Frustration and Delay:
The Secondary Effects of Supply-Side Proliferation Controls

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This is an Accepted Manuscript of an article published in Security Studies on June 30, 2019, available at: https://doi.org/10.1080/09636412.2019.1631383

Do trade barriers help slow the spread of nuclear weapons? Supply-side controls on proliferation equipment and material are often dismissed as ineffective because nuclear weapons–seeking states can develop methods to circumvent the controls. However, these global export controls have important secondary effects. By creating barriers to trade, export controls force states to develop costly and inefficient methods that interfere with progress toward nuclear weapons development. Using case evidence beginning with the advent of the Nuclear Suppliers Group's export control regime in 1974, I argue that the resulting delay and frustration can change leaders' strategic calculations regarding the value of their nuclear weapons programs. These findings demonstrate that proliferation controls do slow the spread of nuclear weapons, both by delaying existing programs, and by decreasing the likelihood that leaders will make decisions to continue with, or even start, nuclear weapons programs.

For decades, nuclear hopefuls like North Korea, Iran, Iraq, and Libya made progress toward acquiring nuclear arsenals. But that progress was neither uniform nor consistent. Leaders made decisions at different times that affected nuclear development, including decisions to reverse the course of their nuclear weapons programs. The nonproliferation regime, although imperfect, has played an important role in creating barriers to program development that have slowed, or even halted, nuclear weapons acquisition. Increasing the difficulty and cost of the pursuit of nuclear weapons can sour leaders' perceptions of the value and necessity of their nuclear weapons programs.

Any state pursing a nuclear weapons capability must acquire a broad range of equipment, parts, and technology. Since the mid-1970s, many nuclear supplier states have cooperated to regulate the sale of proliferation-related goods. But global nuclear trade has evolved from state-to-state commercial technology transfers to complex, network-based trade involving multiple

participants and destinations. These convoluted transactions are more difficult to track, and are intended to increase the odds that suppliers and buyers can evade restrictions on the sale of nuclear technology.

Much of the scholarly and policy-oriented analysis regarding these multilateral restrictions, generally referred to as nuclear export controls, thus tends toward pessimism. The controls do not prevent all prohibited nuclear transfers; states may procure the restricted nuclear goods they desire by bypassing the formal market and turning instead to the complex web of informal networks that make up "proliferation rings."[1] Evidence of the shortcomings of the export control regime abounds; from North Korea, to Iran, to Libya, states pursing nuclear weapons have found ways to work around nuclear controls. Ultimately, the export control regime did not prevent the emergence of Pakistan and North Korea as nuclear weapons states.

Yet the very reason for this complex and convoluted evolution of global nuclear trade is the often unrecognized success of nuclear export controls. If the goal of the export control regime is simply to prevent nuclear-seeking states from achieving nuclear weapons status, then the regime has clearly failed. But if the goal of the regime is to impede states' progress toward nuclear weapons acquisition, then the value of this imperfect regime should instead be measured by whether it has delayed the spread of nuclear weapons.

Over many years, export controls caused delay for the North Korean nuclear weapons program. Despite North Korea's reputation as a state that has developed expertise in thwarting supply-side barriers, export controls have at times succeeded in preventing prohibited goods

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[1] A phrase coined by Chaim Braun and Christopher F. Chyba, "Proliferation Rings: New Challenges to the Nuclear Nonproliferation Regime," *International Security* 29, no. 2 (Fall 2004): 5–49.

from reaching North Korean shores. Enforcement of export controls in 2003 prevented North Korea from receiving twenty-two tons of aluminum tubes suitable for constructing gas centrifuges, which are used to enrich uranium.[2] At high enough levels of enrichment, uranium can be used as the fissile material for the nuclear chain reaction that gives a nuclear weapon its devastating power. A North Korean attempt to use a Thai third-party company for receipt of controlled equipment and re-export to a North Korean front company was foiled by export controlling in 1999, and a second attempt, this time with direct shipment to North Korea, was thwarted in 2002. In those cases, the North Korean nuclear weapons program sought to purchase frequency converters, which convert electric current to the high frequencies needed to power centrifuge motors.[3] Nonproliferation controls on pivot bearings and maraging steel also created "bottlenecks" that slowed the North Korean program's ability to produce centrifuges.[4]

Detailed reports on North Korean nuclear facilities by scientists like Sigfried Hecker provided evidence of progress toward a nuclear weapons capability despite international efforts to counter proliferation. Export controls did not halt the program, but they did buy time, as the program had to resort to complex, costly, and time-intensive workarounds to import controlled

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[2] International Institute for Strategic Studies, *Nuclear Black Markets: Pakistan, A.Q. Khan and the Rise of Proliferation Networks: A Net Assessment* (United Kingdom: Hastings Print, 2007), 56; Mark Hibbs, "Aluminum Tubing North Korea Sought Believed Meant for Pilot Cascade," *Nuclear Fuel*, 13 October 2003; Braun and Chyba, "Proliferation Rings," 13.

[3] Hui Zhang, "Assessing North Korea's Uranium Enrichment Capabilities," Bulletin of the Atomic Scientists, 18 June 2009, https://thebulletin.org/assessing-north-koreas-uranium-enrichment-capabilities; International Institute for Strategic Studies, *Nuclear Black Markets*, 56.

[4] Chaim Braun et al., "North Korean Nuclear Facilities After the Agreed Framework" (Center for International Security and Cooperation, Stanford University, 27 May 2016), 43.

goods or substitutes.[5] In the 1990s and 2000s, the United States and other nations used that time to engage in diplomatic efforts that met with some success in slowing, and even temporarily reversing, North Korea's nuclear program. While those efforts ultimately failed to halt the North Korean program, years-long diplomatic efforts that brought about the suspension of the Iranian nuclear weapons program in 2015 have recently demonstrated how buying time can result in proliferation-reversing outcomes.[6]

I argue that the export control regime created by the Nuclear Suppliers Group (NSG) delays nuclear weapons development and increases the financial and political costs of pursuing a nuclear weapons capability. These obstacles to nuclear development have important implications for nonproliferation. Delaying a nuclear weapons program buys time: time for states to engage in diplomatic efforts to slow or suspend a nuclear pursuer's program, time for policies like economic sanctions to impact leaders' strategic calculations, and time that may allow for changes in leadership or the security environment.

Further, delay causes frustration. Decisions to reverse a nuclear weapons program—to slow or suspend progress—can occur at many points in the process of nuclear weapons

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[5] Bryan Early referred to North Korea's "MacGyver"-like methods for cobbling together various parts to construct equipment and technology. In John Park and Jim Walsh, "Stopping North Korea, Inc.: Sanctions Effectiveness and Unintended Consequences" (Cambridge, MA: MIT Security Studies Program, August 2016), 57, fn 132.

[6] As of this writing, the future of Iran's suspension of nuclear development is uncertain. I refer here to the conditions which contributed to buying time for the negotiations which resulted in Iran's nuclear slowdown, and not whether any party to the JCPOA may cause the deal to collapse in the months or years to come. For a succinct account of those efforts to reverse North Korean proliferation, see Siegfried Hecker, "Lessons Learned from the North Korean Nuclear Crises," *Daedalus* 139, no. 1 (Winter 2010): 44–56.

development, and those decisions may be based on different factors from the initial decision to start the program. Leaders who become frustrated by a program's inability to convert vast quantities of state resources into measurable nuclear progress may reevaluate the decision to invest in the uncertain prospect of a future nuclear capacity. Similarly, leaders who calculate that the costs of pursuing nuclear weapons outweigh the possible future benefits are also more likely to make reversal decisions.

Supply-side nonproliferation controls are not the only explanation for nuclear reversal, nor are they sufficient to explain why nuclear programs experience slowdowns. For example, Jacques Hymans' study of variations in nuclear weapons program efficiency shows how states can impede their own nuclear progress by adopting management approaches that undermine the sense of professionalism held by a program's science workers.[7] The puzzle addressed here, however, is whether nonproliferation policies contribute not only to slowing nuclear weapons development, but also whether they might have the secondary effect of increasing the likelihood that leaders will choose to reduce the state's investment in the nuclear project.

This article begins with a discussion of the scholarly debate regarding supply-side proliferation controls. While prior scholarship points to several different explanations for why states choose to pursue or forego nuclear weapons development, there has been a general lack of attention paid to the important functions of export controls.[8] Next, I describe the origins of the

[7] Jacques E. C. Hymans, *Achieving Nuclear Ambitions: Scientists, Politicians, and Proliferation* (Cambridge: Cambridge University Press, 2012).

[8] One exception in the scholarly literature is a study of dual-use exporting by the United States. Matthew Fuhrmann, "Exporting Mass Destruction? The Determinants of Dual-Use Trade," *Journal of Peace Research* 45, no. 5 (September 2008): 633–52.

Nuclear Suppliers Group's export control regime and the "Trigger List" that first identified which exports would be restricted. I discuss why I claim that the rarely-studied NSG regime has created specific conditions that affect the likelihood of nuclear reversal decisions. I then detail the four practical effects that the regime has had on the ability of states to pursue nuclear weapons programs. The regime has created delay, increased the cost of material and equipment, reduced access to reliable and high-quality equipment, and raised the risk that a nuclear weapons–striving state will be discovered and punished. As a result, leaders after 1974 have been more likely to decide to reverse their nuclear weapons programs. I provide examples from a wide range of cases to illustrate these four practical effects. I then follow the theoretical discussion with a case study of Pakistan, a state that is well-known for its attempts to evade export controls, but that has nonetheless been seriously constrained by the regime. I conclude with a discussion of the uncertainty that the regime has created for those that consider pursuing nuclear weapons.

Nuclear Nonproliferation on the Supply Side

Either the transfer or denial of nuclear technology and equipment is part of the history of every serious state attempt at a nuclear weapons capability since the end of World War II. States have helped each other to pursue the bomb for political, strategic, and economic reasons.[9] States pursue foreign assistance because the supply of nuclear equipment and technology can both

[9] Matthew Fuhrmann, "Taking a Walk on the Supply Side: The Determinants of Civilian Nuclear Cooperation," *Journal of Conflict Resolution* 53, no. 2 (April 2009): 181–208; Matthew Kroenig, "Exporting the Bomb: Why States Provide Sensitive Nuclear Assistance," *The American Political Science Review* 103, no. 1 (February 2009): 113–33; Nicolas Jabko and Steven Weber, "A Certain Idea of Nuclear Weapons: France's Nuclear Nonproliferation Policy in Theoretical Perspective," *Security Studies* 8, no. 1 (Autumn 1998): 108–50; William C. Potter, ed., *International Nuclear Trade and Nonproliferation* (Lexington, MA: Lexington Books, 1990).

hasten the progress a state program can make toward developing nuclear weapons and reduce the government's expected costs of a nuclear program.[10] Leaders become more confident that their programs will be able to succeed in producing nuclear weapons because of the access to, and knowledge gained from, nuclear imports.[11] However, studies of nuclear assistance rarely address the quality of nuclear transfers, with R. Scott Kemp's work being the notable exception. Poor-quality equipment and technology can delay a program's progress, and using the black market rather than licensed exports greatly increases the chances a program will receive unreliable items.[12] The literature has not, however, extended these arguments to consider how leaders might lose confidence in programs that they perceive to be wasting resources and falling behind.

Can states develop nuclear weapons without foreign assistance? Kemp argues that the scholarly focus on foreign assistance is misguided, as most developing states should be able to use open source material and domestic industrial capabilities to achieve nuclear success on their own.[13] Yet the history of nuclear proliferation demonstrates that even if states can pursue a nuclear arsenal on their own, in practice they choose not to try. For example, a state may be able to produce items indigenously, but may still decide to purchase nuclear equipment and technology in order to reduce the time to completion.[14] That states either are able to go it alone or elect to use nuclear exports is a false dichotomy. While nuclear transfers may not be essential

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[10] Fuhrmann, "Taking a Walk on the Supply Side"; Matthew Fuhrmann, "Spreading Temptation: Proliferation and Peaceful Nuclear Cooperation Agreements," *International Security* 34, no. 1 (Summer 2009): 7–41.

[11] Fuhrmann, "Spreading Temptation."

[12] R. Scott Kemp, "The Nonproliferation Emperor Has No Clothes: The Gas Centrifuge, Supply-Side Controls, and the Future of Nuclear Proliferation," *International Security* 38, no. 4 (Spring 2014): 39–78.

[13] Ibid.

[14] Fuhrmann, "Taking a Walk on the Supply Side," 186.

for acquiring nuclear weapons, the more critical question is whether controlling nuclear transfers could derail a nuclear program—either because states actually need the exported items, or because they believe they do.

Others argue that nonproliferation sanctions, including trade restrictions, have slowed the spread of nuclear weapons.[15] These arguments are countered by a significant amount of evidence that sanctions are ineffective.[16] Nicholas Miller contends that nonproliferation sanctions have been largely successful in one particular context: the credible threat of sanctions against proliferating states prevents certain types of states from starting nuclear programs. States that would be adversely impacted by the future imposition of sanctions elect not to pursue nuclear weapons, while those able to bear the costs of the threatened sanctions are undeterred.[17] Thus, those states that choose to bear the costs of sanctions and proceed with nuclear weapons

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[15] Braun and Chyba, "Proliferation Rings"; Alexander H. Montgomery, "Ringing in Proliferation: How to Dismantle an Atomic Bomb Network," *International Security* 30, no. 2 (Fall 2005): 153–87; Etel Solingen, *Nuclear Logics: Contrasting Paths in East Asia and the Middle East* (Princeton, NJ: Princeton University Press, 2007); Ariel E. Levite, "Never Say Never Again: Nuclear Reversal Revisited," *International Security* 27, no. 3 (Winter 2002/03): 59–88.

[16] Robert A. Pape, "Why Economic Sanctions Do Not Work.," *International Security* 22, no. 2 (Fall 1997); Daniel W. Drezner, "The Hidden Hand of Economic Coercion," *International Organization* 57, no. 3 (Summer 2003): 643–59; Daniel W. Drezner, *The Sanctions Paradox: Economic Statecraft and International Relations*, Cambridge Studies in International Relations 65 (Cambridge: Cambridge University Press, 1999); Dean Lacy and Emerson M. S. Niou, "A Theory of Economic Sanctions and Issue Linkage: The Roles of Preferences, Information, and Threats," *Journal of Politics* 66, no. 1 (February 2004): 25–42.

[17] Nicholas L. Miller, "The Secret Success of Nonproliferation Sanctions," *International Organization* 68, no. 4 (Fall 2014): 913–44.

development, which are the states with which this study is concerned, are highly unlikely to be impacted by nonproliferation sanctions.

An alternative explanation to the utility of supply-side restrictions is that states will simply invest unlimited resources in order to achieve nuclear weapons status, whether due to security needs, domestic political coalitions, or out of a desire for national prestige.[18] Supply-side nonproliferation measures would have no effect on a leader who was determined to acquire a nuclear arsenal no matter the cost. At times, and under various regimes, states like Pakistan and North Korea have indeed demonstrated tremendous willingness to pursue the bomb despite the obstacles. However, maximum investment does not necessarily lead to success.[19] And the history of nuclear weapons development shows that leaders do make decisions to slow or stop their nuclear programs.[20] Leaders neither uniformly nor indiscriminately invest the full measure of state resources in their nuclear pursuits. Yet the literature does not systematically examine whether supply-side constraints affect a leader's willingness to continue with a nuclear weapons program.

The Role of the NSG in the Nonproliferation Export Control Regime

The export control regime initiated by the NSG in 1974 divides the nuclear proliferation era into two periods: the time before the regime, and the time after. Prior to the establishment of the

[18] The classic examination of these three motives is Scott D. Sagan, "Why Do States Build Nuclear Weapons: Three Models in Search of a Bomb.," *International Security* 21, no. 3 (Winter 1996/97): 54–86.

[19] Hymans, *Achieving Nuclear Ambitions*.

[20] Mitchell Reiss, *Bridled Ambition: Why Countries Constrain Their Nuclear Capabilities* (Washington, DC: Woodrow Wilson Center Press, 1995); Kurt M. Campbell, Robert J. Einhorn, and Mitchell Reiss, *The Nuclear Tipping Point: Why States Reconsider Their Nuclear Choices* (Washington, DC: Brookings Institution Press, 2004); Levite, "Never Say Never Again: Nuclear Reversal Revisited."

regime, supplier states exported nuclear fuel, equipment, and technology to receiving states with limited or no safeguards to prevent the exports' misuse.[21] Once established, the export control regime made it significantly more difficult for states with nuclear ambitions to obtain key items needed for a nuclear weapons program.

Export controls are used to disrupt the supply of the controlled goods by making the sale of those goods illegal. Under the nuclear export control regime, nuclear supplier states agreed that the sale of nuclear weapons–related fuel, equipment, and technology should be permitted only when accompanied by international monitoring of the items received by the buyer. Monitoring would confirm that nuclear exports were being used only for civilian purposes and were not being diverted to a weapons program.

By using export licenses to govern the sale of these sensitive items, nuclear suppliers create barriers to trade. Sellers and buyers that violate export controls risk punishments ranging from fines to reputational costs to imprisonment. However, enforcement problems, an incomplete accounting of items that can be used to produce nuclear weapons, deliberate violations by supplier governments, deceptive practices by receiving governments, and the

[21] While bilateral safeguards existed prior to the creation of both the NPT and the NSG, they were far from comprehensive. An early IAEA safeguards system emerged in 1961, but the inspectors had to provide at least one week's notice to the country being inspected, and were constrained in their freedom of movement during inspections. Not until 1971 did NPT safeguards allow for slightly less constraining inspection procedures, but these safeguards limited access within nuclear plants even more than before the NPT came into force. Furthermore, safeguards agreements facilitated under the NPT did not immediately result in inspections. For example, not until 1979 were negotiations over the constraints on IAEA inspectors finally resolved by all five EURATOM non–nuclear weapons states. David Fischer, *History of the International Atomic Energy Agency: The First Forty Years* (Vienna: International Atomic Energy Agency, 1997), 244–59.

growth of a nuclear black market have all poked holes in the barriers built by the regime. Motivated buyers have been able to exploit loopholes and weaknesses in the regime in order to acquire controlled goods outside of international safeguards.

Even with these deficiencies, states were no longer able to easily or securely procure the components needed to develop nuclear weapons after 1974. The NSG's export control regime created constraints on the ability to access sensitive nuclear goods that affected the decisions made by states pursuing nuclear weapons programs. I argue that the export control regime imposed costs on existing nuclear weapons programs that increased the likelihood that states pursuing these programs would make reversal decisions.

The NSG is one component of a broader, multilateral export control regime. The Australia Group (AG) was established in 1985 to control chemical weapons precursors; the Missile Technology Control Regime (MTCR) was created in 1987 to control exports of missiles and related technology, and the 1996 Wassenaar Arrangement was created to gather information on transfers of conventional weapons and dual-use items.[22] I use the NSG's export control

[22] For a brief introduction to this broader regime, see Michael D. Beck et al., *To Supply or to Deny: Comparing Nonproliferation Export Controls in Five Key Countries* (The Hague: Kluwer Law International, 2003), 4–8. The Wassenaar Arrangement was formed after the dissolution of the Coordinating Committee for Multilateral Export Controls (COCOM), a group of Western states that planned to coordinate a strategic embargo that would restrict exports to the Soviet Union and Eastern bloc. Disagreement over what technology to control and whether the committee should restrict its efforts to information sharing limited the effectiveness of the group. COCOM's list of controlled items rarely, if ever, changed in response to new technologies or violations. See Aaron Karp, "Controlling Weapons Proliferation: The Role of Export Controls," *Journal of Strategic Studies* 16, no. 1 (March 1993): 18–45; Richard T. Cupitt, "The Future of COCOM," in Gary K. Bertsch and Steven Elliott-Gower, *Export Controls in Transition: Perspectives, Problems, and Prospects* (Durham, NC: Duke University Press, 1992), 234; and Ron

regime, rather than one or more of the other three elements of the broader regime, for three reasons. First, the NSG's formation in 1974 established the first multilateral export control regime that both had a global reach and was aimed at preventing the spread of nuclear weapons.[23] The other three components of the multilateral export control regime were established much later and have different, although complementary, goals. Second, while the MTCR controls items related to certain technologies that can be used to deliver nuclear weapons, such as missiles, neither the AG nor the MTCR controls exports of equipment and technology related to the development of the nuclear weapons themselves.

Third, the NSG regime is explicitly aimed at preventing the unsafeguarded export of proliferation-related items, and involves the International Atomic Energy Agency (IAEA) in verifying that nuclear technology transfers are being used for peaceful purposes. This makes the NSG very different in practical terms from the Wassenaar Arrangement, which primarily collects and exchanges information in the hopes that members will be able to discern alarming patterns of weapons acquisition or the accumulation of sensitive, dual-use technology. Because the Arrangement serves mainly as a tool to allow for the identification and possible prevention of destabilizing or dangerous stockpiling, it supplements the broader nonproliferation regime but does not yet contribute to breaking new ground in nonproliferation export control.[24] The NSG

Smith and Bernard Udis, "New Challenges to Arms Export Control: Whither Wassenaar?," *The Nonproliferation Review* 8, no. 2 (Summer 2001): 81–92.

[23] COCOM first formed in 1949, but was directed at only the Soviet Union and the half-dozen members of the Warsaw Pact.

[24] Smith and Udis, "New Challenges to Arms Export Control"; Richard F. Grimmett, "Military Technology and Conventional Weapons Export Controls: The Wassenaar Arrangement," CRS Report for Congress, 29 September 2006.

export control regime, by contrast, actively works to control sensitive exports through safeguards and prohibition.

The Path to the Trigger List

As the original nuclear states developed their capabilities and shared some of their knowledge and materials with each other, concerns over proliferation grew. In 1953, in his "Atoms for Peace" address to the United Nations General Assembly, US President Dwight D. Eisenhower encouraged nuclear-capable nations to join the United States in providing peaceful nuclear assistance to states eager to reap the benefits of nuclear energy. Nuclear states would provide nuclear material and technology if receiving states would agree to use them only for peaceful purposes. However, by the 1960s, the ready availability of nuclear materials and technology to non–nuclear weapons states, and the lack of monitoring to ensure recipient states were not utilizing nuclear capabilities for military applications, had created serious proliferation concerns. Since the founding of the IAEA in 1957, several agreements had been reached regarding the safeguard the exporting of nuclear equipment from one state to another, but the actual safeguards system was limited to only a few types of equipment.[25]

International discussion of safeguards continued during the negotiations that resulted in the 1968 NPT, which aimed to prevent the spread of nuclear weapons. Article III of the treaty stated that certain fissionable materials and equipment should only be transferred to non–nuclear weapons states under safeguard arrangements. Those safeguards would allow for verification that nuclear imports were being used only for civilian purposes and not for weapons development. However, the language in the NPT regarding these export controls was left intentionally vague.

[25] Jack Boureston, "Strengthening Nuclear Safeguards: Special Committee to the Rescue?," *Arms Control Today* 35, no. 10 (December 2005): 17–18.

Which materials and equipment should be safeguarded, and which fell outside the non-proliferation regime, were not specified. There was thus no legally binding agreement among the five nuclear weapons states at that time, and still nothing that could be termed an export control regime. After the NPT came into effect in 1970, signatories did not take meaningful action to ensure nuclear exports would be used for civilian, rather than military, purposes.

Recognizing that states were unlikely to independently and voluntarily limit profitable exports, a group of states began holding secret, informal meetings in Vienna to discuss the creation of guidelines for export controls.[26] But without international pressure to implement a meaningful export control regime, the committee (known formally as the NPT Exporters' Committee and informally as the Zangger Committee for its chair, Swiss professor Claude Zangger) made little movement toward strengthening controls.[27] The nuclear supplier states present agreed that the decisions of the Committee would not be legally binding.[28]

India's nuclear test in 1974, which took the international community by surprise, was the event that ultimately pushed the committee forward.[29] The CIRUS research reactor that produced

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[26] "Background Paper for the 1995 Review and Extension Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons" (United Nations Secretariat, 18 April 1995), http://www.un.org/Depts/ddar/nptconf/2136.htm.

[27] Carlton E. Thorne, "Nuclear Export Controls," in *IAEA Safeguards for the 21st Century* (Taejon, Republic of Korea, 1999), 3–4.

[28] Fritz W. Schmidt, "The Zangger Committee: Its History and Future Role," *The Nonproliferation Review* 2, no. 1 (Fall 1994): 38.

[29] The US intelligence community, for example, failed to provide warning that the PNE was being planned; see Intelligence Community Staff, "Post Mortem Report, An Examination of the Intelligence Community's Performance

the plutonium for India's "peaceful nuclear explosion" had been built with assistance from Canada and supplied with heavy water from the United States—all unsafeguarded. This vivid demonstration of the possible consequences of unsafeguarded nuclear exporting provided the political will for the Zangger Committee to create what became known as the Trigger List: a list of material and equipment that could not be exported without triggering IAEA safeguards on the receiving end. India's test, which the government named the "peaceful nuclear explosion," or PNE, had been conducted in May. By July, the Zangger Committee had agreed on the initial items that would comprise the Trigger List, and by September, the list was active.[30]

Export controls could be effected so rapidly in 1974 because the controls immediately became a part of contract negotiations. For example, in that year Canada began requiring a government-to-government nuclear cooperation agreement before the Canadian government would consider exporting a controlled item to a non–nuclear weapons state. The receiving state had to be a party to the NPT, accept full-scope safeguards, and provide assurances directly to Canada that the nuclear items would be handled appropriately.[31] International Atomic Energy

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Before the Indian Nuclear Test of May 1974," Top Secret, July 1974, CREST, NARA, College Park, Md., https://nsarchive2.gwu.edu//NSAEBB/NSAEBB187/index.htm.

[30] Tadeusz Strulak, "The Nuclear Suppliers Group," *The Nonproliferation Review* 1, no. 1 (Fall 1993): 2; for an account of the items on the original Trigger List, refer to "INFCIRC/209 Memorandum B" (International Atomic Energy Agency, 3 September 1974). Items range from reactors and reactor equipment, to heavy water, to fuel fabrication plants and equipment, to equipment designed for separating uranium isotopes. The list was further clarified in an Annex.

[31] States have to guarantee that the items will be used for civilian nuclear energy purposes only; that the state will not transfer the items to a third party; that Canada will control any nuclear fuel provided, including the spent fuel that is created in a nuclear reactor as a byproduct; and so on. Ian Anthony, Christer Ahlstrom, and Vitaly

Agency historian David Fischer notes the difference between the NPT and the NSG (he refers to the NSG's restrictions as the "London guidelines") in explaining the changes that were quickly made in three safeguards agreements in 1974–75. The agreements were made between France and South Korea; France and Pakistan; and West Germany and Brazil, and "[they] incorporated the new requirement of the London guidelines that 'sensitive' nuclear technology as well as sensitive nuclear hardware should be subject to IAEA safeguards when exported to a non–nuclear weapon state."[32] As the new regime took hold, requests for nuclear transfers began declining steadily, and, over time, state-to-state transfers of nuclear weapons capabilities virtually ended.[33]

The NPT itself was neither amended nor renegotiated to reflect these changes. While the Zangger committee members were all NPT signatories, the members of the new nuclear suppliers group, which began meeting in 1975 in London, were the United States, the Soviet Union, the United Kingdom, West Germany, Japan, Canada, and France (which would not accede to the NPT until 1992). By 1977, the NSG had grown to fifteen members, each of whom agreed to implement specific, special controls on nuclear exports.[34]

The Advent and Evolution of the Regime

Fedchenko, *Reforming Nuclear Export Controls: The Future of the Nuclear Suppliers Group* (Oxford: Oxford University Press, 2007), 39.

[32] Fischer, *History of the International Atomic Energy Agency*, 262.

[33] Ian J. Stewart, "Export Controls at the Crossroads," *Bulletin of the Atomic Scientists*, 15 October 2015, http://thebulletin.org/export-controls-crossroads8806.

[34] Strulak, "The Nuclear Suppliers Group," 2.

Was this new export control regime effective in preventing the spread of nuclear weapons? In the years since the Trigger List first became active, export controls have not eliminated nuclear proliferation. States that have sought nuclear material and equipment outside of safeguards have found loopholes, falsified records to obscure the nuclear aspects of imported equipment, and turned to the clandestine supply networks commonly referred to as the nuclear black market, with the A.Q. Khan network the most famous among them.[35] No one familiar with the historical record would argue that export controls have succeeded in keeping nuclear material out of the reach of states pursuing nuclear weapons programs. Indeed, experts lament the "gaps" and "leaks" in the export control regime, including cases where nuclear suppliers have chosen not to enforce the regime and have transferred material or equipment without proper safeguards.[36] The story of every nuclear weapons program that emerged after the original five nuclear powers

[35] Khan began smuggling materials for Pakistan's nuclear weapons program, but by 1990 had shifted to exporting lucrative items to other states, originating what would become an extensive black market network. See International Institute for Strategic Studies, *Nuclear Black Markets: Pakistan, A.Q. Khan and the Rise of Proliferation Networks: A Net Assessment*; David Albright, *Peddling Peril: How the Secret Nuclear Trade Arms America's Enemies* (New York: Free Press, 2010); Gordon Corera, *Shopping for Bombs: Nuclear Proliferation, Global Insecurity, and the Rise and Fall of the A.Q. Khan Network* (Oxford: Oxford University Press, 2006).

[36] See, for example: Paul L. Leventhal, "Nuclear Export Controls: Can We Plug the Leaks?" in Jean-François Rioux, *Limiting the Proliferation of Weapons : The Role of Supply-Side Strategies* (Ottawa: Carleton University Press, 1992); Strulak, "The Nuclear Suppliers Group"; Braun and Chyba, "Proliferation Rings"; Kemp, "The Nonproliferation Emperor Has No Clothes"; Leonard S. Spector, *Nuclear Proliferation Today* (New York: Random House, 1984); Feroz Hassan Khan, *Eating Grass: The Making of the Pakistani Bomb* (New Delhi: Cambridge University Press, 2013); Leonard S. Spector, *Nuclear Ambitions: The Spread of Nuclear Weapons 1989–1990* (Boulder, CO: Westview Press, 1990); Reiss, *Bridled Ambition*; Potter, *International Nuclear Trade and Nonproliferation*.

includes either nuclear assistance given outside of the export control regime, or the intentional misuse or covert duplication of safeguarded materials—or both.

But the utility and value of the Trigger List, which has been expanded and strengthened over time, should not be defined by the highest bar: whether proliferation has been eradicated. We know that traffic lights do not always function perfectly, and have not eliminated all car accidents. But traffic lights have improved road safety by reducing the risk of collisions in busy intersections. Similarly, if the export control regime has made proliferation more difficult, then the regime has accomplished a significant part of its goal. The regime has not prevented all nuclear proliferation, but it can manage proliferation.[37] Export controls change proliferation outcomes when they result in slowing the pace of proliferation, or in dissuading interested states from progressing all the way to nuclear weapons acquisition.

In fact, the very process of the talks changed state behavior even before the final agreement of the NSG had been signed. France had been negotiating with South Korea over the sale of a pilot reprocessing plant. When the United States opposed this, France agreed to slow down the talks. South Korea, also facing US pressure, ultimately cancelled the deal. France also slowed its negotiations with Pakistan, finally ending negotiations with no contract.[38] The West German-Brazilian 1975 nuclear deal did not collapse, in spite of US pressure. West Germany

[37] Leventhal in Rioux, *Limiting the Proliferation of Weapons*, 41; Daniel Salisbury and David Lowrie, "Targeted: A Case Study in Iranian Illicit Missile Procurement," *Bulletin of the Atomic Scientists* 69, no. 3 (May 2013): 23–30; Ian J. Stewart, "Antiproliferation: Tackling Proliferation by Engaging the Private Sector," Belfer Center Discussion Paper (Cambridge, MA: Harvard, 2012), 3.

[38] William Burr, "A Scheme of 'Control': The United States and the Origins of the Nuclear Suppliers' Group, 1974–1976," *The International History Review* 36, no. 2 (2014): 269.

instead compromised by honoring new NSG guidelines through the implementation of the most stringent safeguards ever employed in an agreement with a non-NPT state, which included German-Brazilian joint management of future enrichment and reprocessing, and Brazil's pledge to obtain German approval before re-exporting restricted technology to a third party.[39]

The process of buying and selling prohibited nuclear items has evolved over time; both buyers and sellers have developed techniques to attempt to circumvent the export control regime. The evolution itself provides indirect evidence of the success of the supply-side controls. Buyers' and sellers' methods have changed again and again, growing ever more sophisticated, in response to the obstacles created by the export control regime. Why would buyers and sellers engage in increasingly complicated, inefficient, and expensive methods for trade, unless the regime worked well enough to prompt the creation and adoption of those methods? If there were no practical effects of trade barriers, there would be no need to develop ever more costly new tactics. We can observe the success of the export control regime in part by observing the responses of the frustrated buyers and sellers.

This continuing frustration for buyers and sellers, despite their adoption of complex tactics to circumvent the regime, occurs because the NSG responds strategically to new tactics. By operating both as individual members and as an organization, the NSG has reacted to regime circumvention tactics by revising the regime's methods of controlling exports. In this action-reaction dynamic, as buyers and sellers develop new methods to evade the regime, NSG members respond by strengthening the regime.

[39] Peter Tzeng, "Nuclear Leverage," *The Nonproliferation Review* 20, no. 3 (November 2013): 474–75.

The NSG has continuously reviewed, updated, and amended its lists of controlled items.[40] The IAEA maintains records of the dozens of additions to, corrections to, and modifications of the Trigger List, as reported by NSG members.[41] This is an ongoing process of review and revision that itself has evolved over time; currently, a standing technical working group proposes revisions on an annual basis that must then be approved by consensus.[42] The 1991 public disclosure of Iraq's clandestine nuclear weapons program, a program that had relied heavily on exports of dual-use items that fell outside the NSG's control regime, created the political will needed to rapidly bring about the most significant evolution of the NSG Guidelines since their inception. The 1992 revision of the NSG Guidelines resulted in the mandate that IAEA full-scope safeguards would be required for all significant new nuclear exports to non–nuclear weapons states, as well as dual-use guidelines that substantially expanded the control list.[43] The most recent update was agreed to at the 2017 NSG Plenary meeting in Bern, Switzerland.[44]

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[40] In addition to the original Trigger List, the NSG has added further guidelines, such as its list of controlled dual-use items. For NSG guidelines, see "Nuclear Suppliers Group - Guidelines," n.d., http://www.nuclearsuppliersgroup.org/en/guidelines.

[41] Lewis A. Dunn notes in particular the expansions in the 1980s that included new Trigger List items needed for heavy water, reprocessing, and enrichment. Lewis A. Dunn, "The NPT: Assessing the Past, Building the Future," *The Nonproliferation Review* 16, no. 2 (1 July 2009): 143–72.

[42] I thank Mark Hibbs for explaining this process to me in personal correspondence, 12 January 2018.

[43] Anthony, Ahlstrom, and Fedchenko, *Reforming Nuclear Export Controls*, 22–24.

[44] A list of these modifications is maintained at "Communications Received from Members Regarding the Export of Nuclear Material and of Certain Categories of Equipment and Other Material, INFCIRC/209," International Atomic Energy Agency, n.d., https://www.iaea.org/publications/documents/infcircs/communications-received-members-regarding-export-nuclear-material-and-certain-categories-equipment-and-other-material.

Modifications have included expansions of the list to include new items, or clarifications of what technologies and equipment are included under broad terms like "plants for production of heavy water."[45]

When states have signed legal nuclear cooperation agreements under the export control regime, the required safeguards have also contributed to slowing proliferation. International monitoring and inspections, conducted by the IAEA, have made it more costly and difficult to conduct clandestine activity. For example, inspections prevent states from being able to divert safeguarded nuclear fuel to be used in weapons development. States that wish to pursue nuclear weapons despite the safeguards have had to build parallel facilities that are kept secret from the IAEA. Safeguards are not toothless measures, and they impose serious constraints on states that accept them.

Secondary Effects from Practical Difficulties

States pursue nuclear weapons programs for various reasons. Scott D. Sagan developed three theoretical frameworks that are widely used to analyze individual states' motivations for deciding to begin such a program: the desire to mitigate serious threats to national security, the advancement of domestic political interests, and the pursuit of prestige. But once a state has embarked upon a nuclear weapons program, whether the state's leaders will stay the course over

[45] "Communications Received from Members Regarding the Export of Nuclear Material and of Certain Categories of Equipment and Other Material, INFCIRC/209/Add.1/Mod.1" (International Atomic Energy Agency, December 1978).

the years needed to bring a nuclear weapons program to fruition is a different matter. The history of the pursuit of nuclear weapons contains more failures than it does successes.[46]

I argue that the nuclear export control regime is one key factor that has increased the likelihood of a leader deciding to decelerate a state's nuclear weapons program because of the practical difficulties imposed upon states by the new restrictions on the international nuclear market. Beginning from the activation of the Trigger List in 1974, the export control regime has hampered states' pursuits of nuclear weapons in four main ways: by creating delay, by increasing the cost of material and equipment, by reducing access to reliable and high-quality equipment, and by increasing the risk that a nuclear weapons–striving state will be discovered and punished. As a result, the regime ultimately increased the likelihood of a leader deciding to decelerate her state's nuclear weapons program.

Creating Delay

The export control regime begun in 1974 has made it more difficult to procure nuclear supplies. Prior to 1974, the acquisition of nuclear technology, equipment, and fuel functioned largely as an international market where a state interested in procuring an item would have several sellers among which to choose. This allowed a state to negotiate for the best deal, particularly in terms of price and services (such as whether the supplying state would assist the receiving state in constructing a reactor from purchased parts). After 1974, however, the export control regime placed serious restrictions on that market. Safeguards on exported nuclear material meant that states pursuing, or planning to pursue, nuclear weapons development would have four options: find a supplier willing to break the rules; obtain the items on the black market; purchase items

[46] See Reiss, *Bridled Ambition*; Campbell, Einhorn, and Reiss, *The Nuclear Tipping Point*; Hymans, *Achieving Nuclear Ambitions*.

that appear innocuous but can be used to build or manufacture weapons-related equipment or technology; or acquire technology within the export control regime with the hopes of learning how to reverse engineer that technology.

Of these four options that the export control regime created, three cause direct delays in a state's pursuit of nuclear development. (The exception, obtaining items on the black market, delays programs indirectly, largely through providing substandard goods. This will be discussed in a later section.) That delay—which can be measured in months, or often years—makes nuclear development more difficult and costly. Leaders that view the nuclear weapons program as too difficult and costly to pursue at status quo levels are more likely to decide to decelerate, or even end, the program. Delay also has the obvious effect of lengthening the amount of time it takes a program to achieve the goal of nuclear bomb acquisition.[47] The longer the journey to the bomb lasts, the more time and opportunity there is for other states to use pressure and negotiations, and even to conduct targeted strikes against a program, in order to persuade the leader to make a deceleration decision. Export controls delay the path toward progress.[48]

Post-1974, states looking to purchase non-safeguarded Trigger List items from a traditional supplier, such as a nuclear technology firm, had to find a supplier that was willing to export those items in violation of the regime. While some renegade suppliers were known for their willingness to work outside of the regime, the regime's constraints still affected those suppliers' reliability as exporters. In one case, West German suppliers provided nuclear materials

[47] Export controls can "buy time"—time that might be needed for diplomatic pressure to yield results, or time to allow a political transition to occur. Beck et al., *To Supply or to Deny*, 3; Kemp, "The Nonproliferation Emperor Has No Clothes."

[48] Thorne, "Nuclear Export Controls," 10.

to several nuclear weapons–pursuing states throughout the first decade-and-a-half of the new export control regime. In early 1980, Iraq ordered depleted-uranium metal fuel pins from the West German firm NUKEM. Iraq claimed that these pins, which fit the dimensions of Iraq's Osiraq reactor, were needed for research purposes; in actuality, the pins had only one use: to be irradiated for plutonium extraction. NUKEM proceeded with the order under the pretense that the pins would be used for research, until regulatory officials informed NUKEM's subcontractors in the United States and Canada that they would not be granted export licenses.[49] NUKEM canceled the deal, and Iraq was left with no pins and little hope of finding another traditional supplier. The months spent on the contract had been wasted; Iraq's program had been delayed. By 1990, after pressure from the United States, West Germany was no longer willing to skirt the regime, and announced that in the future it would require full safeguards for all nuclear exports.[50]

As the export control regime matured, fewer traditional suppliers were willing to break the rules, and contracts became harder to come by. Variation in the level of enforcement that member states have exercised made suppliers in weak-enforcement states more attractive sources of nuclear equipment and technology than those in strong-enforcement states. However, even weak enforcers such as Russia, or West Germany in the above example, have bowed to outside pressure—particularly from the United States—to block a shipment or cancel an agreement.[51]

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[49] Spector, *Nuclear Ambitions*, 187.

[50] Reiss, *Bridled Ambition*, 63.

[51] For example, in a secret protocol to an agreement between Russian and Iran in January 1995, Russia agreed to export to Iran nuclear technology and facilities that included reactors, fuel fabrication facilities, and a uranium enrichment centrifuge plant. After the United States learned of the secret arrangement, US President Clinton

Neither buyers nor sellers can be certain that the transaction will be completed, even in weak-enforcement states.

The 1974 shift helped to make procurement difficult enough for South Korea that it contributed to the deceleration of Seoul's nuclear weapons program. According to a former high-ranking Korean government official who was a member of the secret Weapons Exploitation Committee (WEC) of senior Korean officials, South Korea had planned to work with France and Belgium and hoped to secure agreements for reprocessing facilities. But after the 1974 PNE, Belgium and Canada withdrew from nuclear technology contract negotiations. France continued to negotiate with South Korea, but deliberately slowed the process.[52] In combination with pressure from the United States, the difficulties the government would face in having to start over and build relationships with willing suppliers were consequential. Leadership decelerated Seoul's program beginning in 1975. Even agreements completed prior to 1974 were jeopardized by the new export control regime, which I examine within the case study of Pakistan later in this article.

Second, states can attempt to work around the export control regime by purchasing items that have civilian applications and are not included in the export control regime, but can be used

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"protested heatedly" to Russian President Yeltsin, and Yeltsin pledged to withdraw Russia from the sensitive aspects of the agreement. Russia did provide nuclear assistance to Iran in subsequent years, but those technology transfers have been conducted in accordance with NSG and NPT guidelines. Anthony, Ahlstrom, and Fedchenko, *Reforming Nuclear Export Controls*, 61.

[52] United States., *Investigation of Korean-American Relations: Report of the Subcommittee on International Organizations of the Committee on International Relations, U.S. House of Representatives, October 31, 1978.*, Investigation of Korean American Relations (Washington, DC: US Govt. Print. Off., 1978), 80, https//catalog.hathitrust.org/Record/011340549.

for military purposes as well. For example, precision steel bearings have many civilian uses, but are also used for uranium-enriching centrifuges. Mass spectrometers are used to determine the composition of chemical samples in civilian industries and laboratories, but may also be used to determine the chemical makeup of uranium and plutonium. Referred to as dual-use items, these materials may be used to build or manufacture weapons-related equipment or technology, or to assist in producing fissile material. Procuring dual-use items has been a common regime circumvention strategy used by clandestine programs operating outside of safeguards.

The primary cause of delay stemming from reliance on dual-use items is simply the fact that building indigenous equipment from dual-use components takes longer than buying off-the-shelf equipment directly. Not only does the construction itself add to the timeline, but identifying, locating, ordering, and receiving dual-use items piecemeal also creates delay. In the 1970s and 1980s, states using the dual-use strategy were already hampered by delay due to the factors explained above. But after 1991, procuring dual-use items grew still more difficult. Iraq's reliance on dual-use items was uncovered after the 1991 Gulf War. Revelations that many of the NSG members had exported significant quantities of dual-use materials and technology, and that Iraq had put those items to use in its nuclear weapons program, led to new measures to close the dual-use gap, as was discussed earlier.[53] Over time, the export control regime has imposed greater barriers to dual-use transfers, making it more difficult for programs to procure these items outside of safeguards. The strategies that states have developed for purchasing these items, despite the stricter regulations, also increase the likelihood of delaying progress.

Dual-use item procurement has since required a significant amount of additional work and subterfuge. The North Korean nuclear program is known for creating phony companies in

[53] Strulak, "The Nuclear Suppliers Group," 4.

other states, and then ordering dual-use items through those front companies to hide North Korea's involvement from nuclear export regulators. This workaround requires a significant amount of work and time. Hibbs describes an incident in which North Korea hoped to purchase a certain amount of aluminum for use in the nuclear program. North Korea first looked to China, then Italy, the United Kingdom, the United States, and Austria, until the program eventually found a German trader who was willing to export some aluminum to China. The trader had been tricked into believing that China would be the end-user; in truth, North Korea was the final destination for the aluminum.[54] Highly motivated states are able to work around the dual-use restrictions in the export control regime, but the process causes delay. Hibbs tellingly refers to the time frame for this type of procurement with the term "over the long haul."[55] The export control regime can't prevent a state from moving its program forward, but it can slow down the process.

Third, states could elect to reverse engineer nuclear technology in order to learn how to recreate it themselves. This strategy requires a state to build a separate, covert program outside of international safeguards. The delay inherent in such a plan is clear. Rather than directly placing the desired technology to work in a weapons program, the nuclear agency spends time first in learning how the equipment has been designed and constructed, and second in having to procure the materials and do the work of constructing that equipment covertly.

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[54] Armin Rosen, "How North Korea Built Its Nuclear Program," *The Atlantic*, 10 April 2013, https://www.theatlantic.com/international/archive/2013/04/how-north-korea-built-its-nuclear-program/274830/.

[55] Ibid.

The US Arms Control and Disarmament Agency (ACDA) identified forcing states to manufacture equipment themselves as an explicit goal of the export control regime. In a 1981 memo to the Joint Atomic Energy Intelligence Committee, an ACDA official wrote:

> "[One of] the specific objectives of the démarche program … [has] been … to force the Pakistanis to manufacture items themselves rather than buy them to specification from more advanced countries. In this way, we hoped to divert managerial and technical talent and thereby delay the program."[56]

According to this rationale, delay would be achieved by occupying science workers with the production of parts and equipment. The more time they would have to spend on these manufacturing-related tasks, the less time they could devote to advancing nuclear weapons development, thus extending the timeline.

Several states have chosen the strategy of domestic production of nuclear items, in part to gain the advantage of an indigenous nuclear weapons program rather than a program dependent on a third party's knowledge and material. Both Brazil and Pakistan responded to the 1974 export control regime, and a halt in the supply of enriched uranium from the United States, by

[56] My thanks to William Burr at The National Security Archive for drawing my attention to this memorandum: Richard L. Williamson, "Report on Diplomatic Actions Taken Concerning Foreign, Nuclear-Related Supplies to Pakistan" (Arms Control and Disarmament Agency, 14 August 1981), 1, National Archives, accessed via The National Security Archive at The George Washington University, https://nsarchive2.gwu.edu/nukevault/ebb352/doc19.pdf. I explain the role of the démarche program, an important feature of coordination among NSG participating governments, within the Pakistan case study.

exercising this reverse engineering option.[57] Each program would complete legitimate contracts with safeguards, meeting export control regime requirements, but would then attempt to reconstruct the safeguarded equipment and technology in a covert, safeguard-free, indigenous program established in parallel to the civilian nuclear program.[58]

This strategy extends a program's timeline. Brazil's program sought to purchase a conversion plant to produce uranium hexafluoride, a costly and technologically sophisticated part of the uranium enrichment process. It purchased such a plant in 1980, but because France required the plant to submit to safeguards, Brazil decided to develop a separate, indigenous conversion plant at the São Paulo Energy and Nuclear Research Institute (IPEN).[59] Both the time and the high level of scientific knowledge and ability required to complete this additional project delayed Brazil's progress.

Iran spent almost two decades attempting to both import and domestically manufacture components for a uranium conversion facility, but delays due to manufacturing errors and the receipt of unreliable parts impeded progress. One crucial technological element was the acquisition of parts for gas centrifuges, which would be used to enrich uranium.[60] Problems with

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[57] The US Atomic Energy Commission could not meet the demand for enriched uranium for several different reasons. For the supply problem on the US side, and the response from Brazil, see Togzhan Kassenova, "Brazil's Nuclear Kaleidoscope: An Evolving Identity" (Washington, DC: Carnegie Endowment for International Peace, 2014), 19.

[58] For Brazil, see Reiss, *Bridled Ambition*, chap. 3; for Pakistan, see Khan, *Eating Grass*, 105–10.

[59] Emanuel Adler, *The Power of Ideology: The Quest for Technological Autonomy in Argentina and Brazil* (University of California Press, 1987), 305.

[60] IAEA Board of Governors, "Implementation of the NPT Safeguards Agreement in the Islamic Republic of Iran," 15 November 2004, https://www.iaea.org/sites/default/files/gov2004-83.pdf.

the production quality of a key component, centrifuge rotors, contributed to delayed construction of the uranium conversion facility. Iran attempted to clandestinely manufacture the rotors in workshops at domestic sites.[61] However, fewer than half of the P-1 centrifuge rotors that Iran had assembled by 2004 were actually suitable for use.[62] And IAEA inspectors noted in 2004 that Iran was still not ready to test its P-2 centrifuges, as more parts from international suppliers were required, along with casings and other components that Iran would need to manufacture.[63]

Delaying proliferation activities is an end in itself, but also contributes to future decelerations. By extending the timeline of nuclear weapons development, other states and organizations gain more time in which to take action against a state's nuclear weapons program, whether through threats, promises, or negotiated settlements.[64] Delay also frustrates leaders who perceive that little is being accomplished after a tremendous outlay of resources. Unsatisfied leaders are more likely to decide to divert resources away from a slow, unproductive program and focus on more promising initiatives.[65] Indeed, this is part of the explanation for Gaddafi's early, failed overtures to enter into negotiations with the United States. After decades of investment, the Libyan government ultimately viewed their delayed nuclear weapons program as

[61] IAEA Board of Governors, Annex 1 to "Implementation of the NPT Safeguards Agreement," 11.

[62] David Albright and Corey Hinderstein, "Iran: Countdown to Showdown," *Bulletin of the Atomic Scientists* 60, no. 6 (November/December 2004): 72.

[63] IAEA Board of Governors, "Implementation of the NPT Safeguards Agreement," 5.

[64] Thorne, "Nuclear Export Controls," 10.

[65] This element of delay is not relevant if the leader is kept uninformed; see Hymans, *Achieving Nuclear Ambitions*, 79–102 for examples of how Saddam Hussein was misled regarding the delays plaguing the Iraqi nuclear weapons program.

still only a "long-term option." Gaddafi hoped to use the nuclear program as a bargaining chip, and planned to trade it away in negotiations with Washington.[66]

Increasing the Cost

Regulatory regimes lead to price increases. The nuclear export control regime has had the effect of increasing the cost of the material and equipment that states need to pursue nuclear weapons programs. The dynamics of supply and demand are observable in nuclear exports just as in other markets. As items were added to the Trigger List, the supply of sensitive nuclear material and equipment decreased, and the number of sellers willing to export those items also decreased. This sellers' market emerged very quickly after 1974 and had a cost impact on buyers. Programs looking to procure nuclear items faced rising prices demanded by legitimate firms willing to violate the regime, as well as by sellers from the covert networks that comprise the black market. Supply-side controls limit buyers' options for procurement. This allows sellers to raise prices, exploiting a buyer's disadvantaged position in the market.[67] Contracts with buyers thus have the potential to generate profits that some firms find "too lucrative to resist."[68]

While a state can circumvent export controls by turning to the black market, using the black market is very expensive.[69] One of Pakistan's importing strategies was to pay high prices

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[66] Målfrid Braut-Hegghammer, *Unclear Physics: Why Iraq and Libya Failed to Build Nuclear Weapons* (Ithaca, NY: Cornell University Press, 2016), 199–200.

[67] Bryan R. Early, *Busted Sanctions: Explaining Why Economic Sanctions Fail* (Stanford, CA: Stanford University Press, 2015), 62. Early discusses this effect with regard to sanctions regimes, but the concept applies equally to export control regimes.

[68] Albright, *Peddling Peril*, 69.

[69] Wyn Q. Bowen, *Libya and Nuclear Proliferation: Stepping Back from the Brink* (Abingdon, Oxon: Routledge, 2006), 45.

to obtain items that were hard to procure. Former Strategic Plans Division Director Feroz Khan recalls that "Pakistan would offer to pay twice the original price."[70] For Pakistan, cost was not a significant barrier to development, but for states without Pakistan's singular focus on nuclear development, the higher costs resulting from the regime interfered with progress. In his monograph on the Libyan effort to acquire nuclear weapons, Wyn Q. Bowen stresses the importance of understanding that the ability to access goods via the black market reduces a government's ability to establish a productive nuclear weapons program. The Libyan government had to pay prices far higher than the "fair market value" for its nuclear technology, despite the fact that the restricted technology Libya sought was not highly sophisticated.[71] The high price was due to the export control regime, not to the complexity of the equipment.

High costs also interfered with Iran's nuclear program. Though use of the A.Q. Khan network offered advantages like reduction in the amount of time needed to procure the desired item, use of the network further increased the cost of doing business. Suppliers helped Khan purchase parts "for a fat profit," the costs of which were passed along to the buyers.[72] The buyers also had to pay commissions to Khan's middlemen—the agents who obtained the desired items. After Iran's costly war with Iraq in the 1980s, financial pressures led the Iranian government to use the Khan network only sparingly. Iran instead invested time and effort to establish its own procurement networks.[73]

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[70] Khan, *Eating Grass*, 172.

[71] Donald Mahley, "Dismantling Libyan Weapons: Lessons Learned," Arena 10 (November 2004), cited in Bowen, *Libya and Nuclear Proliferation*, 45.

[72] Albright, *Peddling Peril*, 22.

[73] Ibid, 80–81.

Export controls often drive the buyer to choose a more costly alternative.[74] Economists Paul Levine and Ron Smith describe how perverse incentives can develop from a regulatory regime; they specify an arms export control scenario. If controls raise the price of the exports beyond a state's tolerance, the state may turn to domestic production instead.[75] While Levine and Smith view this outcome as undesirable, in the history of nuclear proliferation, states that have turned to domestic production under the regulatory regime have, on average, not been successful. While North Korea and Pakistan have successfully pursued nuclear weapons programs under the export control regime by developing indigenous capabilities, Iraq, Iran, Libya, Brazil, and Argentina were unsuccessful.

Developing an indigenous nuclear weapons program is much more costly and difficult than developing other types of armaments. As discussed earlier, developing indigenous technology is a lengthy, time-consuming endeavor; in addition, it is enormously costly.[76] Like Pakistan, Brazil and Argentina responded to the creation of the export control regime by setting out to build indigenous nuclear programs that they hoped would be able to develop and operate independently. Both states were ultimately unable to finance such expensive endeavors on their own.

Reducing Access to Reliable Equipment

[74] Thorne, "Nuclear Export Controls," 10.

[75] Paul Levine and Ron P. Smith, "Arms Export Controls and Proliferation.," *Journal of Conflict Resolution* 44, no. 6 (December 2000): 885–95.

[76] Paul L. Leventhal and Sharon Tanzer, ed., *Averting a Latin American Nuclear Arms Race: New Prospects and Challenges for Argentine-Brazil Nuclear Co-Operation* (New York: St. Martin's Press, 1992), 95.

The imposition of barriers to obtain technology and equipment through the formal economy reduces access to reliable and high-quality items.[77] States that cannot procure reliable technology, equipment, or nuclear material cannot make progress in nuclear weapons development. The typical solution to this lack of access is to try to develop the program indigenously, a monumental effort requiring high levels of political will and government funding that few states can muster. And even states that pursue an indigenous program still rely on international suppliers to some extent.[78]

Second, programs may respond to these barriers by turning to the black market. These programs are less likely to obtain high-quality items, as items sold through the informal economy are more likely to be excess items that other programs have previously used or rejected. Equipment purchased through the black market is not subject to the same rigorous standards of quality that suppliers in the formal economy use, and may arrive damaged or contaminated. States that receive damaged equipment through the informal market have little recourse other than to end their relationship with the untrustworthy supplier.

Lack of access to reliable equipment was one of many problems that plagued Libya's attempt at a nuclear weapons program. In the 1990s, Libya turned to the A.Q. Khan network to procure unsafeguarded equipment. However, the centrifuges that the clandestine network was able to provide to the Libyan program turned out to be used and contaminated. The centrifuge

[77] Thorne, "Nuclear Export Controls," 10.

[78] See Fuhrmann, "Taking a Walk on the Supply Side"; Matthew Kroenig, "Importing the Bomb: Sensitive Nuclear Assistance and Nuclear Proliferation," *Journal of Conflict Resolution* 53, no. 2 (April 2009): 161–180.

parts Libya purchased were discovered also to have been previously used, and were scratched. The cast-off, damaged equipment and parts were unusable.[79]

In addition, significant delays in receiving black market items result from characteristic mechanisms of the informal economy. Since the black market can only offer what it has on hand, a nuclear weapons program may not be able to procure the full quantity or exact type of items it needs. Supply-chain problems can lead to long wait times for hopeful buyers. And when black market activity is detected, export controls against those illegal suppliers expand to cover new items. In response, black market suppliers engage in time-consuming workarounds that extend the timeline even further.[80]

Iran's experience in attempting to work around export controls illustrates the practical difficulties of using the black market. Earlier, I described how the attempt to domestically produce centrifuge rotors contributed to Iran's inability to complete its uranium conversion facility over a time period of almost two decades. Work on the facility was also delayed because of substandard equipment acquired through the informal market.

The Iranian program was intended to be developed with domestic capabilities. However, the staff at the Atomic Energy Organization of Iran (AEOI) could not entirely go it alone. After the Khan network approached an AEOI official with a list of items for purchase, and Iran's leadership gave its approval, the AEOI elected to buy technical drawings and sample parts from the network. But the drawings were incomplete, and were for the P-1 centrifuge, an outdated model that Pakistan no longer produced.[81]

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[79] Bowen, *Libya and Nuclear Proliferation*, 41.

[80] Kemp, "The Nonproliferation Emperor Has No Clothes," 63–74.

[81] Ibid., 67–68.

The sample parts the AEOI ordered from the Khan network were critically important: every part needed to build one P-1 centrifuge.[82] But this attempt to work around the export control regime to obtain restricted components resulted in two problems. First, many of the components were never received. The head of the centrifuge program stated that, during his tenure with the program, fewer than half of the ordered parts were delivered.[83] The AEOI could not reproduce a P-1 centrifuge with such a serious lack of sample components.

Second, the parts delivered by the Khan network were unreliable. Much of the equipment sold to Iran by the Khan network was old and had been discarded from Pakistan's uranium enrichment facility in Kahuta, which Khan directed from 1976 to 2001. Cast-off centrifuges and components sold in one transaction had been slated to be destroyed, but were instead quickly shipped to Iran.[84] Iran received faulty centrifuge bellows from the network in 1994 and 1996, and could not procure new bellows until 1997.[85] Former Iranian Ambassador to the IAEA Ali Akbar Salehi called many of the items Iran purchased from the Khan network "useless."[86] When Iran finally managed to build a modified P-1 centrifuge in the late 1990s, it performed at low levels that recalled humble uranium enrichment capabilities from the early years of the nuclear era.[87]

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[82] Ibid., 68: From Kemp's email interview with Masud Naraghi, head of the centrifuge program at the AEOI at the time.

[83] Ibid.

[84] Corera, *Shopping for Bombs*, 67–70.

[85] Montgomery, "Ringing in Proliferation," 162.

[86] Corera, *Shopping for Bombs*, 70.

[87] Kemp, "The Nonproliferation Emperor Has No Clothes," 70.

Kemp argues that Iran could have avoided this torturous journey of frustration and delay to build a poorly performing P-1 centrifuge. Instead, Iran could have chosen to attempt to build a simple centrifuge indigenously.[88] But Iran did not make that choice, and neither have most nuclear pursuers. Even states that prioritize domestic control of the nuclear fuel cycle pursue that goal via foreign exports and assistance. Circumventing the export control regime results in reduced access to reliable equipment and technology, which delays the program. Without these significant delays, amounting to a decade or more, the Iranian nuclear program's development and technical capabilities likely would have been much further along than they are today.

Increasing the Risk of Discovery

States seeking to import nuclear fuel, equipment, or technology have faced a different series of risks after 1974. The regulatory regime increases the risk that a nuclear weapons–striving state will be discovered. While states may be willing to assume that risk to gain nuclear weapons state status, the material and political consequences of discovery have created incentives that can increase the likelihood of a reversal decision.

Prior to the nuclear export control regime, states were able to purchase nuclear fuel, equipment, and technology from nuclear suppliers without safeguards. Clearly, India's purchases from the United States and Canada were central to India's ability to clandestinely achieve nuclear weapons status and surprise the international community with its 1974 test. After 1974, states either could choose safeguards, which made proliferation more difficult, or could try to acquire materials outside of safeguards. And the regime defined compliant and noncompliant procurement behavior, setting a clear standard that could be visibly violated and that would

[88] Ibid.

reveal a state's intentions. A state that attempted to work around the regulatory regime now raised suspicions that the ultimate goal was a weaponized program.

Raising suppliers' suspicions has material consequences: it becomes more difficult to arrange for imports in the future. Early on, the Nuclear Suppliers Group began sharing information with each other about possible violations of the regime. Pakistan's effort to acquire inverters in the mid-1970s offered one illustration of these material consequences. When the German exporter alerted Britain that Pakistan likely intended to purchase the inverters not for textile manufacturing but for centrifuges to enrich uranium, the British Foreign Office already knew that Pakistan's domestic uranium supplies were not safeguarded, and had gathered information about the state's use of front organizations to illicitly obtain regulated nuclear items. The British government's response was not to act alone, but to involve other NSG members as well. Broad agreement was reached among the nuclear supplier nations that Pakistan would not be permitted to continue purchasing inverters, and the British government signaled the imminent additional export controls on inverters.[89] Supplier states were able to use the structure of the NSG to share information quickly. And since suppliers' suspicions had already been raised by the red flags of Pakistan's lack of safeguards and attempts to work around the regulatory regime, they were willing to act swiftly to increase the cost and difficulty of further imports.

In the mid-1980s, Iraq sought to avoid such consequences by embarking on a long-term deception to obtain technology for chemically enriching uranium. To avoid having to purchase the technology and risk being discovered, Iraq began negotiating with a French firm that supplied chemical enrichment technology. Over several years, Iraqi negotiators would ask

[89] Malcolm Craig, *America, Britain and Pakistan's Nuclear Weapons Programme,1974-1980: A Dream of Nightmare Proportions* (London: Palgrave Macmillan, 2017), 175–78.

questions about the technical details of the process, claiming over and over again that they could not make a purchasing decision without receiving more information. Once the Iraqi program had extracted enough information from the French firm to develop the process themselves, they backed out of the negotiations, claiming that the price was too high.[90] This effort to avoid an actual transaction and thus minimize the risk of discovery caused a years-long delay.

States may face political consequences that outweigh the value of pursuing a costly nuclear weapons program that may not result in a nuclear arsenal for many years. The most extreme case is that of Iraq: although Iraq's nuclear weapons program had been suspended since the 1990–91 Gulf War, the threat of a nuclear Iraq provided part of the George W. Bush administration's justification for toppling the Iraqi regime.

Discovery's more common political consequences involve damage to a state's relationships with foreign allies, the imposition of sanctions, and the loss of foreign aid. These consequences may, under the right circumstances, provide incentives to operate within the regulatory regime. When Brazil and Argentina sought integration into the world economy following military rule, each had to first repair its ties with the United States. Washington stipulated that Brazil and Argentina each had to agree to nuclear safeguards as a necessary component of rebuilding the relationship.[91] Neither state was dependent upon the United States at the time, but each state willingly traded the ability to maintain a covert nuclear program for the political and economic benefits of rapprochement.

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[90] David A. Kay, "Denial and Deception Practices of WMD Proliferators: Iraq and Beyond," *The Washington Quarterly* 18, no. 1 (March 1, 1995): 92–93.

[91] Reiss, *Bridled Ambition: Why Countries Constrain Their Nuclear Capabilities*, 58–60.

Similarly, the government of Taiwan was unwilling to incur the costs that would have been imposed by the United States if the Taiwanese nuclear program had been discovered while attempting to evade safeguards. By the mid-1970s the Taiwanese program had enough unprocessed plutonium to fuel several bombs, but the plutonium was safeguarded; the IAEA periodically inspected Taiwan's reactor to determine its output and monitored where the spent fuel was kept. Surveillance cameras and seals kept track of activity between inspections. As a result, diverting the plutonium that Taiwan had produced would have been extremely difficult, and that path to nuclear weapons was ultimately abandoned.[92]

The political calculation, however, is more complex than determining whether the state with nuclear ambitions can weather economic sanctions or a weaker relationship with a foreign power. The threat of political consequences may not be credible. Pakistan continued to pursue nuclear weapons despite US protestations, knowing the United States needed Pakistan's support to counter the Soviet Union in Afghanistan. States that are discovered may choose to signal that they are willing to bear the costs to achieve nuclear status.

Some states may desire discovery in order to be taken seriously. North Korea famously gave nuclear scientists from the United States remarkable access to their plutonium facilities at Yongbyon in 2004, even showing them sealed glass jars of plutonium products as proof of their capabilities.[93] This demonstration was most likely intended to informally convey North Korea's nuclear prowess to the United States, and to demonstrate that the regime had moved toward weaponizing after the collapse of the Agreed Framework. States seeking side payments from the

[92] Spector, *Nuclear Ambitions: The Spread of Nuclear Weapons 1989–1990*.

[93] Siegfried Hecker, "Visit to the Yongbyon Nuclear Scientific Research Center in North Korea," Senate Committee on Foreign Relations (2004).

United States or other nations may wish to reveal their nuclear ambitions in order to gain leverage in a negotiations process. Recall that Libya likely attempted to use this strategy for years prior to the 2003 discovery of a shipment of nuclear material to the country.[94]

Whether a state wishes to keep its program secret or to advertise its progress, after 1974, the stakes are higher. Importing controlled products risks detection, and even if the government is willing to pay the political costs, detection often results in a tightening of the regulatory regime that has practical implications for a program's ability to procure items in the future. Both political and material consequences factor into a leader's interest in proceeding with a nuclear weapons program.

Case Study: Pakistan, 1972–2018

Pakistan is often cited as an example of how nonproliferation controls do not work. The government began pursuing nuclear weapons in 1972, two years before the Indian PNE, and conducted its first nuclear weapons tests in 1998. The export control regime did not prevent Pakistan from crossing the nuclear threshold; today, Pakistan produces approximately ten nuclear warheads per year.[95] The Pakistani case thus provides a difficult test for the arguments advanced in this article. However, the evidence indicates that the export control regime did indeed create frustration and delay for Pakistan, significantly slowing program development and restricting the pace at which the nuclear arsenal has been able to grow.

Prior to 1974, Pakistan had been engaged in a series of foreign contracts to purchase nuclear equipment and technology. In the 1960s, Islamabad approved spending for the Karachi

[94] Braut-Hegghammer, *Unclear Physics*, 199–200.

[95] Hans Kristensen, Robert S. Norris, and Julia Diamond, "Pakistani Nuclear Forces, 2018," *Bulletin of the Atomic Scientists* 74, no. 5 (2018): 348–58.

Nuclear Power Plant (KANUPP) and two additional nuclear power plants. Only Pakistan's budgetary constraints prevented these projects from proceeding as planned.[96] In 1965, Pakistan signed a deal with Canada for a turnkey CANDU reactor and agreed to establish an independent nuclear safety committee. Canada and India had reached a similar deal without safeguards, but India had paid in full for the reactor before work began. As Pakistan was financing the reactor through loans from the Canadian government, Ottawa informed Islamabad that it would require a contract with the IAEA, including safeguards. The IAEA agreement would specify payment, dispute resolution, and other contract-related stipulations in addition to safeguards. Pakistan could not afford to pay in full, and so accepted the arrangement and the safeguards.[97] Thus, prior to the formation of the NSG, Canada had been willing to supply Pakistan with an unsafeguarded heavy water reactor; it was only the financial conditions that altered the arrangement.

Pakistan's PINSTECH nuclear research and development facility near Rawalpindi was also underway in the mid-1960s, with US assistance: the American firm AMF Atomics designed the PARR-1 reactor and planned and constructed the facilities housing it.[98] The reactor was commissioned in 1965, under IAEA safeguards, and the United States provided the core six kilograms of HEU.[99] The entire project went according to plan, with no significant delays. This stood in stark contrast to the 1970s, when the United States refused to supply more HEU to

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[96] Khan, *Eating Grass*, 53.

[97] Ibid., 54–55.

[98] Ibid., 57.

[99] US Department of Energy, "Highly Enriched Uranium: Striking a Balance," January 2001. HEU stands for highly enriched uranium, and LEU stands for low enriched uranium. It is much easier and faster for a program to enrich HEU to weapons-grade than LEU.

Pakistan, and PINSTECH had to convert the reactor to use LEU in the 1990s. Although "informal restrictions in the flow of technology and expertise" began to slowly impact Pakistan's program after the NPT went into force, the 1974 PNE was the "death knell" that threw the program into a tailspin and caused the suspension of the plutonium route to the bomb.[100]

After India's test, the United States played a significant role in how Pakistan would fare, first by working to create the NSG, and then by placing pressure on NSG participating governments to abide by their pledges. Prior to the PNE, President Richard Nixon and Secretary of State/NSA Henry Kissinger had been openly dismissive of the NPT and unconcerned about safeguards; immediately after the PNE, Kissinger moved the administration toward a nonproliferation stance. However, he "rejected" arguments that the administration should spend its resources pressuring more countries to sign and ratify the NPT.[101] He believed that the better approach focused on limiting the supply of nuclear equipment and material, and rapidly began working to build an export control regime through the concept of the Nuclear Suppliers Group.[102]

The Nixon administration was now newly fearful of the potential for nuclear "violence" by emerging nuclear actors, but also wanted to preserve the advantage the United States held in the nuclear market. Kissinger and Nixon began to view export controls as a way to hold nuclear suppliers to a set of rules that would keep any one state from gaining a competitive advantage

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[100] Khan, *Eating Grass*, 96.

[101] Burr, "A Scheme of 'Control,'" 259.

[102] Burr, "A Scheme of 'Control,'" 259–260. Kissinger continued this work during and after the transition from the Nixon presidency to the Ford presidency.

over another.[103] The United States, which became a leader in the NSG, was not motivated by nonproliferation norms broadly, nor the NPT specifically. US motivation came from two main sources: security concerns, and the potential economic impact of competitors' relative gains on the nuclear market. Fellow NSG participants, including France as a non-NPT member state, had similar concerns. They were able to come to agreement on the Trigger List because the playing field for the nuclear market would, in theory, remain level as long as all participating governments honored the arrangement.[104]

The nuclear program was severely impacted by the NSG's new restrictions, in part because of the loss of existing export agreements.[105] Pakistan had secured an agreement with West Germany for a safeguarded heavy water plant, but West Germany canceled the contract after the formation of the NSG. Canada, in accordance with NSG guidelines, also backed out of a previous arrangement, cutting off its exports of nuclear fuel, heavy water, and even spare parts to KANUPP, which it had supplied for nearly a decade after providing the CANDU reactor in 1965.[106] Pakistan had to develop the means to indigenously produce uranium fuel, setting back

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[103] Burr, "A Scheme of 'Control.'"

[104] For a discussion of the competing economic interests and domestic political coalitions regarding proliferation that evolved in France during the 1970s, see Or Rabinowitz and Jayita Sarkar, "'It Isn't over until the Fuel Cell Sings': A Reassessment of the US and French Pledges of Nuclear Assistance in the 1970s," *Journal of Strategic Studies* 41, no. 1–2 (2018): 275–300.

[105] Khan, *Eating Grass*, 106–7. Khan specifically names the LSG, another name for the NSG, as the cause of Pakistan's woes.

[106] Munir Ahmad Khan, "The Nuclearization of South Asia and its Regional and Global Implications," in *Focus on Regional Issues* (Islamabad: Institute of Regional Studies, 1998), 4 (note that Dr. Khan headed the PAEC from 1972 to 1991); and F. Khan, *Eating Grass*, 106–10.

the program by four years.[107] "It was clear to the Pakistanis," former Pakistani Strategic Plans Division Director Feroz Khan writes, "that Western countries were reneging on their contracts under pressure from the United States as well as the tightening nonproliferation regime."[108]

One of the most critical contracts that Pakistan lost to the new regimes was a 1973 deal with France; the French firm Saint-Gobain Techniques Nouvelles (SGN) was to provide Pakistan with a large-scale plutonium reprocessing plant at Chashma. The United States exerted pressure on France to cancel its contract, and while the French government would not renege on the deal, Paris did agree to stricter controls than had been included in the original deal, and moved to introduce safeguards on transferred technology and prohibit Pakistan from re-exporting the items to third parties.[109] The revised agreement was signed in 1976, but the United States was unsatisfied, and responded by using the next meeting of the NSG, held three months later, to call for the termination of all reprocessing exports.[110] France protested, but the following year the United States was able to provide new evidence of Pakistan's intention to use the Chashma facility for military purposes. After reviewing the intelligence report, Paris responded swiftly by delaying the export licenses and canceling delivery of a fuel-chopping machine that Pakistan would not be able to obtain elsewhere.[111] The French government also established the Conseil de

[107] Khan, *Eating Grass*, 169–71.

[108] Ibid., 105. Khan also discusses Chinese nuclear assistance to Pakistan during these years. China did not join the NSG until 2004. China's nuclear assistance to a nuclear-pursuing Pakistan occurred outside the export control regime, while at the same time, NSG members were limiting Pakistan's nuclear access. This serves to further demonstrate the functioning of the regime.

[109] Spector, *Nuclear Proliferation Today*, 73–78.

[110] Tzeng, "Nuclear Leverage," 479–80.

[111] Ibid., 481–82.

Politique Nucléaire Extérieure, which used the NSG guidelines to reform French nuclear export policy.[112] Although the United States continued to apply pressure to Pakistan to cancel the deal, offering an America arms deal and threatening to suspend economic and military aid, Pakistan remained determined and France finally backed out of the deal in 1978.

Once SGN employees left Pakistan in 1979, Pakistani teams achieved little progress on their own.[113] Pakistan was unable to find a new supplier, and the project was suspended for decades. A much smaller reprocessing plant, with only 10% of the capacity of the French-planned plant, was built at the PINSTECH complex instead. It sat idle for eighteen years, as until 2000 Pakistan did not have the reactor capacity to produce enough spent fuel to reprocess.[114]

Today Pakistan still lacks the reprocessing capacity to separate the plutonium produced by the Chashma complex's four operating reactors, and the country continues to pursue options to increase reprocessing capacity. The substantial reduction in Pakistan's planned ability to reprocess plutonium for nuclear weapons has thus impacted the size of Pakistan's potential arsenal over the course of the last several decades.[115] Around 2007, almost thirty years after the contract was canceled, new work at last began on the original plant, but used illegally procured equipment and material that likely delayed the project further. The plant appeared to finally be

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[112] Rabinowitz and Sarkar, "'It Isn't over until the Fuel Cell Sings,'" 287.

[113] Spector, *Nuclear Proliferation Today*, 78–81.

[114] "Global Fissile Material Report 2010" (International Panel on Fissile Materials, December 2010), 126–33.

[115] Further, historical evidence indicates that some states chose the plutonium route to the bomb in order to shorten the time to acquisition, as the plutonium route has long been viewed as technologically easier than developing and building a facility that can successfully enrich uranium to weapons grade. See, for example, Graham T. Allison et al., *Avoiding Nuclear Anarchy: Containing the Threat of Loose Russian Nuclear Weapons and Fissile Material*, CSIA Studies in International Security no. 12 (Cambridge, MA: MIT Press, 1996), Appendix B.

nearing completion around 2015, although whether it is yet operational is unconfirmed in open source literature.[116] If one assumes that the plant is currently operational and was completed by 1980 under the original contract with SGN, this still represents a nearly forty-year delay and reduction in weapons-grade fissile material, directly traced to the export control regime.

The Pakistani nuclear program also faced delay on another technological front. West Germany had agreed to sell Pakistan a heavy water plant, but canceled that contract after 1974. Pakistan began again, turning to Belgian firm Belgonucleaire for assistance in building a heavy water facility in Multan, but that facility was not completed until 1980 and could not produce enough heavy water to supply Pakistan's Khushab reactor. As a result, Pakistan had to build another facility, and was unable to start that project until 1987. The Pakistan Atomic Energy Commission (PAEC) purchased part of that second facility from an exporter, who, in order to evade the export controls, claimed he was selling Pakistan a gas-purification plant.[117] It thus took several tries with several different exporters, and serious delay, before Pakistan was able to supply heavy water to Khushab; the reactor did not begin operating until 1998.[118]

Evidence that Pakistan intended to acquire nuclear weapons, which had been instrumental in causing France to back out of the contract for the reprocessing plant, continued to mount as the export control regime increased Pakistan's risk of being discovered. Recall the example provided earlier in which, as a textile exporter in the late 1970s, Pakistan attempted to purchase

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[116] David Albright and Serena Kelleher-Vergantini, "Pakistan's Chashma Plutonium Separation Plant: Possibly Operational," *Institute for Science and International Security* 20 (February 2015); Khan, *Eating Grass*, 395.

[117] Khan, *Eating Grass*, 201.

[118] Mark Hibbs, "Bhutto May Finish Plutonium Reactor without Agreement on Fissile Stocks," *Nucleonics Week*, 6 October 1994.

high-frequency inverters that could be used in textile production but also provide a uniform power supply to centrifuges used to enrich uranium. A purchase agreement for inverters being pursued with a British firm was called off when a German exporter who had fulfilled an earlier inverter order alerted Britain that Pakistan seemed to have the nuclear program application in mind. Britain placed the inverters on their export control list. As a result, Pakistan could no longer obtain the inverters from the British firm, and intelligence agencies around the world became aware of the attempt.[119]

The case of Pakistan also demonstrates how individual NSG members have used diplomatic means to try to influence others in the group, either when an official change may be politically difficult to obtain, or when members want to quickly communicate timely information or evidence. Thus, even without formally meeting as an entire group, NSG members exchange intelligence and deliver calls for action. One means for doing this has been the use of démarches—formal diplomatic correspondence from one government to another—to share information about clandestine nuclear programs and gaps in the regime.

The first US démarche to other members of the NSG, sent in late 1978 alongside a démarche from the United Kingdom, sought to enlist the help of other NSG members to delay the Pakistani nuclear program. At that time, Pakistan was trying to conceal its nuclear program's construction of a plutonium reprocessing facility. The démarches shared what the United States and United Kingdom knew about Pakistan's efforts, warned that Pakistan might use "indirect representatives" and "'dummy' purchasing agents," and asked members to join in preventing Pakistan from acquiring the equipment and parts it needed. The US démarche also informed the

[119] Craig, *America, Britain and Pakistan's Nuclear Weapons Programme*, 175–78; Khan, *Eating Grass*, 169–71.

government of Italy that American diplomats would bring up the matter of Pakistan's facility in upcoming US-Italian bilateral talks, indicating that export controls were an ongoing part of diplomatic relations.[120]

This démarche was not a meaningless document, but facilitated intelligence sharing and resulting action, and was intended to delay nuclear progress. For example, Australian diplomats had been aware of Pakistan's activity but assumed that Pakistan was complying with the standards mandated by the company Pakistan was working with, British Nuclear Fuels Limited. Upon receiving the US démarche, Australian diplomats met with British officials and learned that Pakistan's reprocessing activities were, in fact, out of compliance. Australia promptly agreed to cooperate with the United States and United Kingdom in strengthening the regime.[121]

Pakistan's program enjoyed greater success with reverse engineering, but still lost time in the process. A long-standing, cooperative relationship begun between Chinese and Pakistani engineers in the 1960s facilitated Pakistan's nuclear reverse engineering strategy.[122] Pakistani and Chinese nuclear scientists worked together in the 1970s to support Pakistan's safeguarded power reactor, KANUPP. From the Chinese scientists, Pakistani scientists learned reverse engineering techniques, and that knowledge formed the foundation of Pakistan's ability to use

[120] "U.S. Démarche on Pakistani Reprocessing Plant, Department of State Cable 281962 to U.S. Embassy United Kingdom et al.," 4 November 1978, The National Security Archive at The George Washington University, https://nsarchive2.gwu.edu/nukevault/ebb352/#notes.

[121] Craig, *America, Britain and Pakistan's Nuclear Weapons Programme*, 178.

[122] Khan, *Eating Grass*, 81.

this strategy to circumvent sanctions on nuclear equipment.[123] Pakistan began to purchase equipment legally and then reproduce it for the covert program.

A.Q. Khan himself complained about the delay this entailed in a 1978 letter to a friend. As Pakistani engineers began their work to reverse engineer equipment that Khan had been unable to purchase, Khan described the agony of the delay with an evocative simile: "Work is progressing but the frustration is increasing. It is just like a man who has waited thirty years but cannot wait for a few hours after the marriage ceremony."[124] Similarly, General Zia referred to the delays resulting from the regime in an interview, stating that "It takes particularly long when you have to acquire [nuclear] technology through backdoor, clandestine methods."[125]

Ultimately, although Pakistan has succeeded in finding elaborate and costly ways to work around the export control regime, and has benefited from gaps in enforcing the regime, the delays in nuclear development and acquisition caused by the regime have been profound. In reflecting on Pakistan's difficulties, Feroz Khan writes: " . . . the grand plans for Pakistan's nuclear energy program gradually became deeply affected by the emerging international nonproliferation regime, specifically the LSG, as well as the tense international atmosphere after the Indian test."[126]

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[123] Ibid., 109.

[124] Douglas Frantz and Catherine Collins, *The Nuclear Jihadist: The True Story of the Man Who Sold the World's Most Dangerous Secrets...And How We Could Have Stopped Him* (New York: Twelve, 2007), 93.

[125] Kuldip Nayar, "Learn a Lesson from History," *India Today*, 16 February 1980, quoted in George Perkovich, *India's Nuclear Bomb: The Impact on Global Proliferation* (Berkeley: University of California Press, 1999), 222.

[126] Khan, *Eating Grass*, 106.

Conclusion

Despite its imperfections, the nuclear export control regime has been effective at slowing proliferation. Nuclear suppliers have incentives to enforce the regime in order to prevent proliferation and to maintain balance in the nuclear market. Each supplier has an interest in blocking another supplier from circumventing export controls and gaining a competitive advantage. And the regime provides avenues for sharing information and improving nonproliferation cooperation among NSG participating governments that allow the group to respond to new violations by tightening controls.

Former Pakistani Strategic Plans Division Director Feroz Khan has referred to the controls as the nonproliferation regime tightening its screws.[127] The regime has made it significantly more difficult for states with nuclear ambitions to obtain key items needed for a nuclear weapons program and has raised the risk that a covert program will be detected. By creating delay, increasing the cost of material and equipment, reducing access to reliable and high-quality equipment, and increasing the risk of discovery, the nuclear export control regime creates problems in the development of nuclear weapons programs that contribute to leaders' decisions to reverse.

The export control regime is important not just for delaying existing programs, but also for creating a significant obstacle for states that are considering starting a new nuclear weapons program. The export control regime has created direct costs for states that are exploring whether to start a nuclear weapons program. Perhaps more importantly, however, the regime has also created uncertainty. Levine and Smith (2000), in their study of arms export controls, demonstrate that growing uncertainties—about the cost of importing arms, about the ability to import arms in

[127] Ibid., 162.

the future, and about a state's security environment—pose barriers to proliferation. The costs of embarking on the path to developing a domestic weapons program are very high, and they represent a sunk cost—once resources are spent, they are unrecoverable.[128]

Under the export control regime, whether any given formal or informal avenue of procurement will continue to be available to a buyer, and which items can be obtained through those avenues, fluctuates. Since the Nuclear Suppliers Group periodically updates their lists and guidelines, either formally or through diplomatic channels, uncertainty exists over which components and technologies may become illegal or difficult to obtain in the future. When the future ability and inclination of suppliers to sell equipment is uncertain, and when the price of that equipment is also uncertain, a state should be less willing to commit to the massive political and economic investments necessary to pursue a nuclear weapons capability. The less certain leaders are about a nuclear weapons program's cost and necessity, the less likely leaders are to make the decision to start a domestic nuclear program.

Acknowledgements

For their helpful comments, the author would like to thank workshop participants at Claremont McKenna College, and the *Security Studies* editors and anonymous reviewers. The author also thanks the Keck Center for International and Strategic Studies for supporting this research.

[128] Levine and Smith, "Arms Export Controls and Proliferation."