Taking a New Look at the NPT: A Game Theoretic Approach to the Nuclear Nonproliferation Regime

Dianne R. Pfundstein
drp2109@columbia.edu
Ph.D Student, Department of Political Science
Columbia University
New York, NY

Paper Prepared for the Annual Meeting of the International Studies Association
New Orleans, LA, 19 February 2010

DO NOT CITE WITHOUT AUTHOR’S PERMISSION

---

1 This paper draws heavily on the honors thesis that I submitted to the Department of Economics at Williams College in 2006 under the title, “Rewriting the Rules of the NPT: A Game Theoretic Approach to Nuclear Proliferation.” I would like to gratefully acknowledge the help and encouragement of Ashok Rai, my thesis advisor, and thank John Bakija and Steve Sheppard for reading drafts while I was working on this project at Williams. I thank 2009 ISA participants for comments on an earlier version of this paper.
Abstract:

Why has the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) failed to prevent some of its own members from pursuing nuclear weapons? With a series of game theoretic models, I demonstrate that the structure of the NPT fails to provide disincentives for proliferation, and that the Additional Protocol fails to correct the treaty’s major weaknesses. I suggest a revision of the current NPT treaty: by forcing states to choose between signing an Additional Protocol and exiting the NPT, the nuclear nonproliferation regime will be better able to block the spread of nuclear weapons. Yet even this improved structure would suffer from the same problems of monitoring and enforcement that currently plague the NPT and many other international treaties. The international community must recognize the shortcomings of this supply-side approach to nuclear proliferation, and confront the demands motivating states to acquire nuclear weapons, if it hopes to contain the Iranian and North Korean nuclear programs.
Taking a New Look at the NPT: Introduction

North Korea, Iraq, Iran and Libya are all believed to have pursued nuclear weapons while they were signatories to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). Why has the NPT failed to prevent some of its own members from pursuing nuclear weapons? Does membership in the NPT signal anything about a state’s intent to acquire such weapons? The international community is currently embroiled in debates about how to evaluate Iran’s nuclear intentions and how to contain North Korea’s nuclear weapons program. If the policy community hopes to confront these challenges, it must first identify the shortcomings of the current nonproliferation regime.

I employ a series of simple game theoretic models to evaluate the incentive structure of the NPT, and to determine whether membership in the treaty conveys any information about a state’s intent (or lack thereof) to acquire nuclear weapons. Although sometimes criticized as a method with little applicability to policy, game theory is uniquely well suited to the analysis of signaling in the context of private information: the international community would like to know the true intentions of states suspected of pursuing nuclear weapons, but can only update its beliefs about such states based on the behavior that it observes. A game theoretic analysis may therefore yield valuable insights for future policy designed to confront nuclear proliferation.

After introducing the basic structure of the treaty, I evaluate a model in which the international community has no ability to detect states violating the terms of the NPT. I then incorporate an inspections framework similar to that provided under the terms of the Additional Protocol (AP). I find that, under most conditions, these models yield pooling equilibria in which all types of states—both those pursuing nuclear weapons and those
not pursuing such weapons—choose to remain signatories to the NPT, thereby retaining the benefits of nuclear technology exchanges provided by treaty membership and revealing nothing about their intentions. I suggest a possible revision to the NPT structure that may prove more effective in identifying proliferators and denying the benefits of treaty membership, but one that would still be subject to the same challenges of verification and enforcement as many other treaty regimes. I conclude by examining the limitations of these models and of the treaty structure itself, with emphasis on a new direction for future nonproliferation policy.

The Treaty on the Non-Proliferation of Nuclear Weapons: Background

The goals of the NPT were to prevent the “wider dissemination of nuclear weapons,” and to grant states access to the “benefits of peaceful applications of nuclear technology.” The treaty was completed and offered for signature in 1968, and recognized five states that had tested weapons by 1 January 1967 as nuclear weapons states, all of which signed the treaty: the United States, France, the United Kingdom, China and the Soviet Union. Under Article I of the treaty, these states agreed not to transfer nuclear weapons to non-nuclear weapons states, and not to assist such states in the development of nuclear weapons. Accordingly, the non-nuclear weapons states agreed not to solicit or accept any such offers of assistance, and renounced the right to develop nuclear weapons on their own.² As of 2005, when the treaty came up for its latest review, 188 states were

signatories; notably, Israel, India and Pakistan have never signed the treaty and North Korea withdrew in December of 2003.³

The treaty also provides for the transfer of nuclear energy technologies from recognized nuclear weapons states to the non-nuclear weapons states. States receiving such technology transfers must submit to inspections by the IAEA to ensure that they are not violating the terms of the treaty. Article III of the treaty stipulates that such inspections must “avoid hampering the economic or technological development” of a state under investigation, and thus the treaty permits inspectors to visit only those nuclear facilities voluntarily declared by the state in question.⁴ To circumvent the provisions of the treaty, a state pursuing a clandestine weapons program could limit the range of IAEA inspections to sites at which no illicit activity was taking place; or, as in the case of the Iraqi program, to innocuous areas of a site at which weapons were being developed.⁵ A state may also withdraw from the treaty, as North Korea did in late 2003, when “extraordinary events…have jeopardized the supreme interests of its country.”⁶

In addition to providing a state’s nuclear program with a stamp of legitimacy, NPT membership also encourages technology transfers that may aid states in the pursuit of nuclear weapons. Simply possessing a nuclear reactor does not give a state immediate access to a nuclear weapon; however, materials and expertise associated with peaceful nuclear energy activities may, under certain conditions, be transferred from non-weapons applications to the development of a nuclear weapon. A nuclear weapon may be “fueled”

⁴ United Nations, NPT Treaty.
by a core of either highly enriched uranium or plutonium. The naturally occurring concentration of U-235 is only 0.7 percent, and thus mined uranium, which contains a mix of different isotopes, must be enriched for use in either a nuclear reactor or a weapon. Fission reactors use uranium enriched to concentrations of three percent U-235, but much higher levels of enrichment are necessary to build even a crude nuclear weapon. The advanced nuclear powers build more compact, lighter weapons by using uranium enriched to levels of over ninety percent U-235, but functioning weapons could be built at lower levels of enrichment. Plutonium is a more “efficient” fuel for a nuclear weapon, as less plutonium is required to produce the same yield as a given amount of uranium. Plutonium is produced as a by-product of all fission reactors, but the spent fuel from a reactor must be chemically reprocessed to obtain weapons-grade plutonium with a Pu-239 concentration of ninety-three percent or above.7

A state with a nuclear reactor may not necessarily have its own enrichment or reprocessing facilities. Because enrichment or reprocessing is necessary to convert reactor-grade nuclear material into that suitable for a weapon, the development of indigenous enrichment or reprocessing capabilities is often cited as evidence that a suspect state is pursuing nuclear weapons. Recent revelations about Iran’s efforts to build enrichment plants have alarmed the international community for precisely this reason.8 Obtaining nuclear fuels and technologies legitimately through NPT membership does not automatically generate the ability to construct a nuclear weapon; however, the materials and expertise associated with such technologies give would-be proliferators a

head start in establishing a nuclear weapons program. Because of both the sense of legitimacy conveyed by treaty membership and the direct benefits of technology transfers, I argue below that membership in the NPT enhances a state’s ability to pursue a nuclear weapon.

So why has the NPT failed to prevent some of its members from pursuing nuclear weapons? To be effective in preventing proliferation, the NPT should pursue one of two goals: force proliferators to reveal themselves by enacting an incentive structure that drives proliferators out of the NPT treaty, thereby denying them the benefits of peaceful nuclear technology transfers; or, encourage proliferators to remain within the NPT framework, but with a high likelihood of successfully uncovering violations. With a series of models that I develop below, I demonstrate that neither the NPT nor the Additional Protocol has accomplished these goals. Potential proliferators face incentives to remain within the treaty structure, while the inspections regime struggles to detect violations.

1. Limits of the NPT Regime

_Hypothesis A: Untargeted sanctions under the NPT structure fail to separate proliferators from non-proliferators._

The first series of models presented below evaluates the incentive structure of the original NPT framework. This game has two players: the small state (M) that is already a member of the NPT and is suspected of pursuing nuclear weapons;⁹ and the large state (L). Player M may be of two types: a “proliferator” (P), a state actively seeking to develop a nuclear weapon; or a “non-proliferator” (N), a state not seeking nuclear

---

⁹ For example, the small state (Player M) might be North Korea or Iran, but these models do not apply to a state such as Switzerland that is not suspected of pursuing a nuclear weapons program.
We use $\text{ISA 2010}$, $\text{Dianne R Pfundstein}$

weapons. The small state is already a signatory to the NPT, and the game begins when
the small state’s nuclear ambitions are called into question—for example, when the large
state announces on the international stage that it suspects the small state of pursuing a
nuclear weapons program. The small state must now decide whether to remain a member
of the NPT, and may therefore pursue two different strategies: stay within the NPT
(strategy T) or exit the treaty (strategy E). Player M knows his own type and moves first,
while player L must update his beliefs about the type of player he faces in response to
player M’s strategy.

In the first and most basic game below, I assume that the large state has no ability
to directly observe the small state’s nuclear programs. By demonstrating the behavior
that we would expect in the absence of effective inspections, this model serves as the
starting point for all other models. Although the original NPT did provide for
inspections of nuclear facilities in non-nuclear weapons states, these inspections were
extremely ineffective. Later in this paper, I evaluate whether the inspections added by
the Additional Protocol are more effective in preventing proliferation.

This first model therefore assumes that the large state has no ability to detect what
type of player M he is facing, and thus player M is a proliferator (type P) with probability
($\rho$) and a non-proliferator (type N) with probability ($1-\rho$). Player L is unsure about what
type of player M he is facing and must update his beliefs about the small state’s type in
response to player M’s strategy. Player L may then choose to enact general (i.e. non-
targeted) economic sanctions against the target state (strategies S and S’) or maintain the

\[10\] Furthermore, this simplification may be a fairly accurate representation of target states’ expectations
about the effectiveness of inspections, particularly given the regime’s failures to detect proliferation by
NPT-member states such as Iraq during the 1980s (see Kay, “Denial and Deception,” 35-105). Because the
IAEA could inspect only those sites officially declared by the country under observation, the target state
(player M) may have expected that the likelihood of its violations being detected was virtually zero.
status quo (strategies Q and Q’). In later variations, I explore the impact of sanctions designed to directly target a state’s ability to pursue a nuclear weapon.

When player M chooses to remain in the NPT, he receives a payoff of \((y + \varepsilon)\), where \((y)\) represents the value of the nuclear technology transfers provided under the terms of the NPT, and \((\varepsilon)\) represents the positive contribution of this technology transfer to a state’s nuclear weapons ambitions. For the non-proliferator (N), the value of \((\varepsilon)\) is zero, and thus he receives a payoff of \((y)\) when he remains within the NPT. For the player M pursuing nuclear weapons (P), the value of \((\varepsilon)\) is greater than zero. The proliferator’s payoff \((y + \varepsilon)\) is simplified to \((w)\) for ease of notation, and \((w > y)\). When the proliferator chooses to remain within the NPT framework, player L incurs a disutility of \((-x)\), since the proliferator’s ability to develop a nuclear weapon is enhanced by treaty membership. The implementation of sanctions imposes a cost of \((c_M)\) on player M and a cost of \((c_L)\) on player L, and \((x > c_L)\). In some cases, the value of \((c_L)\) is likely to be quite small, particularly in relation to \((c_M)\). On the other hand, there may be cases in which the cost of imposing sanctions on player M might be quite high for player L—for example, if player L chooses to punish player M by discontinuing the purchase of country M’s oil.\(^{11}\)

The basic game is structured as follows, with \((\gamma)\) and \((\delta)\) representing player L’s beliefs that he is at a particular node, and payoffs \((M, L)\). Nature moves first and determines whether player M is of type (P) or (N); player M knows his own type and moves next, followed by player L’s response:

NPT Model A: Solutions

The model is first solved according to the assumption that $(w > y > c_M)$. Under this assumption, the benefits of NPT membership exceed the cost of sanctions for both types of player M. For any strategy pursued by player M, player L’s best response is to play $(Q', Q)$. For a separating equilibrium to exist in which the proliferator exits the treaty and the non-proliferator remains within the structure of the NPT, it must be the case that the payoff to the proliferator from exiting the NPT is greater than or equal to that for remaining within the NPT, and that by remaining in the NPT the non-proliferator receives a payoff that meets or exceeds the payoff from exiting, given the strategy pursued by player L $(Q', Q)$. In this model, the best response of both types of player M is to remain in the NPT. The model thus yields the following equilibrium:

$$\{(T_P, T_N), (Q', Q), 0 \leq \gamma \leq 1, 0 \leq \delta \leq 1, \rho = \delta\} \quad (a.1)$$
I will use this notation to describe equilibria throughout the remainder of this paper. The first set of letters in parentheses, in this case (T_P, T_N), describes player M’s equilibrium strategy. The letters in subscript denote the type of player M pursuing a given strategy. Thus in equilibrium, both the proliferator (P) and the non-proliferator (N) play strategy (T) and remain within the NPT. The second set of letters in parentheses describes player L’s strategy in equilibrium—in this case, player L plays (Q’, Q) and never imposes sanctions. The rest of the equilibrium is described by a unique set of constraints on other variables and specify the conditions under which the equilibrium strategies hold. In this case, the equilibrium specifies parameters for (ρ), (γ) and (δ), all of which are probabilities.

Not surprisingly, the only solution to this model is a pooling equilibrium in which both types of player M choose to remain within the NPT framework. Because of the costs associated with the imposition of sanctions, and because he cannot tell what type of player he is facing, player L never sanctions either type of player M. The positive incentives for joining the NPT encourage both the proliferators and non-proliferators to remain within the NPT, and thus there is no separating equilibrium. Solving the model under either the assumption that (w > c_M > y) or that (c_M > w > y) yields the same equilibrium as solving the model under the conditions stipulated above. Because player L never imposes sanctions, the value of (c_M) never factors into player M’s calculation of the best response to player L’s strategy.\(^\text{12}\)

\(^{12}\) Even if we assume that the cost of imposing sanctions is zero, as long as the benefits of NPT membership exceed the cost of sanctions for both types of player M, then the NPT still fails to separate proliferators from non-proliferators. This “costless sanctions” model yields four equilibria when we assume that (w > y > c_M): \{(T_P, T_N), (Q’, Q), \delta = \rho, 0 \leq \gamma \leq 1\}; \{(T_P, T_N), (Q’, S), \delta = \rho, 0 \leq \gamma \leq 1\}; \{(T_P, T_N), (S’, Q), \delta = \rho, 0 \leq \gamma \leq 1\}; \{(T_P, T_N), (S’, S), \delta = \rho, 0 \leq \gamma \leq 1\}. When (w > c_M > y), and (c_L = 0), there are three pooling equilibria in which both types of player remain within the NPT. There is also one separating equilibrium,
One conclusion that we may draw from this model is that player L would seem to be better off if he could eject players from the NPT. Player L fares just as well or better when player M chooses to leave the NPT as when the small state chooses to stay in the treaty. This would also deprive potential proliferators of legitimate access to nuclear materials; however, the NPT has no provision for ejecting states from membership, even though states may withdraw voluntarily. I will return to the issue of ejecting states from the treaty in the normative model that I develop later in this paper.

**Hypothesis B:** If the large state receives a small net gain in utility from imposing general sanctions on players that remain within the NPT, but the cost of sanctions to player M is sufficiently low, the NPT still fails to separate proliferators from non-proliferators.

What happens if we assume that the large state receives some positive gain in utility from sanctioning those players that remain in the NPT? In the following model, player L receives a small net gain in utility from sanctioning a player that chooses to remain within the treaty. The large state may believe that sanctioning the small state will impede the state’s ability to develop nuclear weapons, even though this may not actually be true, because the sanctions are not specifically designed to prevent nuclear weapons development. When player L imposes sanctions on a state that remains in the NPT, he receives a gain in utility (u), that offsets the costs of imposing sanctions (-cL), or (u - cL). The quantity (u - cL) is assumed to be greater than zero and is represented in the models below as (g). Player L still receives the disutility of (-x) when the proliferator (type P)
remains within the NPT, because the general sanctions that he implements do not directly impact player M’s ability to pursue nuclear weapons, and $(x > g)$. When player M exits the NPT, player L again incurs the disutility of $(-c_L)$ when he imposes sanctions, and $(c_L > 0)$.\(^{13}\) The game is structured as follows, with $(\delta)$ and $(\gamma)$ again representing player L’s beliefs that he is at a particular node:

(Figure B.1: “Bonus” Sanctions Model)

**NPT Model B: Solutions**

The model is first solved under the assumption that $(w > y > c_M)$. Now, for any strategy pursued by player M, player L’s best response is to sanction those players that remain in the NPT, and not to sanction those that exit the NPT $(Q', S)$. Because the benefits of NPT membership exceed the cost of sanctions for both types of player M, the

---

\(^{13}\) In this model, I assume that the net gain in utility occurs only when the large state sanctions a target that remains within the NPT for two reasons: first, a state that leaves that NPT would lose the benefits of nuclear technology transfers, making targeted sanctions unnecessary; second, to punish a state outside the treaty structure would entail greater political costs for the large state, since sanctioning a non-member would essentially force a targeted state to adhere to rules to which he has not agreed.
best response for both the proliferator and non-proliferator is to remain in the NPT. Thus
the model yields the following equilibrium:

\{(T_P, T_N), (Q', S), \delta = \rho, 0 \leq \gamma \leq 1\} \quad (b.1)

The benefits conveyed by the NPT on its signatories are likely to be so large that
sanctions would have to be extremely costly to exceed the benefits that even a non-
proliferating state receives from signing the NPT. The fact that countries such as Iraq
and North Korea (until 2003) chose to remain within the NPT while developing nuclear
weapons suggests that the assumption (w > y > c_M) may best reflect reality.

Nevertheless, it is still useful to solve the model under alternate assumptions.
Solving under the assumption that (w > c_M > y) yields a different equilibrium. Player L
still pursues a strategy of (Q’, S), but now, for the non-proliferator, the cost of sanctions
exceeds the benefits of NPT membership. Since he will not face sanctions if he exits the
treaty, the non-proliferator’s best response is now to leave the NPT. Solving under the
assumption that (w > c_M > y) thus yields the following equilibrium:

\{(T_P, E_N), (Q', S), \gamma = 0, \delta = 1\} \quad (b.2)

This incentive structure has caused a separation of players, but it has driven out the state
not pursuing nuclear weapons, thereby denying her the benefits of NPT membership.
This is probably not an equilibrium that the large state would wish to enforce.

Finally, the model is solved under the assumption that (c_M > w > y). Player L’s
best response is still to sanction those players that stay within the NPT and not to sanction
those that exit the treaty (Q’, S). Now the cost of sanctions exceeds the benefits of
remaining in the NPT for both types of player M, and both choose to exit:

\{(E_P, E_N), (Q', S), \gamma = \rho, 0 \leq \delta \leq 1\} \quad (b.3)
This model assumes that the sanctions implemented against the small state are not targeted at player M’s ability to develop a nuclear weapon. These sanctions thus cannot impact weapons production and may even drive out those states that are not pursuing nuclear weapons (equilibria b.2 and b.3). If the goal of the large state is not to drive non-proliferating states out of the NPT, then the cost of sanctions must be significantly low (equilibrium b.1), and the NPT again fails to separate proliferators from non-proliferators.

Prior to its renunciation of WMD in 2003, Libya pursued nuclear weapons research while a member of the NPT and while targeted by general sanctions from the international community. These sanctions were implemented because of Libya’s sponsor of terrorist activity, and thus were not designed to target its ability to develop nuclear weapons. The sanctions likely did not diminish the benefits of the NPT enough that Libya chose to withdraw. Because these sanctions were implemented as a result of Libya’s sponsor of terrorist activity, it is reasonable to assume that the sanctioning states incurred a net gain in utility (g) from sanctioning Libya. Thus NPT Model B, and equilibria (b.1) and (b.2), likely reflect Libya’s participation in the NPT prior to its renunciation of WMD in 2003.

North Korea has also withstood a series of general sanctions. The state withdrew from the NPT in 2003, when it resumed reprocessing of spent fuel rods to extract plutonium, and tested a nuclear weapon in 2006. Until January 2003, however, North Korea had chosen to remain within the framework of the NPT while pursuing its nuclear weapons program. If we believe that US policymakers worry about the impact of

---

continued sanctions on the North Korean population, then NPT Model B, in which the large state receives a net gain in utility from sanctioning the target state, may not be appropriate. The pooling equilibria of NPT Model A may therefore be most appropriate for considering North Korea prior to 2003. In 2003, North Korea may have felt that the costs of remaining within the NPT and being subjected to sanctions and inspections had been raised, making an exit from the treaty the most attractive option.

Hypothesis C: Under the framework of the original NPT, targeted sanctions that sufficiently increase the costs of developing nuclear weapons can, under limited circumstances, separate proliferators from non-proliferators.

In the following model, player L may impose sanctions that directly impact a state’s ability to develop nuclear weapons. Such sanctions might, for example, ban the import of centrifuges necessary to produce highly enriched uranium. I assume that targeted sanctions may only be implemented effectively when the small state is a member of the NPT, since the large state lacks the authority to administer the type of monitoring and inspections necessary to implement such targeted sanctions when the small state does not remain within the treaty structure. Additionally, the ability to make targeted import controls effective will require the cooperation of many different states, which will be facilitated and legitimated by working through and within the framework of the NPT.

When player L implements the targeted sanctions, he believes that he significantly hampers the ability of player M to develop weapons, and thus his disutility from the small state’s ability to develop nuclear weapons (-x) is eliminated. The targeted sanctions are not guaranteed to eliminate the ability of the small state to develop nuclear weapons, but
rather greatly increase the costs to player M of doing so. Because the large state cannot
tell what type of state he is facing, he would impose the targeted sanctions on both types
of player M that choose to remain within the NPT framework; however, the cost of these
targeted sanctions would not be the same for both types of player M, since they are
designed to directly impact activities associated with the construction of a nuclear
weapon.

Since targeted sanctions directly affect weapons production, I assume that their
cost would be higher for a proliferator than for a non-proliferator. The additional cost of
such targeted sanctions for the proliferator is represented by (k) in the following game,
where the cost to the proliferator from receiving targeted sanctions is now (-kc_M), and (k
> 1). Thus the proliferating player M retains the (w) payoff associated with remaining in
the NPT but incurs a cost of (-kc_M). The other type of player M does not incur the extra
cost represented by (k), because he is not trying to develop weapons and thus the targeted
sanctions do not impact his activities.\(^\text{16}\) As in NPT Model B, player L receives a small
gain in utility from sanctioning the players that remain within the NPT (g), and (x > g).
The strategies remain the same as those in the previous games, and the variables
representing payoffs are the same as those for NPT Model A. The model is structured as
follows:

---

\(^{16}\) For example, if the targeted sanctions ban the sale of certain machine parts needed to produce a weapon
(e.g. centrifuges necessary to produce highly enriched uranium), such a ban would not place an extra cost
on player M, because she is not trying to import such machine parts for the construction of a weapon.
NPT Model C: Solutions

The model is solved under the assumption that \( w > y > c_M \). Player L’s best response to all strategies pursued by player M is to sanction those players that remain in the NPT and not to sanction those that exit the treaty \((Q', S)\). Given the relative values of \( y \) and \( c_M \), the non-proliferating M’s best response is to remain in the NPT. The proliferating player M’s best response to player L’s strategy now depends on the value of \( k \). If the benefits of NPT membership under sanctions exceed the payoff that the proliferator receives from exiting the NPT, then he will remain in the treaty; otherwise, he will leave. Thus the proliferator will remain in the treaty when \([w - kc_M] \geq 0\), and will exit the treaty when \([w - kc_M] \leq 0\). Solving for \( k \) and under the assumption that \( w > y > c_M \), the model yields the following equilibria:
Equilibrium (c.2) is similar to those observed in the other models, in which both types of player M are induced to remain within the NPT. But in equilibrium (c.1), the two types of player M separate. When \([k \geq (w/c_M)]\), or the cost of the targeted sanctions is sufficiently high, the player that is pursuing nuclear weapons exits the NPT, and the non-proliferator remains within the treaty. Note that according to these conditions, the larger the benefit from remaining within the NPT \((w)\), the larger the value of \((k)\) needed to drive the proliferator out of the NPT. By raising the cost of targeted sanctions sufficiently, the large state can cause the proliferator to leave the NPT and forego the benefits of technological exchanges provided by the treaty.

When Model C is solved under the assumption that \((w > c_M > y)\), player L’s best response to all strategies played by player M is still \((Q’, S)\). But since the costs of sanctions exceed the benefits of NPT membership for the non-proliferating player M, his best response to player L’s strategy is to exit the NPT. The proliferator’s best response again depends on the value of \((k)\): he will remain in the treaty when \([(w – kc_M) \geq 0]\), and will leave the treaty when \([(w – kc_M) \leq 0]\). Solving for \((k)\), under the assumption that \((w > c_M > y)\), yields the following equilibria:

\[
\{(E_p, T_N), (Q’, S), \gamma = 1, \delta = 0, k \geq (w/c_M)\} \quad (c.3)
\]

\[
\{(T_p, T_N), (Q’, S), \rho = \delta, 0 \leq \gamma \leq 1, k \leq (w/c_M)\} \quad (c.4)
\]

The value of \((c_M)\) now drives the non-proliferator out of the NPT in both equilibria. As long as the value of \((k)\) is sufficiently low, as in equilibrium (c.3), the proliferator remains within the NPT; when it is too high, both players are driven out of the treaty.
The large state would not want to pursue equilibrium (c.3), since in this case the proliferator retains the benefits of NPT membership while the state not seeking nuclear weapons is driven out of the treaty.

Finally, the model is solved under the assumption that \( c_M > w > y \). Once again, player L’s best response to player M’s possible strategies is \( (Q', S) \). Now, the “basic” cost of sanctions \( (c_M) \) exceeds the benefits of treaty membership for both types of player M. Since the value of \( (k) \) is strictly greater than one, the proliferator’s best response to player L’s strategy is to exit the treaty, yielding the following single, pooling equilibrium:

\[
\{(E_P, E_N), (Q', S), \gamma = \rho, 0 \leq \delta \leq 1\}
\]  

(c.5)

As in Models A and B, when the cost of sanctions is too high, both types of player M are driven out of the NPT.

Targeted sanctions are therefore effective in separating proliferators from non-proliferators only when the basic costs of sanctions \( (c_M) \) are not higher than the benefits conveyed by remaining in the treaty \( (w, y) \), and the additional costs of targeted sanctions for the proliferator \( (k) \) are sufficiently high (equilibrium c.1). By exiting the treaty, the proliferator cuts himself off from the technological exchanges provided by the NPT, and thus faces a much more difficult task in developing a nuclear weapon without outside assistance.

Targeted sanctions were employed against both South Africa and Iraq in efforts to halt their pursuit of nuclear weapons. South Africa never signed the NPT and therefore does not fit these models exactly; but this targeted sanctions model could fit South Africa’s case, if the strategy options from which South Africa chose were not whether to remain within the NPT or not, but rather whether to sign the NPT or not. If this were the
case, then South Africa would fit the equilibria in which the proliferator decides not to be a member of the NPT in its pursuit of nuclear weapons (equilibria c.1, c.4 and c.5). South Africa was forced to pursue its nuclear weapons campaign without the aid of NPT-permitted technology transfers and while subject to both targeted and general sanctions. Although the sanctions were largely imposed too late to effectively halt weapons production, they are believed to have played a large role in limiting the sophistication of South Africa’s weapons program. South Africa is a unique case, however, because it possessed valuable uranium deposits and received a large amount of technical assistance in developing a nuclear program, despite the fact that it was not a member of the NPT.17 For South Africa, these benefits made remaining outside the framework the preferable choice.

Iraq also faced targeted sanctions that had a more direct impact than those imposed on South Africa. Yet Iraq decided to remain within the framework of the NPT while pursuing its weapons program, rendering its behavior more like that of the proliferator in equilibria (c.2) and (c.3). Although the targeted sanctions certainly increased the costs of developing a nuclear weapon, they were not high enough that Iraq chose to withdraw from the treaty and lose the payoff of (w), or to prevent the country from pursuing an advanced program that was only months away from producing a functioning weapon at the time of the Gulf War in 1991. Furthermore, there is evidence to suggest that Iraqi officials deliberately chose to retain NPT membership to deflect suspicion from its clandestine nuclear weapons program.18

---

Note: A “Nervous” player L implementing targeted sanctions fails to separate proliferators from non-proliferators.

If player L believes that it gains utility (g) only when it correctly sanctions a proliferator that is a member of the NPT, then it no longer receives the bonus (g) from sanctioning the non-proliferator that remains within the treaty. Player L may feel nervous about the international community’s outcry if it sanctions a player that is not pursuing nuclear weapons. Under these conditions, and when \((w > y > c_M)\), then the model yields only two equilibria, in which both types of player M choose to remain within the NPT (and player L pursues two different strategies). Because player L is nervous about incorrectly imposing sanctions on a peaceful state, he is unable to separate the proliferators from the non-proliferators.

The model of a “nervous” player L implementing targeted sanctions may be somewhat useful in considering the United States’ current position on nuclear proliferation. The United States endured harsh scrutiny from the international community after the failure to find WMD in Iraq. This may lead the United States to be cautious in its implementation of sanctions against states that it believes are pursuing illicit weapons programs in the future. The reluctance to sanction small states suspected of pursuing nuclear weapons may continue to generate equilibria in which proliferators choose to remain within the NPT.

\(^{19}\) The equilibria of this “nervous sanctions” model, when the benefits of NPT membership exceed the basic cost of sanctions \((w > y > c_M)\), are: \{(T_P, T_N), (Q', S), \rho = \delta, 0 \leq \gamma \leq 1, \delta \geq (c_l/[c_l + g + x]), k \leq (w/c_M)\}; \{(T_P, T_N), (Q', Q), \rho = \delta, 0 \leq \gamma \leq 1, \delta \leq (c_l/[c_l + g + x])\}. Thus the large state cannot separate the proliferators from the non-proliferators. If we assume that \((w > c_M > y)\), then in some cases the non-proliferator is driven out of the NPT. The three equilibria under this assumption are: \{(T_P, E_N), (Q', S), \gamma = 0, \delta = 1, k \leq (w/c_M)\}; \{(T_P, T_N), (Q', Q), \rho = \delta, 0 \leq \gamma \leq 1, \delta \leq (c_l/[c_l + g + x])\}; \{(E_P, E_N), (Q', S), \gamma = \rho, \delta \geq (c_l/[c_l + g + x]), k \geq (w/c_M)\}. Finally, if we assume that \((c_M > w > y)\), then the “nervous sanctions” model yields the following equilibria: \{(T_P, T_N), (Q', Q), \rho = \delta, 0 \leq \gamma \leq 1, \delta \leq (c_l/[c_l + g + x])\}; \{(E_P, E_N), (Q', S), \gamma = \rho, \delta \geq (c_l/[c_l + g + x])\}. 

\(^{19}\) The equilibria of this “nervous sanctions” model, when the benefits of NPT membership exceed the basic cost of sanctions \((w > y > c_M)\), are: \{(T_P, T_N), (Q', S), \rho = \delta, 0 \leq \gamma \leq 1, \delta \geq (c_l/[c_l + g + x]), k \leq (w/c_M)\}; \{(T_P, T_N), (Q', Q), \rho = \delta, 0 \leq \gamma \leq 1, \delta \leq (c_l/[c_l + g + x])\}. Thus the large state cannot separate the proliferators from the non-proliferators. If we assume that \((w > c_M > y)\), then in some cases the non-proliferator is driven out of the NPT. The three equilibria under this assumption are: \{(T_P, E_N), (Q', S), \gamma = 0, \delta = 1, k \leq (w/c_M)\}; \{(T_P, T_N), (Q', Q), \rho = \delta, 0 \leq \gamma \leq 1, \delta \leq (c_l/[c_l + g + x])\}; \{(E_P, E_N), (Q', S), \gamma = \rho, \delta \geq (c_l/[c_l + g + x]), k \geq (w/c_M)\}. Finally, if we assume that \((c_M > w > y)\), then the “nervous sanctions” model yields the following equilibria: \{(T_P, T_N), (Q', Q), \rho = \delta, 0 \leq \gamma \leq 1, \delta \leq (c_l/[c_l + g + x])\}; \{(E_P, E_N), (Q', S), \gamma = \rho, \delta \geq (c_l/[c_l + g + x])\}. 

ISA 2010 22 Dianne R Pfundstein
Failures of the NPT: Summary

Under the current structure of the NPT, the implementation of general sanctions against states suspected of pursuing nuclear weapons fails to separate the proliferators from the non-proliferators. Model A yields only pooling equilibria in which both types of player M choose to remain in the NPT. Even if player L receives a small net gain in utility from sanctioning those players that sign the NPT (g), when the costs of untargeted sanctions are less than the benefits of NPT membership, then the structure fails to separate proliferators from non-proliferators. Implementing targeted sanctions that raise the cost of constructing a nuclear weapon can be effective in separating states seeking nuclear weapons from those with benign intentions: if the additional costs to player M of the targeted sanctions (k) is sufficiently high, the proliferator will reveal its type by exiting the NPT, while the non-proliferator remains within the NPT structure. In reality, the NPT has done a poor job of detecting and punishing proliferators. In the following section I model the Additional Protocol, which was designed to help correct some of the shortcomings of the NPT.

2. The Additional Protocol: A Misguided Attempt to Fix the NPT

The IAEA’s failure to discover Iraq’s nuclear weapons program prior to the Persian Gulf War prompted the international community to search for ways to enhance the nuclear nonproliferation regime. The Additional Protocol (AP) was designed to strengthen the IAEA’s ability to detect illicit nuclear weapons activity. The original NPT limited the IAEA to inspect only a narrow range of sites declared by the state under investigation and cleared with the target government in advance.20 Under the Additional

Protocol, non-nuclear weapons states are required to make broader disclosures about their facilities, including non-nuclear facilities previously outside the scope of the NPT.\textsuperscript{21} The Additional Protocol’s most important provision grants the IAEA “complementary access” (i.e. “special inspection[s]”) to sites not declared by the state to conduct environmental sampling, without lengthy advance notice.\textsuperscript{22} As of 15 December 2009, 94 states have signed and implemented Additional Protocols, including the United States, for which the Additional Protocol went into force on 6 January 2009. Iran signed an Additional Protocol in 2003 but it has not yet gone into force.\textsuperscript{23}

The fact that the AP provides the IAEA with a greater ability to detect illicit nuclear weapons programs should, in theory, deter states that seek to develop nuclear weapons from signing. For the purposes of adapting the NPT signaling game to reflect the conditions imposed by the AP, the following model assumes that the inspections regime has a chance to detect illicit nuclear weapons activity. The first model reflects the structure of the AP as it exists today.

\textit{Hypothesis D: The current structure of the AP is not an effective means of separating proliferators from non-proliferators.}

Once again, the game involves two players: a small state, M, that is suspected of pursuing a nuclear weapons program and that may be either a proliferator (P) with probability ($\rho$) or a non-proliferator (N) with probability (1-$\rho$); and a large state, L, that chooses whether to impose sanctions on the small state (strategies S, S’, S’’).\textsuperscript{21-23}

\begin{footnotesize}
\textsuperscript{22} Hirsch, “The IAEA Additional Protocol,” 144-47.
\end{footnotesize}
maintain the status quo (strategies $Q$, $Q'$, $Q''$). Unlike past games, this model assumes that the large state has a limited ability to detect player M’s type when player M chooses to sign the AP. When player M does not sign the AP, the large state has no ability to detect what type of player M he is facing, as was the case in the NPT models. I assume that, while the inspections could detect the presence of a nuclear weapons program, they could never detect the absence of a nuclear weapons program—that is, they could never determine with certainty that a player was not pursuing nuclear weapons, even though they could determine with certainty that a player was a proliferator. Player L would like to punish a proliferator that he is able to detect.

In the following game, player M chooses whether to sign the AP (strategy A), or refrain from signing the AP and remain within the original framework of the NPT (strategy T). Note that the right half of the game (in which player M does not sign the AP) is identical to the right half of NPT Model A, in which player M decided whether to remain a member of the NPT. The payoff variables remain the same as those from the previous NPT games, with one addition. When the small state is detected as a proliferator and the large state imposes sanctions, the small state receives a punishment or fine of $(f)$, where $(f > c_M)$. In this case, the large state is able to effectively eliminate a weapons program only when player M is detected as a proliferator—under other conditions, the large state implements general, untargeted sanctions. Thus for player L, the payoff associated with player M’s ability to develop nuclear weapons ($-x$) is eliminated only when player M is detected as a proliferator and is sanctioned. This model assumes that player L does incur a cost from implementing sanctions against player M ($c_L > 0$). The game is structured as follows, with $(\pi)$ representing the
probability that player L detects that player M is a proliferator, and \( (\delta) \) and \( (\gamma) \) representing player L’s beliefs that he is at a particular node:

(Figure D.1: Basic Additional Protocol Model)

**AP Model A: Solutions**

The model is solved under the assumption that \( (w > y > c_M) \). Player L’s best response to any combination of strategies pursued by player M is to sanction the proliferator that he is able to detect, and not to impose sanctions under any other circumstances: \( (S, Q', Q'') \). For a separating equilibrium to exist in which the proliferator decides not to sign the AP and the non-proliferator does sign the AP, it must be the case that the proliferator receives a payoff from leaving the NPT equal to or greater than the payoff he would receive by signing the AP, and that the non-proliferator receives a payoff from signing the AP that is greater than or equal to that which she would receive by not signing, given player L’s strategy. Since player L will only
sanction the detected proliferator, the non-proliferating player M is indifferent between signing the AP and not signing the AP under all circumstances, since she receives the same payoff (y) for both strategies.

The calculation for the proliferator is slightly more complicated. Given that the proliferator will be sanctioned if she is detected and will incur a fine of (-f), and given that player L would not impose sanctions in any other case, then the proliferator would choose not to sign the AP if there were any chance that she would be detected. Because the non-proliferator is indifferent between signing the AP and not signing, and given player L’s strategy, there are four possible equilibria in this game that encompass all possible strategy combinations for player M:

\[
\{ (A_p, T_N), (S, Q', Q''), \delta = 0, \gamma = 1, \pi = 0 \} \quad (d.1)
\]

\[
\{ (T_p, A_N), (S, Q', Q''), \gamma = 0, \delta = 1, \pi \geq 0 \} \quad (d.2)
\]

\[
\{ (A_p, A_N), (S, Q', Q''), 0 \leq \delta \leq 1, \rho = \gamma, \pi = 0 \} \quad (d.3)
\]

\[
\{ (T_p, T_N), (S, Q', Q''), 0 \leq \gamma \leq 1, \rho = \delta, \pi \geq 0 \} \quad (d.4)
\]

The most critical feature of this model is the fact that the proliferator signs the AP (strategy \(A_p\)) only when the probability of being detected as rogue is exactly zero (equilibria d.1 and d.3). Because there is no positive incentive to sign the AP, there is no reason for the proliferator to risk detection when he can do just as well by not signing and remaining within the structure of the NPT. When the probability of being detected is greater than zero (equilibria d.2 and d.4), then the proliferator chooses not to sign the AP. This model does yield the desired separating equilibrium, in which the proliferator chooses not to sign an AP and the non-proliferator does (equilibrium d.2), but only because the inspections actually have a chance of detecting a player’s nuclear weapons
activity. If the proliferator does not sign an AP, then the increased inspection capabilities provided by the agreement cannot be applied.24

If the goal of the Additional Protocol is to induce potential proliferators to sign the agreement and then subject them to greater inspections of their nuclear facilities, then this model suggests that the very ability of those inspections to detect the player’s weapons program prevents her from signing. Attempts to increase the ability to detect weapons proliferation thus prevent those inspections from being implemented. If the goal of the AP is to force proliferators to reveal themselves by not signing, then the current structure also fails because there is no deadline by which states must sign. A state’s status as a non-signatory may indicate a conscious decision not to sign an AP, or simply that the state has not yet “played the game” and made a decision about signing.

The fact that so many states (including Iran, which is suspected of pursuing nuclear weapons research) have signed an Additional Protocol suggests that there may be something that this basic model is not capturing. Even non-proliferators should be indifferent between signing the AP and remaining parties to the standard NPT treaty. In the next model, I explore the equilibria that arise when states have a positive incentive to sign an AP.

_Hypothesis E: When small states believe that there is a positive incentive to sign an AP, and when the probability of detecting a proliferator is sufficiently high, then the AP may serve as a mechanism for separating proliferators from non-proliferators._

---

24 Note that solving the model under the assumption that \((w > c_M > y)\), or under the assumption that \((c_M > w > y)\), yields the same set of equilibria as solving under the conditions stipulated above. Because player L always plays a strategy of \((S, Q', Q'')\), the value of \((c_M)\) in relation to \((w)\) and \((y)\) never has any bearing on the solutions to the model.
In the following model, states that sign an AP receive a bonus (b). A state may feel that signing an AP produces intangible benefits, such as goodwill or legitimacy in the eyes of the international community, or tangible benefits, such as increased trade with the large state. Thus both a proliferator and a non-proliferator may perceive that there is a positive incentive to sign an AP. Because a state does not receive any official payment for signing an AP, I assume that the value of this bonus is small: \((b < c_M)\). All other payoff variables remain the same as those in previous models, and \((c_L > 0)\). The game is structured as follows:

(Figure E.1: AP “Bonus” Model)

**AP Model B: Solutions**

The model is solved under the assumption that \((w > y > c_M)\). Player L’s best response to all of player M’s possible strategies is to sanction the detected proliferator, and not to impose sanctions under any other circumstances \((S, Q’, Q’’)\). Because there is
now a bonus associated with signing an AP, the non-proliferator’s best response to player L’s strategy is to sign an AP. The proliferator makes a slightly more complicated calculation. Because there is now a bonus associated with signing an AP, the proliferating player M would prefer to sign an AP when his type is not detected. However, the proliferator knows that by signing an AP, he would risk being detected and must therefore decide what level of “risk” of detection (π) he is willing to accept. For the proliferator to sign an AP, it must be the case that the expected value of the payoff that he receives from signing meets or exceeds the payoff he would receive by not signing, given player L’s strategy. The proliferator will therefore sign an AP when \((\pi)(b – f) + (1 – \pi)(b + w) \geq w\), and will not sign when the reverse is true: \([\pi)(b – f) + (1 – \pi)(b + w) \leq w\). Solving for (π), the model yields the following equilibria:

\[
\{(T_P, A_N), (S, Q’, Q’’), \delta = 1, \gamma = 0, \pi \geq \frac{b}{(f+w)}\} \tag{e.1}
\]

\[
\{(A_P, A_N), (S, Q’, Q’’), 0 \leq \delta \leq 1, \rho = \gamma, \pi \leq \frac{b}{(f+w)}\} \tag{e.2}
\]

In this game, there is finally a meaningful equilibrium that separates the proliferators from those not pursuing nuclear weapons (e.1). Under these conditions, when the probability of being detected (π) is sufficiently high, the proliferator does not sign an AP, while the non-proliferator does choose to sign. Note, however, that the probability of being detected as a proliferator in (e.1) is greater than zero, while the proliferator signed an AP in AP Model A only when the probability of detection was exactly zero.

In the pooling equilibrium (e.2), the probability of detection (π) is sufficiently low that both players choose to sign the AP. As the fine from being detected as a proliferator and sanctioned (f) increases, so the probability of detection (π) must decrease in order for the proliferating player M to sign the AP. Assuming that there is perceived to be a bonus,
(b), associated with signing the NPT, then the second equilibrium (e.2) may represent Iran’s decision to sign the AP in December 2003; however, Iran’s Additional Protocol never went into force. Despite Iran’s declaration in December that its nuclear facilities are intended for peaceful purposes, the IAEA remains convinced that Iran has not fully disclosed the extent of its nuclear activities and facilities. It may be that the perceived probability of detection has increased, leading Iran to back away from the commitments of an Additional Protocol, as these models would suggest.

Note that solving this model under either of the following assumptions yields the same equilibria as solving under the conditions stipulated above: \((w > c_M > y)\) and \((c_M > w > y)\). Because player L always plays the strategy \((S, Q’, Q”)\), the value of \((c_M)\) in relation to \((w)\) and \((y)\) never factors into player M’s best response function.

**Challenges of the Additional Protocol: Summary**

The Model Additional Protocol was intended to correct some of the shortcomings of the original NPT, particularly the weak inspections process that allowed member states such as Iraq to develop nuclear weapons undetected. AP Model A reveals that, under the literal provisions of the AP, proliferators would only sign the agreement if the probability of detecting its nuclear weapons ambitions was exactly zero, and even non-proliferators would be indifferent about signing. Since so many states, including suspected proliferators, have signed an AP, they may believe that there are positive incentives to

---


sign. When states perceive that there is a benefit associated with signing an AP, as in AP Model B, then there can be a meaningful separation of players.

This raises an important question: what are the goals of the NPT-AP nonproliferation framework? If the goal of the nonproliferation regime is for potential proliferators to sign an AP and thereby subject themselves to more intrusive inspections, then the agreement as it currently stands and as it is modeled in AP Models A and B falls short, since raising the effectiveness of inspections actually drives potential proliferators to avoid signing. Note that the pooling equilibrium in AP Model B (e.2) occurs only at a fairly low probability of successful detection, as the value of (b) in the numerator of the fraction determining the value of (π) is quite small in relation to (w) and (f), signifying that even a modest chance of successfully detecting violations will deter the proliferator from signing.

If, on the other hand, the goal of the AP is to force proliferators to reveal themselves by not signing, then the current framework also fails. Because there is no deadline by which states must sign, we cannot identify the “type” of a player that has not signed—she may remain outside the framework due to institutional inertia or lack of interest. Even if rejecting the Additional Protocol could reveal a state’s type, failure to sign an AP does not prevent the state from receiving the technology transfers provided under the terms of the NPT. Could the NPT-AP system be redesigned to more effectively combat nuclear weapons proliferation? I address this issue in the next section of this paper.
3. Restructuring the NPT-AP: A Normative Model

The redesigned treaty structure should accomplish one of two tasks: encourage potential proliferators to sign an AP with a high probability of successful detection; or, force potential proliferators to reveal themselves and then deny them the benefits of NPT membership. To accomplish these goals, the inspections process must be highly capable, and states that do not sign and ratify an Additional Protocol by a certain deadline must be expelled from the NPT. The following model illustrates an NPT-AP structure that will be more effective in curtailing nuclear proliferation.

*Hypothesis F:* Forcing states to choose whether to sign an AP or leave the NPT, and offering positive incentives to sign an AP, can cause proliferators to separate from non-proliferators, or cause both types of state to sign an AP even with a significant probability of detecting violations.

In the following game, the small state must choose whether to sign an AP (strategy A) or exit the NPT (strategy E). Once again, signing an AP grants the large state a limited ability to detect a proliferator’s status, and the probability of detection is represented by \( \pi \). The left side of this game is the same as that of AP Model B, with a positive incentive \( b \) associated with signing the AP. The right side of the model is identical to the *left* side of the earliest NPT model presented in this paper, and represents the payoffs that the players receive when the small state does not sign an AP and exits the NPT. Note that when the small state chooses to leave the NPT, she no longer receives the benefits of \( w \) and \( y \) associated with the transfer of peaceful nuclear energy technologies under the structure of the NPT. All payoff variables remain the same as those in previous models, and the game is structured as follows:
NPT-AP Normative Model: Solutions

The model is solved under the assumption that \((w > y > c_M)\). For all possible strategies pursued by player M, player L’s best response is to sanction those players whose proliferation it is able to detect and not to impose sanctions otherwise \((S, Q', Q'')\). For a separating equilibrium to exist in which the proliferator exits the NPT and the non-proliferator signs an AP, it must be true that the proliferator receives a payoff from leaving the NPT that is greater than or equal to that which it would receive from signing an AP, and that the peaceful player receives a payoff from signing an AP that is greater than or equal to the payoff that it would receive from exiting the NPT, given player L’s strategy. Because player L plays \((S, Q', Q'')\), then the non-proliferator’s best response is to sign an AP and receive the payoff of \((b + n)\). The proliferator must again consider the possibility that signing an AP will grant the large state the ability to detect its weapons;
but the stakes are now much higher, because if she chooses not to sign an AP, then player M loses the benefits of nuclear technology transfer (w). Thus the proliferating player M will not sign an AP when \([(\pi)(b – f) + (1 – \pi)(b + w) \leq 0]\), and will sign an AP when the reverse is true: \([(\pi)(b – f) + (1 – \pi)(b + w) \geq 0]\). Solving for \((\pi)\), given player L’s strategy, the model yields the following equilibria:

\[
\begin{align*}
\{(E_P, A_N), & (S, Q’, Q’’), \delta = 1, \gamma = 0, \pi \geq [(b+w)/(f+w)]\} & \quad \text{(f.1)} \\
\{(A_P, A_N), & (S, Q’, Q’’), 0 \leq \delta \leq 1, \gamma = \rho, \pi \leq [(b+w)/(f+w)]\} & \quad \text{(f.2)}
\end{align*}
\]

In the first, separating equilibrium (f.1), the value of \((\pi)\) is sufficiently high that the proliferator decides not to sign an AP, exits the NPT and surrenders the benefits of technology transfers (w). In the second equilibrium, the value of \((\pi)\) is sufficiently low that both types of player M will sign an AP. Note that because player L is pursuing a strategy of \((S, Q’, Q’’\)), the relative values of (w), (y) and \((c_M)\) do not affect the equilibria, and the same sets of equilibria are obtained when the model is solved under the assumption that \((w > c_M > y)\) or that \((c_M > w > y)\).

The crucial feature of these equilibria is the value of \((\pi)\) under which the proliferator will sign an AP or decide to leave the NPT. Note that the numerator of the fraction determining the value of \((\pi)\) is now \((b+w)\), whereas in AP Model B, the value of the numerator was only \((b)\) (equilibria e.1 and e.2). Since the value of \((b)\) is assumed to be quite small in comparison to the other variables, AP Model B indicated that the proliferator would refuse to sign an AP (but retain the benefits of the NPT) at a very low threshold value of \((\pi)\). In other words, according to AP Model B, if the inspections had even a small chance of succeeding, the proliferator would not sign an AP. Since the large state presumably wants its inspections to be effective, this means that such an equilibrium
is not necessarily an appropriate goal. And in AP Model B, a state that chose not to sign an AP remained a member of the NPT and continued to receive technical assistance from other states.

Under the normative model presented above, the threshold value of ($\pi$) is much higher, as the numerator now includes the term (w). The value of the technical advantage conferred by the NPT (w) did not factor into the equilibria in the previous AP Models because states received those benefits regardless of whether they signed the AP. Under this normative model, however, the state loses these technology transfers if it chooses not to sign an AP. Because there is so much more to lose from not signing an AP, the proliferator will choose to exit the NPT structure at a much higher probability of being detected—that is, at a higher threshold value of ($\pi$). This means that the original Additional Protocol model (AP Model B) was actually more likely to cause states to separate than the NPT-AP Normative Model, given constant values of (b), (w) and (f); however, such separation was meaningless because states that chose not to sign the AP still received nuclear energy technologies. In the NPT-AP Normative Model, the proliferating state is less likely to separate, i.e. less likely to leave the NPT and more likely to sign an AP, but when she does choose not to sign an AP, she loses the benefits of technology transfer (w). When the rogue state does choose to sign an AP in the normative model presented above, she submits herself to inspections that have a much greater chance of detecting her proliferation.

Finally, the separating equilibrium in the normative model becomes very meaningful when states face a deadline by which they must decide whether to sign the AP or leave the NPT. Since there are only two equilibria in this game, one in which both
types of player M sign the NPT, and one in which only the non-proliferating player M signs an AP, then a state that chooses not to sign an AP could be assumed to be a proliferator and sanctioned accordingly. On the other hand, a state that does choose to sign an AP does not necessarily harbor benign intentions, but she does grant the IAEA the ability to inspect her nuclear facilities at a higher likelihood of successfully detecting violations. This structure forces proliferators to choose whether to sign an AP and risk having its weapons detected, or to exit the NPT and thereby signal to the world its nuclear ambitions.

**A New Look at the NPT: Limitations and Conclusions**

The Additional Protocol’s creators hoped to prevent another failure of detection like that which occurred in Iraq during the 1980s. States that sign an Additional Protocol agree to submit themselves to inspections much broader than those provided in the terms of the original NPT. Because signing an AP is not required of all NPT members, and because there is no deadline by which states must sign, the current framework has only a limited ability to check nuclear weapons proliferation.

The Normative AP Model presented herein corrects some of these problems. By forcing states to choose whether to sign an AP or leave the NPT, and by establishing a deadline by which they must make this decision, this new version of the NPT-AP structure may be better able to prevent proliferation. When proliferators do sign an AP, they grant the IAEA the ability to inspect a much wider range of their nuclear facilities, with a much higher probability of successfully detecting violations. Furthermore, the normative model indicates that a state that chooses not to sign an AP must be a proliferator, and may be sanctioned accordingly.
The successful implementation of this structure depends, however, on a number of assumptions. First, it assumes that states cannot obtain nuclear materials and technologies outside the NPT framework. The discovery of the Khan network and so-called “proliferation rings” suggests that this may not be a realistic assumption. This is a general flaw of the treaty structure itself and not merely limited to the models in this paper. Second, for the sake of simplicity, these models assume that player L consists of one large state. In some cases, it may be possible that a single state takes on the role of enforcing the provisions of the NPT, but in many other cases, it will be a collection of states attempting to detect and punish violations. If player L is really a collection of states, then the small state will be more likely to doubt the credibility of inspections and sanctions. This would make a potential proliferator more likely to remain within the treaty structure and to sign an AP than the normative model would suggest.

These models also present no opportunity to evaluate the problem of “false positives.” The failure to find WMD in Iraq after the 2003 invasion has likely raised the burden of proof for any state or organization claiming to have detected a proliferator and further complicates the problems of verification and enforcement. The successful implementation of the normative model presented in this paper and of the current NPT-AP framework depends on the ability to detect violations and enforce the terms of the treaty. I suggest that ejecting those states that do not sign an AP and establishing a deadline for signing may be more effective than the current NPT structure, but it is not necessarily clear who would enforce this deadline, and what the penalties would be for non-compliance. Similarly, even if the model could successfully separate proliferators

from non-proliferators, there would still be a challenge in enforcing the will of the international nonproliferation regime. North Korea left the NPT in 2003 and later tested a nuclear weapon, thereby identifying itself as a proliferator, yet the international community still struggles to contain North Korea’s nuclear program. The improvements suggested in this paper would be incremental, at best, but still worth pursuing in the interest of preventing future proliferation.

The models presented in this paper are designed to evaluate the incentive structure of the NPT as it exists today, and to suggest some incremental improvements to the nonproliferation regime that may be better at preventing future proliferation. The current challenges of containing the Iranian and North Korean nuclear programs suggest, however, that current proliferation has moved beyond the reach of the NPT. The problems of enforcement and verification plaguing the NPT are not unique to the nuclear nonproliferation regime; however, it is time for the international community to confront the fact that this supply-side approach to containing nuclear weapons proliferation has fallen short. The declared nuclear weapons states do not hold a monopoly on nuclear energy technologies or even nuclear weapons, as NPT non-members India, Pakistan and Israel have all developed nuclear weapons despite the treaty’s provisions. Rather, the international community must seriously confront the motivations driving states to pursue nuclear weapons. Robert Litwak argues that Libya surrendered its WMD program in exchange for an implicit guarantee of regime survival; he further notes Colin Powell’s  

28 India and Pakistan both received aid from outside actors that belonged to the NPT. Some of this aid occurred before the creation of the NPT and some directly violated the terms of the treaty. See Praful Bidwai and Achin Vanaik, New Nukes: India, Pakistan and Global Nuclear Disarmament (New York: Olive Branch Press, 2000), 61-65. Israel is probably the only country that has developed a nuclear weapons program without membership in the NPT and without substantial outside assistance. However, its program was already well under way by the time the NPT was implemented, and it did receive some help from France in the wake of the Suez crisis of 1956. See Avner Cohen, Israel and the Bomb (New York: Columbia University Press, 1998), 53-59.
concern that the 2003 war against Iraq may have accelerated rather than halted other states’ nuclear weapons programs. 29 Although securing the supply of nuclear materials is an important goal, it is equally important that the United States and the rest of the international community acknowledge how their behavior may generate demand for nuclear weapons.

The suggestion that the NPT may not be the appropriate framework through which to address the Iranian and North Korean nuclear programs does not mean that the treaty is not useful or important. Securing the world’s nuclear materials and technologies will remain vitally important for preventing non-state actors and terrorist groups from acquiring nuclear weapons. But preventing states from acquiring nuclear weapons will require more than a focus on the supply-side issues of controlling nuclear materials and limiting access to centrifuges. It is time for the international community to confront the demand side of the equation and to construct a nonproliferation framework that more directly addresses states’ reasons for seeking nuclear weapons. Taking a new look at current arms control agreements may be a good place to start, but such frameworks are likely to be most successful where they are least needed, and least successful for addressing the most challenging cases of nuclear proliferation in the twenty-first century.

Works Cited


