comes from enduring cooperation and not quid-pro-quo deals.

Table 1: Proliferator Response to Policies

		Percent Frequency			
		Roll-back	No Change	Proliferation	Total Observations
Nuke Sanc	No	9.13%	76.50%	14.37%	668
	Yes	6.25%	77.40%	16.35%	208
MCT	No	8.08%	77.48%	14.44%	928
	Yes	7.69%	69.23%	23.08%	26
MID	No	6.45%	83.06%	10.48%	248
	Yes	8.64%	75.21%	16.15%	706
Reduce Diplo	No	6.16%	78.20%	15.64%	601
	Yes	11.33%	75.64%	13.03%	353
Increase Diplo	No	7.03%	78.39%	14.58%	782
	Yes	12.79%	72.09%	15.12%	172
NCA	No	5.06%	80.83%	14.10%	553
	Yes	12.22%	72.32%	15.46%	401
Limited DCA	No	6.25%	78.89%	14.86%	720
	Yes	13.68%	72.22%	14.10%	234
Aid	No	9.19%	75.12%	15.69%	631
	Yes	5.88%	81.42%	12.69%	323

Outcomes shown as percent frequency distribution of cases.

The raw data shown in Table 1 shows overall trends, but cannot account for the influence of other factors like evolving nuclear norms. We therefore turn now to the multivariate analysis, which evaluates the effectiveness of each policy while controlling for key alternative explanations. The multivariate results – shown here in Table 2 – uphold the theme found in the raw data, suggesting that the common coercive policies are actually counterproductive for combating proliferation, while enduring cooperation tends to be a more effective policy choice.[47] For example, while military force is often touted as a costly but overwhelming method of last resort to force compliance, its effects on proliferation are highly volatile. A military strike can sometimes unilaterally de-

[47] Alternative specifications and robustness checks uphold the results here and are included in the appendix.

stroy a proliferators existing infrastructure[48] – as Israel demonstrated against Iraq's Osirak reactor in June 1981 – but when military force fails to singlehandedly enforce roll-back it often risk inciting greater proliferation instead as the bereaved weapons-seeker doubles down to deter future aggression.[49] This suggests that supports the Perverse Proliferation Hypothesis that coercion is a risky and often counterproductive strategy, sometimes inducing roll-back but often increasing proliferation instead.

Table 2: Policy Effects on Proliferators

	Proliferation	Roll-back
Nuke Sanc	0.070	0.25
	(0.36)	(0.43)
Other Sanc	0.15	0.072
	(0.26)	(0.26)
MCT	0.81	0.27
	(0.49)	(1.02)
MID	0.64**	1.03***
	(0.29)	(0.34)
Reduce Diplo	-0.33*	0.27
	(0.19)	(0.25)
Increase Diplo	0.21	0.14
	(0.20)	(0.23)
NCA	0.20	0.59**
	(0.28)	(0.23)
Aid	0.19	0.038
	(0.17)	(0.31)
Limited DCA	0.32	0.56
	(0.31)	(0.48)
DCA General	0.13	-0.73
	(0.34)	(0.48)
1940-1960s	0.95***	-1.10
	(0.36)	(0.83)
1970-80s	0.85**	-0.20
	(0.34)	(0.33)
pt	-0.12**	
	(0.05)	
rt		-0.18***
		(0.04)
Constant	-3.53***	-3.41***
	(0.39)	(0.44)
Observations	1029	666
qIC	777.68	514.83

Log likelihood compared to baseline of no change.
Panel binomial logit, s.e. in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Cooperative inducements like nuclear cooperation agreements, on the other hand, are more

[48] Indeed, while destroying existing infrastructure reduces nuclear latency, this physical destruction does not necessarily translate into reduced capacity or desire to rapidly rebuild following an attack.

[49] Existing literature has similarly found that states facing military threats are more likely to initiate nuclear weapons programs, and more likely to follow through to a successful nuclear test than states facing no such existential threat. See Gartzke, E. and D.J. Jo, (2009) "Bargaining, Nuclear Proliferation, and Interstate Disputes" *Journal of Conflict Resolution*, 53: 209-233; Singh, S. and C. Way, (2004) "Correlates of Nuclear Proliferation: A Quantitative Test" *Journal of Conflict Resolution* 48: 859-885

effective and less risky counterproliferation strategies. NCAs provide an enduring platform for cooperation – committing both sides to supporting a peaceful nuclear energy program for the recipient – and significantly increase the likelihood that the recipient proliferator will reduce its contested nuclear program.[50] Just as importantly, we find that cooperative agreements like NCAs do not carry the same counterproductive risks as coercive strategies.[51] Finally, cooperative agreements are often accompanied by requirements that the recipient open its program to international inspections, and these inspections help ensure the peaceful technology is not later repurposed for a weapons program.

However, not all negative punishments have perverse consequences, and not all positive inducements encourage roll back. The risks or rewards of specific policies cannot be generalized across all policy carrots or sticks. Rather, punishments like reducing formal diplomatic ties that do not rely on coercion actually help reduce the likelihood of future proliferation. Instead, these diplomatic signals demonstrate the sender's disapproval without increasing the proliferator's security fears or need for a powerful nuclear deterrent. In addition, positive inducements like foreign aid that do not show enduring commitments to cooperation may actually increase the risk of further proliferation by providing the proliferator with a cash infusion but not an enduring cooperative assurance.[52] This suggests that some carrots might successfully lead to roll-back while others actually discourage it – meaning analysis that examines all carrots or all sticks together could inappropriately attribute the success of one to a riskier alternative, and generating misleading implications for policymaking.

The results here give new insight into effectiveness of common policies, but what lessons can we draw for real counterproliferation attempts? First, foreign policies are rarely offered alone, as senders often present an entire package of related policies to their target. In addition, the historical context within which each policy package is offered can critically impact their effects. We therefore apply the results found here to real historical cases of proliferation, to understand how real proliferators would respond to common counterproliferation packages. Using the key cases of Iraq in 1980, and North Korea and Iran in 2005, we apply the results found above to examine the risks and rewards of different engagement packages in context like the past engagement attempts and the proliferator's past nuclear behavior.

IRAQ IN 1980

Iraq in 1980 provides one good test case. While the international community was collectively concerned about Iraq's potential nuclear program, Iraq denied having a program and did not yet face any counterproliferation engagement. Additionally, this case provides relevant insight as Iraq's enrichment activity would soon become the focus of much of the international community. In 1980, Iraq had just begun a full scale invasion of Iran – a war that would last eight years and lead to massive fatalities on both sides.[53] In addition, Iraq had recently begun receiving highly enriched uranium from France to fuel its new reactors. Under these conditions, what can we estimate about

[50] Recent related research suggests that NCAs are also an effective *non*proliferation strategy, dissuading nonnuclear recipients from initiating new programs: Gibbons, R. (2019) "Supply to Deny: The Benefits of Nuclear Assistance for Nuclear Nonproliferation" Journal of Global Security Studies 0(0) 1-17

[51] This adds important nuance to conventional wisdom on nuclear cooperation. While some seminal work argues that NCAs can spread sensitive technology and enable future proliferation if recipients later face an existential military threat, we find NCAs are in fact quite effective counterproliferation tactics, actually *rolling back* existing programs with none of the risks posed by coercive alternatives.

[52] Note that the results of foreign aid show direction but are not significant at the 95% threshold.

[53] Hiro, Dilip (1991) *The Longest War: The Iran-Iraq Military Conflict*, New York: Routledge

the effectiveness of either an inducement policy package or a coercive package for combating Iraq's burgeoning weapons program?

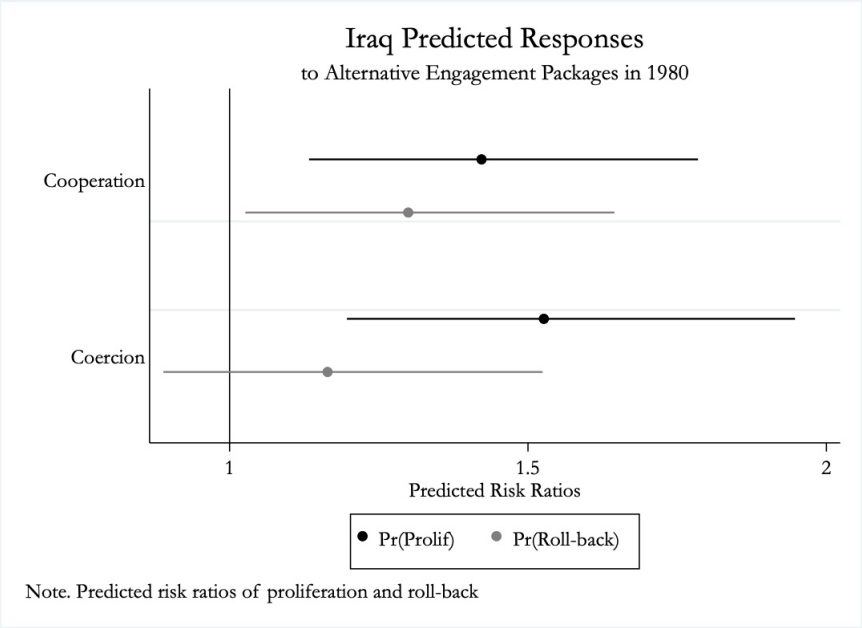

Figure 2: Predicted probability of nuclear response to policy packages.

What we see in Figure 2 is that an inducement package (top) is more effective than the coercive alternatives (bottom).[54] First, regardless of the engagement strategy employed, Iraq in 1980 was likely to continue proliferating (the estimates in black) regardless of which package it received. However, concerned states still hoped to combat this proliferation would prefer a strategy that also increased the chances of roll-back. Of the policy alternatives, an inducement package – including defense cooperation agreements like negative security assurances, increased diplomatic engagement, and civilian nuclear cooperation agreement for peaceful energy purposes – indeed significantly increased the likelihood of roll-back (in grey). A coercive package like those Iraq faced a few years later – including economic sanctions against its nuclear program, military threats, and diplomatic sanctions – is not likely to lead to roll-back at all[55] and had a potentially even greater risk of perverse proliferation than did the more promising inducement package.

IRAN AND NORTH KOREA IN 2005

While Iraq in 1980 had yet to face serious counterproliferation engagement, there are many examples of proliferators already under international pressure to roll back their programs. How then would these persistent proliferators like Iran and North Korea respond to new engagement attempts? Both Iran and North Korea unsuccessfully tried to negotiate nuclear reversal agreements in 2005, and both instead faced new coercive measures when their respective agreements broke

[54]These estimates account for the ongoing war with Iran, the reduced diplomatic engagement this war produced, the static time period, and Iraq's ongoing proliferation with auto-regressive proliferation controls.

[55]The grey confidence interval includes the 1:1 threshold line, meaning coercion has no significant affect roll-back.

down. In both cases, the proliferators requested security guarantees,[56] limited civilian nuclear cooperation agreements, and sanction easement as part of those agreements, but each instead faced threats of military force and new comprehensive economic sanctions. Rather than forcing Iran or North Korea to roll-back or even pause their nuclear programs as intended, coercion backfired. Iran responded to the pressure by opening new enrichment facilities and publicly testing ballistic missile delivery systems, while North Korea tested its first nuclear device in 2006.

What if instead of counterproductive coercion, Iran and North Korea received the cooperative agreements each had requested? We therefore evaluate odds[57] of perverse proliferation (in black) an roll-back (in grey) using the cross-national results shown in Table 2. Once again, a package of cooperative inducements[58] shows promise as an effective engagement strategy. Taking into account the historical context, security environment, and nuclear behavior of each state, we find that cooperative inducements like those the proliferators had tried to negotiate increase the odds of successfully roll-back with little to no risk of counterproductively accelerating proliferation instead.

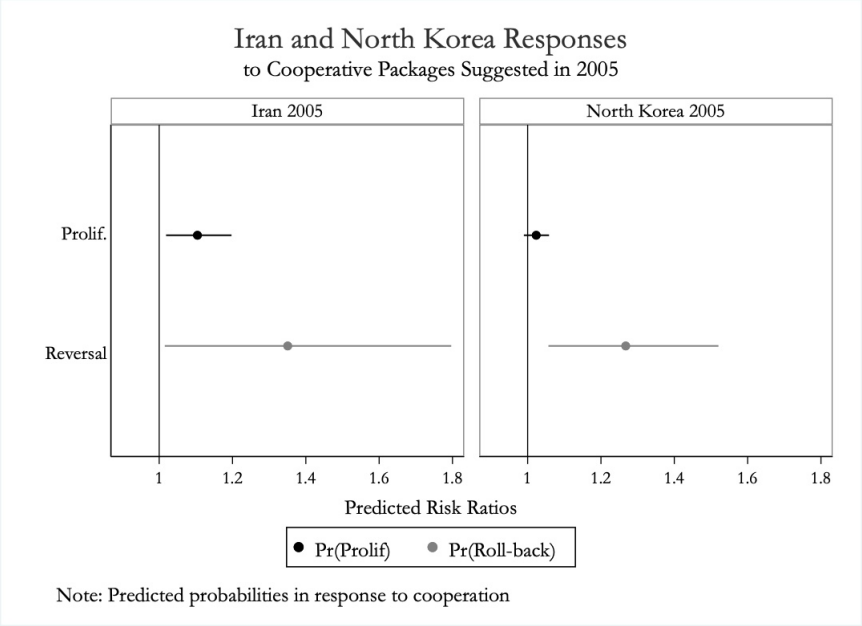

Figure 3: Predicted probability of nuclear response to policy packages.

In the case of Iran, the Islamic Republic had initially broached the possibility of opening its program to international inspectors and nonproliferation safeguards in exchange for a security assurance and normalized relations with the US in 2003, and continued to negotiate with France, Germany, and the UK for these conditions even after the US refused. We find that a cooperative deal like one Iran tried to negotiate during that time actually increased the odds of roll-back by

[56] Both requested negative security assurances from the United States, a limited defense cooperation agreement in which parties agree not to attack one another.

[57] Predicted probabilities of roll back or proliferation, reported as odds ratios compared to baseline of no engagement.

[58] A cooperative inducement package containing limited DCAs (negative security assurance), nuclear cooperation agreements, and increased diplomatic engagement.

more than 40% compared to the alternative of no agreement at all. While we know that Iran in fact increased its nuclear capabilities and its ballistic missile program following sanctions in 2005, we find that a cooperative package poses little risk of such perverse consequences, making cooperation a more effective strategy for rolling back Iran's nuclear program in 2005.

We find similar promise of cooperative inducements in the case of North Korea, At that time, Pyongyang was in the midst of 6-Party Talks, during which the regime requested inducements like security assurances, assistance with a civilian nuclear energy program, and sanction easement. When talks fell through in 2005, North Korea instead faced new economic sanctions and threats. Rather than caving to this pressure, the regime tested its first nuclear warhead in 2006. While coercion backfired 2005, we find that a more cooperative package instead increases the probability of successful roll-back by 25%, all while imposing no significant risk of perverse proliferation.

Taken together, this analysis suggest that cooperation provides a more effective counterproliferation strategy than does the common coercive option. In a number of high-profile historical examples, a package of cooperative policies not only increased the probability of successful roll-back, but perhaps even more promising it did so without the risk of counterproductive consequences often associated with coercive alternatives.

Conclusions and Further Research

The international community has energetically worked to prevent the spread of nuclear weapons and to combat new programs as they emerge. Over thirty states have pursued nuclear weapons in the seventy years since the first bombs were tested in 1945, though only nine of these proliferators still maintain a nuclear arsenal today. However, recent work suggests that nuclear taboos may be eroding, and states that until now had abstained from proliferating have reopened nuclear discussions in response to emerging regional threats.[59] Choosing the most effective policy thus has important consequences for international security today, but recognizing the most effective policies may not be as simple as punishing deviants and rewarding compliers.

Instead, when we recognize that counterproliferation policies can be a double-edged sword – sometimes succeeding, but sometimes backfiring with dangerous consequences – considering both the risks and rewards of each policy has important implications for policy and international security. This article therefore seeks to evaluate which counterproliferation policies most effectively roll back ongoing nuclear weapons programs, and which policies counterproductively incite further proliferation instead. We find that cooperative strategies that promise enduring collaboration can most effectively induce proliferators to roll back their existing nuclear programs, while coercive tactics that incite those proliferators' security fears carry the greatest risks of perversely accelerating proliferation instead.

Some of the most popular counterproliferation policies like nuclear sanctions or military threats are surprisingly ineffective against ongoing proliferation, and may even be worse than doing nothing at all. While these coercive strategies are intended to impose costs for proliferating, they can also fuel the proliferator's desire for a nuclear weapon in a bid to deter future coercion. But not

[59]Ongoing discussions of Saudi Arabia's nuclear ambitions and South Korean hedging can be found in: Bahgat, G. (2006). "Nuclear Proliferation: The Case of Saudi Arabia", *Middle East Journal,* 60(3), 421-443; Gheorghe, E. (2019) "Proliferation and the Logic of the Nuclear Market", *International Security*, 43(4), p88-127; Lim, E. (2019) "South Korea's Nuclear Dilemmas", *Journal for Peace and Nuclear Disarmament,* 2(1), 297-318.

all counterproliferation carry such perverse risks. Instead, we find that cooperative inducements present more effective alternatives for successfully achieving nuclear roll back. Policies like civilian nuclear cooperation agreements and limited security assurances can signal to a proliferator that rolling back their weapons program can offer peaceful benefits without fearing future exploitation in its vulnerable non-nuclear condition. In addition, enduring cooperative inducements can provide a useful incentive for ex-proliferators to maintain their commitments, providing conditional ongoing benefits to prevent relapsing into a weapons program in the future.

This should not lead us to assume that all carrots are effective or that all sticks are risky, however. Not all positive inducements signal cooperative intent, and not all negative sticks risk inciting security fears. While coercive measures like threats or use of force can reinforce the proliferator's desire for a nuclear deterrent, diplomatic signals like recalling diplomats or reducing political ties can isolate the proliferator without inciting its security fears. As a result, though coercion often risks backfiring, this does not imply that senders should foreswear all punitive measures. In fact, caution is also needed in selecting positive inducements. One-time payouts like foreign aid for example, are ineffective and potentially risky as counterproliferation tactics – doing little to reduce a proliferator's security fears while simultaneously filling the target's coffers. Signaling cooperative intent requires more sustained interaction than simply buying off compliance, but is also more effective than providing the proliferator with some short term financial incentives.

This work contributes to existing knowledge on nuclear proliferation dilemmas by providing a framework for assessing the effectiveness of available policies for inducing nuclear reversal in proliferating states. It considers both the prospects for success as well as the risks for each policy individually. Many individual policies are often presented as part of a larger cooperative package — packages that can include more effective policies along side more risky ones. As a result, testing policies as part of a larger package or relying on a limited number of critical case studies risks misattributing the success of more effective policies or overlooking the risks of concurrent but ineffective alternatives. This study helps decipher the effects of common policies, drawing lessons that can help inform more effective counterproliferation strategies in the future.

There is still more work to be done to understand when and why counterproliferation tactics are most effective. For example, we might question whether all senders are equally capable of incentivizing reversal, or equally likely to incite counterproductive responses from proliferators. If this is the case, not all senders can choose the same policies and expect the same results, so further research could examine how prior relations and state alliances impact policy effectiveness. Such research can help address question like: is a powerful rival like the United States or a neighboring benefactor like China more likely to achieve roll back in North Korea? Finally, this article examines the rapid effects of policies on nuclear proliferation, but does not consider the potential for long-term consequences. The effects of some policies may take longer to manifest, masking the potential risks or rewards of these slower strategies. For example, do economic sanctions just take longer work as costs accumulate over time, only gradually extracting nuclear concessions? More work is therefore necessary for understanding both the dyadic nature of counterproliferation interactions, and the long term consequences of these choices.

Appendix

This appendix provides greater detail on the dataset used in the statistical analysis, and performs sensitivity checks using alternative model specifications. First we outline details of the dataset by highlighting the cases and their proliferation or roll-back of existing nuclear capabilities. There are a 32 states between 1945-2012 that are known to have had some form of nuclear capabilities. These enrichment or reprocessing capabilities could be as small as a single pilot scale enrichment plant or as large as many fully functioning commercial facilities.[60] Many of these states have at some point explored the possibility of a military dimension to their nuclear program, but most ended any military pursuits and have since confined their work to purely civilian energy programs. Table 3 shows the total number of years each state had an active or exploratory nuclear weapons program. It then shows the number of years within that time that each state either proliferated (or increased its nuclear capabilities), or rolled back (by decreasing its nuclear capabilities), as well as the number of years on average that each state took between instances of proliferation (proliferation lag) or roll-back (roll-back lag).

Next we examine the independent variables, or foreign policies. Figure 4 shows the frequency with which each foreign policy was used as the number of country-years in which each is observed. Incidents of MIDs are the most common form of foreign engagement cross-nationally, followed closely by foreign aid and then more distantly by general sanctions against non-nuclear specific issues. The data is shown in country-year units of analysis, meaning each proliferator appears only once in any year, but in that year it might face several different policies.

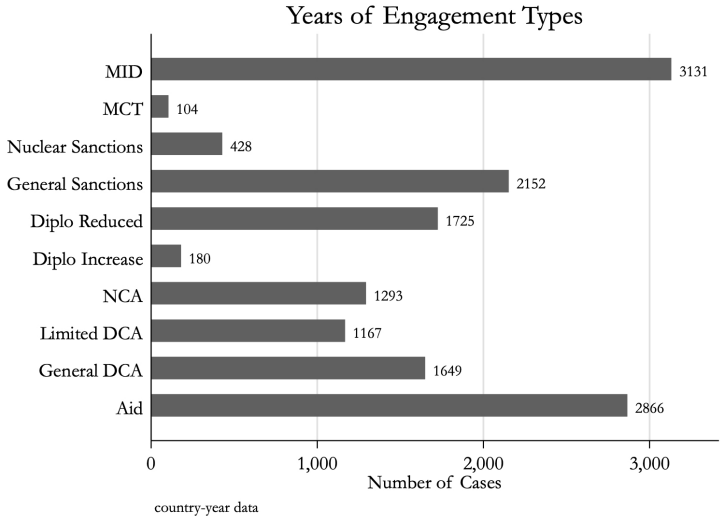

Figure 4: Number of Total Policy Years

[60] Some rare cases like Sweden never even finished the construction of the pilot plant or began producing nuclear fuel before closing their nuclear program.

Table 3: Latency Statistics: Proliferation and Reversal Years

State (COW Code)	Total Years	Prolif Years	Prolif Lag	Roll-back Years	Roll-back Lag
Algeria (615)	30	1	–	0	–
Argentina (160)	45	3	7.78	2	9
Australia (900)	57	2	15.5	2	14.5
Belarus (370)	21	0	–	0	–
Belgium (211)	53	0	–	1	0.31
Brazil (140)	53	5	4.97	2	7.54
Canada (20)	68	2	33	3	28
Czechoslovakia (315)	17	0	–	0	–
China (710)	61	14	2.86	6	4.54
Eqypt (651)	52	1	–	0	–
France (220)	68	17	3.81	13	4.11
(West) Germany (255/260)	56	7	9.16	3	8.12
Italy (325)	57	3	15.38	2	14.5
India (750)	62	9	3.81	0	–
Indonesia (850)	30	0	–	1	–
Iraq (645)	38	6	8.64	3	9
Iran (630)	45	8	1.93	3	3.21
Israel (666)	64	4	11.29	0	–
Japan (740)	67	9	5.81	1	2.45
Kazakhstan (705)	21	0	–	0	–
Libya (620)	43	3	7.26	3	4.76
Netherlands (210)	42	3	7.63	2	9.5
North Korea (731)	51	3	11.28	1	1.5
Norway (385)	60	1	26.5	2	25.5
Pakistan (770)	42	4	5.28	1	12
Romania (360)	35	1	–	1	–
Russia (365)	72	15	6.46	9	6.28
Spain (230)	46	0	–	1	–
South Africa (560)	48	4	9	4	7.7
South Korea (732)	54	4	7.82	3	7.78
Sweden (380)	46	0	–	1	–
Switzerland (225)	40	0	–	0	–
Syria (652)	13	0	–	0	–
Taiwan (713)	42	3	17	1	15.5
Ukraine (369)	22	0	–	0	–
United Kingdom (200)	73	13	4.31	11	3
US (2)	70	20	3.27	19	1.97
Yugoslavia (345)	49	2	19.34	2	–
Observations	1843				

Lag taken as average years between each instance of proliferation or reversal.

SENSITIVITY ANALYSIS

The statistical models used in the body specifically examine the likelihood of either perverse proliferation or successful roll-back in response to specific foreign policies. The model choices reflect the structure and distribution of the empirical data, examining the expected effects of each policy on proliferating states in general, accounting for temporal heterogeneity, and control for within-case proliferation and roll-back trends year to year. However, alternative specifications could instead account for temporal dynamics using alternative control variables, or could test proliferating behavior through alternative population parameters (either state fixed effects or unspecified random effects models). We tests these alternative specifications below, using the AIC values to assess

model fit.We employ Aikake information criteria to assess the fit of each model to the data. [61]

The first tests below examine alternate panel logit specifications, Model 1 using state fixed effects, and Model 2 using population random effects. Unlike the population averaged models used in the body fo this article, both FE and RA models fully specify the population parameters: FE by assuming the population is fixed by group (in this case by proliferating state), and RA models specify the population parameters as a distribution. State fixed effects (Model 1) account for heterogeneity between poliferators by split the sample of proliferators to estimate the unique effects within each rather than across all weapons-seekers. While this is a popular method when dealing with state panel data, its ability to uncover general trends is hampered when there are few observations for each group, and when there is heterogeneity over time.[62] As a result, FE show many simialr estimates as the population averaged model used in the body, but with much less traction on the problem as large confidence intervals induced by small sample sizes =could lead us to believe that no policies have important effects on proliferators nuclear behavior at all.[63] Historical evidence (as well as all other test specifications) suggest that this complete lack of effect of foreign engagement on proliferation is implausible, and more likely the result of over-specifying and sample splitting rather than a reflection of true policy impotency.

Model 2, on the other hand, uses a random effects design, which specifies the population parameters as a distribution.[64] As a result, RE assume that the population parameters are randomly distributed, so each observation of proliferation or reversal is also randomly distributed and the individual state heterogeneity (or nuclear behavior) is not correlated with the independent variables. As a result, random effects models are not well suited for estimating the average effects fo policies across all weapons-seekers (like PA models), and do not control for unobserved state idiosyncrasies (like FE models). They are therefore not commonly used for state-specific panel data but are provided here nonetheless for comparison.

Next we examine alternative specifications for counting the instance of foreign policies. Table 5 shows counts of the number of each foreign policy a proliferator faces in any given year. Using a count model includes more total information, but has several important drawbacks. First, substantively there is no definitive reason why more of any one policy is necessarily better. More likely in fact, the marginal impact of each additional instances would have a smaller impact on the proliferator's sense of security or drive to achieve a nuclear weapon. One militarized dispute, for example, would likely be enough to create a sense of insecurity as it suggests clear foreign threat,

[61] The AIC values are not suitable for estimating generalized estimation equations (GEE) like the population averaged models used in the body. These models instead use the quasi-likelihood under independence model criteria (qIC) to assess model fit to compare between GEE models. The AIC values here are therefore not directly comparable to the qIC values in the body, but can be used to evaluate fit statistics across other AIC values. The criteria penalizes overfitting by inflating k but biases in favor of models with collinear regressors. Like AIC values, lower qIC values represent better model fit. (Pan, W. (2001) Akaike's information criterion in generalized estimating equations. *Biometrics* 57: 120-125; Cui, J. (2007) QIC program and model selection in GEE analyses. *Stata Journal* 7: 209-220)

[62] See the Dirty Pool debate in *International Organizations*, 2001.

[63] Beck and Katz (2001) point to the temptation to therefore throw the proverbial baby out with the bathwater, when overspecifications lead to null results. Beck, N. and J. Katz (2001). "Throwing Out the Baby with the Bath Water: A Comment on Green, Kim, and Yoon," *International Organization* 55 (2): 487-495; Green, D., S. Kim, and D. Yoon (2001). Dirty Pool. *International Organization* 55 (2): 441-468.

[64] Whereas population-averaged models do not make any assumptions about the population parameters at all, and fixed effects models assume the population distribution is fixed by group/state. See Scribney, W. "Comparing RE and PA Models", Stata Corps, https://www.stata.com/support/faqs/statistics/random-effects-versus-population-averaged.

Table 4: Panel Binomial Logit: FE and RE Models

	(1)		(2)	
	Proliferation	Roll-back	Proliferation	Roll-back
Nuke Sanc	0.26	-0.058	0.50	0.27
	(0.25)	(0.39)	(0.26)	(0.40)
Other Sanc	0.13	-0.48	0.31	-0.14
	(0.20)	(0.27)	(0.20)	(0.28)
MCT	0.15	-0.097	0.11	-0.072
	(0.48)	(0.78)	(0.49)	(0.79)
MID	0.098	0.098	0.34	0.38
	(0.23)	(0.30)	(0.23)	(0.29)
Reduce Diplo	-0.35	0.061	-0.41*	0.022
	(0.20)	(0.24)	(0.20)	(0.24)
Increase Diplo	-0.051	0.037	0.059	0.20
	(0.27)	(0.32)	(0.28)	(0.34)
NCA	0.16	0.42	0.48*	1.02***
	(0.21)	(0.28)	(0.22)	(0.31)
Aid	0.48	0.39	0.27	0.0059
	(0.31)	(0.45)	(0.29)	(0.37)
Limited DCA	0.46	0.77	0.66	1.14*
	(0.43)	(0.46)	(0.43)	(0.46)
DCA General	-0.28	-1.08*	-0.20	-0.89
	(0.42)	(0.49)	(0.43)	(0.47)
1940-1960s	0.99**	-1.49***	1.34***	-0.85*
	(0.37)	(0.45)	(0.37)	(0.43)
1970-80s	1.34***	-0.36	1.51***	-0.073
	(0.33)	(0.35)	(0.32)	(0.33)
Constant			-7.65***	-6.52***
			(0.59)	(0.56)
lnsig2u			1.56***	1.23**
			(0.35)	(0.43)
Observations	1821	1534	7208	7208
AIC	899.2	576.7	1213.8	828.7

Standard errors in parentheses
(1) state fixed effects (2) random effects
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

but the 3rd or even 10th instance of a MID may not have nearly the same impact as that first exchange. The same argument of diminishing returns can be made for NCAs, diplomatic sanctions, or any other form of engagement.

Secondly, there are methodological reasons to use dummy variables (the presence of absence of a specific policy in that year), as this maintains comparability to previous work on proliferation. The presence or absence of MIDs, cooperation agreements, or alliances have been used regularly to test the causes of proliferation in the past.[65] Finally, the direction and significance of the results are comparable to the primary results used in the body, meaning that the effects we find are largely upheld regardless of model specifications.

Finally, we test a multinomial logistic regression, which accounts for the potential of simultaneous and competing effects of foreign policies on targets proliferation behavior. This model

[65]Gartzke, E. and D.J. Joo, (2009) "Bargaining, Nuclear Proliferation, and Interstate Disputes" *Journal of Conflict Resolution*, 53: 209-233; Singh, S. and C. Way, (2004) "Correlates of Nuclear Proliferation: A Quantitative Test" *Journal of Conflict Resolution* 48: 859-885

Table 5: Panel Binomial Logit: Changes in Number of Each Treatment

	(1) Proliferation	(2) Reversal
Total Sanc Nuke	0.026	-0.20
	(0.14)	(0.23)
Total Other Sanc	0.034	0.017
	(0.08)	(0.09)
Total MCT	0.26	-0.34
	(0.26)	(0.44)
Total MID	0.038	0.11*
	(0.04)	(0.05)
Total Reduced Diplo	-0.20*	0.042
	(0.09)	(0.05)
Total Increase Diplo	0.026	0.090
	(0.10)	(0.16)
Total NCA	-0.0037	0.066*
	(0.05)	(0.03)
Total Aid	-0.00049	-0.14*
	(0.07)	(0.07)
Total Limited DCA	0.21	-0.35
	(0.33)	(0.40)
Total Gen DCA	0.095	-0.16
	(0.26)	(0.34)
1940-1960s	0.82*	-1.26*
	(0.36)	(0.60)
1970-80s	0.71*	-0.25
	(0.34)	(0.25)
pt	-0.10*	
	(0.04)	
rt		-0.16***
		(0.04)
Constant	-2.59***	-2.36***
	(0.32)	(0.31)
Observations	1154	772
AIC	.	.

Standard errors in parentheses
(1) population averaging with count auto-temp controls
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

uses a multinomial (rather than dichotomous) variable for proliferation changes.[66] This allows the multinomial logit design to separate the effects of proliferation or reversal from no change, unlike the binomial design with collapses lack of proliferation to include both reversal and no change, and collapses lack of reversal to include both proliferation and no change. While this allows for greater nuance here, it is not an entirely appropriate reflection of the data. Multinomial logistic regression models are intended for dependent variables that reflect largely stationary conditions, rather than those tha change year to year. Proliferation behavior is inherently (and can be seen in the data) to be variable, so that a state that proliferates in one year could very well reverse their gains the following year.

[66] Coded as (1) for increases in proliferator ENR capabilities, (0) for no change, and (-1) for a reduction in target ENR capabilities.

Table 6: Pooled Multinomial Logit

	Roll-back	Proliferation
Nuke Sanc	0.025	-0.72
	(0.54)	(0.67)
Other Sanc	0.31	0.28
	(0.29)	(0.38)
MCT	0.81	1.02
	(1.15)	(0.89)
MID	1.38***	1.25*
	(0.38)	(0.52)
Reduce Diplo	0.32	-0.72*
	(0.27)	(0.30)
Increase Diplo	0.62*	0.73*
	(0.26)	(0.36)
NCA	0.69*	-0.27
	(0.31)	(0.42)
Aid	-0.26	0.28
	(0.32)	(0.59)
Limited DCA	0.99	1.32*
	(0.51)	(0.56)
DCA General	-1.33**	-0.20
	(0.42)	(0.62)
1940-1960s	0.37	2.24***
	(0.94)	(0.53)
1970-80s	0.62	1.55***
	(0.49)	(0.41)
pt	0.17***	-0.30***
	(0.03)	(0.07)
rt	-0.29***	0.20***
	(0.06)	(0.05)
Constant	-4.45***	-4.65***
	(0.46)	(0.71)
Observations	666	
AIC	770.1	

Standard errors in parentheses
with mean offset auto-regression controls
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

PAIRWISE CORRELATION MATRICES

Lastly, the following table examines the collinearity of independent variables used in these tests. These tests find that only General and Limited DCAs come close to the standard cutoff of high collinearity (correlation of 0.7 or higher), but even these two do not quite reach this threshold. In addition, these occasionally collinear DCA variables are often used in very different cases and have different proliferation outcomes, and thus we maintain the two separate variables in the analyses.

Table 7: Regressor Correlation Matrix: Basic Conditions

	Nuke Sanc	Other Sanc	MCT	MID	Reduce Diplo	Inrease Diplo	NCA	Aid	Limited DCA	General DCA
Nuke Sanc	1									
Other Sanc	0.034	1								
MCT	0.098	0.0050	1							
MID	0.19	0.046	0.12	1						
Reduce Diplo	0.062	0.077	0.053	0.20	1					
Increase Diplo	0.12	0.086	0.035	0.13	0.13	1				
NCA	0.039	0.073	0.0036	0.071	0.31	0.18	1			
Aid	-0.017	0.22	-0.012	-0.069	0.057	0.045	-0.094	1		
Limited DCA	-0.052	0.19	-0.041	0.070	0.00059	0.100	0.083	0.054	1	
General DCA	-0.067	0.20	-0.045	0.056	-0.0061	0.069	0.084	0.047***	0.69***	1