Why Nuclear Energy Programs Rarely Lead to Proliferation

Nicholas L. Miller

As long as there have been nuclear weapons, policymakers and analysts have worried that the spread of nuclear reactors for energy production would lead to the diffusion of nuclear arms.[1] According to one analyst, "It was obvious from the beginning of the nuclear age that nuclear energy for power and nuclear energy for bombs overlapped."[2] Indeed, the 1946 Acheson-Lilienthal report, which examined the possibility of international control of nuclear technology, determined that "the industry required and the technology developed for the realization of atomic weapons are the same industry and same technology which play so essential a part in man's almost universal striving to improve his standard of living and his control of nature."[3] Writing in the 1970s, Nuclear Regulatory Commissioner Victor Gilinsky warned that nuclear energy programs offer "the quickest, cheapest, and least risky route to nuclear weapons."[4] More recently, José Goldemberg argued that there is a "fundamental contradiction between efforts to avoid the proliferation of nuclear weapons and enthusiasm for the spread, for commercial reasons, of nuclear reactors to many developing countries."[5] Today, some analysts worry that the upsurge in interest in nuclear energy in the Middle East is a prelude to a nuclear arms race.[6]

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1. I use the term "nuclear energy program" to refer to the production of electricity using nuclear reactors, or the construction of reactors for that purpose. I use this term rather than "nuclear power" because the latter term is often used to refer to countries with nuclear weapons. I define proliferation to include both the pursuit and acquisition of nuclear weapons.
2. Victor Gilinsky, "Nuclear Power, Nuclear Weapons—Clarifying the Links," in Henry Sokolski, ed., *Moving beyond Pretense: Nuclear Power and Nonproliferation* (Carlisle, Pa.: U.S. Army War College Press, 2014), p. 119.
3. Chester I. Barnard et al., "A Report on the International Control of Atomic Energy" (Washington, D.C.: U.S. Secretary of State's Committee on Atomic Energy, March 16, 1946), p. 9, http://fissilematerials.org/library/ach46.pdf.
4. Victor Gilinsky, "Nuclear Energy and the Proliferation of Nuclear Weapons," in Albert Wohlstetter et al., eds., *Nuclear Policies: Fuel without the Bomb* (Cambridge, Mass.: Ballinger, 1978), p. 89.
5. José Goldemberg, "Nuclear Energy in Developing Countries," *Daedalus*, Vol. 138, No. 4 (Fall 2009), p. 75, doi:10.1162/daed.2009.138.4.71.
6. For a recent example, see Karl Vick, "The Middle East Nuclear Race Is Already Under Way,"

International Security, Vol. 42, No. 2 (Fall 2017), pp. 40–77, doi:10.1162/ISEC_a_00293

In contrast to the conventional wisdom, this article argues that the link between nuclear energy programs and proliferation is overstated. Although such programs increase the technical capacity of a state to build nuclear weapons, they also have important countervailing political effects that limit the odds of proliferation. Specifically, nuclear energy programs (1) increase the likelihood that a parallel nuclear weapons program is detected and attracts outside nonproliferation pressures, and (2) increase the costliness of nonproliferation sanctions. These countervailing mechanisms are largely the product of policy interventions by actors who have worried since the beginning of the nuclear age that nuclear energy programs would lead to proliferation. In this sense, the long-standing belief that the expansion of such programs would result in an expansion in the number of nuclear weapons states might be at least partially viewed as a self-defeating prophecy, much like policymakers' beliefs in nuclear domino effects or tipping points.[7]

Understanding the relationship between nuclear energy and the spread of nuclear weapons may be particularly pressing now for three reasons. First, nuclear energy has the potential to reduce carbon emissions and thereby help combat climate change, potentially making it an attractive option.[8] Second, many observers have argued that the world is in the midst of a nuclear energy "renaissance," or at least it was prior to the 2011 Tohoku tsunami, which caused nuclear meltdowns at Japanese nuclear power plants in Fukushima and dampened global enthusiasm for nuclear energy.[9] Third, many countries currently developing nuclear energy programs are located in unstable security environments (e.g., Egypt, Saudi Arabia, Turkey, and the United Arab Emirates), which may provide them with incentives to seek nuclear weapons. Even though the relative costs of nuclear energy production have grown over time, particularly as natural gas has become cheaper,[10] there are still dozens of

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Time, March 23, 2015, http://time.com/3751676/iran-talks-nuclear-race-middle-east/; and Harold A. Feiveson, "A Skeptic's View of Nuclear Energy," *Daedalus*, Vol. 138, No. 4 (Fall 2009), pp. 65–66, doi:10.1162/daed.2009.138.4.60.

7. See Nicholas L. Miller, "Nuclear Dominoes: A Self-Defeating Prophecy?" *Security Studies*, Vol. 23, No. 1 (2014), pp. 33–73, doi:10.1080/09636412.2014.874189.

8. See, for example, Joshua William Busby, "Vaunted Hopes: Climate Change and the Unlikely Nuclear Renaissance," in Adam N. Stulberg and Matthew Fuhrmann, eds., *The Nuclear Renaissance and International Security* (Stanford, Calif.: Stanford University Press, 2013), pp. 124–153; and Robert H. Socolow and Alexander Glaser, "Balancing Risks: Nuclear Energy and Climate Change," *Daedalus*, Vol. 138, No. 4 (Fall 2009), pp. 31–44, doi:10.1162/daed.2009.138.4.31.

9. See Stulberg and Fuhrmann, *The Nuclear Renaissance and International Security*; Steven E. Miller and Scott D. Sagan, "Nuclear Power without Nuclear Proliferation?" *Daedalus*, Vol. 138, No. 4 (Fall 2009), pp. 7–18, doi:10.1162/daed.2009.138.4.7; and World Nuclear Association, "The Nuclear Renaissance" (London: World Nuclear Association, September 2015), http://www.world-nuclear.org/info/Current-and-Future-Generation/The-Nuclear-Renaissance/.

10. See, for example, Alan Neuhauser, "Nuclear Power, Once Cheap, Squeezed by Mounting Costs," *US News and World Report*, March 30, 2016, https://www.usnews.com/news/articles/2016-03-30/nuclear-power-once-cheap-squeezed-by-mounting-costs; Joe Romm, "The Nuclear In-

countries that are at different stages of considering or developing nuclear energy programs.[11] As a result, although such programs are unlikely to spread as quickly as many analysts anticipated prior to the Fukushima disaster, additional countries are still likely to pursue them over time.

This article begins by outlining the conventional wisdom about how nuclear energy programs contribute to proliferation. It then offers an alternative argument, which emphasizes that nuclear energy programs generate important political obstacles to proliferation. Next, the article empirically assesses the relationship between nuclear energy programs and proliferation historically. It finds that states with such programs have not been significantly more likely to pursue nuclear weapons. Moreover, conditional on having a nuclear weapons program, states with nuclear energy programs have not been significantly more likely to acquire nuclear weapons. The article also finds preliminary support for the political restraints that I hypothesize weaken the link between energy and weapons. After addressing several counterarguments, the article concludes with a discussion of the implications of the findings for theory and policy.

The Conventional Wisdom on Nuclear Energy and Nuclear Weapons

The conventional wisdom identifies three main pathways through which a nuclear energy program might facilitate proliferation. In short, an energy program could provide (1) the means, (2) the motivation, or (3) the political cover for developing a nuclear weapons program.[12]

First, a nuclear energy program involves training scientists in nuclear physics and engineering, providing them with basic skills and know-how that could be used in a nuclear weapons program and potentially reducing the expected costs of such a program.[13] Moreover, nuclear energy programs re-

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dustry Prices Itself Out of Market for New Power Plants," *ThinkProgress*, March 8, 2016, https://thinkprogress.org/the-nuclear-industry-prices-itself-out-of-market-for-new-power-plants-1421750327c3; and Jessica R. Lovering, Arthur Yip, and Ted Nordhaus, "Historical Construction Costs of Global Nuclear Power Reactors," *Energy Policy*, Vol. 91 (2016), pp. 371–382, doi:10.1016/j.enpol.2016.01.011.

11. World Nuclear Association, "Emerging Nuclear Energy Countries" (Washington, D.C.: World Nuclear Association, March 2017), http://www.world-nuclear.org/information-library/country-profiles/others/emerging-nuclear-energy-countries.aspx.

12. For a similar typology of pathways linking nuclear energy programs and proliferation, see 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), pp. 190–191.

13. For a similar argument on nuclear cooperation agreements, see Matthew Fuhrmann, "Spreading Temptation: Proliferation and Peaceful Nuclear Cooperation Agreements," *International Security*, Vol. 34, No. 1 (Summer 2009), pp. 7–41, doi:10.1162/isec.2009.34.1.7.

quire the construction of power reactors, which produce plutonium as a natural by-product of the fission process. Although graphite- and heavy water–moderated reactors have generally been considered optimal for producing plutonium for weapons,[14] even light water reactors (LWRs)—by far the most common type of power reactor—are capable of producing plutonium usable in nuclear weapons.[15] Indeed, Henry Sokolski describes LWRs as "nuclear bomb starter kits."[16] When coupled with a reprocessing facility, which can be used in a nuclear energy program to reduce nuclear waste and recycle plutonium for use in reactor fuel, power reactors provide states with the capability to acquire fissile material for a nuclear bomb.[17] Alternatively, states with nuclear energy programs might develop uranium enrichment technology to produce low-enriched uranium fuel for their reactors, thus also providing the state with the capability to produce highly enriched uranium for use in nuclear weapons.[18] Because energy programs lower the costs of proliferation, "they may constitute an irresistible temptation to produce nuclear weapons under provocation insufficient to motivate undertaking a weapons program from scratch."[19] This mechanism would predict that countries with nuclear energy programs are more likely to pursue nuclear weapons (because the expected costs of a weapons program are lower) and more likely to acquire them (because they possess increased technical capabilities).

Second, analysts have worried that the development of nuclear energy infrastructure could increase a state's motivation to seek nuclear weapons. The technology itself could create an irresistible demand for weapons where one did not previously exist.[20] Alternatively, a nuclear energy program could em-

14. M.D. Zentner, G.L. Coles, and R.J. Talbert, "Nuclear Proliferation Technology Trends Analysis" (Oak Ridge, Tenn.: Pacific Northwest National Laboratory, September 2005), pp. 60–83.
15. See Gilinsky, "Nuclear Power, Nuclear Weapons," pp. 125–161; Victor Gilinsky, Marvin Miller, and Harmon Hubbard, "A Fresh Examination of the Proliferation Dangers of Light Water Reactors" (Arlington, Va.: Nonproliferation Policy Education Center, October 2004); and J. Carson Mark, Frank von Hippel, and Edward Lyman, "Explosive Properties of Reactor-Grade Plutonium," *Science and Global Security*, Vol. 17, Nos. 2–3 (2009), pp. 170–185, doi:10.1080/08929880903368690.
16. Henry Sokolski, *Underestimated: Our Not So Peaceful Nuclear Future* (Arlington, Va.: Nonproliferation Policy Education Center, 2015), p. 98.
17. Zentner, Coles, and Talbert, "Nuclear Proliferation Technology Trends Analysis," pp. 83–102.
18. See Gilinsky, "Nuclear Power, Nuclear Weapons," pp. 133–134; and Steven E. Miller and Scott D. Sagan, "Alternative Nuclear Futures," *Daedalus*, Vol. 139, No. 1 (Winter 2010), p. 128, doi:10.1162/daed.2010.139.1.126.
19. John P. Holdren, "Nuclear Power and Nuclear Weapons: The Connection Is Dangerous," *Bulletin of the Atomic Scientists*, Vol. 39, No. 1 (1983), p. 42, doi:10.1080/00963402.1983.11458937.
20. See Stephen M. Meyer, *The Dynamics of Nuclear Proliferation* (Chicago: University of Chicago Press, 1986); Peter R. Lavoy, "Nuclear Myths and the Causes of Nuclear Proliferation," *Security Studies*, Vol. 2, Nos. 3–4 (1993), pp. 194–195, doi:10.1080/09636419309347524; and 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. 862–863, doi:10.1177/0022002704269655.

power a bureaucracy that might later push for the development of a weapons program for parochial reasons, such as increasing its budget or prestige. In his seminal article on motives for proliferation, Scott Sagan notes, "Whether or not the acquisition of nuclear weapons serves the national interest of a state, it is likely to serve the bureaucratic or political interests of at least some individual actors within the state." He identifies "the nuclear energy establishment" as one such actor.[21] This mechanism would predict that a country with a nuclear energy program is more likely to pursue nuclear weapons.

Third, nuclear energy programs could provide political cover for the acquisition of enrichment, reprocessing, or other weapons-related technology from foreign countries, allowing a proliferator to plausibly deny any weapons intentions.[22] Having a peaceful justification for the possession of such technology could help weaken international opposition and avert or complicate any nonproliferation intervention. Indeed, Article 4 of the Nonproliferation Treaty (NPT) explicitly guarantees the right of signatories to peaceful nuclear technology, which can include reactors, reprocessing, and enrichment facilities. Because of this "giant loophole,"[23] proliferators can use the cover of the NPT itself to justify the acquisition of the technology to produce fissile material, a strategy used most recently by Iran. As John Holdren argues, "[A] power program provides a legitimating cover for nuclear activities which would otherwise be unambiguously weapons-oriented."[24] This "political cover" mechanism does not suggest that having a nuclear energy program increases the odds of a state initiating a weapons program. Rather, it indicates that having a nuclear energy program might make the subsequent acquisition of nuclear weapons more likely.

In line with the conventional wisdom, the academic supply-side literature has largely coalesced around demonstrating the links between the spread of nuclear know-how and technology and an increased probability of proliferation. According to recent findings, states are more likely to pursue or acquire nuclear weapons when they have greater numbers of peaceful nuclear cooperation agreements with other states (including agreements related to nuclear

21. 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), p. 63, doi:10.1162/isec.21.3.54.
22. See Gilinsky, "Nuclear Power, Nuclear Weapons," pp. 127–128; Susan Voss, "Scoping Intangible Proliferation Related to Peaceful Nuclear Programs: Tracking Nuclear Proliferation within a Commercial Nuclear Power Program," in Sokolski, *Moving beyond Pretense*, pp. 149–152; Feiveson, "A Skeptic's View of Nuclear Energy," pp. 65–66; and Miller and Sagan, "Nuclear Power without Nuclear Proliferation?" p. 13.
23. Thomas C. Reed and Danny B. Stillman, *The Nuclear Express: A Political History of the Bomb and Its Proliferation* (Minneapolis, Minn.: Zenith, 2010), p. 144.
24. Holdren, "Nuclear Power and Nuclear Weapons," p. 42.

energy production),[25] receive sensitive nuclear assistance,[26] are recipients of technical aid on the fuel cycle from the International Atomic Energy Agency (IAEA),[27] or have greater latent nuclear capacity (e.g., uranium deposits, nuclear scientists, and chemical engineers).[28] Other studies make the more nuanced argument that competition among nuclear suppliers is particularly likely to generate proliferation risks, triggering a "race to the bottom" in export standards.[29]

Although several scholars have critiqued this literature, they have not directly assessed the link between nuclear energy programs and proliferation.[30] The quantitative research that comes closest to doing so often finds that the association is surprisingly weak, although these studies tend to look only at bivariate relationships or to address the question obliquely, rather than treat it as the primary focus.[31]

At least two qualitative analyses come to similar conclusions. Matthew Bunn finds that "civilian nuclear energy is by no means the driving force behind nuclear proliferation."[32] Fred McGoldrick observes that the majority of nuclear weapons states acquired their arsenals "primarily through dedicated military programs, clandestine and illegal procurements, and deliberate assis-

25. Fuhrmann, "Spreading Temptation"; and Matthew Fuhrmann, *Atomic Assistance: How "Atoms for Peace" Programs Cause Nuclear Insecurity* (Ithaca, N.Y.: Cornell University Press, 2012).
26. Matthew Kroenig, *Exporting the Bomb: Technology Transfer and the Spread of Nuclear Weapons* (Ithaca, N.Y.: Cornell University Press, 2010).
27. Robert L. Brown and Jeffrey M. Kaplow, "Talking Peace, Making Weapons: IAEA Technical Cooperation and Nuclear Proliferation," *Journal of Conflict Resolution*, Vol. 58, No. 3 (2014), pp. 402–428, doi:10.1177/0022002713509052.
28. Dong-Joon Jo and Erik Gartzke, "Determinants of Nuclear Weapons Proliferation," *Journal of Conflict Resolution*, Vol. 51, No. 1 (February 2007), pp. 167–194, doi:10.1177/0022002706296158.
29. See Eliza Gheorghe, "Proliferation and the Logic of the Nuclear Marketplace," Harvard University, October 2016; and Sungyeol Choi and Il Soon Hwang, "Effects of Nuclear Technology Export Competition on Nuclear Nonproliferation," *Nonproliferation Review*, Vol. 22, Nos. 3–4 (2015), pp. 341–359, doi:10.1080/10736700.2016.1154267.
30. R. Scott Kemp, "The Nonproliferation Emperor Has No Clothes: The Gas Centrifuge, Supply-Side Controls, and the Future of Nuclear Proliferation," *International Security*, Vol. 38, No. 4 (Spring 2014), pp. 39–78, doi: 10.1162/ISEC_a_00159; Jacques E.C. Hymans, *Achieving Nuclear Ambitions: Scientists, Politicians, and Proliferation* (New York: Cambridge University Press, 2012); and Alexander N. Montgomery, "Stop Helping Me: When Nuclear Assistance Impedes Nuclear Programs," in Stulberg and Fuhrmann, *The Nuclear Renaissance and International Security*, pp. 177–202.
31. See Matthew Fuhrmann, "Splitting Atoms: Why Do Countries Build Nuclear Power Plants?" *International Interactions*, Vol. 38, No. 1 (2012), pp. 29–57, doi:10.1080/03050629.2012.640209; Brown and Kaplow, "Talking Peace, Making Weapons"; Michael C. Horowitz, "Nuclear Power and Militarized Conflict: Is There a Link?" in Stulberg and Fuhrmann, *The Nuclear Renaissance and International Security*, pp. 288–312; Kroenig, *Exporting the Bomb*, pp. 162–168; and Man-Sung Yim and Jun Li, "Examining Relationship between Nuclear Proliferation and Civilian Nuclear Power Development," *Progress in Nuclear Energy*, Vol. 66 (2013), pp. 108–114, doi:10.1016/j.pnucene.2013.03.005.
32. Matthew Bunn, "Civilian Nuclear Energy and Nuclear Weapons Programs: The Record," Harvard University, June 29, 2001, p. 8, https://ocw.mit.edu/courses/nuclear-engineering/22-812j-managing-nuclear-technology-spring-2004/readings/prolif_history.pdf.

tance from nuclear-weapon states," not through nuclear energy programs.[33] Neither of these works, however, examines whether the probability of pursuing or acquiring nuclear weapons is significantly higher in countries with nuclear energy programs compared to countries that do not have them. Importantly, the lack of sustained scholarly focus on the relationship between nuclear energy and nuclear weapons programs helps explain why, in 2011, Sagan identified as a significant future research question, "Does the civilian nuclear power industry constrain states or does it make nuclear weapons proliferation easier?"[34]

How Nuclear Energy Programs Restrain Proliferation

As the conventional wisdom emphasizes, a nuclear energy program increases the technical capability of a state to build nuclear weapons. However, policymakers in states that favor nonproliferation—most prominently, the United States—have long been aware of this fact and have worked hard to weaken this linkage. As a result of their actions, a variety of political restraints have been put in place to counterbalance the ability of energy programs to make proliferation technically easier. The remainder of this section elaborates two such restraints.

HIGHER LIKELIHOOD OF DETECTION AND NONPROLIFERATION PRESSURE

States with nuclear energy programs face increased international scrutiny and therefore pressure not to proliferate. From the time a country announces its intention to build nuclear power reactors, the possibility of this being cover for a weapons program becomes apparent, particularly if the country is located in an unstable security environment. As Harold Feiveson wrote in 2009, "It is well understood that one of the factors leading several countries now without nuclear power programs to express interest in nuclear power is the foundation that such programs could give them to develop weapons."[35]

Once a country formally launches a nuclear energy program, its activities are likely to trigger outside intelligence gathering, for three reasons: energy programs (1) involve regular acquisitions of material and technology from foreign firms, providing more collection opportunities for intelligence agencies and allowing the program to be infiltrated; (2) offer observable targets—such

33. Fred McGoldrick, "Nuclear Trade Controls: Minding the Gaps" (Washington, D.C.: Center for Strategic and International Studies [CSIS], January 2013), p. v.
34. Scott D. Sagan, "The Causes of Nuclear Weapons Proliferation," *Annual Review of Political Science*, Vol. 14 (2011), p. 240, doi:10.1146/annurev-polisci-052209–131042.
35. Feiveson, "A Skeptic's View of Nuclear Energy," pp. 65–66.

as reactors, research centers, and nuclear scientists—for intelligence agencies to focus on; and (3) generally come with safeguards on relevant facilities, either because of the recipient country's membership in the NPT or supplier requirements. These factors do not make it impossible for a country to use an energy program to develop a nuclear weapons program, but they do make it more likely that the latter program will be detected. In monitoring nuclear energy programs and detecting nuclear weapons research, both national intelligence agencies and the IAEA play important and, increasingly synergistic, roles.[36]

International scrutiny is likely to be particularly harsh, both in the media and from intelligence agencies, when the energy program involves efforts to acquire enrichment or reprocessing facilities. After all, these are technologies required for producing fissile materials for bombs, and enrichment and reprocessing programs are hard to justify economically for small nuclear energy programs.[37] This sort of scrutiny explains the vigorous response of the United States to the proposed export of reprocessing and enrichment technology to Brazil, Iran, Pakistan, South Korea, and Taiwan in the 1970s—which in every case was publicly justified with reference to nuclear energy programs. In each, the United States was partially or entirely successful in preventing the exports or increasing safeguards, thus complicating the path to the bomb for the nuclear aspirants.[38]

States that want to acquire nuclear weapons while minimizing the chances of detection and nonproliferation pressure are likely better off adopting a more covert approach, without an energy program. As Scott Kemp has demon-

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36. See James M. Acton, "International Verification and Intelligence," *Intelligence and National Security*, Vol. 29, No. 3 (2014), pp. 341–356, doi:10.1080/02684527.2014.895592.
37. On the economics of reprocessing, see Matthew Bunn et al., "The Economics of Reprocessing vs. Direct Disposal of Spent Fuel" (Cambridge, Mass.: Belfer Center for Science and International Affairs, John F. Kennedy School of Government, Harvard University, December 2003); and Paul L. Joskow and John E. Parsons, "The Economic Future of Nuclear Power," *Daedalus*, Vol. 138, No. 4 (Fall 2009), p. 56, doi:10.1162/daed.2009.138.4.45. On the economics of enrichment in small nuclear energy programs, see S.M. Short et al., "Economic and Non-Proliferation Policy Considerations of Uranium Enrichment in Brazil and Argentina" (Oak Ridge, Tn.: Pacific Northwest National Laboratory, August 2008); and Joseph Cirincione, "The Continuing Problem of Nuclear Weapons: Controlling Iran's Nuclear Program," *Issues in Science and Technology*, Vol. 32, No. 3 (Spring 2006), http://issues.org/22-3/cirincione/.
38. On Brazil, see William Glenn Gray, "Commercial Liberties and Nuclear Anxieties: The U.S.-German Feud over Brazil, 1975–7," *International History Review*, Vol. 34, No. 3 (2012), pp. 449–474, doi:10.1080/07075332.2012.675221. On Iran, see William Burr, "A Brief History of U.S.-Iranian Nuclear Negotiations," *Bulletin of the Atomic Scientists*, Vol. 65, No. 1 (2009), pp. 21–34, doi:10.2968/065001004. On Pakistan, see Samina Ahmed, "Pakistan's Nuclear Weapons Program: Turning Points and Nuclear Choices," *International Security*, Vol. 23, No. 4 (Spring 1999), pp. 184–185, doi:10.2968/065001004. On South Korea and Taiwan, see Nicholas L. Miller, "The Secret Success of Nonproliferation Sanctions," *International Organization*, Vol. 68, No. 4 (Fall 2014), pp. 913–944, doi:10.1017/S0020818314000216.

strated, a country with relatively modest technological skills could indigenously build and operate gas centrifuges to produce highly enriched uranium. Such an operation would not require a nuclear reactor or an energy program, would produce virtually no technical signatures, and would therefore be relatively easy to conceal; indeed, most countries that developed gas centrifuges indigenously did so without being detected.[39] Or, as Richard Rhodes has argued, "[T]here are better, faster, surer, cheaper, and secret alternative means to proliferation" than using power reactors.[40] Such a "hiding" strategy, Vipin Narang argues, may permit a state to "present its development of nuclear weapons as a fait accompli," allowing it to "reap all the benefits of a nuclear deterrent while avoiding the external duress of the proliferation process."[41] Although enrichment programs are easier to conceal than plutonium-based programs, either can be attempted secretly without a public energy program, as the cases of Israel, North Korea, and Syria illustrate. Even if a covert program is unlikely to remain secret to the point of acquisition, the aspiring proliferator may nonetheless seek to delay detection, thereby reducing opportunities for preventive action. Certainly elements of any nuclear weapons program are likely to be covert, including in countries using an energy program as cover. For example, a country pursuing nuclear weapons with an energy program is still likely to do weapons design work in secret, may build additional covert facilities based on technology in overt facilities, and might seek to secretly divert materials for use in weapons. Nonetheless, countries engaged in this kind of tactical secrecy display qualitative differences from those without energy programs that conceal all or most of their key nuclear facilities.

Several historical cases illustrate the viability of this more covert proliferation pathway. Following Israel's attack on Iraq's Osirak reactor in 1981, Iraq managed to acquire enrichment technology largely without the knowledge of the international community. As a result, Baghdad was likely only a few years away from achieving a rudimentary nuclear weapons capability when its nuclear program was dismantled in the aftermath of the 1990–91 Gulf War, which was not primarily a nonproliferation intervention.[42] Interestingly, part of the reason U.S. intelligence officials underestimated Iraq's program was be-

39. Kemp, "The Nonproliferation Emperor Has No Clothes," pp. 47–55.
40. Richard Rhodes, "Nuclear Power and Proliferation," in Leventhal, Tanzer, and Dolley, *Nuclear Power and the Spread of Nuclear Weapons*, p. 63.
41. Vipin Narang, "Strategies of Nuclear Proliferation: How States Pursue the Bomb," *International Security*, Vol. 41, No. 3 (Winter 2016/17), p. 121, doi:10.1162/ISEC_a_00268.
42. Målfrid Braut-Hegghammer, "Revisiting Osirak: Preventive Attacks and Nuclear Proliferation Risks," *International Security*, Vol. 36, No. 1 (Summer 2011), pp. 116–119, 125, doi:10.1162/ISEC_a_00046.

cause they wrongly assumed that Baghdad would follow the energy program route. A 1983 Central Intelligence Agency report found "no identifiable nuclear weapon program in Iraq" and judged that achieving a nuclear weapons capability by the 1990s "[would depend] critically on the foreign supply of a nuclear reactor—preferably a power reactor—of substantial size fairly soon."[43]

By the time U.S. intelligence officials became convinced that North Korea was pursuing nuclear weapons in 1989,[44] Pyongyang had already secretly constructed a reactor for plutonium production and begun work on a reprocessing facility.[45] The United States first detected the construction of the reactor in 1982,[46] two years after construction had begun.[47] It was not until 1984, however, that Washington realized that it was a larger reactor better suited to plutonium production.[48] When the United States was ultimately able to mobilize international action against North Korea in 1992, IAEA analysis concluded that North Korea had probably already produced enough plutonium for one or two bombs.[49] Finally, without the cover of a nuclear energy program, Israel was able to secretly build a reactor and reprocessing facility with French help starting in the late 1950s.[50] U.S. intelligence did not learn of the Israeli weapons program until a few years later,[51] and tended to underestimate the progress of the program through the 1960s.[52]

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43. Central Intelligence Agency (CIA), Directorate of Intelligence Appraisal, "The Iraqi Nuclear Program: Progress Despite Setbacks," June 1983, in Joyce Battle, ed., *Shaking Hands with Saddam Hussein: The U.S. Tilts toward Iraq, 1980–1984*, National Security Archive Electronic Briefing Book (NSA EBB) No. 82, doc. 19, http://nsarchive.gwu.edu/NSAEBB/NSAEBB82/index.htm.

44. William M. Drennan, "Nuclear Weapons and North Korea: Who's Coercing Whom?" in Robert J. Art and M. Patrick Cronin, eds., *The United States and Coercive Diplomacy* (Washington, D.C.: U.S. Institute of Peace Press, 2003), pp. 164–165.

45. CIA, "North Korea's Expanding Nuclear Efforts," May 3, 1988, in Robert A. Wampler, ed., *North Korea and Nuclear Weapons: The Declassified U.S. Record*, NSA EBB No. 87, doc. 10, http://www.gwu.edu/~nsarchiv/NSAEBB/NSAEBB87/; Etel Solingen, *Nuclear Logics: Contrasting Paths in East Asia and the Middle East* (Princeton, N.J.: Princeton University Press, 2007), p. 129; and CIA, "North Korea: Potential for Nuclear Weapon Development—The Declassified Record," September 1986, in Wampler, *North Korea and Nuclear Weapons*, doc. 7, http://nsarchive.gwu.edu/NSAEBB/NSAEBB87/nk07.pdf.

46. [CIA], "North Korea: Nuclear Reactor," July 9, 1982, in Wampler, *North Korea and Nuclear Weapons*, doc. 1, http://nsarchive.gwu.edu/NSAEBB/NSAEBB87/nk01.pdf.

47. Jeffrey T. Richelson, *Spying on the Bomb: American Nuclear Intelligence from Nazi Germany to Iran and North Korea* (New York: W.W. Norton, 2007), p. 346.

48. CIA, "East Asia Brief," April 20, 1984, in Wampler, *North Korea and Nuclear Weapons*, doc. 4, http://nsarchive.gwu.edu/NSAEBB/NSAEBB87/nk04.pdf; and Michael Mazarr, "Going Just a Little Nuclear: Nonproliferation Lessons from North Korea," *International Security*, Vol. 20, No. 2 (Fall 1995), p. 94.

49. See Drennan, "Nuclear Weapons and North Korea," p. 167.

50. See Avner Cohen, *Israel and the Bomb* (New York: Columbia University Press, 1998), p. 59; and Solingen, *Nuclear Logics*, p. 187

51. Cohen, *Israel and the Bomb*, pp. 91–94

52. See Alexander H. Montgomery and Adam Mount, "Misestimation: Explaining U.S. Failures to

HEIGHTENED COSTS FROM NONPROLIFERATION SANCTIONS

Nuclear energy programs impose another political restraint on states by increasing the potential costs of nonproliferation sanctions, which are likely to disrupt the international trade and fuel supplies essential to most nuclear energy programs. Sanctions are especially threatening to the majority of nuclear energy programs that rely on LWR technology. As Richard Lester and Robert Rosner note, "[N]uclear power is one of the most highly globalized of all industries. The nuclear power plant supply industry is dominated by a small number of large global suppliers of light water reactor equipment and technology."[53] Christopher Lawrence likewise argues that the LWR fuel cycle "is one of the most globalized technologies in existence."[54] Only twelve countries currently produce fuel rods for light water reactors,[55] compared to thirty-one countries with operational nuclear energy programs.[56] At the same time, most nuclear power reactors are designed and constructed by a few American, Chinese, French, Russian, and South Korean firms.[57] Eleven out of twelve LWR fuel producers and all five major reactor-supplying countries are members of the Nuclear Suppliers Group (NSG), an organization founded in the 1970s that calls for IAEA safeguards on exports and a commitment to peaceful uses of imported materials.[58] For countries operating light water power reactors, the choice is either to develop enrichment technology—and risk international suspicion and pressure, as described above—or to import enriched uranium fuel, thus rendering the energy program vulnerable to disruptions in supply.

As early as 1957, U.S. policymakers were aware that exports for nuclear energy programs provide leverage that can be used to enforce nonproliferation regulations. As one National Security Council report argued, "U.S. preeminence and influence in peaceful uses of atomic energy overseas and nu-

Predict Nuclear Weapons Programs," *Intelligence and National Security*, Vol. 29, No. 3 (2014), pp. 372, 375–377, doi:10.1080/02684527.2014.895593.

53. Richard K. Lester and Robert Rosner, "The Growth of Nuclear Power: Drivers and Constraints," *Daedalus*, Vol. 138, No. 4 (Fall 2009), pp. 20–21, doi:10.1162/daed.2009.138.4.19.

54. Christopher Lawrence, "Normalization by Other Means: The Failed Techno-diplomacy of Light Water Reactor Export in the North Korean Nuclear Crisis," Harvard University, July 2016, p. 9.

55. See World Nuclear Association, "Nuclear Fuel Fabrication" (London: World Nuclear Association, April 2017), http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Conversion-Enrichment-and-Fabrication/Fuel-Fabrication/.

56. See World Nuclear Association, "Nuclear Share Figures, 2006–2016" (London: World Nuclear Association, April 2017), http://www.world-nuclear.org/information-library/facts-and-figures/nuclear-generation-by-country.aspx.

57. See Suzanne Hobbs Baker, Ryan Fitzpatrick, and Matt Goldberg, "Getting Back in the Game: A Strategy to Boost American Nuclear Exports," *Third Way*, January 10, 2017, http://www.thirdway.org/report/getting-back-in-the-game-a-strategy-to-boost-american-nuclear-exports.

58. Tadeusz Strulak, "The Nuclear Suppliers Group," *Nonproliferation Review*, Vol. 1, No. 1 (Fall 1993), pp. 2–10, doi:10.1080/10736709308436518.

clear technology will enhance general acceptance of effective safeguards to minimize diversion of nuclear material to weapons purposes."[59] A 1974 government study on nonproliferation likewise contended, "[A] vigorous US program of commercial nuclear cooperation with other nations can help maintain influence over foreign programs through proper safeguards, dependence on external supply, and the confidence of a constructive association in peaceful programs."[60] The Soviet Union similarly used fuel supplies and safeguards to maintain control over its clients' nuclear programs.[61]

As George Quester wrote in 1977, many countries will "be ready to accommodate to the halting of weapons proliferation in various ways, as long as it seems that this is required to speed or maintain the availability of such American imports" for their energy programs.[62] According to Steven Miller and Scott Sagan, "The leaders and bureaucratic organizations that run successful nuclear power enterprises will want to maintain strong ties to the global nuclear power industry, to international capital and technology markets, and to global regulatory agencies—and hence will be more likely to cooperate with the nuclear nonproliferation regime."[63] U.S. and international nonproliferation policy has been guided by this logic for decades and has tightened over time. In 1978, the United States made nuclear exports conditional on a country's acceptance of safeguards on all of its nuclear facilities, including those not provided by the United States.[64] The NSG followed suit in 1992.[65] Although the U.S. position in the nuclear marketplace has substantially eroded in recent decades,[66] the United States continues to play a pivotal role in setting the rules in the NSG, which sets guidelines for other key suppliers.

Having outlined the conventional wisdom and offered an alternative argu-

59. National Security Council Report, "Peaceful Uses of Atomic Energy," December 13, 1957, doc. NP00367, Digital National Security Archive (DNSA), http://nsarchive.chadwyck.com/home.do.
60. National Security Council, NSSM 202 Study Group, "U.S. Non-Proliferation Policy," May 23, 1974, doc. PR01261, DNSA, http://nsarchive.chadwyck.com/home.do.
61. See Sonja Schmid, "Nuclear Colonization? Soviet Technopolitics in the Second World," in Gabrielle Hecht, ed. *Entangled Geographies: Empire and Technopolitics in the Global Cold War* (Cambridge, Mass.: MIT Press, 2011), pp. 125–154.
62. George H. Quester, "Reducing the Incentives to Proliferation," *Annals of the American Academy of Political and Social Science*, March 1977, p. 79, doi:10.1177/000271627743000108.
63. Miller and Sagan, "Alternative Nuclear Futures," pp. 132–133.
64. See Sharon Squassoni, "Looking Back: The 1978 Nuclear Nonproliferation Act," *Arms Control Today*, December 4, 2008, https://www.armscontrol.org/act/2008_12/lookingback_NPT.
65. See Nuclear Threat Initiative, "Nuclear Suppliers Group (NSG)" (Washington, D.C.: Nuclear Threat Initiative, January 31, 2017), http://www.nti.org/learn/treaties-and-regimes/nuclear-suppliers-group-nsg/.
66. Viet Phuong Nguyen and Man-Sung Yim, "Post–Cold War Civilian Nuclear Cooperation and Implications for Nuclear Nonproliferation," *Progress in Nuclear Energy*, November 2016, pp. 253–254, doi:10.1016/j.pnucene.2016.08.019.

ment about the relationship between nuclear energy and proliferation, the article now turns to an empirical examination of this relationship.

Energy Programs and Weapons Pursuit: An Empirical Assessment

The conventional wisdom suggests that states with nuclear energy programs should be significantly more likely to initiate nuclear weapons programs, as the expected costs of developing nuclear weapons should be lower and the nuclear energy establishment may advocate for the bomb for parochial reasons. By contrast, this article suggests that countervailing political obstacles make a strong positive relationship unlikely.

DESCRIPTIVE AND BIVARIATE RESULTS

Table 1 lists the countries with nuclear energy programs, defined as having a power reactor under construction or in operation, that did not pursue nuclear weapons from 1945 to 2009, the dates covered by Way's coding of nuclear pursuit.[67] "Pursuit" is defined as the taking of important steps toward the acquisition of nuclear weapons, "such as a political decision by cabinet-level officials, movement toward weaponization, or development of single-use, dedicated technology."[68] The number of countries on this list—twenty-eight—should give pause to those who view nuclear energy programs and nuclear weapons programs as tightly linked. Indeed, many countries with nuclear energy programs located in threatening security environments have not actively pursued the bomb (e.g., Cuba, Finland, both Germanys, Japan, Sweden, and Ukraine).

Four of the countries on the list—Romania, Sweden, Switzerland, and Yugoslavia—did explore the nuclear weapons option. According to Way's codings, exploration is a lower level of proliferation activity than pursuit and encompasses countries that "seriously considered building nuclear weapons, even if they never took major steps toward that end."[69] Only Romania, however, launched its nuclear energy program prior to exploring a nuclear weapons option.

Table 2 summarizes the level and timing of nuclear energy activity among countries that sought nuclear weapons from 1954, when the Soviet Union be-

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67. See appendix of Christopher Way and Jessica L.P. Weeks, "Making It Personal: Regime Type and Nuclear Proliferation," *American Journal of Political Science*, Vol. 58, No. 3 (July 2014), pp. 705–719, doi:10.1111/ajps.12080. This is Way's updated coding of Singh and Way, "The Correlates of Nuclear Proliferation." Note that several countries have begun constructing nuclear power reactors since 2009, including Belarus, Turkey, and the United Arab Emirates.
68. Singh and Way, "The Correlates of Nuclear Proliferation," p. 866.
69. Ibid., p. 867.

Table 1. States with Nuclear Energy Programs That Did Not Pursue Nuclear Weapons, 1945–2009

Belgium (1957)	Japan (1960)	Hungary (1974)	Armenia (1991)*
Sweden (1957)	Spain (1964)	Yugoslavia (1975)	Kazakhstan (1991)*
Canada (1958)	Netherlands (1965)	Mexico (1976)	Lithuania (1991)*
Czechoslovakia (1958)	Switzerland (1965)	Philippines (1976)**	Slovenia (1991)*
Italy (1958)	Bulgaria (1970)	Poland (1982)**	Ukraine (1991)*
West Germany (1958)	Finland (1971)	Romania (1982)	Czech Republic (1993)*
East Germany (1960)	Austria (1972)**	Cuba (1983)**	Slovakia (1993)*

NOTE: Year when construction on first power reactor begun (or when reactor inherited at independence) appears in parentheses.

*Inherited power reactors at independence rather than constructing them.

**Construction on power reactors never completed/reactors never became operational.

Table 2. Nuclear Energy Programs and Pursuit, 1954–2009

No Energy Program during Pursuit	Energy Program during Pursuit	Energy Program Predated Pursuit	Power Reactor Operating before Pursuit
Australia	Argentina	Argentina	Argentina
China	Brazil	Brazil	
Egypt	France	India	
Iraq	India	Iran	
Israel	Iran	Pakistan	
Libya	North Korea*		
Syria	Pakistan		
	South Africa		
	South Korea		
	Taiwan		

*North Korea briefly had light water power reactors under construction in the early 2000s as part of the Agreed Framework.

came the first country to connect a power reactor to the grid, to 2009, when Way's coding of nuclear proliferation ends.[70] I adopt 1954 as the starting date to be charitable to the argument linking nuclear energy programs and proliferation, because the countries that proliferated before 1954 arguably did not have the option of pursuit with an energy program. While the table demon-

70. See World Nuclear Association, "Russia's Nuclear Fuel Cycle" (Washington, D.C.: World Nuclear Association, May 4, 2017), http://world-nuclear.org/information-library/country-profiles/countries-o-s/russia-nuclear-fuel-cycle.aspx; and appendix of Way and Weeks, "Making It Personal." For a graphical representation of this information, see figure A1 in the online appendix, doi:10.7910/DVN/8EMSFK. For a full list of nuclear proliferation and nuclear energy program dates for countries that have pursued nuclear weapons since 1954, see table A1 in the online appendix.

strates that more countries pursued nuclear weapons in the presence of a nuclear energy program than without one, only in five of these countries (Argentina, Brazil, India, Iran, and Pakistan) did the energy program predate the nuclear weapons program, thus casting doubt on the notion that energy programs are a common cause of weapons pursuit. Moreover, the coding of Iran is questionable at best. Although construction on a power reactor at Bushehr started in 1975, operations were suspended during the Iran-Iraq War; it was during this war that Iran began its nuclear weapons program.[71] In only one of these countries, Argentina, was a power reactor actually operating prior to the launch of a weapons program. Further, scholars debate whether Argentina ever intended to acquire nuclear weapons.[72] In five other cases—France, North Korea, South Africa, South Korea, and Taiwan—construction on power reactors began after the initiation of a nuclear weapons program. There is thus no unambiguous historical case of a country having an operational nuclear energy program prior to pursuing nuclear weapons.[73]

Perhaps the most relevant comparison is the probability of pursuing nuclear weapons in a country that has a nuclear energy program to the probability in a country that does not. To assess whether there is a difference in probability across these groups, I analyze a country-year dataset from 1954 to 2000.[74] For each country in each year, the dataset measures whether there is a power reactor in operation, or a power reactor under construction, and whether a nuclear weapons program is initiated, again using Way's coding of nuclear pursuit. Data for the power reactor variables are from the World Nuclear Association's Reactor Database.[75] This database includes active, planned, and decommissioned nuclear reactors. It does not include historical reactors for which construction began but was not completed. I use secondary sources to find such cases, although it is possible that some are still missing from the data.[76]

71. See Nuclear Threat Initiative, "Bushehr Nuclear Power Plant" (Washington, D.C.: Nuclear Threat Initiative, December 6, 2013), http://www.nti.org/facilities/184/.
72. See Jacques E.C. Hymans, "Of Gauchos and Gringos: Why Argentina Never Wanted the Bomb, and Why the United States Thought It Did," *Security Studies*, Vol. 10, No. 3 (Spring 2001), pp. 153–185, doi:10.1080/09636410108429440.
73. After Argentina, Pakistan is the closest case. Its first power reactor, KANUPP-I, began operating in December 1972. See World Nuclear Association, "KANUPP, Pakistan" (London: World Nuclear Association, n.d.), http://www.world-nuclear.org/reactor/default.aspx/KANUPP. This occurred eleven months after Pakistan launched a nuclear weapons program. See Richelson, *Spying on the Bomb*, p. 328.
74. The dataset ends in 2000 to facilitate comparison with prior quantitative studies. This is also the last year that Way codes a new country (Syria) as seeking nuclear weapons.
75. World Nuclear Association, "Reactor Database" (London: World Nuclear Association, n.d.), http://world-nuclear.org/NuclearDatabase/Default.aspx?id=27232.
76. Countries that started construction of power reactors but never finished them or connected them to an electrical grid from 1954 to 2000 include Austria, Cuba, the Philippines, and Poland.

I use a dependent variable with a one-year lead to mitigate reverse causality concerns—in other words, the possibility that nuclear weapons programs lead countries to start nuclear energy programs, rather than the other way around.

I do not include research reactors, which are used for training, research, and isotope production rather than the generation of electricity, because I am interested in assessing the effect of nuclear energy programs rather than the broader category of nuclear research programs. This wider category is closer to what is captured in previous work by Matthew Fuhrmann, which analyzes a broad range of nuclear cooperation agreements between countries, regardless of whether the agreement involved supply or construction of a power reactor.[77] Fuhrmann does disaggregate types of nuclear cooperation agreements and finds that agreements related to nuclear energy programs are associated with a higher likelihood of nuclear weapons pursuit.[78] These agreements often involve countries that considered but never started a nuclear energy program, however; indeed, more than twenty countries in Fuhrmann's dataset signed cooperation agreements related to nuclear power but never began construction of a power reactor during the 1945–2003 period covered by the dataset.[79]

I concentrate instead on power reactors in operation or under construction for three primary reasons. First, this focus directly corresponds to current public policy debates about the implications of the spread of nuclear energy in the Middle East. After all, countries such as Algeria, Egypt, and Turkey already have research reactors; have signed nuclear cooperation agreements; and have received various types of foreign nuclear assistance. The debate is about whether developing power reactors and all that goes along with this will lead to nuclear weapons proliferation. Second, many countries that have research reactors have not gone on to develop nuclear energy programs; this group includes countries as diverse as Bangladesh, Colombia, Denmark, Ghana, Greece, Indonesia, Jamaica, Morocco, Norway, Peru, and Portugal.[80] Defining a nuclear energy program to include research reactors, therefore, risks overaggregation. Third, energy programs are different in scope and have different political vulnerabilities from those of smaller research programs, which suggests that they should be examined as an analytically separate category. The goal of this article, therefore, is not to test whether nuclear supply or nuclear

77. See Fuhrmann, "Spreading Temptation," p. 24.
78. Fuhrmann, *Atomic Assistance*, pp. 174–179.
79. These include Algeria, Australia, Bangladesh, Chile, Colombia, Denmark, Egypt, Greece, Indonesia, Iraq, Ireland, Libya, Luxembourg, Morocco, New Zealand, Norway, Peru, Portugal, Syria, Thailand, Turkey, Uruguay, Venezuela, and Vietnam. See Fuhrmann, *Atomic Assistance*.
80. For a list of research reactors, see the IAEA Research Reactor Database, https://nucleus.iaea.org/RRDB/RR/ReactorSearch.aspx?filter=0.

Table 3. Nuclear Energy Programs and the Probability of Pursuit, 1954–2000

	Annual Probability of Pursuit	Number of Observations
No power reactor operating	0.25%	5,606
Power reactor operating	0.17%	592

P-value from a chi-square test assessing the difference across the two groups: 0.70.

Table 4. Nuclear Energy Programs and the Probability of Pursuit, 1954–2000

	Annual Probability of Pursuit	Number of Observations
No power reactor operating or under construction	0.20%	5,418
Power reactor operating or under construction	0.51%	780

P-value from a chi-square test assessing the difference across the two groups: 0.10.

know-how writ large is associated with proliferation—indeed, doing so would be close to tautological given that developing nuclear weapons requires some degree of nuclear knowledge and infrastructure. Rather, it is to assess whether ongoing nuclear energy programs specifically have this effect.

If a nuclear energy program increases the odds that a state will pursue nuclear weapons, one should expect to find a significantly higher probability of pursuit in country-years when a power reactor is operating or is under construction. As table 3 shows, however, the annual probability of starting a nuclear weapons program is somewhat lower in countries with operating power reactors compared to countries without them. The results in table 4 are more in line with the conventional wisdom, suggesting that the annual probability of starting a weapons program is more than twice as high in countries with nuclear energy programs, if one defines an energy program as having an operating power reactor or one under construction. The *p*-value from a chi-square test assessing the difference across these two groups is 0.10, which is near traditional benchmarks of statistical significance.

MULTIVARIATE MODELS

Although suggestive, these data should not be taken at face value, because they do not account for potential confounding variables. Countries with nuclear energy programs are likely to be systematically different from countries without them, and these differences may lead them to proliferate at different rates for reasons that have nothing to do with energy programs. For example, countries with nuclear energy programs almost certainly are wealthier and have higher levels of industrial development than those without such programs. These factors could increase their capability to pursue or acquire nuclear weapons independently of whether they have nuclear energy programs. Alternatively, countries with nuclear energy programs may have fewer incentives to seek nuclear weapons because they live in less threatening security environments or have nuclear-armed allies.

To address this issue, I estimate a series of logistic regression models, controlling for potential confounders while taking care to avoid post-treatment bias—in other words, I do not control for possible mechanisms through which energy programs might influence the likelihood of proliferation. I start with the same country-year dataset described above, incorporating data on potential confounders from Fuhrmann and Singh and Way.[81] As above, the dependent variable is drawn from Way and equals 1 when a country initiates pursuit of nuclear weapons, with a one-year lead.[82] States exit the dataset while nuclear weapons programs are ongoing and reenter if they abandon their program. To measure nuclear energy programs, I construct three separate variables: (1) a binary variable that equals 1 if a state has a nuclear power reactor in operation or under construction, the most inclusive measure, (2) a binary variable that equals 1 if a state has a nuclear power reactor in operation, and (3) the total number of operating nuclear power reactors.[83]

I estimate three separate models for each measure of energy programs. The first includes only t, t^2, and t^3 to account for temporal dependence.[84] The second controls for basic industrial capacity and gross domestic product per capita and its square.[85] As noted above, these are likely to be important confounders, associated with both energy programs and proliferation. The third model controls for potentially confounding political variables measuring a state's regime type, trade openness, and security environment that have been found to be significant in quantitative studies.[86] Standard errors are clustered by country in all models.

81. Fuhrmann, "Spreading Temptation"; and Singh and Way, "The Correlates of Nuclear Proliferation."
82. See appendix of Way and Weeks, "Making It Personal."
83. Data from World Nuclear Association, "Reactor Database."
84. David B. Carter and Curtis S. Signorino, "Back to the Future: Modeling Time Dependence in Binary Data," *Political Analysis*, Vol. 18, No. 3 (Summer 2010), pp. 271–292, doi:10.1093/pan/mpq013.
85. I use Singh and Way's binary measure of industrial capacity, which is based on steel production and electricity production and consumption. See Singh and Way, "The Correlates of Nuclear Proliferation," pp. 868–869.
86. These include a binary indicator for rivalry, a five-year moving average of militarized interstate dispute (MID) involvement, a binary measure of alliances with nuclear powers, trade openness, and polity score. Controlling for personalist regime type as well produces similar results; I

To avoid post-treatment bias, I omit measures of peaceful nuclear cooperation agreements, sensitive nuclear assistance,[87] indigenous nuclear resources,[88] and NPT membership. After all, the literature suggests that each of these might be pathways through which energy programs facilitate proliferation—by increasing the acquisition of nuclear technology and know-how, both from abroad and indigenously, or by providing political cover for the acquisition of sensitive technology, perhaps using the NPT's Article 4 as a shield. Because controlling for these variables may attenuate the association between energy programs and proliferation, omitting them amounts to making the analysis an "easy test" for theories linking energy programs with an increased likelihood of proliferation.

Figure 1 summarizes the results of these nine models (full regression tables are provided in tables A2–A4 in the online appendix).[89] In seven of them, the coefficient on the variables measuring nuclear energy programs is negative, suggesting that energy programs reduce rather than increase the odds of nuclear pursuit. More important, in none of the models is the coefficient distinguishable from zero at the 95 percent confidence level, suggesting that there is no clear linkage between energy programs and the probability of pursuing nuclear weapons.[90]

It should be acknowledged that the statistical power of these tests is limited, as both the dependent variable (pursuit of nuclear weapons) and the key independent variable (nuclear energy programs) are relatively rare, making it relatively hard to obtain statistically significant results. This would be a significant concern if the results featured large positive coefficients with large standard errors, which might suggest more data are needed to detect a significant result. Most of the estimated effects are small and negative, however, which contra-

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opt to exclude this control from the core models because a significant amount of data are missing on that variable.

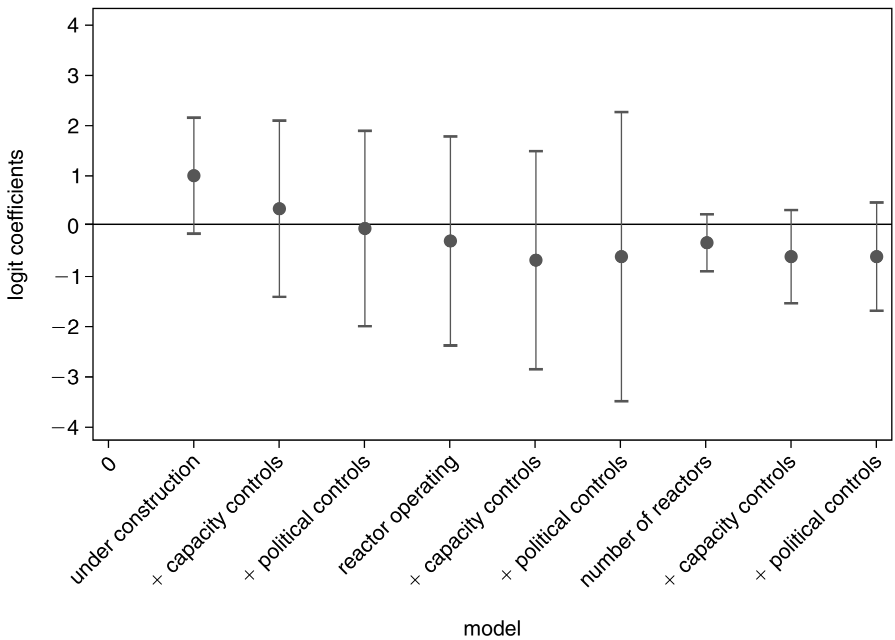
87. This is defined by Kroenig as including transfers of enrichment technology, reprocessing technology, or bomb designs. See Kroenig, *Exporting the Bomb*.

88. This is an eight-point scale coded by Jo and Gartzke that sums up how many of the following capacities a country possesses in a given year: "uranium deposits, metallurgists, chemical engineers, and nuclear engineers/physicists/chemists, electronic/explosive specialists, nitric acid production capacity, and electricity production capacity." See Jo and Gartzke, "Determinants of Nuclear Weapons Proliferation," pp. 172–173.

89. For all tables cited in the remainder of this section, see the online appendix at doi:10.7910/DVN/8EMSFK.

90. Including each of the capacity and political control variables sequentially for each of the three measures of energy programs—thus generating twenty-four distinct models—shows that energy programs are associated with a significantly higher likelihood of proliferation ($p < 0.05$) in only one case (with the control for recent militarized disputes and the measure of power reactors operating or under construction). Even this effect, however, quickly vanishes after accounting for industrial capacity in the same model. Moreover, in sixteen of twenty-four models, the measure of nuclear energy programs has a negative rather than a positive coefficient.

Figure 1. Nuclear Energy Programs and the Odds of Pursuit



dicts the conventional wisdom that energy programs should have a strong positive effect. Although the coefficient for the variable measuring power reactors operating or under construction is positive and marginally statistically significant in the first model ($p = 0.09$), once one accounts for economic and industrial capacity, this effect dramatically shrinks and is nowhere close to significance. Moreover, this result is highly sensitive to coding of individual cases, even without controlling for economic and industrial capacity. For example, if Iran—a country whose nuclear energy program was dormant when it started its nuclear weapons program—is dropped from the analysis, the coefficient falls from 1.0 to 0.76 and is no longer near statistical significance ($p = 0.26$).

If ones ignores statistical significance and focuses on the coefficient in the model that accounts for economic and industrial capacity, the result is an odds ratio of 1.4, suggesting that countries with nuclear energy programs have 40 percent higher odds of seeking nuclear weapons in a given year compared to countries without nuclear energy programs. Although not trivial, this effect pales in comparison to that of other predictors. For example, in the same model, the industrial capacity variable has an estimated odds ratio of 7.24—more than five times as powerful.

Thus, although statistical power may be an issue, the data at hand do not make a strong case for a large, positive effect of nuclear energy programs, as the conventional wisdom would predict. Given that the quantitative literature has identified more than thirty ostensibly significant predictors of nuclear proliferation,[91] a null result that goes against received wisdom is notable.

Finally, although it is important to avoid post-treatment bias, one could quibble over whether any individual variable I identified as post-treatment should be treated instead as a confounder. As a robustness check, I therefore run models that control for NPT membership and alternate measures of nuclear capacity and find that this does not significantly alter the results (see tables A5–A8). Likewise, if one switches the dependent variable to the exploration of nuclear weapons, again as coded by Way, the results do not substantially change (as shown in tables A9–A11). Using the nuclear weapons program codings of Dong-Joon Jo and Erik Gartzke and Philipp Bleek yields similar findings (see tables A12 and A13), with no significant effect of energy programs on the odds of pursuit once economic and industrial capacity controls are included.[92] The results are also robust to using ReLogit (see table A14), to including separate dummy variables for membership in the North Atlantic Treaty Organization or the Warsaw Pact (table A15), or to including a variable measuring whether a country hosts foreign nuclear weapons (table A16).[93]

Energy Programs and Weapons Acquisition: An Empirical Assessment

This section examines whether states have historically been more likely to acquire nuclear weapons if they have started an energy program. Table 5 assesses whether the presence of an energy program (defined as a power reactor in operation or under construction) is indeed associated with an increased likelihood of acquisition, conditional on pursuit, again starting in 1954. Because of the small number of observations (seventeen nuclear weapons programs with seven cases of nuclear acquisition), I rely on simple bivariate analyses rather than complex multivariate models. The coding of acquisition is likewise drawn from Way. I code the presence of an energy program in the last

91. See Mark S. Bell, "Examining Explanations for Nuclear Proliferation," *International Studies Quarterly*, Vol. 60, No. 3 (September 2016), pp. 520–529, doi:10.1093/isq/sqv007.
92. See Jo and Gartzke, "Determinants of Nuclear Weapons Proliferation"; and Philipp Bleek, "Does Proliferation Beget Proliferation? Why Nuclear Dominoes Rarely Fall," Ph.D. dissertation, Georgetown University, 2010.
93. Data on foreign nuclear deployments are from Matthew Fuhrmann and Todd S. Sechser, "Signaling Alliance Commitments: Hand-Tying and Sunk Costs in Extended Nuclear Deterrence," *American Journal of Political Science*, Vol. 58, No. 4 (October 2014), pp. 919–935, doi:10.1111/ajps.12082.

Table 5. Nuclear Energy Programs and Nuclear Weapons Acquisition, 1954–Present

	Did Not Acquire Nuclear Weapons	Acquired Nuclear Weapons	% Acquired
No energy program	Australia, Egypt, Iraq, Libya, Syria	China, Israel, North Korea	3/8 (37.5%)
Energy program	Argentina, Brazil, Iran, South Korea, Taiwan	France, India, Pakistan, South Africa	4/9 (44%)

year of a country's nuclear weapons program, when the country either acquires a nuclear capability or abandons its pursuit. In the cases of Iran and Syria, where nuclear weapons programs may be ongoing, the coding of energy programs is from 2017.

It should be noted that coding whether North Korea had a nuclear energy program before it acquired nuclear weapons is challenging. Although Pyongyang has long expressed an interest in developing nuclear energy,[94] it still did not have an operational program as of 2017. Moreover, its behavior from the 1980s onward often suggested a different aim for its nuclear program. Unlike nearly every other country that has developed a nuclear energy program, either inside or outside the NPT, North Korea kept the construction of its reactors (both at Yongbyon and Taechon) secret for many years.[95] It did not formally notify the IAEA of their existence until 1992, despite having joined the NPT seven years prior.[96] Further, satellite imagery from the early 2000s revealed that the reactors were not connected to power lines, casting doubt on the notion they were intended for electricity production.[97] Although the Soviet Union did agree in 1985 to help North Korea build a nuclear power reactor,[98] construction never began. Finally, an international consortium, led by the United States, did start construction of a light water power reactor in North Korea in 2002 as part of the 1994 Agreed Framework, which froze Pyongyang's plutonium program. Construction was halted the following year,[99] however,

94. See Lawrence, "Normalization by Other Means."
95. CIA, "North Korea's Nuclear Efforts," April 28, 1987, in Wampler, *North Korea and Nuclear Weapons*, doc. 8, http://nsarchive.gwu.edu/NSAEBB/NSAEBB87/nk08.pdf.
96. David Fischer, *History of the International Atomic Energy Agency: The First Forty Years* (Vienna: IAEA, 1997), pp. 288–289.
97. See Larry A. Niksch, "North Korea's Nuclear Weapons Program," February 27, 2003, in Wampler, *North Korea and Nuclear Weapons*, doc. 24, http://nsarchive.gwu.edu/NSAEBB/NSAEBB87/nk24.pdf. See also Federation of American Scientists, "Yongbyon" (Washington, D.C.: Federation of American Scientists, March 2000), https://fas.org/nuke/guide/dprk/facility/yongbyon.htm.
98. CIA, "East Asia Brief," December 27, 1985, in Wampler, *North Korea and Nuclear Weapons*, doc. 6, http://nsarchive.gwu.edu/NSAEBB/NSAEBB87/nk06.pdf.
99. See Arms Control Association, "The U.S.-North Korean Agreed Framework at a Glance" (Washington, D.C.: Arms Control Association, August 2004), https://www.armscontrol.org/factsheets/agreedframework.

prior to North Korea's acquisition of nuclear weapons in 2006. It therefore seems most reasonable to code North Korea as pursuing nuclear weapons in the absence of an energy program.

Table 5 demonstrates that countries that pursued nuclear weapons while they had a nuclear energy program were only marginally more likely to acquire nuclear weapons.[100] Only France, India, Pakistan, and South Africa acquired nuclear weapons while they had such programs. If one uses alternative codings of nuclear weapons programs from Bleek or Jo and Gartzke (see tables A17 and A18 in the online appendix), the data suggest that countries that pursued nuclear energy programs have been less likely to acquire nuclear weapons.

If one instead codes North Korea as pursuing nuclear weapons with an energy program, the acquisition rate for countries with energy programs would be 50 percent, versus 28.5 percent for countries without energy programs. This is a substantial difference in success rate, and it is in line with the conventional wisdom.[101] If one uses the codings of Bleek or Jo and Gartkze, however, there is little support for the conventional wisdom, regardless of how North Korea is coded. If one codes North Korea as pursuing nuclear weapons without an energy program, Bleek's codings yield a 60 percent success rate for countries without energy programs, compared with a 50 percent success rate for those with energy programs. Coding North Korea as having an energy program changes these figures to 50 percent and 55 percent, respectively. Either way, there is no clear advantage for countries pursuing nuclear weapons with an energy program. Based on Jo and Gartzke's codings, countries pursuing nuclear weapons without an energy program have a higher success rate irrespective of how North Korea is classified. No matter how one treats North Korea, then, the evidence that a nuclear energy program is associated with a higher success rate is inconsistent and sensitive at best.

Political Restraints on Nuclear Weapons Pursuit or Acquisition

This section considers two hypothesized political restraints that may help account for the finding that countries with nuclear energy programs are not significantly more likely to pursue or acquire nuclear weapons.

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100. The difference is statistically insignificant according a Fisher's exact test, with a one-sided p-value of 0.581.
101. It is not a statistically significant difference, with a one-sided p-value of 0.354 from a Fisher's exact test.

HIGHER LIKELIHOOD OF DETECTION AND PRESSURE

The existence of a nuclear energy program increases the likelihood of detection of a parallel weapons program and, thus, outside nonproliferation pressure. To systematically assess this proposition, I utilize data on U.S. proliferation intelligence assessments collected by Alexander Montgomery and Adam Mount,[102] as well as data on U.S. nonproliferation sanctions.[103] Montgomery and Mount coded dozens of declassified intelligence assessments relevant to sixteen countries' nuclear weapons programs, examining whether the assessment was correct or whether it underestimated or overestimated the current or future progress of the program. One important caveat is that these data are based entirely on declassified assessments. Because the declassification process is nonrandom, the result could be a biased sample of assessments—for example, an undersampling of cases where the United States underestimated a country's nuclear weapons program.[104] Nonetheless, given inevitable data constraints, it is a useful starting point.

After harmonizing the assessments with Way's coding of nuclear pursuers (i.e., including only assessments of countries coded as pursuing nuclear weapons in Way's dataset), I am left with sixty distinct intelligence assessments across fifteen countries. If the argument about nuclear energy programs increasing the odds of timely detection is valid, one should find that the United States is less likely to underestimate the progress of a nuclear weapons program when it is coupled with an energy program. To assess this proposition, I construct a binary dependent variable equal to 1 when the assessment underestimated the progress of the country's nuclear weapons program and 0 otherwise.

The results show that U.S. intelligence agencies were substantially less likely to underestimate nuclear weapons programs of countries with power reactors

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102. Montgomery and Mount, "Misestimation."
103. Data are from Nicholas L. Miller, *Stopping the Bomb: The Sources and Effectiveness of U.S. Nonproliferation Policy* (Ithaca, N.Y.: Cornell University Press, forthcoming).
104. Three countries that pursued nuclear weapons according to Way's updated codings—Australia, Egypt, and Syria—do not appear in Montgomery and Mount's dataset, because the authors were basing their analysis on an earlier version of Singh and Way's data. See Montgomery and Mount, "Misestimation," pp. 359–360. Each of these countries pursued weapons without an energy program. The two cases for which declassified assessments are available—Australia and Egypt—seem to support the notion that the United States is more likely to underestimate weapons programs that are not paired with an energy program. A 1966 National Intelligence Estimate, for example, concluded that neither Australia nor Egypt (then part of the United Arab Republic) was seeking nuclear weapons. See "The Likelihood of Further Nuclear Proliferation," National Intelligence Estimate (NIE) 4-66, January 20, 1966, in William Burr, ed., *China May Have Helped Pakistan Nuclear Weapons Design, Newly Declassified Intelligence Indicates*, NSA EBB No. 423, doc, 1, http://nsarchive .gwu.edu/nukevault/ebb423/docs/1.%201966%20NIE.pdf. This is in contrast to Way's codings, which show both countries as pursuing nuclear weapons at this time.

in operation or under construction when compared to countries without them (14.8 percent vs. 51.5 percent).[105] This difference is statistically significant ($p < 0.01$) according to a chi-square or Fisher's exact test. The difference in the likelihood of underestimates across these two groups remains statistically and substantively significant if one uses a logistic regression model that controls for whether the proliferating country is a U.S. ally or a U.S. adversary and the year of the assessment.[106] Interestingly, the lower rate of underestimates for countries with nuclear energy programs does not correspond to a significantly higher rate of accurate assessments. Instead, assessments of proliferators with nuclear energy programs are much more likely to be overestimates (48.1 percent vs. 15.2 percent), a difference that is statistically significant according to a chi-square or Fisher's exact test. Results from multinomial logit models, which likewise control for the country's relationship with the United States and the year of the assessment, confirm that overestimates are significantly more likely when a country has a power reactor in operation or under construction.[107]

I now turn to examining whether proliferators with energy programs are more likely to experience nonproliferation pressure. To do so, I assess whether countries pursuing nuclear weapons with an energy program are more likely to face U.S. nonproliferation sanctions. I focus on the United States because it has arguably been the strongest advocate for nonproliferation historically, and it has imposed nonproliferation sanctions far more than any other country.[108]

Based on an analysis of all country-years from 1945 to 2000 in which states were pursuing nuclear weapons, the data suggest that countries with power reactors in operation or under construction were more than three times as likely as those without an energy program to face U.S. sanctions in a given

105. The descriptive results are displayed graphically in figure A2 in the online appendix.
106. See table A19 in the online appendix. Montgomery and Mount find that the status of the relationship with the United States is a key factor influencing assessments. See Montgomery and Mount, "Misestimation," p. 383. I code China, Iran, Iraq from 1991 onward, Libya, North Korea, and the Soviet Union as adversaries. I code Argentina, Brazil, France, Pakistan, South Korea, and Taiwan as allies. That leaves India, Israel, and South Africa as unaligned. Results are similar if the data are restricted to post-1954. The alternative measures of energy programs (power reactor operating or the number of operating reactors) are also associated with a lower likelihood of underestimates, but the difference is not statistically significant.
107. See figures A3 and A4 and table A20 in the online appendix. Results using the alternative measures of energy programs suggest that both overestimates and underestimates are less likely when a country has a power reactor in operation (as opposed to under construction), indicating that U.S. estimates about countries with functioning reactors are more likely to be correct.
108. On the U.S. commitment to nonproliferation, see Francis J. Gavin, "Strategies of Inhibition: U.S. Grand Strategy, the Nuclear Revolution, and Nonproliferation," *International Security*, Vol. 40, No. 1 (Summer 2015), pp. 9–46, doi:10.1162/ISEC_a_00205. For a list of historical sanctions episodes, see "Summary of Economic Sanctions Episodes, 1914–2006" (Washington, D.C.: Peterson Institute of International Economics, n.d.), https://piie.com/summary-economic-sanctions-episodes-1914-2006.

year (29 percent of country-years compared to 8.9 percent of country-years without an energy program).[109] This result is significant statistically according to either a chi-square or Fisher's exact test. The result remains substantively and statistically significant if one uses a logistic regression model, which controls for t, t^2, and t^3, whether the proliferator is a U.S. ally or a U.S. adversary,[110] as well as a dummy variable for the post-1976 era, when the United States had congressionally mandated sanctions policies in place.[111]

In sum, the evidence suggests that proliferators with nuclear energy programs are (1) significantly less likely to have their nuclear weapons program underestimated, and (2) significantly more likely to be the target of sanctions. These results may help explain why countries with energy programs are not more likely to pursue or acquire nuclear weapons, despite the technological advantages that an energy program brings. Even if the imposition of unilateral U.S. sanctions has not been very effective in coercing countries to end their nuclear weapons programs,[112] they may nevertheless complicate the process and lengthen the amount of time needed to build a bomb, thus buying time for exogenous factors such as leadership changes, an improved security environment, or inducements from the international community to emerge.[113] U.S. sanctions may also catalyze the imposition of multilateral sanctions, which are generally more effective than unilateral sanctions.[114]

HEIGHTENED COSTS FROM NONPROLIFERATION SANCTIONS

Countries with nuclear energy programs that are thinking about whether to proliferate are confronted by the prospect of becoming the target of nonproliferation sanctions. Evidence suggests that the threat of sanctions targeted at their nuclear energy programs may help explain why Japan, Sweden, Taiwan, and South Korea have not acquired nuclear weapons, despite being located in

109. For a graphical representation, see figure A5 in the online appendix. If one includes threats of sanctions in addition to imposed sanctions, the difference is even larger in magnitude.
110. I code as U.S. allies Argentina, Australia, Brazil, France, Pakistan, South Korea, Taiwan, and the United Kingdom. I code as U.S. adversaries China, Iran, Iraq (1990–95), Libya, North Korea, the Soviet Union, and Syria. I code as unaligned Egypt, India, Iraq (1982–89), Israel, and South Africa.
111. On U.S. sanctions policies, see Miller, "The Secret Success of Nonproliferation Sanctions." The results are similar if the data are restricted to after 1954. For the regression results, see table A21 in the online appendix.
112. See Miller, "The Secret Success of Nonproliferation Sanctions."
113. On the importance of buying time for nonproliferation, see Ariel E. Levite, "Never Say Never Again: Nuclear Reversal Revisited," *International Security*, Vol. 27, No. 3 (Winter 2002/03), pp. 59–88, doi:10.1162/01622880260553633.
114. Navin A. Bapat and T. Clifton Morgan, "Multilateral versus Unilateral Sanctions Reconsidered: A Test Using New Data," *International Studies Quarterly*, Vol. 53, No. 4 (December 2009), pp. 1075–1094, doi:10.1111/j.1468-2478.2009.00569.x.

threatening security environments. In some sense, these are easy cases for the argument that nuclear energy programs make countries more vulnerable to nonproliferation pressure; all four countries are allied to or friendly with the United States, making them more likely to respond positively to U.S. pressure not to proliferate. These cases should therefore be viewed as probing the plausibility of the mechanism rather than providing a definitive test.

Japan has not actively pursued nuclear weapons for reasons whose independent effects are difficult to disentangle, including the U.S. security commitment and nuclear umbrella, public opposition to nuclear weapons, and nonproliferation norms disseminated by the NPT.[115] There is also strong reason to believe, however, that Japan's nuclear energy program has served as an additional brake on a nuclear weapons program. Starting in the 1960s, Japan began an ambitious nuclear energy program with the aim of ending its dependence on energy imports. As Jacques Hymans documents, Japan's nuclear establishment and its allies in government have become powerful veto players in nuclear policymaking, with a strong stake in maintaining the peaceful nature of the country's program, in part because of their desire to preserve foreign trade opportunities.[116] At least before the Fukushima disaster and resulting suspension of Japan's nuclear energy program, a key component of the Japanese strategy for energy independence had involved reprocessing spent nuclear fuel and extracting plutonium for eventual use in mixed-oxide fuel and fast breeder reactors.[117] Given the centrality of nuclear energy to Japanese economic and foreign policy, Llewelyn Hughes argues that the nuclear establishment would oppose any weapons effort, because this would likely lead to a cutoff in uranium imports from abroad. Following North Korea's 2006 nuclear test, Japanese nuclear industry officials opposed even considering the nuclear weapons option "because of its potential impact on Japan's spent fuel reprocessing planning."[118]

In Sweden, the presence of a nuclear energy program may also help explain why the country chose not to engage in a full-fledged pursuit of the bomb, de-

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115. See Yuri Kase, "The Costs and Benefits of Japan's Nuclearization: An Insight into the 1968/70 Internal Report," *Nonproliferation Review*, Vo. 8, No. 2 (Summer 2001), pp. 55–68, doi:10.1080/10736700108436850; and Maria Rost Rublee, "Taking Stock of the Nuclear Nonproliferation Regime: Using Social Psychology to Understand Regime Effectiveness," *International Studies Review*, Vol. 10, No. 3 (2008), pp. 420–450, doi:10.1111/j.1468-2486.2008.00799.x.
116. Jacques E.C. Hymans, "Veto Players, Nuclear Energy, and Nonproliferation: Domestic Institutional Barriers to a Japanese Bomb," *International Security*, Vol. 36, No. 2 (Fall 2011), pp. 176–181, doi:10.1162/ISEC_a_00059.
117. Llewelyn Hughes, "Why Japan Will Not Go Nuclear (Yet): International and Domestic Constraints on the Nuclearization of Japan," *International Security*, Vol. 31, No. 4 (Spring 2007), pp. 81–82, doi:10.1162/isec.2007.31.4.67.
118. Ibid., pp. 82–83.

spite having flirted with the idea of developing a weapons program. Sweden's creation of a nuclear energy program in the late 1940s was explicitly designed to help lay the foundation for a nuclear weapons program,[119] as the conventional wisdom would expect. The idea was to "let the main aim be the generation of nuclear energy, with plutonium production, which made possible the manufacture of nuclear weapons, as a side effect."[120] The energy program ultimately served to restrain Sweden's nuclear weapons ambitions, however, as Stockholm belatedly realized that a weapons program could not be undertaken without crippling the country's nuclear energy plans.

By the early 1960s, as Sweden mulled its options for producing plutonium for weapons, it faced a dilemma: its power reactors were moderated by heavy water acquired from the United States, and using the reactors for military purposes would violate the spirit of Stockholm's nuclear cooperation agreement with Washington.[121] In fact, as of April 1960, an official U.S. policy aim was to "discourage Sweden from producing its own nuclear weapons."[122] Even if Sweden were willing to utilize the heavy water from the United States, it would still need a reprocessing facility to extract the plutonium from the spent reactor fuel. Yet given the small size of the Swedish nuclear energy program, a reprocessing facility would not be economically justifiable for peaceful purposes until 1975.[123] By 1963, officials in the nuclear energy program had determined that fueling power reactors with enriched uranium and using light water as a moderator made more financial sense than using natural uranium and heavy water. This type of reactor, however, would produce lower-quality plutonium and would require buying enriched uranium fuel from the United States. In turn, the program would be subject to U.S. safeguards and inspections, effectively putting an obstacle in the way of a weapons program.[124] Indeed, the United States kept the cost of enriched uranium low in this period to incentivize countries to follow this more proliferation-resistant route.[125] According to Thomas Jonter, "[A]s a consequence of integrating the production of nuclear weapons within the civilian nuclear energy program, Sweden,

119. Thomas Jonter, "Sweden and the Bomb: The Swedish Plans to Acquire Nuclear Weapons, 1945–1972," SKI Report 01:33 (Stockholm: September 2001), p. 23.
120. Ibid.
121. Ibid., pp. 53–54.
122. National Security Council Report, "Statement of U.S. Policy toward Scandinavia (Denmark, Norway, and Sweden)," April 6, 1960, *Foreign Relations of the United States, 1958–1960*, Vol. 7, part 2: *Western Europe* (Washington, D.C.: Government Printing Office, 1993), doc. 300.
123. Jonter, "Sweden and the Bomb," p. 56.
124. Ibid., pp. 60–61; and Thomas B. Johansson, "Sweden's Abortive Nuclear Weapons Project," *Bulletin of the Atomic Scientists*, Vol. 43, No. 3 (1986), pp. 31–34, doi:10.1080/00963402.1986.11459339.
125. Johansson, "Sweden's Abortive Nuclear Weapons Project," pp. 32–33.

despite contrary intentions, grew dependent on U.S. technology. This technological dependence vis-à-vis the United States increased over the years and provided the United States with leverage to dissuade Sweden from using its civilian program for producing weapon-grade plutonium."[126] Although this was not the only factor dissuading Sweden from developing nuclear weapons,[127] it was a significant one.

Reliance on nuclear energy is also important to understanding why Taiwan and South Korea have not acquired nuclear weapons despite being located in volatile security environments. Both countries initiated nuclear energy programs in the 1970s, shortly after launching weapons programs. Rather than serving as cover, however, the energy programs fueled their desire for nuclear trade with the United States and acted as a lever that Washington exploited to help forestall proliferation. Although threats of security abandonment and foreign aid cutoffs played a key role in the success of U.S. nonproliferation efforts in these cases,[128] the prospect of a cutoff in nuclear trade was also a potent factor.

In Taiwan, the possibility of an end to U.S. nuclear supplies was highly concerning, because Taiwanese officials viewed nuclear energy as a way to end dependence on oil imports. During this period, "Taiwan imported over 80 percent of its energy needs, mostly oil, and nuclear power had become critical" to the country's economic plans, which relied on U.S.-supplied low-enriched uranium fuel.[129] Evidence shows that the need to maintain U.S. nuclear fuel supplies played an important role in Taiwanese decisionmaking. At a meeting in 1977 where Taiwanese officials discussed how to respond to U.S. pressure over its nuclear program, for example, "[m]ost of the officials . . . stated that Taiwan must accept the [U.S.] requirements because nuclear power plants would produce 50% of Taiwan's electricity in the near future and the US controlled Taiwan's nuclear fuel supplies."[130]

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126. Thomas Jonter, "The Swedish Plans to Acquire Nuclear Weapons, 1945–1968: An Analysis of the Technical Preparations," *Science and Global Security*, Vol. 18, No. 2 (2010), p. 82, doi:10.1080/08929882.2010.486722.
127. See, for example, Paul M. Cole, "Atomic Bombast: Nuclear Weapon Decision-Making in Sweden, 1946–72," *Washington Quarterly*, Vol. 20, No. 2 (Spring 1997), pp. 233–251, doi:10.1080/01636609709550250; Jonter, "The Swedish Plans to Acquire Nuclear Weapons, 1945–1968"; and Maria Rost Rublee, *Nonproliferation Norms: Why States Choose Nuclear Restraint* (Athens: University of Georgia Press, 2009).
128. See Rebecca K.C. Hersman and Robert Peters, "Nuclear U-Turns: Learning from South Korean and Taiwanese Rollback," *Nonproliferation Review*, Vol. 13, No. 3 (November 2006), pp. 539–554, doi:10.1080/10736700601071629.
129. Solingen, *Nuclear Logics*, p. 112.
130. Alan Chang, "Crisis Avoided: The Past, Present, and Future of Taiwan's Nuclear Weapons Program," master's thesis, Hawaii Pacific University, 2011, p. 54.

In South Korea, the U.S. threat to cut off nuclear supplies was likewise powerful. Daniel Drezner points out that a cut-off "would have completely devastated ROK [Republic of Korea] plans for energy autonomy."[131] Etel Solingen concurs, judging that "without US equipment and fuel supplies for South Korea's first nuclear plant . . . the economy might have stalled at an already critical period following the [1973] oil crisis."[132] Canada joined the United States in applying pressure, threatening to stop South Korea from acquiring power reactors unless Seoul agreed not to build a reprocessing plant.[133]

Taiwan and South Korea gave up their nuclear weapons programs in the late 1970s.[134] In both cases, they were reacting partly to the threat of having their access to nuclear-related supplies cut off.

THE LIMITS OF POLITICAL RESTRAINTS

Even though states with nuclear energy programs are more likely than those without such programs to be the subject of aggressive intelligence gathering by outside actors—and be the target of sanctions if they start a nuclear weapons program—some have nonetheless acquired nuclear weapons. France, South Africa, India, and Pakistan all acquired nuclear weapons while their energy programs were ongoing. This fact does not contradict this article's argument, which holds that nuclear energy programs do not significantly increase the likelihood of proliferation, not that they never contribute to it. Still, it is worthwhile to briefly examine these cases to tease out the limits of the political restraints discussed above.

As the conventional wisdom would expect, France's nuclear energy and nuclear weapons programs were intimately linked. In planning the construction of reactors for the country's nuclear energy program, French officials chose a design that would facilitate the production of weapons-grade plutonium without relying on external supplies. The French ultimately used these gas-graphite reactors to produce both electricity and plutonium for weapons.[135] Consistent with the notion that energy programs do not serve as effective cover, the United States tended to overestimate the status of the French pro-

131. Daniel W. Drezner, *The Sanctions Paradox: Economic Statecraft and International Relations* (New York: Cambridge University Press, 1999), p. 262.
132. Solingen, *Nuclear Logics*, p. 92.
133. See William Burr, ed., *Stopping Korea from Going Nuclear, Part II*, NSA EBB No. 584, April 12, 2017, http://nsarchive.gwu.edu/nukevault/ebb584-The-U.S.-and-the-South-Korean-Nuclear-Program,-1974-1976,-Part-2/.
134. See Miller, "The Secret Success of Nonproliferation Sanctions."
135. Gabrielle Hecht, "Political Designs: Nuclear Reactors and National Policy in Postwar France," *Technology and Culture*, Vol. 35, No. 4 (October 1994), pp. 663–674.

gram.[136] The second political restraint, however—higher costs from nonproliferation sanctions—did not come into play, as the United States did not threaten or impose sanctions against France. Here, France benefited from having proliferated before 1964, when China's nuclear test led the United States to develop a stronger nonproliferation policy.[137]

South Africa's nuclear weapons program likewise benefited technologically from its nuclear energy program, as Pretoria used the energy program as justification for building an enrichment facility that would ultimately produce highly enriched uranium for nuclear weapons.[138] Despite having an energy program, South Africa managed to confuse U.S. intelligence, which for the most part underestimated its weapons program.[139] While South Africa faced U.S. and multilateral nonproliferation sanctions starting in the mid-1970s, these sanctions were also motivated by anti-apartheid sentiment, which led South African leaders to believe that halting their nuclear weapons program would not lead to the sanctions being lifted.[140]

Like South Africa, both India and Pakistan used their nuclear energy programs to justify the construction of fuel-cycle facilities that ultimately allowed them to produce fissile material for weapons.[141] Unlike the South African nuclear program, however, the United States generally correctly estimated or overestimated those of India and Pakistan.[142] Both countries faced U.S. nonproliferation sanctions in the late 1970s that were waived in the face of conflicting geopolitical priorities.[143]

Together, these four cases reinforce the argument that states with nuclear energy programs that seek to proliferate have a higher likelihood of timely detection. The costs or efficacy of sanctions were significantly limited in each case, however. This outcome suggests that breaking the link between nuclear energy programs and proliferation strongly depends on the threat or imposition of costly sanctions.

136. See Montgomery and Mount, "Misestimation," pp. 371–374.
137. See Francis J. Gavin, "Blasts from the Past: Proliferation Lessons from the 1960s," *International Security*, Vol. 29, No. 3 (Winter 2004/05), pp. 100–135, doi:10.1162/0162288043467504.
138. See Peter Liberman, "The Rise and Fall of the South African Bomb," *International Security*, Vol. 26, No. 2 (Fall 2001), pp. 49–51, doi:10.1162/016228801753191132.
139. See Montgomery and Mount, "Misestimation," pp. 371–374.
140. Liberman, "The Rise and Fall of the South African Bomb," p. 69.
141. On India, see George Perkovich, *India's Nuclear Bomb: The Impact on Global Proliferation* (Berkeley: University of California Press, 1999), p. 71. On Pakistan, see, for example, Feroz Khan, *Eating Grass: The Making of the Pakistani Bomb* (Stanford, Calif.: Stanford University Press, 2012), pp. 105–106; and Frank Prial, "Pakistani Repeats Nuclear Pledge," *New York Times*, January 26, 1982.
142. See Montgomery and Mount, "Misestimation," pp. 371–374.
143. See Perkovich, *India's Nuclear Bomb*, pp. 234–239, 249; and Ahmed, "Pakistan's Nuclear Weapons Program," p. 186.

Potential Counterarguments

There are at least four counterarguments to the analysis above. The first counterargument is that the trends identified in this article may not continue, particularly if the U.S. role in the nuclear marketplace continues to decline and supplier competition increases. Indeed, despite its past dominance, the position of the United States in the international export market today is quite precarious. As Daniel Poneman noted in 2017, "[O]f the 60 reactors currently under construction around the world today, US vendors have won only four export sales."[144] At the same time, the role of nuclear energy in the United States has stagnated, and the country has fallen behind in the production of enriched uranium fuel, further reducing its ability to export.[145] In March 2017, Westinghouse Electric Company—one of the largest U.S.-based nuclear exporters—filed for bankruptcy, eleven years after being acquired by the Japanese giant Toshiba.[146] As the U.S. nuclear export industry has declined, Russia has assumed a dominant role in the market, with South Korea and France also playing significant roles.[147] Japan and China aspire to become major nuclear exporters as well, although the former's ambitions have been damaged by Vietnam's decision to cancel its nuclear energy program.[148]

Given the important role of the United States historically in using nuclear exports to enforce nonproliferation standards, these trends raise the question of whether the relationship between nuclear energy programs and proliferation will change in a world where the United States is a marginal supplier. Although countries proliferating under the cover of an energy program might still face higher odds of detection and pressure in this environment, one could argue that they would no longer face higher costs from nonproliferation sanctions if the United States had less to offer in the way of nuclear supplies. There is no doubt that the United States is less able to use nuclear exports for nonpro-

144. Daniel B. Poneman, "The Case for American Nuclear Leadership," *Bulletin of the Atomic Scientists*, Vol. 73, No. 1 (2017), p. 45, doi:10.1080/00963402.2016.1264211.
145. Nguyen and Lim, "Post–Cold War Civilian Nuclear Cooperation and Implications for Nuclear Nonproliferation," p. 254.
146. Diane Cardwell and Jonathan Soble, "Westinghouse Files for Bankruptcy, in Blow to Nuclear Power," *New York Times*, March 29, 2017, https://www.nytimes.com/2017/03/29/business/westinghouse-toshiba-nuclear-bankruptcy.html.
147. See CSIS Commission on Nuclear Energy Policy in the United States, "Restoring U.S. Leadership in Nuclear Energy: A National Security Imperative" (Washington, D.C.: CSIS; and Lanham, Md.: Rowman and Littlefield, June 2013), p. xi; and Baker, Fitzpatrick, and Goldberg, "Getting Back in the Game."
148. See Jost Wübbeke and Guan Ting, "China's Nuclear Industry Goes Global," *Diplomat*, February 11, 2016, http://thediplomat.com/2016/02/chinas-nuclear-industry-goes-global/; and Aaron Sheldrick and Ho Binh Minh, "Japan's Nuclear Export Ambitions Hit Wall as Vietnam Set to Rip Up Reactor Order," Reuters, November 18, 2016.

liferation leverage today than it was twenty or thirty years ago. The question thus becomes whether other suppliers are likely to enforce nonproliferation with similar vigor and/or whether the United States can substitute other forms of leverage.

On the first count, there are reasons for both optimism and pessimism. On the positive side, all the key suppliers noted above are members of the NPT and NSG, institutions shaped by the United States that call for safeguards on exports and acceptance of other nonproliferation norms. Importantly, these institutions were founded partly to address the risk of a competitive nuclear marketplace leading to proliferation, and there is substantial evidence that they have succeeded.[149] An examination of countries that are likely to play a growing role in the nuclear marketplace going forward, however—in particular, China and Russia—yields a more mixed picture.

China has a history of dangerous export behavior, including providing enrichment or reprocessing technology to Algeria, Iran, and Pakistan and gifting a few bombs' worth of highly enriched uranium to Pakistan in the early 1980s.[150] In recent years, however, China has increasingly accepted a variety of nonproliferation principles. After joining the NPT in 1992, it became a member of the NSG in 2004. Thereafter, it "reduced the geographic scope, technological content, and frequency of its WMD [weapons of mass destruction]-related exports."[151] China cooperated in the negotiation and conclusion of the 2015 Joint Comprehensive Plan of Action (JCPOA), which has significantly limited Iran's nuclear program in exchange for sanctions relief, although it still engages in nuclear trade in Pakistan despite the country's status as a nonproliferation pariah.[152] As China continues to rise, it is likely to adopt a firmer nonproliferation policy, given that stronger powers have more to lose from other states' proliferation activities.[153]

Russia, meanwhile, may be following the opposite trajectory. Moscow has a strong nonproliferation track record historically; for example, it has a longstanding policy, dating from the Soviet era, of providing enriched uranium fuel and taking back the spent fuel from the reactors it supplies, which reduces

149. See Gheorghe, "Proliferation and the Logic of the Nuclear Marketplace"; and Choi and Hwang, "Effects of Nuclear Technology Export Competition on Nuclear Nonproliferation."
150. See Kroenig, *Exporting the Bomb*, p. 129; and Khan, *Eating Grass*, p. 188.
151. Evan S. Medeiros, *Reluctant Restraint: The Evolution of China's Nonproliferation Policies and Practices, 1980–2004* (Redwood City, Calif.: Stanford University Press, 2007), p. 2.
152. See Roncevert Ganan Almond, "China and the Iran Nuclear Deal," *Diplomat*, March 8, 2016, http://thediplomat.com/2016/03/china-and-the-iran-nuclear-deal/; and Rohan Joshi, "China, Pakistan, and Nuclear Non-Proliferation," *Diplomat*, February 16, 2015, http://thediplomat.com/2015/02/china-pakistan-and-nuclear-non-proliferation/.
153. See Kroenig, *Exporting the Bomb*.

the need and ability of additional countries to enrich or reprocess.[154] Russia supported the conclusion of the JCPOA and has no recent history of exporting enrichment or reprocessing technology, in contrast to China.[155] That said, growing tensions with the United States have led Russia to scale back some its nonproliferation advocacy efforts,[156] and it is possible that its declining power may lead it to adopt more permissive export policies in the future.[157]

However, even if other suppliers are less enthusiastic nonproliferation advocates, the United States still maintains powerful leverage outside the nuclear export realm—including access to trade and financial institutions, economic and military aid, and security commitments—that it can bring to bear. It can apply this leverage not only on proliferators, but also on other suppliers to convince them to cut off nuclear trade with proliferators. For example, the economic sanctions that ultimately brought Iran to the negotiating table and led to the 2015 JCPOA succeeded to a large degree because the United States coerced and cajoled other countries into cooperating with the sanctions regime, which included but extended far beyond nuclear trade restrictions.[158] It is therefore conceivable—although by no means guaranteed—that the United States could achieve similar results by substituting alternative sources of leverage, both directly on proliferators and indirectly on other nuclear suppliers.

A second potential counterargument is that over-aggregating different time periods may bias the article's quantitative findings. For example, the development of nuclear weapons preceded the creation of nuclear energy programs; therefore, early proliferators in some sense did not have the option of starting with an energy program. As Gilinsky argues, the first five nuclear powers (the nuclear weapons states under the NPT) acquired weapons largely without the aid of energy programs. Subsequent proliferators, however, have faced a different landscape, where the NPT delegitimizes overt proliferation, meaning that using an energy program as cover or working covertly are the only two feasible options.[159] The findings above already partially address this concern by starting the analysis in 1954, when the world's first power reactor came online. Yet energy programs are still not associated with a significantly increased

154. See Nguyen and Yim, "Post–Cold War Civilian Nuclear Cooperation and Implications for Nuclear Nonproliferation," pp. 255–256.
155. On enrichment and reprocessing exports, see Kroenig, *Exporting the Bomb*.
156. See Robert Einhorn, "Russia—An Increasingly Unreliable Nonproliferation Partner," (Washington, D.C.: Brookings Institution, February 26, 2016), https://www.brookings.edu/research/prospects-for-u-s-russian-nonproliferation-cooperation/.
157. Kroenig, *Exporting the Bomb*.
158. See Suzanne Maloney, "Sanctions and the Iran Nuclear Deal: Silver Bullet or Blunt Object?" *Social Research*, Vol. 82, No. 4 (Winter 2015), pp. 887–911.
159. Gilinsky, "Nuclear Power, Nuclear Weapons," pp. 132–133.

likelihood of nuclear pursuit or acquisition if one restricts the sample to the post-1968 period, after the acquisition of nuclear weapons by the permanent five members of the UN Security Council and the conclusion of the NPT (see tables A22 and A23 in the online appendix).

Third, one could argue that selection effects bias the article's findings. For example, it is possible that the United States or other countries have prevented even the beginning of construction of power reactors in countries at high risk of proliferation, thus suppressing the observed relationship between energy programs and proliferation. This bias is theoretically possible, and there are examples of the United States and other countries seeking to prevent others from constructing power reactors (e.g., Libya and Iran).[160] Prevention succeeded only in the Libya case, however; and in both cases, the country in question had already started a nuclear weapons program. Moreover, there is little evidence that this is a widespread phenomenon; indeed, it cuts against the basic principles of the Atoms for Peace program and the NPT, which promise support for peaceful nuclear development in exchange for safeguards and nonproliferation commitments.

Another potential selection effect critique is that countries that develop nuclear energy are less motivated to seek nuclear weapons for reasons unaccounted for by the quantitative models, or that they are the type of countries that are more vulnerable to outside pressure in general, thus making their weapons ambitions easier to deter or derail. Although it is possible that there are unobserved differences in motivation between countries with and without energy programs, the models seek to capture the most important predictors of proliferation identified in the extant literature, such as characteristics of the country's security environment. Controlling for measurable confounders is generally the most that can be done in the absence of an experimental manipulation, which is impossible on this topic—a researcher (thankfully) cannot randomly assign nuclear energy programs to countries and observe whether or not they proliferate at greater rates than a control group. The argument that countries that develop nuclear energy are less motivated to acquire nuclear weapons also runs counter to the conventional wisdom, which argues that establishing a nuclear energy program is the best route for countries that want to acquire nuclear weapons. Empirically, meanwhile, there is little evidence that countries with energy programs are more likely to be vulnerable to outside nonproliferation pressure, unless they depend on nuclear trade. Countries with nuclear energy programs actually have had significantly lower levels of

160. On Libya, see Richelson, *Spying on the Bomb*, pp. 324–327. On Iran, see ibid., p. 504.

trade openness and are less likely to receive U.S. economic or military aid, though they are more likely to have nuclear-armed allies (see table A24 in the online appendix). Thus, although the selection effects critiques cannot be ruled out, there is not much evidence in favor of them.

A fourth counterargument is that energy programs have created widespread nuclear latency, where many countries can build nuclear weapons on relatively short notice, which is hardly an encouraging outcome for nonproliferation. Indeed, some research suggests that countries with latent nuclear capabilities—usually defined as having enrichment and/or reprocessing facilities—may derive political or security benefits without fully proliferating, such as greater bargaining leverage and deterrence of military threats.[161] Moreover, demonstrating the close association between energy programs and latency, Mark Fuhrmann and Benjamin Tkach's data show that twenty-one countries have developed fuel-cycle facilities without acquiring nuclear weapons; fifteen of these had nuclear energy programs.[162] While such political or security benefits suggest that latency may represent a weak form of proliferation, the effect on the balance of power is almost surely lower than that of the full-fledged acquisition of nuclear weapons. Although not a perfect outcome for nonproliferation, countries with latent nuclear capabilities cannot start nuclear wars, intentionally or otherwise.

Moreover, the political restraints outlined above are a key reason why many of these countries have latent rather than actual nuclear weapons capabilities. According to Narang, one of the reasons that states interested in nuclear weapons adopt a hedging strategy, which relies on latent nuclear capabilities, is to avoid "paying the costs of overt proliferation, such as sanctions, reactive proliferation by adversaries, or the financial obligation of maintaining an overt deterrent."[163] Ariel Levite likewise finds that states often adopt nuclear hedging postures "as a way of retaining the option of restarting a weapons program that has been halted or reversed."[164] Indeed, several countries that currently have energy programs and latent nuclear capabilities—Germany, Iran, Japan, South Korea, and Sweden—arguably would have acquired nuclear weapons if

161. See Matthew Fuhrmann and Benjamin Tkach, "Almost Nuclear: Introducing the Nuclear Latency Dataset," *Conflict Management and Peace Science*, Vol. 32, No. 4 (2015), pp. 443–461, doi:10.1177/0738894214559672; Levite, "Never Say Never Again"; Narang, "Strategies of Nuclear Proliferation"; and Tristan A. Volpe, "Atomic Leverage: Compellence with Nuclear Latency," *Security Studies*, Vol. 26, No. 3 (2017), pp. 517–544, doi:10.1080/09636412.2017.1306398.
162. These include Argentina, Belgium, Brazil, Canada, the Czech Republic/Czechoslovakia, Germany/West Germany, Iran, Italy, Japan, the Netherlands, Romania, South Korea, Sweden, Taiwan, and Yugoslavia.
163. Narang, "Strategies of Nuclear Proliferation," p. 120.
164. Levite, "Never Say Never Again," p. 69.

not for the mechanisms identified above—namely, timely intelligence and the threat or use of sanctions by the United States.[165]

Conclusion

Contrary to the conventional wisdom, states with nuclear energy programs have not historically had a significantly higher likelihood of nuclear pursuit or acquisition. Although nuclear energy programs increase the technological know-how of a potential proliferator, policymakers in the United States and internationally are aware of this fact and have taken steps to mitigate the risks associated with proliferation. Two political restraints are important. First, countries that attempt to use their energy programs as political cover for weapons programs are less likely to see these latter programs underestimated by outside intelligence agencies, and they more likely to be the target of U.S. nonproliferation sanctions. Second, countries with nuclear energy programs face higher costs from sanctions, because the penalties are likely to include a cutoff of nuclear trade that may be crucial to their economy. As a result, while energy programs may make nuclear proliferation technically easier, they make it substantially more difficult politically, thus producing a near-zero effect in the aggregate.

The findings in this article add nuance to existing theoretical understandings of the supply side of the nuclear proliferation equation. That peaceful nuclear cooperation agreements and technical cooperation with the IAEA may increase the odds of proliferation, whereas energy programs do not, suggests that greater nuclear know-how does not always increase the odds of nuclear weapons spreading. This may be because the political restraints on proliferation highlighted above operate much more strongly on energy programs than they do on the broader category of nuclear activities captured by peaceful nuclear cooperation agreements and IAEA assistance. Energy programs are not only much larger in political and economic scope; they also offer greater potential economic benefits. As a result, they are likely to draw greater outside attention and potentially more painful sanctions: crippling a nuclear energy program is much costlier economically and politically than cutting off IAEA technical aid or tearing up a nuclear cooperation agreement, which may or may not be linked to any substantial transfer of technology and knowledge.

165. On Japan, South Korea, and Sweden, see above. On Germany, see Gene Gerzhoy, "Alliance Coercion and Nuclear Restraint: How the United States Thwarted West Germany's Nuclear Ambitions," *International Security*, Vol. 39, No. 4 (Spring 2015), pp. 91–129, doi:10.1162/ISEC_a_00198. On Iran, see Maloney, "Sanctions and the Iran Nuclear Deal."

As for policy implications, the findings indicate that nonproliferation policies intended to sever the links between nuclear energy and nuclear proliferation have been largely successful. As such, these policies should be maintained (or strengthened) if the goal is to observe similar trends in the future.

The findings also suggest three more specific policy implications. First, the United States should prioritize funding for the IAEA and nonproliferation intelligence activities within the U.S. government, which have been crucial in the past in detecting nuclear weapons programs. Second, the United States should seek to revive its role as a nuclear supplier, because doing so would provide greater leverage over countries with nuclear energy programs that can be used to enforce nonproliferation; it would also increase the ability of Washington to promote general nonproliferation standards with other suppliers. As part of an effort to increase nuclear exports, the United States should not demand the "gold standard" in its nuclear cooperation agreements, which would require the recipient country to publicly foreswear enrichment or reprocessing. The United States has alternative, quieter means—including diplomacy and the threat of sanctions—to prevent the spread of these technologies. Demanding the "gold standard" has the effect of further reducing the U.S. market share, as recipient states can turn to other suppliers, such as Russia, which do not require such restrictions.[166] Third, if the United States seeks to prevent a country from developing nuclear weapons, stopping them from starting a nuclear energy program is no panacea. A more covert proliferation approach may be just as likely to succeed, while limiting U.S. access to and leverage over the potential proliferator's program.

166. See, for example, Poneman, "The Case for American Nuclear Leadership," pp. 44–45.