Spreading Temptation

Proliferation and Peaceful Nuclear Cooperation Agreements

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Peaceful nuclear cooperation—the transfer of nuclear technology, materials, or knowledge from one state to another for peaceful purposes—has figured prominently in international politics since the dawn of the atomic age.[1] During an address before the United Nations General Assembly in December 1953, U.S. President Dwight Eisenhower encouraged the nuclear suppliers to promote international peace and prosperity by sharing their technology and know-how.[2] Since this "atoms for peace" speech, countries have signed more than 2,000 bilateral civilian nuclear cooperation agreements (NCAs) pledging to exchange nuclear technology, materials, or knowledge for peaceful purposes.[3] Recently, NCAs have been signed at an increasingly rapid rate, as countries look for solutions to global climate change and for assistance in combating energy shortages and high oil prices. For example, since coming to office in May 2007, French President Nicolas Sarkozy has signed NCAs with a plethora of states seeking to begin or revive civilian nuclear programs, including Algeria, Jordan, Libya, Qatar, the United Arab Emirates, and Vietnam.

This article examines the relationship between peaceful nuclear cooperation and nuclear weapons proliferation. Specifically, it explores whether countries receiving civilian nuclear aid over time are more likely to initiate weapons programs and build the bomb. The conventional wisdom is that civilian nuclear cooperation does not lead to proliferation. Most scholars argue that nuclear weapons spread when states have a demand for the bomb—not when they have the technical capacity to proliferate.[4] Those who recognize the im-

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1. I use the terms "peaceful nuclear cooperation," "civilian nuclear cooperation," and "nuclear assistance" interchangeably throughout this article.
2. Dwight D. Eisenhower, "Address by Mr. Dwight D. Eisenhower, President of the United States of America, to the 470th Plenary Meeting of the United Nations General Assembly," December 8, 1953, http://www.iaea.org/About/history_speech.html.
3. See Matthew Fuhrmann, "Taking a Walk on the Supply Side: The Determinants of Civilian Nuclear Cooperation," *Journal of Conflict Resolution*, Vol. 53, No. 2 (April 2009), pp. 181–208.
4. See, for example, George H. Quester, *The Politics of Nuclear Proliferation* (Baltimore, Md.: Johns

International Security, Vol. 34, No. 1 (Summer 2009), pp. 7–41

portance of the supply side of proliferation argue that certain types of nuclear assistance enable countries to build nuclear weapons but that others are innocuous or even positive from a nonproliferation standpoint. Nuclear suppliers, for instance, generally restrict the sale of uranium enrichment or plutonium reprocessing facilities because these can be used directly to produce fissile material for a bomb, but suppliers routinely build research or power reactors in other countries and train foreign scientists.[5] A recent study finds that countries receiving enrichment and reprocessing facilities, bomb designs, or significant quantities of weapons-grade fissile material are more likely to acquire the bomb.[6] The implication of this research is that other forms of atomic assistance do not lead to the spread of nuclear weapons.

This article argues that the conventional wisdom is wrong—and dangerous. All types of civilian nuclear assistance raise the risks of proliferation. Peaceful nuclear cooperation and proliferation are causally connected because of the dual-use nature of nuclear technology and know-how.[7] Civilian cooperation provides technology and materials necessary for a nuclear weapons program and helps to establish expertise in matters relevant to building the bomb. I develop four hypotheses based on this general insight. First, receiving civilian nuclear assistance over time increases the likelihood that states will begin nuclear weapons programs because it reduces the expected costs of such a campaign and inspires greater confidence among leaders that the bomb could be successfully developed. Second, militarized disputes with other countries condition the effect of civilian nuclear assistance on program initiation. The likelihood that nuclear assistance causes countries to begin weapons programs increases as their security environments worsen. Third, peaceful aid increases

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Hopkins University Press, 1973); Etel Solingen, "The Political Economy of Nuclear Restraint," *International Security,* Vol. 19, No. 2 (Fall 1994), pp. 126–169; Mitchell Reiss, *Bridled Ambition: Why Countries Constrain Their Nuclear Capabilities* (Washington, D.C.: Woodrow Wilson Center Press, 1995); Scott D. Sagan, "Why Do States Build Nuclear Weapons? Three Models in Search of a Bomb," *International Security,* Vol. 21, No. 3 (Winter 1996/97), pp. 54–86; T.V. Paul, *Power versus Prudence: Why Nations Forgo Nuclear Weapons* (Montreal: McGill-Queens University Press, 2000); Jacques E.C. Hymans, *The Psychology of Nuclear Proliferation: Identity, Emotions, and Foreign Policy* (Cambridge: Cambridge University Press, 2006); and Etel Solingen, *Nuclear Logics: Contrasting Paths in East Asia and the Middle East* (Princeton, N.J.: Princeton University Press, 2007).

5. See, for example, Office of the Press Secretary, "Statement by Bush on Nonproliferation of Nuclear Weapons Treaty" (Washington, D.C.: White House, July 1, 2008), http://www.america.gov/st/texttrans-english/2008/July/20080701141025eaifas0.9588587.html. The guidelines of the Nuclear Suppliers Group, an informal organization of countries designed to harmonize nuclear export policies, explicitly discourage the supply of enrichment or reprocessing facilities.

6. Matthew Kroenig, "Importing the Bomb: Sensitive Nuclear Assistance and Nuclear Proliferation," *Journal of Conflict Resolution,* Vol. 53, No. 2 (April 2009), pp. 161–180.

7. On the dual-use dilemma, see Matthew Fuhrmann, "Exporting Mass Destruction: The Determinants of Dual-Use Trade," *Journal of Peace Research,* Vol. 45, No. 5 (September 2008), pp. 633–652.

the probability that countries will successfully build nuclear weapons. Fourth, this is especially true when a country's security environment deteriorates.

To test these hypotheses, I produced a data set on civilian nuclear assistance based on the coding of all NCAs signed from 1945 to 2000.[8] A combination of qualitative and quantitative analysis yields support for my arguments, even when controlling for the other variables thought to influence proliferation. The results from my statistical analysis indicate that other factors, such as industrial capacity and membership in the nuclear Nonproliferation Treaty (NPT), also have significant effects on proliferation. But peaceful cooperation is among the few variables that is consistently salient in explaining both nuclear weapons program onset and weapons acquisition.

The conclusions reached in this article should raise concern among policymakers in the United States and abroad. For more than fifty years, the international community has behaved as though peaceful atomic assistance could serve as an effective arms control policy. The United Nations established the International Atomic Energy Agency (IAEA) in 1957 to help bring nuclear energy to countries around the world and establish a system of safeguards to ensure that countries did not use peaceful assistance for military purposes.[9] A decade later, Eisenhower's notion of "atoms for peace" was codified in the NPT, which obligates signatories to forgo nuclear weapons in exchange for access to nuclear technology for peaceful purposes. The findings in this article reveal that efforts to promote the spread of nuclear technology for peaceful use have largely backfired. Given that a nuclear energy renaissance looms on the horizon, the United States and other supplier countries should reevaluate their export practices.

Previous research has noted that illicit proliferation networks operated by "rogue" states can contribute to nuclear proliferation.[10] Most infamously, the Pakistan-based Abdul Qadeer (A.Q.) Khan network served as a "Wal-Mart for

8. I end the analysis in 2000 because of data restrictions. More than 2,000 agreements were signed during this period. These efforts build on James F. Keeley's work and are described in more detail below. See Keeley, "A List of Bilateral Civilian Nuclear Cooperation Agreements," University of Calgary, 2003.

9. See Leonard Weiss, "Atoms for Peace," *Bulletin of the Atomic Scientists*, Vol. 59, No. 6 (November–December 2003), p. 40.

10. See, for example, Chaim Braun and Christopher F. Chyba, "Proliferation Rings: New Challenges to the Nuclear Nonproliferation Regime," *International Security*, Vol. 29, No. 2 (Fall 2004), pp. 5–49; Alexander H. Montgomery, "Ringing in Proliferation: How to Dismantle an Atomic Bomb Network," *International Security*, Vol. 30, No. 2 (Fall 2005), pp. 153–187; Sheena Chestnut, "Illicit Activity and Proliferation: North Korean Smuggling Networks," *International Security*, Vol. 32, No. 1 (Summer 2007), pp. 80–111; and Gordon Corera, *Shopping for Bombs: Nuclear Proliferation, Global Insecurity, and the Rise and Fall of the A.Q. Khan Network* (Oxford: Oxford University Press, 2006).

proliferators," selling weapons-relevant technology to Iran, North Korea, and Pakistan, and possibly other countries.[11] This article does not dispute that illicit commercial activities conducted by second-tier suppliers can facilitate the spread of nuclear weapons. Rather, it demonstrates that legal nuclear commerce conducted under the auspices of the NPT can also have damaging effects for national and international security.

The next section offers an overview of the existing research on the causes of nuclear proliferation. In subsequent sections, I lay out my hypotheses linking peaceful nuclear cooperation and proliferation. I then draw from several cases to illustrate the plausibility of my argument and describe how civilian nuclear cooperation can contribute to the spread of nuclear weapons. Next I describe the statistical tests used to evaluate the hypotheses and discuss the results. I conclude by summarizing the article's findings, underscoring the contributions of this study, and offering directions for future research.

Why Do States Pursue Nuclear Weapons?

There is a rich literature on why states pursue nuclear weapons. In recent years this scholarship has turned its attention toward factors influencing a country's demand for nuclear weapons and has treated technological considerations as a secondary concern. For example, Scott Sagan argues that scholars and practitioners should focus on "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.'"[12] The extant literature identifies a number of demand-side considerations that are salient in explaining nuclear proliferation, including: a state's security environment, international norms, domestic politics, and intangible or symbolic motivations.[13] These studies are often dismissive of supply-side approaches because several countries—most notably Germany and Japan—have the technical capacity to build nuclear bombs but have chosen not to do so. This critique fails to

11. IAEA Director-General Mohamed ElBaradei compared the Khan network to Walmart. See especially Corera, *Shopping for Bombs.*
12. Sagan, "Why Do States Build Nuclear Weapons?" p. 56 (emphasis in original).
13. Quester, *The Politics of Nuclear Proliferation;* Richard K. Betts, "Paranoids, Pygmies, Pariahs, and Nonproliferation," *Foreign Policy,* No. 26 (Spring 1977), pp. 157–183; Sagan, "Why Do States Build Nuclear Weapons?"; Hymans, *The Psychology of Nuclear Proliferation;* William Epstein, "Why States Go—and Don't Go—Nuclear," *Annals of the American Academy of Political and Social Science,* Vol. 430 (March 1977), pp. 16–28; Lewis A. Dunn and Herman Kahn, *Trends in Nuclear Proliferation, 1975–1995: Projections, Problems, and Policy Options* (Washington, D.C.: Hudson Institute, 1976); Ashok Kapur, *International Nuclear Proliferation: Multilateral Diplomacy and Regional Aspects* (New York: Praeger, 1979); and Solingen, *Nuclear Logics.*

consider, however, that technology-based arguments are probabilistic, not deterministic.[14]

Recent research focuses on the supply side of nuclear proliferation. This author has examined why states transfer dual-use technology that could be employed to build weapons of mass destruction and why countries export nuclear technology, materials, and know-how for peaceful purposes.[15] Matthew Kroenig has analyzed reasons why states provide "sensitive" nuclear assistance to help other countries to build nuclear weapons.[16] Other quantitative studies examine the links between technical capacity and the spread of nuclear weapons.[17] These studies have found that indicators of economic capacity, such as a state's gross domestic product (GDP) and the nuclear-related resources it possesses, are correlated with weapons proliferation. Despite its many contributions, this work has not adequately addressed the links between civilian nuclear cooperation and weapons proliferation. In particular, it fails to sufficiently test the argument that the diffusion of knowledge and technology makes proliferation more likely. Dong-Joon Jo and Erik Gartzke include a variable in their model measuring the natural log of the number of years between 1938 and time *t*, which allows the authors to test the systemic effects of diffusion, but diffusion does not occur equally across all states.[18] Kroenig examines the relationship between nuclear assistance and proliferation more directly, although he does not explore how peaceful aid can encourage countries to pursue nuclear weapons.[19] He also does not examine how strategic factors such as militarized interstate disputes could interact with nuclear assistance. Kroenig argues that only certain sensitive nuclear assistance helps countries acquire the bomb.[20] This type of aid makes up a mere fraction of all nuclear assistance,

14. For more on this point, see Sonali Singh and Christopher R. Way, "The Correlates of Nuclear Proliferation: A Quantitative Test," *Journal of Conflict Resolution,* Vol. 48, No. 6 (December 2004), pp. 859–885.
15. Fuhrmann, "Exporting Mass Destruction"; and Fuhrmann, "Taking a Walk on the Supply Side."
16. Matthew Kroenig, "Exporting the Bomb: Why States Provide Sensitive Nuclear Assistance," *American Political Science Review,* Vol. 103, No. 1 (February 2009), pp. 113–133.
17. See Singh and Way, "The Correlates of Nuclear Proliferation"; Dong-Joon Jo and Erik Gartzke, "Determinants of Nuclear Weapons Proliferation," *Journal of Conflict Resolution,* Vol. 51, No. 1 (February 2007), pp. 167–194; and Kroenig, "Importing the Bomb." For an earlier study, see Stephen M. Meyer, *The Dynamics of Nuclear Proliferation* (Chicago: University of Chicago Press, 1984).
18. Jo and Gartzke, "The Determinants of Nuclear Weapons Proliferation." For example, a state that receives a significant amount of civilian nuclear assistance (e.g., India) will experience a great deal of diffusion, whereas a state that receives no assistance (e.g., Lebanon) will not experience the same effects.
19. Kroenig, "Importing the Bomb."
20. He defines "sensitive nuclear assistance" as assistance in the design and construction of nuclear weapons, the supply of weapons-grade fissile material, or assistance in building uranium enrichment or plutonium reprocessing facilities.

however. Of the more than 2,000 bilateral civilian nuclear cooperation agreements signed from 1945 to 2000, only 14 (less than 0.7 percent) meet Kroenig's definition of sensitive assistance. I argue that the relationship between nuclear aid and atomic weapons is much broader. All forms of atomic assistance—whether it involves training scientists, supplying reactors, or building fuel fabrication facilities—raise the likelihood that nuclear weapons will spread.

Civilian Nuclear Cooperation and the Bomb

Decades ago scholars offered a "technological momentum" hypothesis, suggesting that countries are more likely to pursue nuclear weapons once they obtain civilian nuclear technology and expertise.[21] The logic driving this hypothesis is that the accumulation of nuclear technology and knowledge leads to incremental advances in the field of nuclear engineering that ultimately makes progress toward developing a nuclear weapons capability before a formal decision to build the bomb is made.[22] John Holdren illustrates this argument well when he states that the proliferation of nuclear power represents the spread of an "attractive nuisance."[23] This logic highlights the relationship between the peaceful and military uses of the atom, but it underplays the political dimensions of proliferation.[24]

Peaceful nuclear cooperation and nuclear weapons are related in two key respects. First, all technology and materials linked to a nuclear weapons program have legitimate civilian applications. For example, uranium enrichment and plutonium reprocessing facilities have dual uses because they can produce fuel for power reactors or fissile material for nuclear weapons. Second, civilian nuclear cooperation increases knowledge in nuclear-related matters. This knowledge can then be applied to weapons-related endeavors. Civilian nu-

21. Lawrence Scheinman, *Atomic Energy Policy in France under the Fourth Republic* (Princeton, N.J.: Princeton University Press, 1965); Dunn and Kahn, *Trends in Nuclear Proliferation;* Richard N. Rosecrance, *The Dispersion of Nuclear Weapons: Strategy and Politics* (New York: Columbia University Press, 1964); and William C. Potter, *Nuclear Power and Nonproliferation: An Interdisciplinary Perspective* (Cambridge, Mass.: Oelgeschlager, Gunn, and Hain, 1982).
22. Potter, *Nuclear Power and Nonproliferation;* John Holdren, "Nuclear Power and Nuclear Weapons: The Connection Is Dangerous," *Bulletin of the Atomic Scientists,* Vol. 39, No. 1 (January 1983), pp. 40–45; Roberta Wohlstetter, "U.S. Peaceful Aid and the Indian Bomb," in Albert Wohlstetter, Victor Gilinsky, Robert Gillette, and Roberta Wohlstetter, *Nuclear Policies: Fuel without the Bomb* (Cambridge, Mass.: Ballinger, 1978), pp. 57–72; and Peter Lavoy, "Nuclear Myths and the Causes of Nuclear Proliferation," in Zachary S. Davis and Benjamin Frankel, eds., *The Proliferation Puzzle: Why Nuclear Weapons Spread (and What Results)* (Portland, Ore.: Frank Cass, 1993), pp. 192–212.
23. Holdren, "Nuclear Power and Nuclear Weapons," p. 42.
24. Meyer, *The Dynamics of Nuclear Proliferation;* Matthew Bunn, "Realist, Idealist, and Integrative Approaches to Proliferation Policy," Harvard University, 2003.

clear programs necessitate familiarity with the handling of radioactive materials, processes for fuel fabrication and materials having chemical or nuclear properties, and the operation and function of reactors and electronic control systems. They also provide experience in other crucial fields, such as metallurgy and neutronics.[25] These experiences offer "a technology base upon which a nuclear weapon program could draw."[26]

These linkages suggest that peaceful nuclear assistance reduces the expected costs of a weapons program, making it more likely that a decision to begin such a program will be made. Considerable political and economic costs—such as international sanctions, diplomatic isolation, and strained relationships with allies—can accompany nuclear weapons programs.[27] Leaders may be reluctant to take on these burdens unless they believe that a weapons campaign could succeed relatively quickly.[28] As Stephen Meyer argues, "When the financial and resource demands of [beginning a weapons program] become less burdensome, states might opt to proceed . . . under a balance of incentives and disincentives that traditionally might have been perceived as insufficient for a proliferation decision."[29]

Sometimes, nuclear assistance can cause leaders to initiate nuclear weapons programs in the absence of a compelling security threat. This usually happens when scientists and other members of atomic energy commissions convince the political leadership that producing a nuclear weapon is technologically possible and can be done with relatively limited costs.[30] Scientists do not always push leaders down the nuclear path, but in many cases they do.[31] Leaders are persuaded by this lobbying because they are keenly aware that the quicker the bomb can be developed, the less likely other national priorities will suffer.

Although nuclear assistance occasionally produces bomb programs in the

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25. Donald MacKenzie and Graham Spinardi, "Tacit Knowledge, Weapons Design, and the Uninvention of Nuclear Weapons," *American Journal of Sociology*, Vol. 101, No. 1 (July 1995), pp. 44–99.
26. U.S. Congress, United States Office of Technology Assessment, *Technologies Underlying Weapons of Mass Destruction* (Washington, D.C.: U.S. Government Printing Office, December 1993), No. OTA-BP-ISC-115, p. 153.
27. See, for example, Solingen, *Nuclear Logics*.
28. Ted Greenwood, Harold A. Feiveson, and Theodore B. Taylor, *Nuclear Proliferation: Motivations, Capabilities, and Strategies for Control* (New York: McGraw-Hill, 1977), p. 150.
29. Meyer, *The Dynamics of Nuclear Proliferation*, p. 143.
30. Peter Liberman, "The Rise and Fall of the South African Bomb," *International Security*, Vol. 26, No. 2 (Fall 2001), pp. 45–86; Lavoy, "Nuclear Myths and the Causes of Nuclear Proliferation"; Matthew Bunn, "Civilian Nuclear Energy and Nuclear Weapons Programs: The Record," working draft, Belfer Center for Science and International Affairs, Harvard University, June 29, 2001.
31. In Germany and Brazil, for example, scientists lobbied leaders not to develop the bomb. I thank Etel Solingen for this insight.

absence of a security threat, the relationship between such assistance and proliferation is usually more nuanced. Countries that have received considerable assistance are especially likely to initiate bomb programs when threats arise because they have greater demand for the strategic advantages that nuclear weapons offer.[32] In other words, peaceful nuclear assistance typically conditions the effect that a security environment has on a state's political decision to begin a weapons program. A state that suffers a defeat in war or feels threatened for another reason is unlikely to initiate a program if it lacks a developed civilian nuclear program. Without the technical base in place, it is too costly to venture down the weapons path. This explains, in part, why Saudi Arabia has yet to begin a nuclear weapons program even though it faces considerable security threats.[33] Likewise, countries are unlikely to nuclearize—even if they have accumulated significant amounts of assistance—if they do not face security threats. On the other hand, initiation of a weapons program is more likely in states that operate in dangerous security environments and possess peaceful nuclear facilities and a cadre of trained scientists and technicians.

There are also strong theoretical reasons to suggest the existence of a relationship between civilian nuclear cooperation and the acquisition of nuclear weapons. Given the links described above, civilian nuclear energy cooperation can aid nuclear weapons production by providing the technology and items necessary to produce fissile material.[34] This is noteworthy because fissile material production is the most difficult step in building the bomb.[35] Cooperation also establishes a technical knowledge base that permits advances in nuclear explosives and related fields, ultimately facilitating bomb production. Occasionally, technical capacity alone causes states to produce the bomb. But just as all states receiving nuclear aid do not begin weapons programs, every country that acquires assistance does not assemble bombs. Security threats, which pro-

32. On the strategic benefits of the bomb, see Thomas C. Schelling, *The Strategy of Conflict* (Cambridge, Mass.: Harvard University Press, 1960); Bruce Bueno de Mesquita and William H. Riker, "An Assessment of the Merits of Selective Nuclear Proliferation," *Journal of Conflict Resolution*, Vol. 26, No. 2 (June 1982), pp. 283–306; Robert Powell, *Nuclear Deterrence Theory: The Search for Credibility* (Cambridge: Cambridge University Press, 1990); Erik Gartzke and Dong-Joon Jo, "Bargaining, Nuclear Proliferation, and International Disputes," *Journal of Conflict Resolution*, Vol. 53, No. 2 (April 2009), pp. 209–233; Michael Horowitz, "The Spread of Nuclear Weapons and International Conflict: Does Experience Matter?" *Journal of Conflict Resolution*, Vol. 53, No. 2 (April 2009), pp. 234–257; Robert Rauchhaus, "Evaluating the Nuclear Peace Hypothesis: A Quantitative Approach," *Journal of Conflict Resolution*, Vol. 53, No. 2 (April 2009), pp. 258–277; and Kyle Beardsley and Victor Asal, "Winning with the Bomb," *Journal of Conflict Resolution*, Vol. 53, No. 2 (April 2009), pp. 278–301.
33. Singh and Way include Saudi Arabia on a list of "Dogs That Did Not Bark." Singh and Way, "The Correlates of Nuclear Proliferation."
34. Bunn, "Civilian Nuclear Energy and Nuclear Weapons Programs."
35. Joseph Cirincione, Jon B. Wolfsthal, and Miriam Rajkumar, *Deadly Arsenals: Nuclear, Biological, and Chemical Threats* (Washington, D.C.: Carnegie Endowment for International Peace, 2005).

vide the political motivation to build the bomb, coupled with atomic aid are a recipe for the acquisition of nuclear weapons.

Four hypotheses flow from this logic:

Hypothesis 1: Countries receiving peaceful nuclear assistance are more likely to begin nuclear weapons programs.

Hypothesis 2: Countries receiving peaceful nuclear assistance are more likely to begin nuclear weapons programs when a security threat arises.

Hypothesis 3: Countries receiving peaceful nuclear assistance are more likely to acquire nuclear weapons.

Hypothesis 4: Countries facing security threats and receiving peaceful nuclear assistance are more likely to acquire weapons.

Below I apply these hypotheses to several cases to show how peaceful nuclear cooperation can lead to proliferation.

Case Studies

In this section I briefly discuss why my argument is salient in explaining nuclear decisionmaking in three proliferation cases. Then I examine two cases in more detail: (1) India's decision to begin a weapons program in 1964, and (2) Pakistan's acquisition of the bomb in 1987. The qualitative evidence shows that nuclear assistance can lead to proliferation—especially when combined with security threats. After discussing these cases, I turn to the statistical analysis.

The South African experience illustrates how peaceful nuclear assistance can contribute to the onset of a weapons program in the absence of a security threat. U.S. assistance to South Africa's peaceful nuclear program, which began in July 1957, had a salient effect on that country's decision to begin a nuclear weapons program. U.S. aid included the construction of a nuclear research reactor in Pelindaba, the supply of highly enriched uranium, and the training of nuclear scientists. This cooperation led to significant technological advancements and provided key scientists in the South African atomic energy complex with tremendous political influence.[36] Particularly significant was the president of the Atomic Energy Corporation, A.J. "Ampie" Roux, who reportedly quipped, "I can ask [the South African] government for anything I want and I'll get it."[37] Indeed, Roux convinced Prime Minister John Vorster to fund construction of a pilot uranium enrichment plant in 1968, despite the latter's

36. See David Albright, "South Africa and the Affordable Bomb," *Bulletin of the Atomic Scientists*, Vol. 50, No. 4 (July/August 1994), pp. 37–47.
37. Quoted in Liberman, "The Rise and Fall of the South African Bomb," p. 64.

concerns about the costs of such a program.[38] In the 1970s Roux then lobbied the prime minister to develop nuclear bombs on the grounds that doing so was technologically feasible.[39] Vorster decided to authorize a nuclear weapons program in part because he recognized that South Africa's civil nuclear infrastructure would permit the quick and successful development of these weapons. As Mitchell Reiss notes, "With the [civilian nuclear] capability already in place, the subsequent decision to build nuclear weapons was made that much easier."[40] This logic is especially compelling in light of revelations from recently declassified documents that security motivations—particularly the need for a deterrent against a Soviet-supported attack from Angola or Mozambique—had little role in influencing the onset of South Africa's weapons program.[41] Because the nuclear program could not have developed as it did without U.S. assistance beginning in the late 1950s, this short narrative exemplifies how peaceful nuclear cooperation can enable proliferation decisions.

Evidence from two other cases also reveals that peaceful nuclear cooperation can enable acquisition of the bomb. French reprocessing aid to Israel between 1958 and 1965 enhanced Israel's ability to assemble a nuclear weapon much quicker than it would have been able to through solely indigenous means.[42] But this assistance alone was insufficient for Israel to cross the nuclear threshold. Heavy water supplied by Norway, the United Kingdom, and the United States also facilitated Israel's acquisition of nuclear weapons.[43] Gary Milhollin highlights the importance of foreign-supplied heavy water for Israel's weapons program when he notes that "the reactor at Dimona is Israel's only means of making plutonium, and plutonium is Israel's primary nuclear weapon material. When Dimona opened in 1963 . . . Israel was producing heavy water only in laboratory quantities. Therefore, it was physically impossible to start Dimona without U.S. or Norwegian heavy water."[44]

I argued above that the knowledge acquired from peaceful nuclear coopera-

38. Verne Harris, Sello Hatang, and Peter Liberman, "Unveiling South Africa's Nuclear Past," *Journal of Southern African Studies,* Vol. 30, No. 3 (September 2004), pp. 457–476; and Reiss, *Bridled Ambition,* p. 29.
39. Waldo Stumpf, "South Africa's Nuclear Weapons Program: From Deterrence to Dismantlement," *Arms Control Today,* Vol. 25, No. 10 (December/January 1995/96), p. 4; and Liberman, "The Rise and Fall of the South African Bomb."
40. Reiss, *Bridled Ambition,* p. 29.
41. Harris, Hatang, and Liberman, "Unveiling South Africa's Nuclear Past."
42. Kroenig, "Importing the Bomb"; and Avner Cohen, *Israel and the Bomb* (New York: Columbia University Press, 1998).
43. Gary Milhollin, "Heavy Water Cheaters," *Foreign Policy,* Vol. 69 (Winter 1987/88), pp. 100–119; Astrid Forlan, "Norway's Nuclear Odyssey: From Optimistic Proponent to Nonproliferator," *Nonproliferation Review,* Vol. 4, No. 2 (Winter 1997), pp. 1–16; and "UK Helped Israel Get Nuclear Bomb," *BBC News,* August 4, 2005, http://news.bbc.co.uk/2/hi/uk_news/4743987.stm.
44. Milhollin, "Heavy Water Cheaters," p. 105.

tion also plays a major role in enabling countries to manufacture nuclear bombs.[45] The North Korean case illuminates this point. The Soviet Union trained North Korean nuclear scientists beginning in the late 1950s and completed construction of a research reactor at Yongbyon in 1965. This technical aid provided a base of knowledge in nuclear matters sufficient to help the North Koreans build an "experimental nuclear installation" in the 1980s.[46] Pyongyang employed this facility to produce plutonium, which it then used to explode a nuclear bomb in October 2006.[47] As the case studies presented below make clear, this experience is not atypical.

THE ORIGINS OF INDIA'S NUCLEAR WEAPONS PROGRAM, 1964

In 1955 India built its first research reactor using British-supplied designs. This facility, known as the Apsara research reactor, became operational in 1956 using enriched uranium fuel also supplied by the United Kingdom. In April 1956 Canada agreed to supply India with a 40-megawatt research reactor known as the Canada-India-United States research reactor (CIRUS). The CIRUS reactor was built as part of the Colombo Plan, a developmental aid program for countries of South Asia modeled after the Marshall Plan.[48] It was intended to help the Indians develop their knowledge in nuclear engineering.[49] The United States provided heavy water to moderate the CIRUS reactor, enabling it to begin operating in 1960. In addition, beginning in 1955, it invited 1,104 Indian nuclear scientists to train at the Argonne Laboratory School of Nuclear Science and Engineering, among other facilities.[50]

U.S. and Canadian assistance continued in the 1960s. In April 1961 India began construction of a reprocessing plant designed to extract plutonium from spent nuclear fuel. This facility, named Phoenix, was designed in part by an American firm, Vitro International, and based on declassified U.S. plans for reprocessing using the PUREX method.[51] In 1964 Canada agreed to assist India in developing its first power reactor, known as Rajasthan Atomic Power Plant (RAPP-1), and supply one-half of the initial uranium fuel charge. This assistance enabled India to obtain "detailed design data, including plans and work-

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45. Bunn, "Civilian Energy Programs and Nuclear Weapons Programs."
46. Alexander Zhebin, "A Political History of Soviet-North Korean Nuclear Cooperation," in James Clay Moltz and Alexander Y. Mansourov, eds., *The North Korean Nuclear Program: Security, Strategy, and New Perspectives from Russia* (New York: Routledge, 2000), pp. 27–40.
47. Faye Flam, "American Scientists Explain North Korean Nuclear Test," *Philadelphia Inquirer,* October 10, 2006.
48. Shyam Bhatia, *India's Nuclear Bomb* (Ghaziabad, India: Vikas, 1979).
49. Duane Bratt, *The Politics of CANDU Exports* (Toronto: University of Toronto Press, 2006), p. 89.
50. George Perkovich, *India's Nuclear Bomb: The Impact on Global Proliferation* (Berkeley: University of California Press, 1999), p. 30.
51. Ibid., p. 64.

ing drawings regarding the design and construction of nuclear power stations of the heavy water type."[52] Canada additionally agreed to provide one-half of the initial uranium fuel charge for the Rajasthan reactor. In December 1966 it agreed to offer assistance in the design and construction of a second nuclear power reactor at Rajasthan (RAPP-2). At the same time, the United States agreed to supply plutonium to India for research purposes.[53]

These transfers were highly consequential for India's civilian nuclear program. In the 1950s and 1960s, India could not have developed a nuclear program in the absence of foreign assistance.[54] Peaceful nuclear assistance also spurred India's decision to begin a nuclear weapons program. To begin, it decreased the expected costs of obtaining the bomb and increased the likelihood that one could be produced relatively quickly. The training and technology that India received had applications for both peaceful and military programs. Key Indian decisionmakers were well aware of this. In September 1956 Homi Bhabha, the chairman of the Indian Atomic Energy Commission, argued that countries can easily use know-how and experiences obtained through peaceful programs to develop a separate military program.[55] Bhabha expressed a similar opinion in January 1964 when he indicated that "any knowledge of operating a reactor for peaceful purposes can be employed later for operating a reactor for military purposes."[56] Prime Minister Jawaharlal Nehru was equally aware that nuclear assistance could serve both peaceful and military programs, and he expressed this belief publicly on several occasions.[57] By 1964 U.S. and Canadian peaceful nuclear assistance had yielded results that would have important implications for India's civilian and military nuclear programs. In June of that year, the first spent fuel from the Canadian-supplied CIRUS reactor was delivered to the reprocessing plant at Trombay. This meant that India would soon separate plutonium for the first time. Plutonium can be used to power certain types of nuclear reactors, but it is also an important component of nuclear weapons. Using this plutonium in a nuclear weapon, however, would have broken New Delhi's prior commitments that it would use technology and training provided by Canada and the United States

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52. "India Profile: Nuclear Chronology, 1960–1964" (Monterey, Calif.: Center for Nonproliferation Studies, Monterey Institute for International Studies, August 2003), http://www.nti.org/e_research/profiles/India/Nuclear/2296_2346.html.
53. Bratt, *The Politics of CANDU Exports.*
54. Wohlstetter, "U.S. Peaceful Aid and the Indian Bomb."
55. Perkovich, *India's Nuclear Bomb,* p. 29.
56. Homi J. Bhabha, "The Implications of a Wider Dispersal of Military Power for World Security and the Problem of Safeguards," proceedings of the Twelfth Pugwash Conference on Science and World Affairs, January 27–February 1, 1964, Udaipur, India, pp. 78–79.
57. See, for example, Ashok Kapur, *India's Nuclear Option: Atomic Diplomacy and Decisionmaking* (New York: Praeger, 1976), p. 193.

only for peaceful purposes. Nevertheless, developments in the civilian sector had a salient effect on Prime Minister Lal Bahadur Shastri's decisionmaking.

Shastri was highly sensitive to the expected costs of a nuclear weapons program because India faced economic hardship and massive food shortages during his tenure. He was initially reluctant to initiate a weapons program because this would force New Delhi to abandon plans for economic development and divert substantial resources away from other domestic programs.[58] These sentiments were captured in an editorial published in the *Statesman* in August 1964: "Both bomb production and effective delivery could be secured if the price is paid for it in terms of economic deprivation. But no responsible person has suggested that the object is worth that price."[59]

Fears that the bomb would be technically too difficult to produce and would command substantial resources initially led Shastri to oppose beginning a nuclear weapons program. But Bhabha relentlessly lobbied the prime minister in asserting that the bomb could be produced with relative ease due to developments in India's civilian nuclear program. In October 1964 Bhabha proclaimed that India could acquire a nuclear bomb within eighteen months of a political decision to develop it and that a 10-kiloton blast would cost only $350,000.[60] These estimates were overly optimistic because India would not acquire weapons-usable plutonium until 1965 (even though the spent fuel was loaded into the reprocessing facility in June 1964), and it lacked a reliable bomb design.[61] But these challenges were overlooked, in part because Bhabha had an extraordinary amount of power, and information relevant to the nuclear program was so tightly guarded that others did not have a chance to question his assertions. Eventually, Bhabha convinced Shastri that a bomb could be built relatively quickly without diverting substantial resources away from development programs. This argument was especially compelling because the country's rivalry with China provided strategic incentives to build the bomb.[62]

On November 27, 1964, after meeting with Bhabha, Shastri officially endorsed a nuclear weapons program. This decision, which marked the official beginning of the Indian program, resulted from the combination of foreign nuclear assistance and security threats emanating from China. But the former factor played an especially crucial and underappreciated role.

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58. K. Rangaswami, "Leaders Reject Demand for Atom Bomb," *Hindu,* November 9, 1964.
59. Quoted in Perkovich, *India's Nuclear Bomb,* p. 65.
60. Ibid., p. 65.
61. Ibid., p. 71.
62. Brahma Chellaney, "India," in Mitchell Reiss and Robert S. Litwak, eds., *Nuclear Proliferation after the Cold War* (Washington, D.C.: Woodrow Wilson Center Press, 1994), pp. 165–190; Kapur, *India's Nuclear Option;* and Ashok Kapur, *Pokhran and Beyond: India's Nuclear Behaviour* (Oxford: Oxford University Press, 2001).

Pakistan's Bomb Acquisition, 1987

Pakistan's civilian nuclear program began in the 1950s with the help of foreign assistance. In August 1955 the United States signed a nuclear cooperation agreement with Pakistan that led to the construction of a small research reactor at the Pakistan Institute of Nuclear Science and Technology (PINSTECH) and the supply of highly enriched uranium to fuel it. The PINSTECH reactor, which began operation in 1963, was used to provide training to Pakistani technicians, produce isotopes, and conduct neutron physics experiments.[63] In the 1960s Canada signed a nuclear cooperation agreement with Pakistan allowing the Canadians to build the Karachi Nuclear Power Plant and supply heavy water and uranium to fuel the reactor. This reactor began operation in 1972. Canada also helped Pakistan develop a fuel fabrication facility at Chasma in the late 1970s.[64] Western European suppliers offered considerable amounts of assistance to Pakistan as well. The United Kingdom, for example, provided hot cells capable of separating plutonium on a laboratory scale.[65] Similarly, Belgium and France assisted Pakistan in developing the "New Laboratories" at PINSTECH to reprocess spent nuclear fuel.[66] Brussels also provided Islamabad with a heavy water production facility that came online at Multan in 1980.[67] Paris agreed in 1976 to supply a large-scale reprocessing center at Chasma, but it suspended this deal in 1978.[68]

In addition to transferring these materials and technology, many suppliers provided substantial know-how to Pakistan.[69] For instance, the United States trained promising young scientists from Pakistan at Argonne National Laboratory just outside of Chicago between 1955 and 1961.[70] These scientists were trained in the design and construction of nuclear reactors, the handling of radioactive materials, chemistry and metallurgy, and other peaceful applications of atomic energy.[71] The United Kingdom, Belgium, and other countries in Western Europe provided similar training to Pakistani personnel.[72]

63. Central Intelligence Agency, "Pakistan's Nuclear Program," National Intelligence Estimate, April 26, 1978.
64. Ashok Kapur, *Pakistan's Nuclear Development* (London: Croom Helm, 1987), p. 75.
65. Given its size, this facility was not well suited to producing plutonium for bombs. Ibid., p. 156.
66. U.S. Department of State, "The Pakistani Nuclear Program," briefing paper, June 23, 1983.
67. Andrew Koch and Jennifer Topping, "Pakistan's Nuclear-Related Facilities," fact sheet (Monterey, Calif.: Center for Nonproliferation Studies, Monterey Institute of International Studies, 1997), http://cns.miis.edu/reports/pdfs/9707paki.pdf.
68. U.S. Department of State, "Apprehensions Regarding Pakistan's Nuclear Intentions," memorandum of conversation, September 3, 1975.
69. Central Intelligence Agency, "Pakistan's Nuclear Program."
70. *International Institute of Nuclear Science and Engineering Classbook* (Argonne, Ill.: Argonne National Laboratory, 1961).
71. Argonne National Laboratory, "International School Focused on Peaceful Uses of Nuclear Energy" (Washington, D.C.: U.S. Department of Energy, October 12, 1996), http://www.anl.gov/Media_Center/News/History/news961012.html.
72. Shahid-Ur Rehman, *Long Road to Chagai* (Islamabad: Print Wise, 1999), pp. 36–37.

After Pakistan suffered a humiliating defeat at the hands of India in the 1971 Indo-Pakistani War, it initiated a nuclear weapons program. Islamabad redoubled its efforts to acquire nuclear weapons after India tested a nuclear explosive device in May 1974.[73] Prime Minister Zulfikar Ali Bhutto famously proclaimed that all Pakistani citizens would "eat grass or leaves, even go hungry" to develop the bomb for Pakistan to counter the Indian nuclear threat.[74] When Bhutto initiated the program, he planned to develop reactors and reprocessing centers to produce plutonium for nuclear weapons. The prime minister tapped Munir Ahmad Khan, the chairman of the Pakistan Atomic Energy Commission (PAEC), to implement this plan. Khan was one of the Pakistanis trained at Argonne National Laboratory more than a decade earlier.[75] Not only did Khan personally benefit from that training, but as chairman of the PAEC, he was able to share his expertise with others once he returned to Pakistan. Others who received training abroad were also able to share their experiences with Pakistani scientists. This accumulation of nuclear know-how enabled Pakistan to develop a technical base that was "equally adept" to India's scientific abilities in the early 1970s.[76] It also increased the PAEC's confidence that it could deliver the bomb for Pakistan.[77]

Bhutto and Khan believed that Pakistan could use facilities built for peaceful purposes to develop nuclear weapons—just as India would do in 1974.[78] But ultimately, Islamabad chose a slightly different path, focusing instead on the uranium route to the bomb. The history of Pakistan's enrichment program is well known.[79] In September 1974 a young metallurgist named A.Q. Khan wrote a letter to Prime Minister Bhutto offering to help Pakistan build the bomb.[80] Khan had been working in the Netherlands for a subcontractor of the European enrichment consortium URENCO. While employed by URENCO, he stole sensitive information dealing with centrifuge technology that could be used to enrich uranium. At the end of 1975, he suddenly left the

73. See, for example, Kapur, *Pakistan's Nuclear Development;* Corera, *Shopping for Bombs;* and Hassan Abbas, "Causes That Led to Nuclear Proliferation from Pakistan to Iran, Libya, and North Korea," Fletcher School of Law and Diplomacy, Tufts University, 2008.
74. Bhutto made this statement as defense minister in the 1960s. Mitchell B. Reiss, "The Nuclear Tipping Point: Prospects for a World of Many Nuclear Weapons States," in Kurt M. Campbell, Robert J. Einhorn, and Reiss, eds., *The Nuclear Tipping Point: Why States Reconsider Their Nuclear Choices* (Washington, D.C.: Brookings Institution Press, 2004), p. 6.
75. Walter Kato, interview by author, Cambridge, Massachusetts, November 20, 2008. Dr. Kato was personally involved in the training that took place at Argonne National Laboratory.
76. Kapur, *Pakistan's Nuclear Development,* p. 169.
77. See ibid., p. 136.
78. See ibid., p. 169; and Central Intelligence Agency, "Pakistan's Nuclear Program."
79. See especially Corera, *Shopping for Bombs.*
80. Michael Laufer, "A.Q. Khan Nuclear Chronology, *Nonproliferation Issue Brief,* Vol. 8, No. 8 (Washington, D.C.: Carnegie Endowment for International Peace, September 7, 2005), http://www.carnegieendowment.org/static/npp/Khan_Chronology.pdf.

Netherlands and returned to Pakistan with stolen blueprints for centrifuges and a Rolodex containing information on 100 companies that supplied enrichment technology.[81]

Pakistan used this information to purchase subcomponents from abroad and to construct covert enrichment facilities dedicated to a nuclear bomb program.[82] As a result of Khan's activities, Pakistan had virtually everything it needed to build a centrifuge enrichment plant as early as 1979.[83] With this equipment in hand, Pakistan began to construct enrichment facilities at Sihala and Kahuta using stolen blueprints.[84] In the end, highly enriched uranium produced at these plants enabled Islamabad to assemble at least one bomb by 1987 and conduct nuclear tests eleven years later.[85]

Pakistan was able to master sophisticated enrichment technology and produce highly enriched uranium for nuclear weapons because of the peaceful assistance it received beginning in the mid-1950s. Islamabad was able to draw on training provided by the United States, Canada, and West European countries to construct and operate the enrichment centers at Sihala and Kahuta. Pakistani scientists received training in uranium metallurgy—the physical and chemical behavior of uranium and its alloys. Expertise in metallurgy is vital to enriching uranium using the gas centrifuge method. Without this know-how, Islamabad would not have known what to do with the technology and materials it procured from abroad. As a developing country, Pakistan could not have obtained the requisite expertise solely through indigenous means. Munir Kahn underscored the significance of foreign assistance:

> I have no place from which to draw talented scientists and engineers to work in our nuclear establishment. We don't have a training system for the kind of cadres we need. But, if we can get France or somebody else to come and create a broad nuclear infrastructure, and build these plants and these laboratories, I will train hundreds of my people in ways that otherwise they would never be able to be trained. And with that training, and with the blueprints and the

81. Ibid.
82. James M. Markham, "Bonn Checks Report of Smuggling of Atomic Technology to Pakistan," *New York Times,* May 5, 1987; Corera, *Shopping for Bombs,* p. 23; and Shelby McNichols, "Chronology of Pakistani Nuclear Development" (Monterey, Calif.: Center for Nonproliferation Studies, Monterey Institute of International Studies, July 2000).
83. Corera, *Shopping for Bombs,* p. 27.
84. Ibid., p. 22.
85. David Albright and Kevin O'Neill, "ISIS Technical Assessment: Pakistan's Stock of Weapon-Grade Uranium" (Washington, D.C.: Institute for Science and International Security, June 1998), http://www.isis-online.org/publications/southasia/ta-pak060198.html; Christopher Clary, "Dr. Khan's Nuclear WalMart," *Disarmament Diplomacy,* No. 76 (March/April 2004); David Albright and Mark Hibbs, "Pakistan's Bomb: Out of the Closet," *Bulletin of the Atomic Scientists,* Vol. 48 (July/August 1992), p. 39; Corera, *Shopping for Bombs,* p. 49; and Kapur, *Pakistan's Nuclear Development,* p. 208.

other things that we'd get along the way, then we could set up separate plants that would not be under safeguards, that would not be built with direct foreign assistance, but I would not have the people who could do that. If I don't get the cooperation, I can't train the people to run a weapons program.[86]

Samar Mubarakmand, who headed the team of scientists that orchestrated Pakistan's 1998 nuclear tests, expressed similar sentiments.[87] He suggested that any country can procure dual-use equipment relevant to a weapons program, but states cannot build the bomb "unless there is a human resource available . . . which understands [nuclear-related] work to such an extent that it is able to develop and raise this program from zero to 100% all by itself."[88] He added that countries such as Libya were unable to develop the bomb because they lacked what Pakistan had: the requisite knowledge base. Between 1970 and 2003, Libya attempted to procure nuclear weapons–relevant technology on the black market but was never able to develop the bomb.

Statistical Tests

Given that every empirical approach has drawbacks, a multimethod assessment of my theory can inspire greater confidence in the findings presented in this article.[89] The case study analysis above provides rich descriptions of my argument and illustrates that the causal processes operate as expected in actual instances of proliferation.[90] Statistical analysis allows me to minimize the risks of selection bias and determine the average effect of independent variables on proliferation aims and outcomes.[91] Additionally, it permits me to control for confounding variables and to show that peaceful nuclear cooperation—and not some other factor—explains nuclear proliferation. This is especially important because proliferation is a complicated process, and there is rarely only one factor that explains why nuclear weapons spread.[92]

For the statistical analysis, I use a data set compiled by Sonali Singh and

86. Quoted in George Perkovich, "Nuclear Power and Nuclear Weapons in India, Pakistan, and Iran," in Paul Leventhal, Sharon Tanzer, and Steven Dolley, eds., *Nuclear Power and the Spread of Nuclear Weapons: Can We Have One without the Other?* (Washington, D.C.: Brassey's, 2002), p. 194.
87. Samar Mubarakmand, *Capital Talk Special,* Geo-TV, May 3, 2004, http://www.pakdef.info/forum/showthread.php?t+9214.
88. Ibid.
89. For a similar discussion, see Alexander B. Downes, *Targeting Civilians in War* (Ithaca, N.Y.: Cornell University Press, 2008), pp. 40–41.
90. See, for example, Alexander L. George and Andrew Bennett, *Case Studies and Theory Development in the Social Sciences* (Cambridge, Mass.: MIT Press, 2005).
91. Will H. Moore, "Synthesis v. Purity and Large-N Studies: How Might We Assess the Gap between Promise and Performance?" *Human Rights and Human Welfare,* Vol. 6 (2006), pp. 89–97.
92. Sagan, "Why Do States Build Nuclear Weapons?"

Christopher Way to identify the determinants of nuclear proliferation.[93] I adopt a standard time-series cross-sectional data structure for the period 1945 to 2000, and the unit of analysis is the country (monad) year. For my analysis of nuclear weapons program onset, a country exits the data set once it initiates a weapons acquisition campaign. Similarly, for my analysis of nuclear weapons acquisition, a country exits the data set once it obtains at least one nuclear bomb.

DEPENDENT VARIABLES

To analyze nuclear proliferation, I coded two dependent variables, both of which are dichotomous. The first is coded 1 if the country initiated a nuclear weapons program in year *t* and 0 otherwise. The second is coded 1 if the country acquired nuclear weapons in year *t* and 0 otherwise. To create these variables, I consulted a list of nuclear proliferation dates compiled by Singh and Way.[94]

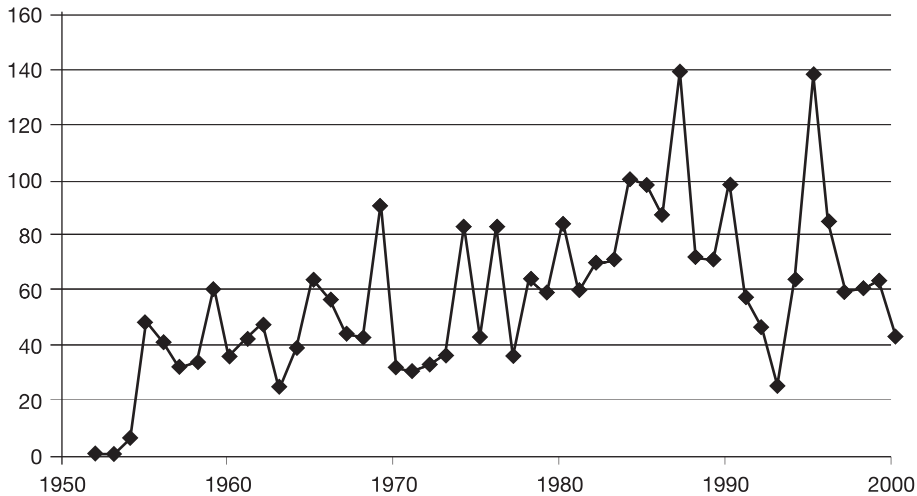
EXPLANATORY VARIABLES

I hypothesized above that the accumulation of civilian nuclear assistance makes states more likely both to begin nuclear weapons programs and to acquire such weapons—especially when security threats are also present. To operationalize civilian nuclear assistance, I collected and coded new data on NCAs signed from 1945 to 2000. NCAs are an appropriate independent variable for this analysis because they must be in place in virtually all cases before the exchange of nuclear technology, materials, or knowledge can take place. These agreements typically lead to the construction of a nuclear power or research reactor, the supply of fissile materials (e.g., plutonium or enriched uranium), the export of fissile material production facilities, or the training of scientists and technicians. Related agreements that are not classified as NCAs include: (1) agreements that are explicitly defense related; (2) financial agreements; (3) agricultural or industrial agreements unrelated to nuclear power; (4) agreements dealing with the leasing of nuclear material; and (5) liability agreements.

To produce these data, I consulted a list compiled by James Keeley of more than 2,000 NCAs.[95] Figure 1 plots the number of NCAs signed from 1950 to

93. Singh and Way, "The Correlates of Nuclear Proliferation."
94. Ibid.
95. See Keeley, "A List of Bilateral Civilian Nuclear Cooperation Agreements." I conducted further research on all of the agreements in Keeley's list to ensure that I included only deals that actually provide the basis for the exchange of nuclear technology, materials, or knowledge. Additionally, Keeley included some NCAs that are simply amendments to earlier agreements, and

Figure 1. Total Number of Nuclear Cooperation Agreements Signed, 1950–2000



SOURCES: Matthew Fuhrmann, "Taking a Walk on the Supply Side: The Determinants of Civilian Nuclear Cooperation," *Journal of Conflict Resolution,* Vol. 53, No. 2 (April 2009), pp. 181–208; and James F. Keeley, "A List of Bilateral Civilian Nuclear Cooperation Agreements," University of Calgary, 2003.

2000. The figure shows a general increase in the number of NCAs over time, which is explained by the emergence of a greater number of capable nuclear suppliers. The number has fluctuated slightly, with peaks in the late 1980s and the mid-1990s. The first NCA was signed in 1952, after which the average number of agreements signed each year was 58.

I created an independent variable that measures the aggregate number of NCAs that a state signed in a given year entitling it to nuclear technology, materials, or knowledge from another country.[96] If a state signed an NCA but only supplied—and did not receive—nuclear assistance as part of the terms of the deal, then this would not be captured by the nuclear cooperation agreements variable. Table 1 lists the thirty countries that received the most nuclear assistance via these agreements from 1945 to 2000.[97]

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do not authorize the supply of additional nuclear technology, materials, or know-how. I excluded these agreements from the coding of the independent variable.

96. Sometimes there is a delay between the time an NCA is signed and the time that nuclear technology, materials, or know-how are actually transferred. To account for this possibility, I lag the independent variables five years, so that if a state signed an agreement in 1975, it would not "count" until 1980. I estimate all models using this alternate coding of the variable, and the results are the same.

97. Some of these countries are included in my sample for only a limited number of years because

Table 1. Top Recipients of Nuclear Cooperation Agreements, 1945–2000

Country	Total Number of Agreements
United States	396
France	221
Germany	171
Russia	136
United Kingdom	133
Japan	122
Italy	112
Belgium	93
Argentina	92
Netherlands	80
Canada	77
Brazil	70
Spain	70
Switzerland	68
Luxembourg	63
Sweden	56
Denmark	55
China	53
South Korea	49
India	39
Ireland	36
Romania	35
Portugal	33
Czechoslovakia (1945–91)	30
Greece	30
Egypt	29
Finland	29
Poland	28
Australia	25
Indonesia	22

NOTE: summary statistics: N = 186; mean = 15.34; minimum = 0; maximum = 396

To operationalize security threats, I created a variable measuring the five-year moving average of the number of militarized interstate disputes (MIDs) per year in which a country was involved. This variable is based on version 3.0 of the Correlates of War's MID data set.[98] I coded a third variable that interacts these two measures to test for the conditional effect of nuclear cooperation on proliferation.

states are removed once they pursue or acquire nuclear weapons. The first NCA was not signed until 1952.

98. Faten Ghosn, Glenn Palmer, and Stuart A. Bremer, "The MID3 Data Set, 1993–2001: Procedures, Coding Rules, and Description," *Conflict Management and Peace Science,* Vol. 21, No. 2 (2004), pp. 133–154.

CONTROL VARIABLES

I controlled for other factors thought to affect proliferation.[99] To control for technological capacity, I included a variable measuring a country's GDP per capita and a squared term of this measure to allow for the possible curvilinear relationship between economic development and the pursuit of nuclear weapons.[100] To measure a state's industrial capacity, I included a dichotomous variable that is coded 1 if it produced steel domestically and had an electricity-generating capacity greater than 5,000 megawatts and 0 otherwise. I included a dichotomous variable that is coded 1 if the state was involved in at least one enduring rivalry as an additional proxy for a state's security environment.[101] A dichotomous variable that is coded 1 if a state shared a defense pact with one of the nuclear-capable great powers and 0 otherwise is also included because security guarantees of this magnitude could reduce states' incentives to develop their own nuclear weapons.[102]

There are a number of "internal determinants" that could affect incentives to proliferate. I included two variables related to democracy. The first measures the country's score on the Polity IV scale.[103] The second variable, which measures whether a state is democratizing, calculates movement toward democracy over a five-year span by subtracting a state's Polity score in year *t*-5 from its Polity score in year *t*. To control for a state's exposure to the global economy, I included a variable measuring the ratio of exports plus imports as a share of GDP.[104] I also included a measure of trade liberalization that mirrors the democratization measure described above.

For the sake of robustness, I included one variable that Singh and Way excluded from their model.[105] I created a dichotomous variable and coded it 1 if the state signed the NPT in year *t* and 0 otherwise. NPT membership could be

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99. These are generally the same variables used by Singh and Way, "The Correlates of Nuclear Proliferation."
100. See ibid., p. 868.
101. Singh and Way code this variable based on D. Scott Bennett's 1998 list of rivalries. See Bennett, "Integrating and Testing Models of Rivalry Duration," *American Journal of Political Science,* Vol. 42, No. 4 (October 1998), pp. 1200–1232.
102. Singh and Way rely on version 3.0 of the Correlates of War alliance data set to code this variable. Douglas M. Gibler and Meredith Reid Sarkees, "Measuring Alliances: The Correlates of War Formal Interstate Alliance Dataset," *Journal of Peace Research,* Vol. 41, No. 2 (March 2004), pp. 211–222.
103. The Polity IV data are based on a 21-point scale that measures the relative openness of political institutions. See Monty G. Marshall and Keith Jaggers, "Polity IV Project: Political Regime Characteristics and Transitions, 1800–2002," http://www.systemicpeace.org/polity/polity4.htm.
104. Singh and Way take their GDP data from version 6.1 of the Penn World Tables. A. Heston, R. Summers, and B. Aten, *Penn World Table* (Philadelphia: Center for International Comparisons, University of Pennsylvania, 2002), ver. 6.1.
105. See Singh and Way, "The Correlates of Nuclear Proliferation."

salient in explaining decisions to proliferate because states make legal pledges not to pursue nuclear weapons when they sign this treaty.

METHODS OF ANALYSIS

I used probit regression analysis to estimate the effect of independent variables on nuclear weapons program onset and bomb acquisition. Given that the proliferation outcomes analyzed here occurred relatively infrequently, I also used rare events logit to estimate the effect of independent variables on nuclear weapons program onset and nuclear weapons acquisition.[106] This estimator is appropriate when the dependent variable has thousands of times fewer 1's than 0's. I used clustering over states to control for heteroskedastic error variance. To control for possible temporal dependence in the data, I also included a variable to count the number of years that passed without a country pursuing nuclear weapons or acquiring the bomb.[107] Finally, I lagged all independent variables one year behind the dependent variable to control for possible simultaneity bias.

Results of the Statistical Tests

Before moving to the multivariate analysis, I considered cross tabulations of nuclear cooperation agreements against nuclear weapons program onset and nuclear weapons acquisition. The results are presented in tables 2 and 3. These simple cross tabulations underscore that proliferation is a relatively rare event. Decisions to begin weapons program occur in fifteen of the observations in the sample (0.22 percent), and bomb acquisition occurs in nine observations in the sample (0.13 percent). Even though proliferation occurs infrequently, these cross tabulations show that nuclear cooperation strongly influences whether countries will go down the nuclear path. Participation in at least one nuclear cooperation agreement increases the likelihood of beginning a bomb program by about 500 percent. The combination of militarized conflict and nuclear assistance has an even larger substantive effect on program onset. Experiencing both of these phenomenon increases the probability of initiating

106. Gary King and Langche Zeng, "Logistic Regression in Rare Events Data," *Political Analysis*, Vol. 9, No 2 (February 2001), pp. 137–163. I also use a Cox proportional hazard model to estimate all models, and the results are virtually identical. I do not list the Cox results because of space constraints.
107. Nathaniel Beck, Jonathan N. Katz, and Richard Tucker, "Taking Time Seriously: Time-Series-Cross-Section Analysis with a Binary Dependent Variable," *American Journal of Political Science*, Vol. 42, No. 4 (October 1998), pp. 1260–1288. Cubic splines are not included because proliferation outcomes cannot recur; once a country begins a program or acquires the bomb, it is removed from the sample.

Table 2. Nuclear Cooperation, Militarized Disputes, and Nuclear Weapons Program Onset, 1945–2000

		Civilian Nuclear Cooperation			Civilian Nuclear Cooperation and Militarized Disputes		
		No	Yes	Total	No	Yes	Total
Nuclear weapons program onset	No	4,066 (99.93%)	2,865 (99.58%)	6,931 (99.78%)	5,080 (99.92%)	1,851 (99.41%)	6,931 (99.78%)
	Yes	3 (0.07%)	12 (0.42%)	15 (0.22%)	4 (0.08%)	11 (0.59%)	15 (0.22%)
	Total	4,069 (100%)	2,877 (100%)	6,946 (100%)	5,084 (100%)	1,862 (100%)	6,946 (100%)
		Pearson Chi2(1) = 9.22, Pr = 0.002			Pearson Chi2(1) = 16.59, Pr < 0.0001		

Table 3. Nuclear Cooperation, Militarized Disputes, and Nuclear Weapons Acquisition, 1945–2000

		Civilian Nuclear Cooperation			Civilian Nuclear Cooperation and Militarized Disputes		
		No	Yes	Total	No	Yes	Total
Nuclear weapons program onset	No	4,077 (99.95%)	3,050 (99.77%)	7,127 (99.87%)	5,099 (99.96%)	2,028 (99.66%)	7,127 (99.78%)
	Yes	2 (0.05%)	7 (0.23%)	9 (0.13%)	2 (0.04%)	7 (0.34%)	9 (0.13%)
	Total	4,079 (100%)	3,057 (100%)	7,136 (100%)	5,101 (100%)	2,035 (100%)	7,136 (100%)
		Pearson Chi2(1) = 4.49, Pr = 0.034			Pearson Chi2(1) = 10.73, Pr = 0.0001		

a weapons program by about 638 percent. This simple analysis emphasizes that these relationships are not deterministic. Although countries that receive peaceful assistance were more likely to begin weapons programs, the majority of countries that benefit from such aid do not proliferate. It is also noteworthy that 80 percent of the countries that began programs did so after receiving civilian aid. The four countries that initiated nuclear weapon programs without receiving such assistance—France, the Soviet Union, the United Kingdom, and the United States—did so in the 1940s and early 1950s when peaceful nuclear cooperation was not an option. From 1955 to 2000, no country began a nuclear weapons program without first receiving civilian assistance. This suggests that after the early days of the atomic age, nuclear aid became a necessary condition for launching a nuclear weapons program.

Table 4. Determinants of Nuclear Weapons Proliferation, 1945–2000

Atomic Assistance	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Peaceful nuclear cooperation	0.023***	0.062***	0.016**	0.049***	0.019***	0.055***	0.004	0.014
	(0.009)	(0.023)	(0.007)	(0.018)	(0.006)	(0.020)	(0.011)	(0.033)
Militarized disputes	0.152***	0.286***	0.132***	0.265***	0.107**	0.206	0.069*	0.155
	(0.040)	(0.095)	(0.030)	(0.066)	(0.047)	(0.126)	(0.041)	(0.121)
Peaceful nuclear cooperation × militarized disputes			0.025**	0.057***			0.013**	0.024**
			(0.010)	(0.022)			(0.006)	(0.011)
Control Variables								
Nuclear protection	0.085	0.105	0.043	0.005	−0.297	−0.544	−0.340	−0.693
	(0.264)	(0.742)	(0.274)	(0.775)	(0.348)	(1.042)	(0.360)	(1.121)
Nuclear Nonproliferation Treaty	−1.040**	−2.375*	−1.168**	−2.642*				
	(0.463)	(1.286)	(0.536)	(1.435)				
Democracy	−0.000	0.007	−0.006	−0.008	0.016	0.025	0.010	0.011
	(0.016)	(0.045)	(0.016)	(0.042)	(0.016)	(0.053)	(0.017)	(0.055)

Democratization	−0.014	−0.034	−0.015	−0.036	−0.036	−0.079	−0.036	−0.099
	(0.022)	(0.065)	(0.024)	(0.075)	(0.035)	(0.103)	(0.040)	(0.127)
Economic openness	0.002	0.008	0.001	0.008	0.003	0.014	0.003	0.015
	(0.005)	(0.013)	(0.005)	(0.015)	(0.003)	(0.012)	(0.003)	(0.009)
Liberalization	−0.001	−0.004	0.003	0.019	0.005	0.040***	0.005	0.036***
	(0.006)	(0.017)	(0.006)	(0.017)	(0.004)	(0.012)	(0.003)	(0.011)
GDP per capita	0.000*	0.000	0.000**	0.001	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
GDP per capita squared	−0.000***	−0.000*	−0.000***	−0.000**	−0.000***	−0.000	−0.000**	−0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Industrial capacity threshold	0.874***	2.150**	0.878***	2.219***	1.259***	2.666**	1.268***	2.867***
	(0.334)	(0.875)	(0.340)	(0.861)	(0.233)	(1.056)	(0.248)	(1.099)
Rivalry	0.909***	2.385**	0.758***	1.863**	0.884**	1.977	0.769*	1.688
	(0.317)	(0.975)	(0.286)	(0.816)	(0.394)	(1.286)	(0.404)	(1.323)
No proliferation years	0.012	0.031	0.007	0.015	−0.017**	−0.038	−0.021**	−0.049*
	(0.009)	(0.026)	(0.009)	(0.026)	(0.008)	(0.024)	(0.009)	(0.026)
Constant	−4.510***	−9.280***	−4.417***	−9.097***	−4.431***	−8.787***	−4.232***	−8.155***
	(0.459)	(1.195)	(0.430)	(1.067)	(0.481)	(1.433)	(0.461)	(1.264)
Observations	5,511	5,511	5,511	5,511	5,702	5,702	5,702	5,702

NOTE: Robust standard errors in parentheses; *significant at 0.10; **significant at 0.05; ***significant at 0.01. GDP = gross domestic product.

Similar patterns emerged between nuclear assistance and weapons acquisition. Nuclear aid increases the likelihood of acquiring the bomb by about 360 percent; the combination of atomic assistance and militarized disputes increases the probability of building nuclear weapons by 750 percent. The relationship between nuclear assistance and weapons acquisition is also probabilistic—not deterministic—because not all countries that receive aid cross the nuclear threshold. Table 3 indicates that atomic assistance was not always a necessary condition for bomb acquisition, although the vast majority of all proliferators did receive help. Seventy-eight percent of the countries that produced the bomb received some assistance, and no country acquired weapons without receiving aid from 1953 to 2000.

To explore the role of possible confounding variables, I turn now to the multivariate analysis. Table 4 presents the initial results from the multivariate statistical analysis. The odd-numbered models were estimated using probit, and the even-numbered models were estimated using rare events logit. In models 1–4, the dependent variable is weapons program onset. Models 1 and 2 exclude the interaction term and allow me to evaluate whether peaceful nuclear assistance affects decisions to begin bomb programs independent of the security environment. Models 3 and 4 include the interaction term and enable me to evaluate the conditional effect of atomic assistance on the initiation of nuclear weapons campaigns. In models 5–8 the dependent variable is acquisition. Models 5–6 exclude the interaction term, allowing me to evaluate the unconditional effect of nuclear aid on bomb development. Models 7 and 8 include the interaction term, so I can assess the conditional effect of atomic assistance on a country successfully building nuclear weapons.

The results show that peaceful nuclear assistance continues to contribute to both nuclear weapons program onset and bomb acquisition, even when accounting for confounding variables. In models 1–2 the coefficient on the variable measuring the cumulative amount of atomic assistance a country has received is positive and highly statistically significant.[108] This indicates that, on average, countries receiving nuclear aid are more likely to initiate bomb programs. The substantive effect of this variable is also strong. Raising the value of the NCA variable from its mean (6.69) to one standard deviation above the mean (22.72) increases the likelihood of beginning a weapons program by 185 percent.[109] The findings in table 4 reveal a similar relationship be-

108. One could argue that there is a threshold effect involving NCAs whereby making a few agreements increases the risk of proliferation but many agreements make states more likely to foreswear the bomb. To test for this, I add a squared term of the NCA variable to the models displayed in table 4. This does not affect the results.
109. These calculations are based on the results from model 2.

tween atomic assistance and bomb acquisition. As shown in models 5–6, the coefficient on the variable measuring the number of NCAs a country has signed is positive and highly significant, indicating that countries receiving peaceful nuclear aid are more likely to build the bomb. Increasing the NCA variable from its mean to one standard deviation above the mean raises the probability that a country will build nuclear weapons by 243 percent.[110]

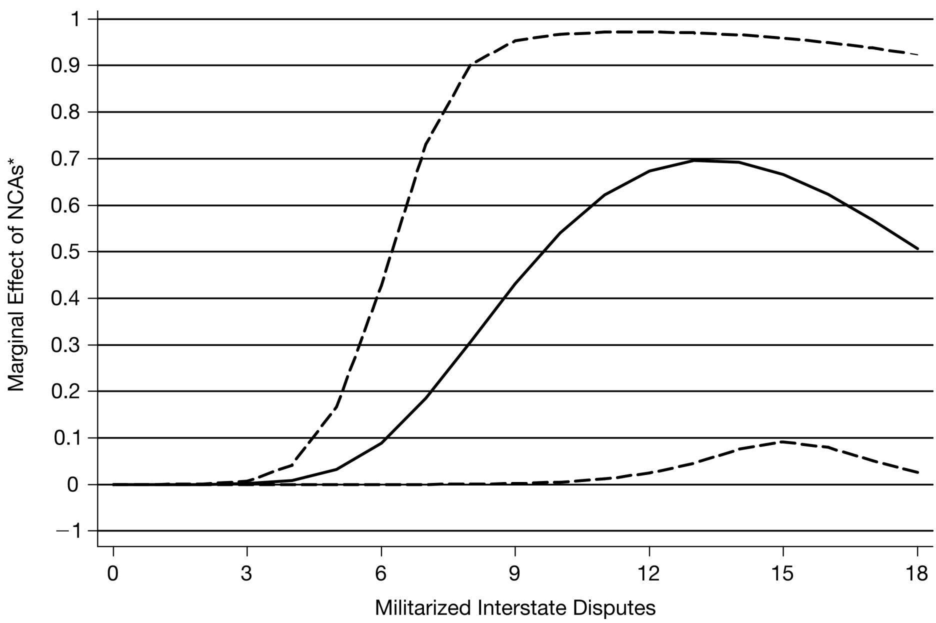
Does peaceful nuclear assistance have an especially strong effect on proliferation when countries also face security threats? Because I use an interaction term to test this part of my argument, it is not possible to evaluate this effect based solely on the information presented in table 4. The appropriate way to interpret interaction terms is to graph the marginal effect of atomic assistance and the corresponding standard errors across the full range of the militarized interstate dispute variable.[111] If zero is included in the confidence interval, then atomic assistance does not have a statistically significant effect on proliferation at that particular level of conflict. Figures 2 and 3 allow me to evaluate how the combination of atomic aid and militarized conflict affect proliferation.

Figure 2 plots the marginal effect of nuclear aid on weapons program onset as the number of militarized disputes rises.[112] It is difficult to see in the figure, but atomic assistance has a statistically significant effect on weapons programs across all levels of conflict because zero is never included in the confidence interval. At low levels of conflict, increases in peaceful nuclear assistance have relatively small substantive effects on the likelihood of bomb program onset. But as the security environment worsens, the substantive effect of atomic assistance on initiating a bomb program is magnified.

The probability that an average country experiencing six militarized disputes will develop the bomb rises from 0.000936 to 0.0902 when the country receives increases in atomic aid.[113] This indicates that countries are highly unlikely to begin weapons programs in the absence of such assistance—even if they face security threats. But if threats are present and states receive additional atomic assistance, the likelihood of beginning a bomb program spikes dramatically. If that same country were to be involved in twelve militarized disputes in one year, increases in nuclear assistance would raise the probability of program initiation from 0.0625 to 0.737, an increase of 1,078 percent. If an

110. These calculations are based on the results from model 6.
111. Thomas Brambor, William Roberts Clark, and Matt Golder, "Understanding Interaction Models: Improving Empirical Analyses," *Political Analysis,* Vol. 14, No. 1 (Winter 2006), pp. 63–82.
112. Figure 2 is based on the results in model 3. To calculate the marginal effects, I increase the value of the peaceful nuclear cooperation variable from its mean to one-half standard deviation above the mean.
113. To calculate these figures, I set all other variables at their mean.

Figure 2. Marginal Effect of Nuclear Assistance on Weapons Program Onset as Number of Disputes Increases



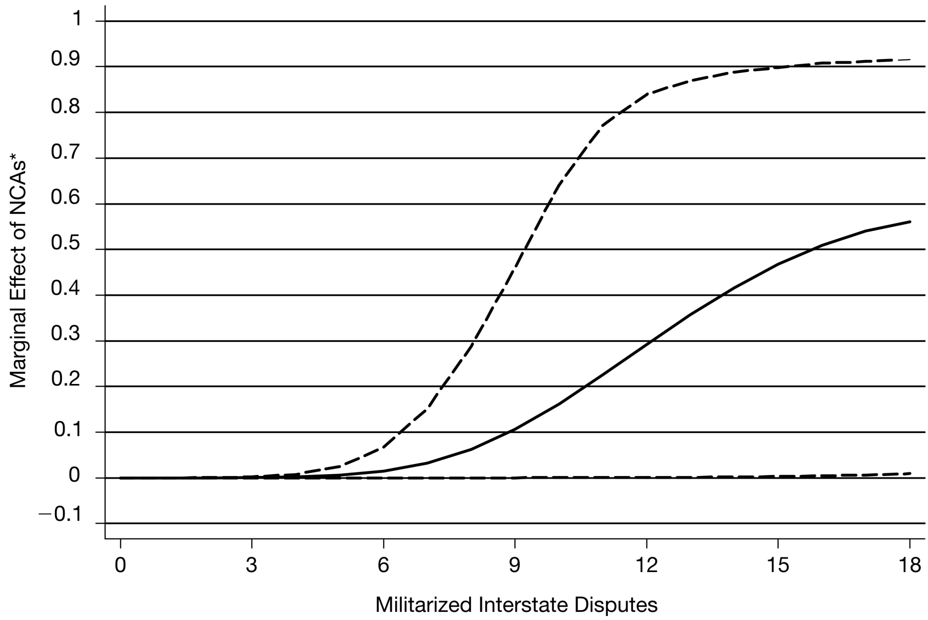
*NCAs = nuclear cooperation agreements

average country that experiences eighteen militarized disputes in a year receives additional atomic assistance, the likelihood that it will begin a weapons program rises from 0.426 to 0.933, an increase of 119 percent. Note that at high levels of conflict, the probability of weapons program onset approaches 1 with increases in peaceful aid, but countries that face numerous security threats are also likely to proliferate in the absence of assistance. Consequently, increases in nuclear assistance yield smaller rises in the probability of proliferation at high levels of conflict. This is why the marginal effect displayed in figure 2 declines slightly after about thirteen disputes.

Figure 3 illustrates the conditional effect of nuclear aid on weapons acquisition as the number of disputes rises.[114] Nuclear assistance does not have a statistically significant effect on acquisition when countries experience an average of zero militarized disputes, because zero is included in the confidence inter-

114. Figure 3 is based on the results in model 7.

Figure 3. Marginal Effect of Nuclear Assistance on Weapons Acquisition as Number of Disputes Increases



*NCAs = nuclear cooperation agreements

val. For all other levels of conflict, atomic assistance has a statistically significant effect. If countries experience an average of one militarized dispute, the substantive effect of atomic aid is modest. Increases in peaceful assistance raise the probability of bomb acquisition from 0.0000165 to 0.0000122, an increase of 43 percent. For an average state experiencing six disputes, receiving nuclear aid raises the probability it will acquire nuclear weapons more substantially, from 0.000504 to 0.00202. If that same state were to experience twelve disputes in a year, the probability of acquisition would rise from 0.0144 to 0.306, an increase of 2,031 percent. Likewise, receiving atomic assistance and experiencing eighteen conflicts increases the probability of bomb development by 511 percent, from 0.110 to 0.671. These results indicate that, on average, countries that receive atomic assistance are more likely to proliferate—especially when security threats arise.

Turning to the control variables, the coefficient on the variable measuring whether a state shares a military alliance with a nuclear-armed power is statistically insignificant in all eight models, suggesting that nuclear protection has no effect on whether a country pursues the bomb or successfully builds it. The coefficients on the variables measuring whether a country is democratic or is democratizing are also statistically insignificant, indicating that regime type has little effect on proliferation aims and outcomes. Many policymakers assume that proliferation is a problem caused by "rogue" or undemocratic states. Although some autocratic states such as North Korea have proliferated in recent years, on average democracy is less salient in explaining the spread of nuclear weapons than the conventional wisdom suggests. The results also fail to support the argument that trade dependence influences nuclear proliferation. The coefficients on the variables measuring trade dependence and liberalization are not statistically significant in models 1–4, meaning that these factors have no effect on states' decisions to build the bomb. Economic openness also has an insignificant effect on bomb acquisition. But interestingly, liberalization has a positive and statistically significant effect in models 6 and 8, indicating that liberalizing states are more likely to cross the nuclear threshold. Future research should explore whether these results may be due to imperfect measurement of these concepts.

Some of the control variables do behave as expected. The coefficient on the variable measuring whether a country has signed the NPT is negative and statistically significant in models 1–4, indicating that countries making nonproliferation commitments are less likely to initiate bomb programs. Substantively, NPT membership reduces the likelihood that a country will begin a nuclear weapons program by more than 90 percent. For statistical reasons, it was necessary to exclude the NPT variable from models 5–8.[115] The coefficient on the variable measuring whether a country is involved in a rivalry is positive and statistically significant across models 1–4, but it is insignificant in models 6 and 8. Likewise, the GDP variables have statistically significant effects in models 1 and 3, but these results are sensitive to model specification. Industrial capacity has a positive and statistically significant effect in all eight models, indicating that countries with high industrial capabilities are more likely to begin weapons programs and successfully build the bomb. This is the only variable other than the factors operationalizing my argument that has a statistically significant effect across model specifications. Having adequate industrial capacity increases the probability of program initiation from 0.00000226 to 0.000105 and the probability of acquisition from 0.000487 to 0.000804.

To further assess the robustness of my findings, I conducted a sensitivity analysis. I used a new estimator to account for possible endogeneity and an alternate coding for the dependent variable. In addition, I excluded "sensitive"

115. The NPT variable is not included in the acquisition analysis because it predicts failure perfectly. This poses problems for standard statistical techniques.

nuclear cooperation agreements from the coding of my key independent variable. For space considerations, I discuss only briefly the results of these robustness checks. Detailed discussions of the results and procedures, as well as all of the tables displaying the statistical results, are available in an online appendix.[116]

ENDOGENEITY

My argument is that the accumulation of nuclear cooperation agreements encourages states to begin nuclear weapons programs and that receiving atomic aid ultimately enables states to acquire nuclear weapons. But it is also possible that states seek nuclear assistance when they are pursuing nuclear weapons.[117] Thus, nuclear cooperation may be endogenous to nuclear weapons pursuit.

One standard approach to address the endogeneity issue is to lag the independent variables one year behind the dependent variable.[118] I adopted this approach in the analysis presented above. As an additional way to address this issue, I estimated two endogenous equations simultaneously. The first equation represents the total number of nuclear cooperation agreements a state has made in a particular year, and the second estimates the likelihood that it is pursuing nuclear weapons. As was the case above, the proliferation equation parallels the work of Singh and Way.[119] The nuclear cooperation equation that I employed is based on a recent study of the causes of atomic assistance.[120] To estimate these equations simultaneously, I used a technique originally developed by G.S. Maddala and practically implemented by Omar Keshk.[121] This method is designed for simultaneous equation models where one of the endogenous variables is continuous and the other is dichotomous, which is precisely the nature of the variables in this analysis. The two-stage estimation technique generates instruments for each of the endogenous variables and then substitutes them in the respective structural equations. The first equation (with the continuous variable) is estimated using ordinary least squares, and the second (with the dichotomous variable) is estimated using probit.[122]

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116. See data section, http://people.cas.sc.edu/fuhrmann.
117. See Fuhrmann, "Taking a Walk on the Supply Side."
118. See, for example, Erik Gartzke and Quan Li, "Measure for Measure: Concept Operationalization and the Trade Interdependence-Conflict Debate," *Journal of Peace Research,* Vol. 40, No. 5 (September 2003), pp. 553–571.
119. Singh and Way, "The Correlates of Nuclear Proliferation."
120. Fuhrmann, "Taking a Walk on the Supply Side."
121. G.S. Maddala, *Limited-Dependent and Qualitative Variables in Econometrics* (Cambridge: Cambridge University Press, 1986); and Omar Keshk, "CDSIMEQ: A Program to Implement Two-Stage Probit Least Squares," *Stata Journal,* Vol. 3, No. 2 (June 2003), pp. 157–167.
122. For other work in political science that uses this approach, see Omar M.G. Keshk, Brian M. Pollins, and Rafael Reuveny, "Trade Still Follows the Flag: The Primacy of Politics in a Simulta-

The results of the two-stage probit least squares model that addresses the simultaneity issue are generally consistent with the findings presented above.[123] Most important, nuclear cooperation has a positive and statistically significant effect on nuclear weapons pursuit. This result is robust to alternate model specifications.[124]

DEPENDENT VARIABLE CODING

It is often difficult to determine the year that a country begins a nuclear weapons program or acquires the bomb, given the secrecy that surrounds such military endeavors. As a result, there is some disagreement among scholars on the dates that certain countries began to proliferate. To explore whether my results are sensitive to proliferation codings, I used an alternate set of proliferators and dates compiled by Jo and Gartzke.[125] Estimating the same models displayed above but with the alternate proliferation dates also does not affect the results relating to my argument.

REMOVAL OF SENSITIVE AGREEMENTS

Recent research finds that countries receiving certain "sensitive" nuclear assistance are more likely to acquire nuclear weapons.[126] For the reasons I argued above, the relationship between nuclear assistance and proliferation is broader. Training in nuclear engineering, the supply of research or power reactors, and

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neous Model of Interdependence and Armed Conflict," *Journal of Politics,* Vol. 66, No. 4 (November 2004), pp. 1155–1179; Hyung Min Kim and David L. Rousseau, "The Classical Liberals Were Half Right (or Half Wrong): New Tests of the 'Liberal Peace,' 1960–88," *Journal of Peace Research,* Vol. 42, No. 5 (September 2005), pp. 523–543; and Cameron Thies, "Of Rules, Rebels, and Revenue: State Capacity, Civil War Onset, and Primary Commodities," paper presented at the Pan-European Conference on International Relations, Torino, Italy, September 12–15, 2007.

123. I did not include the interaction term in the simultaneous equations model. It is possible to include interaction terms in such models by calculating the predicted value of the endogenous variable (peaceful nuclear cooperation), interacting this predicted variable with the exogenous variable (militarized disputes), estimating the second equation. This approach is problematic, however, because it does not appropriately correct the standard errors. See Jeffrey M. Wooldridge, *Introductory Econometrics: A Modern Approach* (New York: South-Western College, 2000), pp. 501–528.

124. One of the weaknesses of simultaneous equations models is that the independent variables in the first equation should be exogenous. In other words, they should be unrelated to the dependent variable in the second equation. In international relations, it is difficult for scholars to meet this assumption when using simultaneous equations models. For instance, international trade and militarized conflict are endogenous variables because trade suppresses conflict but conflict also reduces trade. This is why some scholars use the same estimator applied in this article to examine the trade-conflict nexus. But many of the correlates of trade—such as the distance between two countries—are also correlated with conflict. See Keshk, Pollins, and Reuveny, "Trade Still Follows the Flag." The best I can do to address this issue is to reestimate the models while excluding the variables in the first equation that are clearly related to nuclear proliferation. This alteration does not change my core findings.

125. Jo and Gartzke, "Determinants of Nuclear Weapons Proliferation."

126. Kroenig, "Importing the Bomb."

the transfer of certain nuclear materials also affect proliferation. To test whether my results may be driven by a few sensitive deals, I excluded them from the coding of my independent variable. This type of sensitive agreement is extremely rare, so this change resulted in the removal of a small number of agreements. I then estimated all models displayed in table 4 with this alternate coding of the independent variable. The findings relevant to my argument are generally unaltered when sensitive agreements are excluded from my coding of atomic assistance.[127]

Conclusion

Aided by a new data set, this article systematically explored the relationship between civilian nuclear cooperation and nuclear proliferation. It argued that civilian assistance and weapons proliferation are linked because the former leads to the supply of technology and materials that have applications for nuclear energy and nuclear weapons, and because civilian assistance establishes an indigenous base of knowledge in nuclear matters that could be useful for a weapons program. These linkages reduce the expected costs of a nuclear weapons program, making states more likely to begin such a campaign when they have accumulated peaceful assistance—especially when a crisis or security threat arises. Similarly, countries receiving civilian aid are more likely to acquire nuclear bombs because important technological hurdles are lowered.

The analysis conducted in this article lends support for these arguments, even when controlling for the other variables believed to influence proliferation. Other factors are also strong predictors of proliferation, but peaceful nuclear cooperation is one of the more salient variables in explaining why atomic weapons spread. Thus, this article suggests that students of proliferation should take greater stock of civilian nuclear assistance. This is particularly true given that the links between the peaceful and military uses of the atom appear broader than previously believed. Even seemingly "innocuous" nuclear cooperation such as providing training to nuclear scientists or supplying power/research reactors can produce deleterious effects. There is no such thing as "proliferation-proof" atomic assistance.

Since the early days of the atomic age, policymakers have attempted to pro-

127. In a related robustness check unreported here, I removed the sensitive agreements from my independent variable and included a separate dichotomous variable that is coded 1 beginning in the first year a state received sensitive nuclear assistance. I then reestimated all of the models displayed in table 4. The results still show that atomic assistance has a strong effect on both stages of nuclear proliferation. The only noteworthy difference is that at high levels of conflict (more than seven militarized disputes per year), nuclear assistance loses its statistical significance. But it is unclear that sensitive aid explains why this happens. The dummy variable measuring only sensitive nuclear assistance did not attain conventional levels of statistical significance in any of the models.

mote the peaceful uses of nuclear energy. These initiatives were based, at least in part, on the belief that spreading technology would make states less likely to want nuclear weapons. This analysis reveals that "atoms for peace" policies have, on average, facilitated—not constrained—nuclear proliferation. Atoms for peace become atoms for war. From a nonproliferation standpoint, this is a troubling conclusion that carries tremendous policy implications, especially given the looming renaissance in nuclear power. The global nuclear marketplace is more active today than it has been in at least twenty years. Countries in Latin America, Southeast Asia, the Middle East, and Africa have expressed a desire to begin or revive civilian nuclear programs. And many of them are receiving assistance in developing such programs from France, Japan, Russia, the United States, and other capable suppliers.

This article suggests that proliferation will occur as the nuclear renaissance unfolds. But there are measures policymakers can implement to reduce the risks that accompany the spread of nuclear technology. After all, as former U.S. senator and nonproliferation advocate Sam Nunn frequently argues, policymakers are in the business of "risk reduction," not "risk elimination." To reiterate a point made previously, most instances of civilian assistance do not result in proliferation, and there is little reason to expect deterministic links between these two phenomena. Thus, swift and meaningful action by the international community might be able to reverse past trends. In particular, countries should provide additional resources to the IAEA. Safeguards agreements implemented by the IAEA allow it to monitor nuclear facilities to ensure that they are used strictly for peaceful purposes. But the agency is grossly underfunded. IAEA Director-General Mohamed ElBaradei recently stated that the agency's budget "does not by any stretch of the imagination meet our basic, essential requirements," and "our ability to carry out our essential functions is being chipped away."[128] This is troubling because the rise in demand for nuclear energy will increase the IAEA's requirements for safeguards and inspections. Countries must ensure that the agency has adequate resources to fulfill its mission. It would also be prudent to consider ways that the IAEA's mission could be expanded to further decrease the likelihood that civilian nuclear cooperation will aid weapons acquisition.

Additionally, nuclear suppliers should adopt responsible export practices and avoid the temptation to sacrifice long-term nonproliferation objectives in pursuit of short-term economic or political gains. They should be especially cautious when supplying technology or know-how to countries that

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128. Quoted in Paul Kerr, "ElBaradei: IAEA Budget Problems Dangerous," *Arms Control Today*, Vol. 37, No. 6 (July/August 2007), http://www.armscontrol.org/act/2007_07-08/IAEABudget.

face significant security threats. Many of the countries currently beginning or expanding their civilian nuclear programs are in the Middle East—the world's most dangerous region. Algeria, Jordan, Libya, Saudi Arabia, and the United Arab Emirates have all received pledges of support from at least one supplier country since 2006. None of these countries currently intends to build nuclear weapons. But that could change if Iran crosses the nuclear threshold or if Israel conducts an atomic test and reverses its policy of opacity. One of the important conclusions of this article is that the combination of atomic assistance and security threats is a recipe for the spread of nuclear weapons. Suppliers such as France and the United States, therefore, should rethink their offers of atomic assistance to states in the Middle East and other dangerous regions.

There is still more work to be done to advance scholarly understanding of the relationship between peaceful nuclear cooperation and proliferation. Future research should examine illicit nuclear trade and explore how it relates to peaceful nuclear assistance. It would be productive to analyze additional cases of licit and illicit nuclear commerce to confirm or invalidate the propositions advanced in this article. Additional case studies that examine why some countries receiving peaceful assistance pursue the bomb whereas others do not would be particularly welcome because they might reveal useful policy recommendations for how to promote nuclear energy while minimizing proliferation risks.

This study also raises an interesting puzzle: Why do suppliers provide civilian assistance? If countries generally want to limit the spread of nuclear weapons and if nuclear cooperation agreements lead to proliferation, then it seems puzzling that supplier states would engage in civilian nuclear cooperation. Recent research suggests that countries ignore proliferation risks in pursuit of strategic or economic benefits.[129] For example, France's recent NCAs with Saudi Arabia and the United Arab Emirates are motivated in part by a desire to obtain assurances on the supply of oil. Another possibility is that countries offer assistance to intentionally spread the bomb and constrain other countries.[130] Additional work examining suppliers' motivations would be welcome, as it could shed further light on how and why nuclear weapons spread.

129. Fuhrmann, "Taking a Walk on the Supply Side."
130. Kroenig, "Exporting the Bomb."