Security Studies
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713636712

Proliferation Implications of Civil Nuclear Cooperation: Theory and a Case Study of Tito's Yugoslavia

Jacques E. C. Hymans[a]
[a] University of Southern California,

Online publication date: 15 March 2011

To cite this Article Hymans, Jacques E. C.(2011) 'Proliferation Implications of Civil Nuclear Cooperation: Theory and a Case Study of Tito's Yugoslavia', Security Studies, 20: 1, 73 — 104
To link to this Article: DOI: 10.1080/09636412.2011.549013
URL: http://dx.doi.org/10.1080/09636412.2011.549013

Security Studies, 20:73–104, 2011

ISSN: 0963-6412 print / 1556-1852 online
DOI: 10.1080/09636412.2011.549013

Routledge
Taylor & Francis Group

Proliferation Implications of Civil Nuclear Cooperation: Theory and a Case Study of Tito's Yugoslavia

JACQUES E. C. HYMANS

Programs of international civil nuclear cooperation—of "Atoms for Peace"—have come under growing criticism for unintentionally fostering nuclear weapons proliferation in developing countries. However, drawing on the literature on international technology transfer and on Albert Hirschman's theory of exit, voice, and loyalty, this article argues that Atoms for Peace efforts may often seriously hamper developing countries' nuclear weapons ambitions by empowering their scientific workers and by facilitating the brain drain to the developed world. The article then presents a case study of the historical nuclear program of Yugoslavia, which received very generous help from the Atoms for Peace programs of the United States, Soviet Union, and European states at a time when nonproliferation controls were minimal. The international ties of the Yugoslav nuclear program made its scientific workers much less likely to choose simple loyalty to the Tito regime, and much more likely to choose voice or exit, accelerating the program's ultimate collapse.

Jacques E. C. Hymans is assistant professor of international relations at the University of Southern California.

Thanks to the many who consented to be interviewed and who provided me with historical documentation, including numerous librarians and archivists in the United States and Europe. Special thanks to William Potter and Gaukhar Mukhatzhanova for their great encouragement of my research. Deniz Kuru provided excellent research assistance and translations from Serbian and Croatian. Eirik Løkke and Erik Baekkeskov provided translations from Norwegian. Mario Carranza, Robert English, Astrid Forland, Frank Gavin, Thomas Jonter, Rieko Kage, John Mueller, Olav Njølstad, Scott Sagan, Karthika Sasikumar, participants at the 2009 Nobel Symposium in Oscarsborg, Norway and at the 2009 ISSS/ISAC Conference in Monterey, California, and two anonymous reviewers and the editors of *Security Studies* provided very helpful feedback on earlier versions of the article.

In recent years, proponents of nuclear nonproliferation have grown increasingly hostile toward programs of international civil nuclear cooperation—the idea of "Atoms for Peace" that was first propounded by U.S. President Dwight Eisenhower in 1953 and was eventually enshrined in the founding statute of the International Atomic Energy Agency (IAEA) and in Article IV of the Non-Proliferation Treaty (NPT).[1] In this article, I reconsider such negative evaluations by focusing on their apparently strongest point: the notion that Atoms for Peace programs dangerously enhance developing states' technical capacity to go nuclear, with the magnitude of the effect depending on the level of help provided. I argue that, in fact, international civil nuclear cooperation may often subtly but seriously hamper the growth of developing countries' nuclear weapons capacities by empowering their scientific workers and by facilitating the brain drain to the developed world. This argument has important implications for contemporary policy at a time when the world appears to be standing on the cusp of a civil nuclear "renaissance."[2]

ATOMS FOR PEACE'S GROWING CHORUS OF CRITICS

The first harsh criticisms of Atoms for Peace's proliferation consequences were made in the 1960s by Albert and Roberta Wohlstetter, who argued that the conventional separation between the civilian and military atom was "a distinction without much difference."[3] Leonard Beaton also lambasted Atoms for Peace, calling it "one of the most inexplicable political fantasies in history. Only a social psychologist could hope to explain why the possessors of the most terrible weapons in history should have sought to spread the necessary industry to produce them in the belief that this could make the world safer."[4]

At first these were minority opinions, but they gained many new adherents after the Indian "peaceful nuclear explosion" of 1974, and even more after the revelations of Iraq's illicit nuclear weapons project in 1991. Thus in recent years it has become commonplace to condemn Atoms for Peace for having unwittingly promoted proliferation by dramatically increasing developing states' nuclear weapons capacities. Thomas Reed and Danny Stillman charge that Atoms for Peace "tore a gaping hole into the dikes holding

[1] In this article I use the term "Atoms for Peace" not just to indicate Eisenhower's specific policy initiative but as a shorthand referring to all aboveboard international civil nuclear technology cooperation activities. This is in keeping with standard usage; for instance, the IAEA still today labels itself the "Atoms for Peace agency." See http://www.iaea.org/About/index.html.

[2] Steven E. Miller and Scott D. Sagan, "Nuclear Power Without Nuclear Proliferation?" *Daedalus* 138, no. 4 (Fall 2009): 7–18.

[3] See Henry S. Rowen, "How He Worked," in *Nuclear Heuristics: Selected Writings of Albert and Roberta Wohlstetter*, eds., Robert Zarate and Henry Sokolski (Carlisle, PA: Strategic Studies Institute, 2009), 111, complete text available online at http://www.albertwohlstetter.com/.

[4] Leonard Beaton, *Must the Bomb Spread?* (Baltimore: Penguin Books, 1966), 88–89.

back the spread of nuclear weapons."[5] Henry Sokolski offers a more precise historical counterfactual: "To be sure, had Eisenhower not pushed his program, nuclear proliferation would have occurred. Yet without his program, this proliferation would have been far more limited and would have come much later."[6] Zia Mian and Alexander Glaser detail that Atoms for Peace, by "providing nuclear research reactors, fuel for these reactors, and training scientists and engineers in the new technology," ultimately "became the bane of the international community."[7] Meanwhile Joseph Cirincione offers this pithy conclusion about the Indian bomb: "We basically gave it to them."[8]

As the above examples indicate, Atoms for Peace's aggressive nuclear promotion policies of the 1950s and 1960s have been roundly condemned, but many analysts also harshly criticize the much more modest contemporary policies of civil nuclear cooperation as well. For instance, Alisa Carrigan has gone so far as to attack regular international student exchange and scientific conferences, due to their supposed role in aiding the global diffusion of dangerous nuclear "knowledge."[9] The dim view many proliferation experts today take toward all forms of international civil nuclear cooperation can be seen in the title of a major recent edited volume, *Atoms for Peace: A Future After Fifty Years?*[10] Indeed, even Atoms for Peace's dwindling band of defenders now contend that the diplomatic benefits of the policy are only worth it if nuclear supplier states can construct an "updated, security-conscious Atoms for Peace program" that imposes much stricter controls on states' use of the technologies they receive.[11]

The academic IR literature has also recently begun to focus on the proliferation implications of civil nuclear cooperation. Some high-profile works by scholars marshalling advanced statistical methods have seconded the

---

[5] Thomas C. Reed and Danny B. Stillman, *The Nuclear Express: A Political History of the Bomb and Its Proliferation* (Minneapolis, MN: Zenith Press, 2009), 56.

[6] Henry Sokolski, *Best of Intentions: America's Campaign Against Strategic Weapons Proliferation* (Westport, CT: Praeger, 2001), 105.

[7] Zia Mian and Alexander Glaser, "A Frightening Nuclear Legacy," *Bulletin of the Atomic Scientists* 64, no. 4 (September/October 2008): 42, 47. For a similar verdict, see also Leonard Weiss, "Atoms for Peace," *Bulletin of the Atomic Scientists* 59, no. 6 (November/December 2003): 34.

[8] Joseph Cirincione quoted in Laura Myers, "Nuke Rivalry Fuels Pakistan, India," Associated Press report reprinted in Nautilus Institute Northeast Asia Peace and Security Network Daily Report, May 28, 1998, at http://www.nautilus.org/archives/pub/ftp/napsnet/daily_reports/1998/05-98-May/MAY28.txt.

[9] Alisa Carrigan, "Learning to Build the Bomb," *Physics Today* (December 2007): 54–55; Alisa Carrigan, "A Peripheral Threat? Addressing Dissemination of Human Capital in the Nuclear Non-Proliferation Regime" (paper presented at the International Studies Association annual meeting, March 2005), at http://www.allacademic.com//meta/p_mla_apa_research_citation/0/6/9/8/5/pages69859/p69859-1.php.

[10] Joseph F. Pilat, ed., with foreword by Mohammed ElBaradei, *Atoms for Peace: A Future After Fifty Years?* (Washington, DC: Woodrow Wilson Center Press, 2007).

[11] Michael M. May and Tom Isaacs, "Stronger Measures Needed to Prevent Proliferation," *Issues in Science and Technology* 20, no. 3 (Spring 2004), at http://www.issues.org/20.3/may.html. For a broadly parallel view see Peter R. Lavoy, "The Enduring Effects of Atoms for Peace," *Arms Control Today* (December 2003), at http://www.armscontrol.org/act/2003_12/Lavoy.

widespread view that access to foreign technology, materials, and know-how will supercharge a state's nuclear progress far beyond its overall level of economic and technological development.[12] These studies make somewhat different conclusions about how much and what types of nuclear cooperation are necessary to permit such technical overachievement when it comes to building nuclear weapons. Matthew Kroenig limits his critique to the provision of "sensitive nuclear assistance" such as the export of fuel reprocessing technology, which once was permissible for Atoms for Peace-type aboveboard programs of civil nuclear cooperation, but now is limited to illicit nuclear proliferation networks.[13] By contrast, Matthew Fuhrmann makes a strong charge against even routine civil nuclear cooperation: "Atoms for peace policies have, on average, facilitated—not constrained—nuclear proliferation. Atoms for peace become atoms for war."[14] On the other hand, Philipp Bleek's hazard models do not support either Kroenig or Fuhrmann's claims, and indeed Bleek notes that some of his models actually reveal a statistically significant negative correlation between civil nuclear assistance and the acquisition of nuclear weapons. However, since Bleek does not believe that civil nuclear assistance could have had this negative effect on proliferation, he surmises that some unknown omitted third variable may have produced the irksome result.[15]

In short, although some analysts continue to see Atoms for Peace as having a dampening effect on states' nuclear weapons intentions, few contest the idea that Atoms for Peace programs have allowed several—or even many—developing countries to acquire a robust technical capacity to launch a serious nuclear weapons drive at a time of their choosing. The Atoms for Peace practices of the 1950s and 1960s have been widely castigated on this score, but quite a few proliferation analysts see even today's watered-down civil nuclear cooperation efforts as being highly suspect.

This article takes a rather different view on the matter. It is true that Atoms for Peace programs especially during the 1950s and 1960s aggressively promoted nuclear development without enough concern for nonproliferation. The most obvious example of the excesses of Atoms for Peace

[12] Matthew Kroenig, *Exporting the Bomb: Technology Transfer and the Spread of Nuclear Weapons* (Ithaca, NY: Cornell University Press, 2010); and Matthew Fuhrmann, "Spreading Temptation: Proliferation and Peaceful Nuclear Cooperation Agreements," *International Security* 34, no. 1 (Summer 2009): 7–41. See also Erik Gartzke and Matthew Kroenig, "A Strategic Approach to Nuclear Proliferation," *Journal of Conflict Resolution* 53, no. 2 (April 2009): 151–60.

[13] Kroenig, *Exporting the Bomb*, esp. 10–14.

[14] Fuhrmann, "Spreading Temptation," 40.

[15] Philipp C. Bleek, "Why Do States Proliferate? Quantitative Analysis of the Exploration, Pursuit, and Acquisition of Nuclear Weapons," in *Forecasting Nuclear Proliferation in the 21st Century, Vol. 1: The Role of Theory*, eds., William C. Potter and Gaukhar Mukhatzhanova (Stanford: Stanford University Press, 2010), 173 and 272–73, n49. Alexander Montgomery gets a similar result and is more receptive to it. See Alexander Montgomery, "Stop Helping Me: Why Nuclear Assistance Impedes Nuclear Programs," unpublished manuscript, Reed College, Portland, OR, February 2010. I discuss Montgomery's work more fully in the next section of the article.

during that period is the export of sizeable quantities of weapons-grade enriched uranium as fuel for research reactors around the world.[16] But to jump from there to the conclusion that Atoms for Peace has only increased states' potential to build the bomb is to indulge in an oversimplified, and misleading, techno-centric view of proliferation. IR scholars have gradually learned to distrust techno-centric explanations of nuclear weapons intentions—the tendency to deduce a regime's ultimate nuclear goals from, say, its purchase of a certain type of aluminum tubes. But they have continued to embrace techno-centric explanations of nuclear weapons capacities, relying on crude quantitative indicators to assess a regime's ultimate ability to get nuclear weapons.[17] Yet this is a critical mistake, for actually a state's "technical" capacities are also highly dependent on political variables such as the level of commitment it is able to elicit from its scientific workers. This article will show that the international linkages forged as a result of international civil nuclear cooperation can greatly complicate a state leadership's task of motivating its top scientists and engineers to devote years of their lives to a secret and internationally frowned-upon project. Therefore, although Atoms for Peace has advanced the nuclear weapons capacity of some states, it has constrained that of others—even during its most "naïve" heyday of the 1950s and 1960s. Since Atoms for Peace has had such mixed overall effects on states' capacity to "go nuclear," the proliferation literature should stop taking it as a convenient scapegoat for "how we got into this fix."[18]

The article is organized as follows. First, drawing on the literature on international technology transfer and on Albert Hirschman's theory of exit, voice, and loyalty, I show deductively how international civil nuclear cooperation can seriously hamper many, although not all, developing countries' proliferation drives by making their scientific workers much more difficult to control, and by facilitating the brain drain to the developed world. Second, I demonstrate the point empirically via a hard test for the theory: the historical nuclear program of Yugoslavia, which received very substantial nuclear assistance from the Atoms for Peace programs of the United States, Soviet Union, and European states at a time when nonproliferation controls were minimal. Far from paving the way to a nuclear bomb, the international ties of the Yugoslav nuclear program made its scientific workers much less likely to choose loyalty to the regime, and much more likely to choose voice or exit. The sum of their individual choices seriously undermined the nuclear program's progress toward its grand initial goals, and indeed accelerated its ultimate collapse.

---

[16] See "The Global Elimination of Civilian Use of Highly Enriched Uranium," special issue, *Nonproliferation Review* 15, no. 2 (July 2008).

[17] A tendency strongly criticized in Scott D. Sagan, "Nuclear Latency and Nuclear Proliferation," in *Forecasting Nuclear Proliferation in the 21st Century*, 80–101.

[18] Albert Wohlstetter, "Spreading the Bomb Without Quite Breaking the Rules," *Foreign Policy* 25 (Winter 1976), reprinted in Sokolski and Zarate, eds., *Nuclear Heuristics*, 304.

THEORIZING THE PROLIFERATION CONSEQUENCES OF SCIENTIFIC WORKERS' INTERNATIONAL TIES

Political scientists have often failed to recognize that proliferation outcomes are affected not only by the availability of money, nuclear hardware, and scientific information, but also by the organizational and political contexts that shape scientific workers' ability and willingness to participate wholeheartedly in a nuclear weapons drive.[19] In this section of the article I fill this gap in the literature, arguing in particular that the international ties forged by Atoms for Peace, through their effects on scientific workers' career opportunities, can actually seriously undermine the top state leadership's capacity to implement its nuclear weapons ambitions.

This argument can be clearly distinguished from the usual "bureaucratic politics" approach to proliferation. Scholars taking that approach have focused mainly on the policy interests and lobbying efforts of nuclear bureaucracies to get the lucrative assignment to build nuclear weapons.[20] By contrast, this article focuses on the perceived career interests of individual scientific workers and the effects of their self-interested behavior on the top leadership's ability to implement its nuclear weapons ambitions. Thus both in its level of analysis and in its dependent variable, the theory presented in this article is different from—albeit not necessarily incompatible with—typical bureaucratic politics arguments.

Atoms for Peace in Light of the Literature on International Technology Transfer

I begin by stepping back and situating my argument about the effects of Atoms for Peace within the broader literature on international technology transfer. Indeed, one of the striking limitations of both the academic and the policy literatures on the effects of international nuclear cooperation is an oversimplified model of the technology transfer relationship. The overwhelming majority of analysts simply assume that what one side "gives," the other side "gets." Indeed, this "give-get" model is apparently considered so

[19] Nuclear historians have demonstrated much better intuitions. See, for example, John Lewis and Xue Litai, *China Builds the Bomb* (Stanford: Stanford University Press, 1991), esp. 232–36.

[20] See, for example, Scott D. Sagan, "Why Do States Build Nuclear Weapons? Three Models in Search of a Bomb," *International Security* 21, no. 3 (Winter 1996/67): 54–86; Jim Walsh, "Bombs Unbuilt: Power, Ideas, and Institutions in International Politics" (PhD diss., Massachusetts Institute of Technology, 2001); Jim Walsh, "Learning from Past Success: The NPT and the Future of Non-Proliferation" (paper prepared for the Weapons of Mass Destruction Commission, Stockholm, Sweden, October 2005); and Peter R. Lavoy, "Nuclear Proliferation over the Next Decade: Causes, Warning Signs, and Policy Responses," *Nonproliferation Review* 13, no. 3 (November 2006): 433–54. A more nuanced but as-yet undeveloped bureaucratic politics hypothesis is broached in Steven E. Miller and Scott D. Sagan, "Alternative Nuclear Futures," *Daedalus* 139, no. 1 (Winter 2010): 132–33.

self-evident that it is hardly ever discussed. But it needs to be, because the implications it leaves are deeply misleading.

Ironically, despite its pessimistic implications, the proliferation literature's "give-get" model of technology transfer is actually quite reminiscent of the naïvely optimistic "science for development" model that was popular in development circles during the 1950s.[21] Those early hopes for easy and rapid transfer of technology to the developing world proved illusory. In response to that disappointment, a large, interdisciplinary literature on international technology transfer emerged and offered many demonstrations of the limitations of the simple "give-get" model.[22] Yet this important literature has remained curiously marginal to political scientists' research on proliferation, with the important exception of some work by Alexander Montgomery.[23] Even Kroenig's finely crafted book, although it employs the term "technology transfer" in its subtitle, does not cite any article or book from the broader technology transfer literature.

One of the basic points made by the technology transfer literature, and whose importance for the case of nuclear proliferation has been stressed by Montgomery, is that the genuine diffusion of technical capacities is often quite limited. A first reason why is that supplier countries often do not or cannot transfer the crucial tacit knowledge that comes from hands-on experience, and without which the technology's potential will remain dormant.[24] The relevance of this point for nuclear proliferation has been shown by Liu Yanqiong and Liu Jifeng, whose detailed study of the 1950s Soviet assistance to China's nuclear weapons project shows that because Soviet technicians were not very forthcoming with their knowledge, the assistance was not nearly as seminal as many have claimed.[25] A second reason why technology transfer is often less than meets the eye is that developing countries often lack sufficient "absorptive capacity"—for instance, their technical bureaucracy may not be well-organized enough to learn to do anything more than run a turnkey facility.[26] A recent statistical analysis by Montgomery suggests

[21] On "science for development," see Gili S. Drori et al., *Science in the Modern World Polity: Institutionalization and Globalization* (Stanford, CA: Stanford University Press, 2003), esp. chap. 4.

[22] For a general introduction, see Bruce E. Seely, "Historical Patterns in the Scholarship of Technology Transfer," *Comparative Technology Transfer and Society* 1, no. 1 (April 2003): 7–48.

[23] Alexander Montgomery, "Ringing in Proliferation: How to Dismantle an Atomic Bomb Network," *International Security* 30, no. 2 (Fall 2005): 153–87; and Montgomery, "Stop Helping Me."

[24] Montgomery, "Ringing in Proliferation," 175–79. Kroenig accepts Montgomery's point about the importance of tacit knowledge but retorts that this is yet another reason to fear sensitive nuclear assistance. Kroenig, *Exporting the Bomb*, 154–56.

[25] Liu Yanqiong and Liu Jifeng, "Analysis of Soviet Technology Transfer in China's Development of Nuclear Weapons," *Comparative Technology Transfer and Society* 7, no. 1 (April 2009): 66–110.

[26] Also known as "adsorptive capacity." Jonathan D. Hagood, "Why Does Technology Transfer Fail? Two Technology Transfer Projects from Peronist Argentina," *Comparative Technology Transfer and Society* 4, no. 1 (April 2006): 73–98.

that this factor may be an important limitation on technology transfer in the nuclear weapons area as well.[27]

But the technology transfer literature does not limit itself simply to identifying frictions, transaction costs, and other hindrances to the seamless operation of the "give-get" model. It has also stressed that international linkages forged for the purpose of technology transfer actually create a decidedly two-way street. Beginning in the early 1970s, social scientists attached to the United Nations Conference on Trade and Development (UNCTAD) developed the concept of "reverse transfer of technology."[28] The clearest case of reverse transfer of technology can be seen in the serious and persistent "brain drain" of developing country scientists and other highly skilled workers to developed countries. In other words, international technical "assistance" programs actually often morph into avenues for the poaching of developing country talent. The implication of these points for proliferation is that the greater the brain drain of nuclear scientific workers out of a developing country, the lower its nuclear weapons capacity becomes.

Strangely, the proliferation literature has focused on brain drain only in its most sensationalist aspect—the possibility that a few former Soviet weapons scientists, for instance, might have gone to work for Kim Jong Il or Saddam Hussein.[29] But the brain drain's most typical pattern is the movement of "brains" from developing countries, or more recently from the post-Soviet area, to the advanced industrialized states. And nuclear scientific workers are no exception to the rule.

The causes of the brain drain are complex, but UNCTAD's research "clearly locates the problem within international cooperation policies," of which Atoms for Peace is an ideal-typical example.[30] It is no wonder that international cooperation policies such as Atoms for Peace have served as key facilitators of the brain drain. After all, institutionalized interactions provide developed states' scientific organizations with vastly more information about the talents and qualities of a given developing country scientific worker than they could get from a CV and a letter of recommendation from an unknown home country professor. They are therefore much more willing and able to recruit that scientific worker to join them. Likewise, the scientific worker will be more willing and able to move to the developed world if there is a clear job opportunity waiting there. Later in the article I will offer more comments

[27] Montgomery, "Stop Helping Me."

[28] See, for example, United Nations Conference on Trade and Development, *The Reverse Transfer of Technology: A Survey of Its Main Features, Causes and Policy Implications* (New York: United Nations, 1979).

[29] A recent example of the genre is Deborah Yarsike Ball and Theodore P. Gerber, "Russian Scientists and Rogue States: Does Western Assistance Reduce the Proliferation Threat?" *International Security* 29, no. 4 (Spring 2005): 50–77.

[30] Jacques Gaillard and Anne Marie Gaillard, "Introduction: The International Mobility of Brains: Exodus or Circulation?" *Science, Technology & Society* 2, no. 2 (September 1997): 203.

on the mechanisms via which Atoms for Peace impacts scientific workers' behavior, and therefore also the cause of nonproliferation.[31]

Neoliberal economists have come up with various arguments to minimize the brain drain's negative impacts on sending countries. The keywords here include "brain circulation," "brain bank," "brain diaspora," "brain replacement," and "brain waste."[32] More cynically, economists also often stress the value of financial remittances from emigrant "brains."[33] But the most fair-minded recent work on the subject finds that brain drain is a real and damaging phenomenon for the majority of developing countries, although a handful of large developing countries such as China or India have scientific and technical communities that are sufficiently big and advanced to absorb the brain drain hit and still benefit from the compensating factors the economists have identified.[34]

As hinted in the previous sentence, I am not arguing that the nonproliferation consequences of Atoms for Peace are equally strong on all nuclear programs around the world. First, the theory I am elaborating here is clearly most applicable to developing countries' nuclear programs. Whereas the critics of Atoms for Peace argue that developing countries are its prime beneficiaries, I argue that the brain drain it facilitates can actually imperil the nuclear weapons capacity of all but the biggest among them (for example, giant states like India and China). Second, the theory is most applicable to nuclear programs that have significant organizational and management problems. Of course, we should not assume that all developing countries' nuclear programs will be poorly managed, but in fact many appear to be if their widely reported failings, even in terms of elementary nuclear safety and fissile materials control measures, can be taken as a gauge.[35] Whereas the critics argue that Atoms for Peace allows developing countries to leapfrog many of the issues that might otherwise have exposed their organizational and management deficits, I argue that it can actually expose those deficits even more glaringly. Indeed, via the brain drain and other mechanisms, it can accentuate the nuclear program's negative trajectory so much

[31] Here I am thinking primarily of the effects of Western states' Atoms for Peace programs. It would be interesting to explore the hypothesis that the Atoms for Peace program of the totalitarian Soviet Union generated less brain drain.

[32] These arguments are all well summarized in Louise Ackers and Bryony Gill, *Moving People and Knowledge: Scientific Mobility in an Enlarging European Union* (Cheltenham, Glos, UK: Edward Elgar Publishing 2008), chap. 8.

[33] Ibid., 224–25.

[34] Devesh Kapur and John McHale, *Give Us Your Best and Brightest: The Global Hunt for Talent and its Impact on the Developing World* (Washington, DC: Center for Global Development and Brookings Institution, 2005), esp. 178–79; and Jacques Gaillard, "Measuring Research and Development in Developing Countries: Main Characteristics and Implications for the Frascati Manual," *Science, Technology and Society* 15, no. 1 (March 2010): 77–111.

[35] For a brief description see Miller and Sagan, "Alternative Nuclear Futures," 127–28.

that the political leadership becomes practically powerless to turn things around.

Hypotheses on Exit, Voice, and Loyalty in Developing Country Nuclear Programs

I have argued that analyses of the proliferation consequences of international civil nuclear cooperation efforts have ignored the possibility that such efforts may also engender reverse technology transfer and, notably, brain drain. But the nonproliferation-promoting effects of international linkages are not limited solely to the brain drain. In addition, by creating the mere possibility of brain drain, international linkages can significantly change the internal balance of power within the nuclear program, negatively impacting the state's capacity to implement its nuclear ambitions as much as the brain drain itself. To explain how this happens, in line with the mainstream brain drain literature, I turn to Albert Hirschman's famous typology of exit, voice, and loyalty.[36]

Hirschman portrays three generic behavioral choices that are available to consumers, workers, and others when interacting with a given organization: "loyalty" (simply accepting the organization as is), "voice" (loudly complaining to it about its defects), or "exit" (cutting off ties with the organization entirely).[37] In this section of the article I detail how Atoms for Peace, by promoting international ties among scientific workers, can decrease the most talented and energetic workers' willingness and ability to choose simple loyalty to a nuclear weapons project, while increasing their willingness and ability to choose vocal opposition to it and/or definitive exit from it.

Loyalty

My first Hirschman-inspired point is that Atoms for Peace-created international ties significantly raise scientific workers' costs of choosing loyalty to a nuclear weapons project. The resulting decrease in the number of fully committed workers naturally impedes the project's progress.

Atoms for Peace makes the choice for loyalty more costly by giving developing countries' scientists the chance to build an international scientific reputation. Having achieved such a reputation, most scientific workers will want to protect it. The result in most cases is that they become drastically

[36] Albert O. Hirschman, *Exit, Voice, and Loyalty: Responses to Decline in Firms, Organizations, and States* (Cambridge, MA: Harvard University Press, 1970). Hirschman himself elaborates on the linkage between his theory and the brain drain literature in his "Exit, Voice, and the Fate of the German Democratic Republic," *World Politics* 45, no. 2 (January 1993): 173–202.

[37] Since Hirschman's original formulation an enormous literature has grown up around it: for a critical review, see Keith Dowding et al., "Exit, Voice, and Loyalty: Analytic and Empirical Developments," *European Journal of Political Research* 37, no. 4 (June 2000): 469–95.

less willing to devote years of their lives to a secret and internationally disapproved nuclear weapons project.

One mechanism here is their internalization of the international scientific norm of publish-or-perish. The international fields of nuclear science and engineering are focused overwhelmingly on basic science or on peaceful applications of the atom. A scientific worker cannot burnish his or her reputation at the annual conference of the World Association of Nuclear Weapons Designers or by publishing in the *International Journal of Nuclear Weapons Physics*. Of course, the dual-use nature of nuclear technology makes it theoretically possible to publish some weapons-related research. But in the interest of secrecy, the scientific workers' political bosses will likely try to keep most if not all weapons-related research from leaking out into the public domain. In short, for internationally connected scientific workers, to work on nuclear weapons is to commit professional suicide.

In addition to their pragmatic reasons to detach themselves from a nuclear weapons project, internationally connected scientific workers are also likely to have philosophical reasons for doing so. The international epistemic community of nuclear scientists and engineers exerts strong socializing pressures on its members, and in particular it enforces the view that working on nuclear weapons is uninteresting and dishonorable.[38] To ask internationally connected scientific workers to commit themselves to building nuclear weapons is to ask them to reject the basic values of their professional community. Of course they may still make this choice due to nationalism or some other reason, but the point is that having international connections considerably raises the perceived costs of that choice. Therefore, on average one may expect less loyalty from them.

Recognizing this fact, top management is likely to become increasingly distrustful of its international scientific stars and accordingly discount the advice they are giving.[39] It may also try to ensure their continued loyalty by encouraging others to snitch on them and otherwise keep them in line. Indeed there should be many people within the nuclear program's rank and file who harbor a wish to see their high-flying internationalized colleagues cut down to size. But in the long run this management tactic is likely to have significant negative impacts on the functioning of the nuclear weapons project. The encouragement of snitching can easily spiral into an organizational culture of competition and backbiting, to the point where no one in the program trusts anyone else and no one can be trusted. Such an atomized organizational culture is especially damaging for "big science" projects like nuclear weapons drives, because they depend so heavily upon high levels

[38] It takes an intense resocialization process to counteract the power of these international scientific community norms. See Hugh Gusterson, *Nuclear Rites: A Weapons Laboratory at the End of the Cold War* (Berkeley: University of California Press, 1996), esp. chap. 3.

[39] The tendency to distrust even loyal agents has been amply explored in rational choice signaling models of delegation. See J. Bendor, A. Glazer, and T. Hammond, "Theories of Delegation," *Annual Review of Political Science* 4 (2001): 249–51.

of trust and cooperation among large teams of scientific workers with complementary skill sets.[40] In this and other ways, poor management and Atoms for Peace interact to send the nuclear program into a tailspin.

Voice and Exit

My second Hirschman-inspired point is that Atoms for Peace-created international ties also significantly lower the costs to scientific workers of exercising vocal opposition to a nuclear weapons project, and even of definitively exiting from the nuclear program or the country altogether. When voice or exit takes place on a small scale it usually just creates management headaches, but when a critical mass of scientific workers choose either or both of these behavioral pathways, the nuclear program can slow down dramatically and even be mortally wounded.

Why are scientific workers with international ties more likely to exercise various forms of voice, from speaking truth to power all the way up to engaging in public whistle-blowing or industrial actions? One reason why is that such scientists are likely to see themselves as a kind of aristocracy within the nuclear program, a special status that gives them the responsibility to speak up against what they perceive as flaws in the program's management or ultimate objectives. In addition, for the reasons noted previously they should be more likely to disagree with the trajectory of the nuclear program than their internationally disconnected peers. Finally, they may perceive their international connections as protecting them somewhat from reprisals and as an ultimate escape hatch in the case that the reprisals become too severe.

It takes a very self-confident and far-sighted leadership to react with restraint to such challenges from below. Restraint is especially difficult in typical developing country contexts, where challenges to policy are often indistinguishable from challenges to authority. But the decision to crack down on internationally connected scientific workers' exercise of voice tends to make them surly and unmotivated and ultimately encourages them to seek a definitive exit out of the program. Moreover, when prominent scientific workers do decide to exit, they are likely to take others with them. Thus here again, we see that the interaction of Atoms for Peace and poor management can send a developing country's nuclear program into a tailspin.

Internationally connected scientific workers may also choose to skip the voice step and quietly exit the program in favor of moving to superior career alternatives outside it. Indeed, Hirschman suggests that such a choice to leave "secretly, softly, and silently" is often the path of least resistance, particularly when dealing with authoritarian states.[41] But although quieter, this form of exit is at least as destructive as its noisier cousin—perhaps more

[40] For the general point see J. Richard Hackman, *Leading Teams: Setting the Stage for Great Performances* (Boston: Harvard Business School Press, 2002).

[41] Hirschman, "Exit, Voice, and the Fate of the German Democratic Republic," 194.

so—because it does not communicate clear information about the causes of the scientific worker's unhappiness to the nuclear program's top leaders.

In sum, growing international connections can render a nuclear program's most talented and energetic scientific workers much less likely (or even able) to remain loyal, and much more likely and able to exercise voice or to choose exit.[42] The departure or demoralization of a critical mass of discontented scientific workers is most likely in poorly managed, developing country nuclear programs; and if it happens, there is no reasonable chance for the program to regroup from its organizational defects and achieve the technical feat of building nuclear weapons.

A CASE STUDY: TITO'S YUGOSLAVIA

The theory sketched above focuses on the direct and indirect effects of international scientific contacts on individual scientific workers' calculations and behavior. Therefore to test the theory's empirical purchase, we need very detailed information about specific cases. So at this stage an in-depth, low-to-the-ground process-tracing analysis seems most appropriate.[43] In this article, I probe the theory's plausibility through a close consideration of the historical nuclear program of the Federal Republic of Yugoslavia during the rule of President Josip Broz Tito.[44]

There are at least three reasons why Tito's Yugoslavia should be a hard test for the theory presented in this article, and an easy test for the conventional wisdom about Atoms for Peace. First, this was no banana republic. Until the 1980s Yugoslavia was a politically stable, fiercely independent Communist state that boasted not only the fourth largest army in Europe but also a rapidly modernizing economy. The economist Carl-Ulrik Schierup notes that according to conventional criteria, in the 1970s Yugoslavia stood "at the upper end of a continuum in the group of countries aspiring to an entry into the category of 'core' industrial countries."[45] Impressed by Yugoslavia's nuclear and overall economic development, the U.S. "official estimate" in 1964 named Yugoslavia among only eleven countries worldwide that "have

[42] Admittedly a scientist's "exit" should not be seen as absolutely definitive. The most spectacular example of "exit" followed by dangerous "return" in the realm of proliferation is the career path of the Pakistani metallurgist Abdul Qadeer Khan. To say that Khan's activities encouraged proliferation is an understatement, but at the same time it is clear that if his Dutch employers had simply followed the rudimentary security precautions they already had on the books circa 1975, his career as a nuclear spy would have ended almost as soon as it began. See David Albright, *Peddling Peril: How The Secret Nuclear Trade Arms America's Enemies* (New York: Free Press, 2010), esp. 16–24.

[43] In principle, a quantitative social network analysis of the international ties of nuclear program scientists and engineers might provide a more systematic test than the qualitative approach employed here, but the data requirements for such a study would be prodigious.

[44] Standard English spellings of Yugoslav names have varied over the years. In this article I generally try to follow today's norms, but I do not "update" the spellings used in documents or publications or those adopted by Yugoslav emigrants to the United States or other countries.

[45] Carl-Ulrik Schierup, *Migration, Socialism, and the International Division of Labour: The Yugoslavian Experience* (Aldershot, UK: Avebury, 1990), 205.

or will soon have the capability of making nuclear weapons, given the requisite nuclear decision."[46] If Atoms for Peace restrained the nuclear progress of even a country as formidable as Tito's Yugoslavia, we may reasonably surmise that it had at least comparable effects in many other cases.

Second, Yugoslavia was a major recipient of Atoms for Peace largesse. Indeed it parlayed its strategic position in Cold War Europe to garner a lavish amount of nuclear technical assistance from the United States, European states, and the Soviet Union. This aid included three research reactors and the sensitive technology of fuel reprocessing, among other prizes.[47] Indeed, Yugoslavia was one of only seven countries worldwide to receive the trifecta of U.S. Atoms for Peace aid—a reactor grant, a research and equipment grant, and monetary and technical assistance.[48] The 1950s and 1960s, of course, were the era of nuclear good feeling prior to the NPT when, as Daniel Poneman has put it, "we did not worry too much about a state taking 99 steps out of 100 towards nuclear weapons under the cover of Atoms for Peace and then bolting from the regime."[49] Focusing on a case from the 1950s and 1960s therefore stacks the deck in favor of a finding supporting the conventional wisdom about Atoms for Peace's dire consequences for nonproliferation, and against my theoretical argument.

Third, Yugoslavia is not just a "dog that did not bark." All four existing quantitative proliferation datasets concur that Yugoslavia actually did conduct nuclear weapons activities over a minimum total of fifteen years between the early 1950s and the late 1980s.[50] The quantitative data sets should not be taken as the last word on such matters.[51] But careful historical work also suggests that Tito's Yugoslavia may be a classic example of the naïveté of Atoms for Peace.[52]

---

[46] Russell Murray (U.S. Department of State), "Problems of Nuclear Proliferation Outside Europe," note marked "Secret," December 7, 1964, DDRS Document no. CK3100281620. Document also cited in Francis J. Gavin, "Same As It Ever Was: Nuclear Alarmism, Proliferation, and the Cold War," *International Security* 34, no. 3 (Winter 2009/10): 17.

[47] William C. Potter, Djuro Miljanic, and Ivo Slaus, "Tito's Nuclear Legacy," *Bulletin of the Atomic Scientists* 56, no. 2 (March/April 2000): 63–70.

[48] As of 1981 Yugoslavia also ranked seventh in terms of cumulative historical IAEA technical assistance. See Jonathan Schiff, *International Nuclear Technology Transfer: Dilemmas of Dissemination and Control* (Totowa, NJ: Rowman and Allanheld, 1984), 194.

[49] Daniel B. Poneman, "A New Bargain," in Pilat, ed. *Atoms for Peace: A Future After Fifty Years?* 177.

[50] Harald Müller and Andreas Schmidt, "The Little Known Story of De-Proliferation: Why States Give Up Nuclear Weapon Activities," in *Forecasting Nuclear Proliferation in the 21st Century*, 157; Bleek, "Why Do States Proliferate?" in *Forecasting Nuclear Proliferation in the 21st Century*, 169; Dong-Joon Jo and Erik Gartzke, "Determinants of Nuclear Weapons Proliferation," *Journal of Conflict Resolution* 51, no. 1 (February 2007): 189 n17, data and codebook at http://dss.ucsd.edu/~egartzke/; and Sonali Singh and Christopher R. Way, "The Correlates of Nuclear Proliferation: A Quantitative Test," *Journal of Conflict Resolution* 48, no. 6 (December 2004): 872 n21, at http://falcon.arts.cornell.edu/crw12/.

[51] Alexander H. Montgomery and Scott D. Sagan, "The Perils of Predicting Proliferation," *Journal of Conflict Resolution* 53, no. 2 (April 2009): 302–28.

[52] Potter et al., "Tito's Nuclear Legacy"; Gaukhar Mukhatzhanova, "Nuclear Weapons in the Balkans: Why Yugoslavia Tried and Serbia Will Not," in *Forecasting Nuclear Proliferation in the 21st Century*, *vol.*

Despite being a hard test, the nuclear experience of Yugoslavia largely confirms the theoretical perspective that I have advanced in this article. Yugoslavia did not come anywhere close to achieving its initial grand nuclear ambitions. Indeed, over the course of the decades the federal Yugoslav nuclear program careened, in Dušan Ražem's well-articulated summation, from "Big Science" down to "Nullity."[53] Atoms for Peace was not the only reason why Yugoslavia's nuclear program failed, but it did contribute significantly to that ultimate outcome. For, even as Atoms for Peace was apparently advancing the Yugoslav nuclear program in terms of providing hardware and scientific information, at the same time it was constraining the program by changing the incentives of top Yugoslav scientists to work hard for the regime's nuclear objectives—and in many cases, even to remain in Yugoslavia at all. These subtle nonproliferation constraints imposed by Atoms for Peace were ultimately much more important than the hardware that the developed states sent to Yugoslavia. The rest of the article demonstrates that Atoms for Peace intensified and locked in the Yugoslav nuclear program's downward trajectory, and indeed accelerated its ultimate collapse.

Nuclear Yugoslavia's International Connections Before 1950

In order to assess the effects of Atoms for Peace on Yugoslavia's nuclear progress, it is first necessary to separate out the effects of international connections that Yugoslavia had prior to the launching of Atoms for Peace. During the prewar period, there had been a flourishing, cosmopolitan world of nuclear science, and in the postwar period, despite the national security walls the United States, USSR, and other governments tried to erect around their nuclear research, scientific internationalism persisted in many quarters.[54] The fact that Yugoslavia's nuclear effort benefited substantially from these international ties cannot be "blamed" on Atoms for Peace.

In particular, when Tito came to power at war's end Yugoslavia had two scientists, Dragoljub Jovanović and Pavle Savić, who had each spent several years conducting advanced research at Marie Curie's Institut du Radium in Paris. Indeed in 1938, Savić and Irène Joliot-Curie had published a crucial article on transuranium elements that led directly to the discovery of nuclear fission by Otto Hahn, Fritz Strassmann, and Lise Meitner.[55] In 1947 Tito

---

2: A Comparative Perspective, eds., Potter and Mukhatzhanova (Stanford: Stanford University Press, 2010), esp. 206–9.

[53] Dušan Ražem, "Radiation Processing in the Former Yugoslavia, 1947–1966: From 'Big Science' to Nullity," *Minerva* 32, no. 3 (Autumn 1994): 309–26.

[54] Jean-Jacques Salomon, "The *Internationale* of Science," *Science Studies* 1, no. 1 (January 1971): 23–42.

[55] Glenn T. Seaborg, "Discovery of Fission and the Transuranium Elements," in *Collection of Papers Devoted to Pavle Savić on the Occasion of his Seventieth Birthday*, ed. Academician Milutin Garasanin (Belgrade: Serbian Academy of Sciences and Arts, 1980), 40.

put Savić, a committed Communist, in charge of the new nuclear research institute at Vinča, Serbia. The fledgling Yugoslav nuclear program received a further boost with the 1948 arrival in Vinča of Robert J. Walen, a Dutch national who had worked with Savić at the Institut du Radium and moved to Yugoslavia for a mix of political and personal reasons.[56] Other internationally trained physicists who joined the nuclear program included Anton Peterlin, an experimentalist who had received his doctorate at Berlin's Humboldt University in 1938, and Ivan Supek, a theoretician who had received his doctorate under Werner Heisenberg at Leipzig in 1940. Peterlin was put in charge of the new Jožef Stefan Institute at Ljubljana, Slovenia, in 1949, and Supek was put in charge of the new Rudjer Bošković Institute at Zagreb, Croatia, in 1950.

It was this core of scientific talent that found itself tasked to carry out the regime's grand nuclear ambitions. And although small in number and at first barred from significant international interchange on nuclear topics, they were able to build up a basic nuclear research program prior to the launching of Atoms for Peace that impressed the first outsiders who came to visit in the early 1950s. For instance, the Norwegian nuclear chief, Gunnar Randers, visited Yugoslavia's nuclear institutes in the fall of 1952 and declared himself "pleasantly surprised" by what he saw. He had high praise for the "skillful" scientists Savić and Walen, admired how "intensely" they were working to educate young scientists, found the physical plant "impressive," and was amazed at how much equipment they had been able to develop "from scratch." Indeed, Randers came away with the impression that the only thing holding Yugoslavia back from rising to the technical level achieved by his own highly successful nuclear program was money.[57] During the long Yugoslav economic boom that began soon after Randers' visit, that money started pouring in.[58]

In sum, prior to Atoms for Peace the Yugoslav nuclear program, although starting from a very low base, was on a steep upward trajectory. This upward trajectory was greatly aided by the country's prewar international scientific connections. But it is important to stress again that the effects of these preexisting conditions must be taken as a baseline and should not be confused with the effects of Atoms for Peace. Indeed, part of the reason why Atoms for Peace was launched in the first place was that the prior policy of suppressing the internationalism of the scientific community was proving increasingly ineffective.[59]

---

[56] Walen had Communist leanings, and his wife was Serbian. See "Archives Frédéric Curie," Folder F154, docs. 272 and 273, in Archives Historiques du Musée Curie, Paris, France.

[57] Gunnar Randers, *Lysår* (Oslo: Gyldendal, 1975), 180–83.

[58] The budget increased every year from 1947 to 1961. Slobodan Nakićenović, *Nuclear Energy in Yugoslavia* (Belgrade: Export Press, 1961), 22.

[59] Eisenhower explicitly made this point in his December 1953 "Atoms for Peace" speech at the UN, at http://www.atomicarchive.com/Docs/Deterrence/Atomsforpeace.shtml.

Yugoslav Participation in Atoms for Peace

As a key borderline state in the Cold War, Yugoslavia was positioned strategically to gain handsomely from the Atoms for Peace-type programs of both East and West. The United States actually began extending its nuclear hand to Yugoslavia even before Eisenhower formally launched the Atoms for Peace idea in 1953. In 1951, as part of its bid to woo Belgrade to join the Western Alliance, the United States arranged for Yugoslavia to join the group of nations that was to found the European nuclear energy institute CERN.[60] After Eisenhower's Atoms for Peace speech in 1953, U.S. nuclear aid to Yugoslavia increased greatly.[61] U.S. allies such as France, Britain, and Norway did likewise in proportion to their size.

The Soviet Union upped the ante in 1956, agreeing to build a natural uranium fueled and heavy water-moderated research reactor with a power of 6.5 megawatts (MWt) at the atomic research institute at Vinča, including transferring the title to the reactor's nuclear fuel to the Yugoslavs "without strings at all."[62] The Soviets also aided the Yugoslavs' construction of a zero-power reactor at Vinča as a training system. Thanks to this Soviet assistance, Yugoslavia became the first Balkan state to create a nuclear chain reaction when the zero-power reactor went critical in April 1958.

Not to be outdone, in 1960 the United States also offered Yugoslavia a research reactor—this one an enriched uranium fueled and light water moderated Triga Mark II version with 250 kilowatts (KW) of power—to be built at the Jožef Stefan Institute in Slovenia. It also provided the Yugoslavs with $150,000 worth of equipment to construct a "hot laboratory" for extraction of plutonium from spent fuel on an experimental scale.[63] The Norwegians then gave the Yugoslavs extensive training in fuel reprocessing starting in 1962, and in 1966 the scientific staff at Vinča succeeded in extracting its first small quantities of plutonium from spent fuel rods.[64]

From the conventional, techno-centric perspective on nuclear capacity all of this assistance seems very worrisome. Indeed in 1974, despite Yugoslavia's recent accession to the NPT, Tito gave a direct order to start a nuclear weapons project.[65] The secret Yugoslav nuclear weapons project

[60] John Krige, *American Hegemony and the Postwar Reconstruction of Science in Western Europe* (Cambridge, MA: MIT Press, 2006), 67.

[61] Schiff, *International Nuclear Technology Transfer*, 194.

[62] John. A. Hall and Louis H. Roddis, U.S. Army Environmental Command (USAEC), memorandum for the Department of State, "Yugoslavia Atomic Energy Program," June 17, 1957, document provided by William Potter.

[63] A. A. Wells (USAEC), memorandum for Philip J. Farley, Department of State, "Equipment Grant for Yugoslavia," 27 June 1960. Document provided by William Potter.

[64] Interview with Bjørn Gaudernack, Norwegian nuclear engineer who personally instructed the Yugoslavs in fuel reprocessing techniques, Oslo, October 2008.

[65] Potter et al., "Tito's Nuclear Legacy."

remained active all the way up to 1987.[66] But in fact, despite Tito's order, Yugoslavia in 1974 was certainly not in a position to launch a serious nuclear weapons project, and in the end the project went nowhere. This was because the Yugoslav nuclear program had actually been gradually collapsing over the course of the prior decades.[67] Atoms for Peace was an important reason why.

International Ties and Scientific Workers' Exercise of Voice and Exit

The article now turns to a detailed study of the proliferation consequences of Atoms for Peace in the case of Yugoslavia. I do not claim that if Atoms for Peace had not existed, Yugoslavia would have achieved a nuclear weapons arsenal. The serious problems in the Yugoslav nuclear program's organization and management were the primary reason why the nuclear program failed to fulfill the regime's grand initial ambitions.[68] However, it would be wrong to think that therefore the case can tell us little about the proliferation implications of Atoms for Peace. For as noted previously, according to the conventional wisdom the bountiful international technology transfer received by Yugoslavia, even including the hardware and know-how necessary to extract plutonium from spent fuel rods, should have simplified many of its nuclear management problems and allowed Yugoslavia to overachieve in nuclear development relative to its overall level of scientific and technological development. But the case study clearly shows that Atoms for Peace did not do this for Yugoslavia. Indeed, Atoms for Peace actually ultimately accelerated the collapse of the Yugoslav nuclear program. This is a much stronger effect than merely slowing down a state's nuclear progress, which is the most that can be claimed for standard nonproliferation tools like export controls. One crucial way in which Atoms for Peace had its nonproliferation-promoting effects was by encouraging the country's best scientific workers to leave the program and indeed the country. The brain drain was a disaster for this small country's nuclear development aspirations. Atoms for Peace also empowered some courageous scientific workers to exercise voice about not just the organizational problems but also the overall policy objectives of the nuclear program. The presence of internal dissidents whose international connections rendered them difficult to muzzle further impeded the top leadership's pursuit of its nuclear goals.

---

[66] Ibid.

[67] This is not to ignore the ongoing construction at that time of the turnkey nuclear power plant at Krško, on the Croatia-Slovenia border. This was a major, and ultimately successful, joint undertaking by the republics of Croatia and Slovenia, exercising their greater autonomy under the new constitution. Indeed for this very reason Krško should be seen not as an advance for the "Yugoslav" nuclear program, but rather as a sign of its lack of progress and indeed regional splintering.

[68] I have written a draft manuscript paper on this subject, "Neither Duck Nor Chicken: Yugoslavia's Botched Nuclear Program" (May 2010), available upon request.

Ambitious Departures

Beginning in the early 1950s a considerable number of budding young Yugoslav nuclear scientists received student or research fellowships from the Atoms for Peace programs of the United States and other countries. Although the Western governments clearly intended these fellowships as a form of development aid, many of the most ambitious and talented young Yugoslavs who received them actually ended up remaining in their host countries for their entire careers.

The most important reason why so many young Yugoslav scientists who were hosted by Western scientific institutions in the 1950s decided not to go home was the "pull factor" of opportunities to do advanced scientific research, in addition to the general attractiveness of living in the West. For ambitious young scientists from a poor and closed country such as Yugoslavia, having the chance to become a member of the Western scientific community was akin to winning the lottery. But in addition to this strong pull factor, even at this early date the chaotic management of the Yugoslav nuclear program was also creating a significant push factor. Particularly notable in this regard were the consequences of a falling-out between Savić and Jovanović. In 1948 Jovanović left Vinča and resumed full-time work at the University of Belgrade, where he strongly counseled his prize students to take the first chance to get out of Yugoslavia while they were still young.[69] Thanks to the new friendliness of the West toward Yugoslavia, in the mid-1950s Jovanović's best students, including his own son, did in fact use Atoms for Peace-related scholarships to find their way to lifelong scientific careers in North America.[70] Without those scholarships, given the strict general controls on emigration from Yugoslavia at that time they would likely have been unable to leave.

The Yugoslav scientific brain drain of the 1950s was most severe from Vinča, but it affected the other, smaller Yugoslav nuclear institutes as well. For instance, Vladimir Jurko Glaser studied under Werner Heisenberg in the early 1950s. He then returned to his home base at the Rudjer Bošković Institute in Zagreb for a brief period, but in 1957 he took a permanent position in the theoretical physics division at CERN in Switzerland, where he was known as the "pope" because of his infallible mathematical skills.[71]

When one considers how few international-quality scientific workers Yugoslavia had in the mid-1950s, even a mere trickle of émigrés at this stage represented a serious blow to the future realization of Tito's grand nuclear ambitions. The Tito regime gradually realized that this was indeed a significant problem. For instance, when it decided to withdraw from CERN in

---

[69] Drasko Jovanovic, son of Dragoljub Jovanović, email communication, 10 April 2009.

[70] Stanka Jovanovic, ed., *Yugo Reunions 1956–2003: Eleven Friends and their Life Stories* (Urbana, IL: DJ Publishing, 2006).

[71] Dubravko Tadić, "Ivan Supek and Theoretical Physics in Zagreb," *Fizika A* 1, no. 1 (1992): 7–10.

1961, it cited "the difficulties with Yugoslavs who do not want to return" as one of its reasons.[72] Why did the regime make only half-hearted attempts to staunch the outward flow, during a time when it was still a quite harsh and closed police state? One key to explaining this puzzle is that the problem of scientific emigration did not appear all at once, but rather one scientific worker at a time; and as anticipated by the theoretical section of this article, those who had remained behind in Yugoslavia showed great ambivalence and sometimes even open hostility toward their Western-educated peers. Jovan Jovanovich, a physicist who left Vinča for North America in 1955, recalls that he actually wanted to return to Yugoslavia but noticed that those who were returning were not getting "leading jobs. It looked strange to me. Very few who were abroad and learned a lot abroad—whether intellectuals or tradesmen—were really given the chance to do what they had learned when they came back."[73] The difficulties foreign-educated scientists faced upon returning to Vinča reflected a much broader historical problem of reintegration in Yugoslavia, dating back to the unhappy experiences of the "Amerikanci" returnees around the turn of the twentieth century.[74] In Jovanovich's case, since the choice for loyalty was so potentially costly for his career, he decided not to return.

Of course, not everyone who left Yugoslavia to study or do research abroad decided to stay abroad forever. Over the course of the 1950s, a total of 440 scientists received specialized training outside of the country, and while we do not have exact numbers on the number who returned, it certainly was the majority.[75] On the other hand, many of those who returned did so simply because they could not make the grade in the West. Indeed, as the Slovenian physicist Črtomir Zupančič commented half-jokingly, the regime should have adopted a policy of letting any scientist go abroad, but upon his return only let him work as a scientist in Yugoslavia if he could prove that he had received a job offer from a respectable foreign scientific institution.[76] In the early 1950s, Vinča's Robert Walen actually did block the return of one physics student who had received terrible grades in his studies in Belgium; but after Walen himself left the institute, the politically well-connected young man was quickly taken back in.[77]

[72] Though this was not the main reason, which had to do with financing issues. Letter from Victor F. Weisskopf, CERN Director, to Jean Willems, President of the CERN Council, 11 December 1961, CERN/7464, DG-F02, CERN Library and Archives, Geneva, Switzerland.

[73] Interview with Jovan Jovanovich, Toronto, Canada, 7 September 2009.

[74] Schierup, *Migration, Socialism, and the International Division of Labour*, 264.

[75] Nakićenović, *Nuclear Energy in Yugoslavia*, 123. Nakićenović notes that another 152 left for specialized training in the year 1960.

[76] Email communication with Črtomir Zupančič, 14 October 2009. Zupančič himself returned despite having international job opportunities. But he left the nuclear program in 1959, not long after mounting a protest against work conditions in the Jožef Stefan Institute. He left the country permanently in 1966.

[77] Richard Harmstone (State Department) to Political Section, Department of State, "Boris Kidric Institute for Atomic Physics at Vinca," marked "Secret," 20 September 1954, document provided by William Potter.

Still, it is true that among the returnees there were also a few real stars, now with enormously enriched scientific skills and know-how, who were given posts commensurate with their talents. So can it be said that their choice for loyalty compensated for the choice for exit by the others? In fact, again, the truth is otherwise. Take the case of Dragoslav Popović, who spent two very productive years at Norway's national nuclear institute from 1952–54. Popović returned to Vinča despite having received a permanent job offer from his Norwegian hosts.[78] During his time in Norway, Popović had caused a small international sensation by publishing a paper detailing the fission cross section of the uranium isotope U-235, a topic that up to that point had been a closely guarded secret by the nuclear weapons states since U-235 is weapons-grade.[79] Indeed, as a result of his interesting choice of research topics in Norway, Popović has the dubious honor of being the only scientist Yugoslavia sent abroad who is mentioned by name either in Potter et al.'s important article or in the well-known nuclear chronology of the Nuclear Threat Initiative (NTI).[80] But while the clear implication of such mentions is that Popović's case confirms the counterproductive naïveté of Atoms for Peace programs, in fact the rest of Popović's story, which they do not recount, suggests a different conclusion. During his stint in Norway, Popović was socialized into the international nuclear community, and he became so trusted internationally that in 1961 he was recruited to serve as the IAEA's second director of safeguards, a key post in the budding nonproliferation regime.[81] As IAEA director of safeguards, Popović helped to shepherd Yugoslavia to sign an IAEA safeguards agreement. Yugoslavia was one of the very first countries to do so.[82] Popović was to hold the post at the IAEA until 1964.[83]

Disgruntled Departures

Beginning in the mid-1950s, not only young talent but also the senior scientists and administrators who had formed the original backbone of the Yugoslav nuclear program began departing from it. By 1961, six of the seven men who had led one of the three main nuclear institutes during the program's first decade had resigned, and four had even left the country. The seventh resigned and left the country in 1964. In most cases the immediate

---

[78] Telephone interview with Dragoslav Popović, 25 January 2009.

[79] Dragoslav Popović, "Validity of the Inverse Velocity Law for the Fission Cross Section of U-235," *Physica* 20, no. 6 (1954): 406–12.

[80] Potter et al., "Tito's Nuclear Legacy," Nuclear Threat Initiative website, at http://www.nti.org/e_research/profiles/Yugoslavia/Nuclear/chronology.html.

[81] "Yugoslav Scientist in Charge of IAEA's Safeguards Division," IAEA Press Release PR 61/13, 15 March 1961, accessed at IAEA Archives, Vienna, Austria.

[82] David Fischer, *History of the International Atomic Energy Agency: The First Forty Years* (Vienna: IAEA, 1997), 248.

[83] "IAEA Appoints First Inspector General," IAEA Press Release PR 64/37, 3 August 1964, accessed at IAEA Archives, Vienna, Austria.

cause of this high-level attrition was political infighting, but as Atoms for Peace greatly increased these men's opportunities to exercise voice or exit, it made it much easier for them to definitively break with the regime.

In 1954, Robert Walen became the first of these major figures to leave the program. As noted above, the Dutch-born former Institut du Radium scientist had come to Vinča to serve as Principal Consultant to the Director, Pavle Savić, in 1948. Walen thus represents the kind of free agent of nuclear knowledge that so concerns many contemporary nonproliferation advocates. But Walen was clearly unhappy in Yugoslavia, so only a few years later he chose to go back to France and, as Popović puts it, "disappeared from our lives."[84]

Stevan Dedijer made a rather noisier exit. A Princeton graduate, Dedijer came to Vinča in 1950 and became its top administrator in 1952. He also cut a fine diplomatic figure as Yugoslavia's peripatetic representative to the nascent European nuclear community. But Dedijer's career was sent reeling after his brother Vladimir—a top Communist cadre—chose in 1954 to vote against condemning Tito's former top lieutenant, Milovan Djilas, for his heretic proposal that Yugoslavia become a multiparty democracy. Removed from his post at Vinča, Stevan Dedijer moved in 1955 to the Rudjer Bošković Institute in Zagreb, whose director Ivan Supek welcomed him as a visiting researcher. At Bošković, Dedijer chose to devote himself not to physics but to social science, and especially to the pointed question of why developing country scientific research programs tended to be so unproductive. Using his international connections, Dedijer published his answer—that science cannot flourish without democracy—in the September 1957 *Bulletin of the Atomic Scientists*.[85] In May 1958, Dedijer broadened his implicit critique of the Tito regime in a second *Bulletin* article attacking developing countries' nuclear weapons ambitions.[86] His August 1960 article in *Nature* introduced a more quantitative measurement of national science policies, pointedly placing Yugoslavia near the bottom.[87] By this point Dedijer, stripped of his passport, was well on his way to becoming an Andrei Sakharov-style internal exile. But influential contacts Dedijer had made in the West during his days as a nuclear diplomat, and notably the Danish physicist Niels Bohr and the Swedish physicist Torsten Gustafson, made considerable efforts to rescue him from his predicament.[88] In 1961, after the Swedish Prime Minister Tage Erlander—a good friend of Gustafson's—intervened directly with Tito on his

[84] Interview with Popović, 22 January 2009.

[85] Stevan Dedijer, "Research and Freedom in Undeveloped Countries," *Bulletin of the Atomic Scientists* 13, no. 7 (September 1957): 238–42.

[86] Stevan Dedijer, "Birth and Death of a Myth," *Bulletin of the Atomic Scientists* 14, no. 5 (May 1958): 164–68.

[87] Stevan Dedijer, "Scientific Research and Development: A Comparative Study," *Nature* 187, no. 4736 (6 August 1960): 458–61.

[88] See letters regarding Dedijer's situation in Niels Bohr General Correspondence, folder "Stevan Dedijer," Niels Bohr archive, Niels Bohr Institute, Copenhagen, Denmark.

behalf, Dedijer was allowed to emigrate permanently.[89] Dedijer ended up in Sweden, where he taught, researched, and consulted on R&D management for the rest of his days.

A third major figure to leave was Anton Peterlin. As previously noted, Peterlin was the founding director of the Jožef Stefan Institute in Ljubljana, Slovenia, which was the second largest institute after Vinča. In 1958, Peterlin finally lost the political chess match and had to resign as chair of the institute's scientific council.[90] Stung by these events, Peterlin activated his international contacts and in 1959 left Yugoslavia for a series of research stints in Germany (University of Mainz) and then the United States (Wayne State University and Harvard). Then while at Harvard in 1960, he was offered and accepted a permanent position as professor of physics at the Technical University in Munich. Upon learning of Peterlin's prestigious new post, the Yugoslav authorities tried to lure him back, but he rebuffed them. The following year Peterlin was recruited again, this time to become the director of the new Camille Dreyfus Laboratory at the Research Triangle Institute in North Carolina. He remained there for the rest of his career.

These disgruntled departures of top scientific workers were even more damaging to Yugoslavia's nuclear plans than the ambitious departures of the younger scientific workers that were discussed in the previous section. For instance, after Peterlin's exit a nonscientist, Lucijan Šinkovec, was appointed director of the Jožef Stefan Institute. A disciplinary martinet, Šinkovec caused major personnel troubles and a further exodus of scientific talent. For instance Šinkovec attempted to force the Cal Tech-educated physicist Bogdan Povh to remain permanently in Yugoslavia, denying him permission even to attend foreign conferences. This treatment led Povh, who had never before considered emigrating, to sneak out to Germany on a tourist visa in 1962.[91] Povh soon had a chair in physics at Heidelberg and later served as the director of the renowned Max Planck Institute for Nuclear Physics in that city.

Another effect of the departure of top professionals was the demise of any semblance of a rational technology procurement plan for the nuclear program. A French visitor to Vinča in 1961 commented on the institute's "disorderly efforts and rather heterogeneous equipment. . . . [They] take whatever is the latest thing, without great discernment or a coherent plan. The certain result is waste."[92] This example further shows the limits of a techno-centric analysis that focuses narrowly on the hardware benefits of

[89] Jan Annerstedt and Andrew Jamison, "Stevan Dedijer: An 'Elitist Egalitarian,'" in *From Research Policy to Social Intelligence: Essays for Stevan Dedijer*, eds., Annerstedt and Jamison (London: Macmillan, 1988), 3. On the Gustafson-Erlander relationship, see "Torsten Gustafson 1904–1987," *CERN Courier*, September 1987.

[90] All the information in this paragraph comes from Peterlin, "My Scientific Life."

[91] Email communication with Bogdan Povh, 12 February 2009.

[92] CEA Direction des Productions, Recherches et Exploitations Minières, "Rapport de la mission effectuée en Yougoslavie du 25 juin au 8 juillet 1961," CEA Archives, Fontenay-aux-Roses, France, dossier 2006-119-100/1961.

Atoms for Peace. In fact due to the workings of the "softer" variables that I am focusing on in this article, the actual hardware benefits can be much less than the dollar figure might suggest.

The Choice for Voice

Ivan Supek, the founding director of the Rudjer Bošković Institute in Zagreb, deserves special attention because unlike most of the others discussed here, he chose to remain in Yugoslavia and to use his international connections as a platform for becoming a strong dissident against Yugoslavia's nuclear policies. The case of Supek thus provides an even clearer example than Dedijer's of how Atoms for Peace encourages the choice for "voice" by scientific workers against a regime's nuclear weapons ambitions.

Supek had enjoyed considerable initial credibility with the Yugoslav top leadership because of his passionate antifascism, which during his student days in Germany had briefly landed him in a Gestapo jail, and because of his services to Tito's Partisans during the war. Informed in 1950 that he was to head Yugoslavia's third nuclear institute, this one in Zagreb, Supek used his influence to convince the regime to permit a focus not on applications of nuclear energy, like the other two institutes, but rather on theoretical physics and elementary particle research.[93] Supek wanted to shelter his institute and its scientists from regime demands to participate in a nuclear weapons drive.[94] But by 1955 the regime's patience was becoming very short, and it pressed Supek to make nuclear energy applications the focus of research at Bošković, too. In line with this, it began using the carrot of foreign fellowships to divert many of Supek's brightest young colleagues away from pure theory and into applied topics.[95] Even more to the point, in 1955 it transferred the task of designing a graphite moderated and natural uranium fueled reactor to Bošković from the Jožef Stefan Institute, over the objections of both Supek and Peterlin.[96]

But even as the regime pushed, Supek was pushing back. For instance, as noted above, in 1955 he brought Stevan Dedijer to Bošković after Dedijer was ousted from Vinča, supporting the former Vinča boss as he developed his dissident critique of Yugoslavia's science policies. In 1956 at the scientific council of the Federal Nuclear Energy Commission (FNEC), Supek, in alliance with Peterlin, strenuously opposed the import of the Russian experimental reactors to Vinča.[97] In addition, perhaps needless to say, the Bošković

[93] Ivan Supek, "Notes from the Biography of Rudjer Bošković," in Supek, *Opstati Usprkos* (Zagreb: Skolska Knjiga, 1972), 73–81.

[94] Dorde Licina and Vlado Rajic, "Dr. Ivan Supek: An Evening with Heisenberg," *Vjesnik*, 5 February 1990, translation. Document provided by William Potter.

[95] Tadić, "Ivan Supek and Theoretical Physics in Zagreb," 9.

[96] Peterlin, "My Scientific Life."

[97] Ivan Supek interview in Georges Ripka, ed., *Vivre savant sous le Communisme* (Paris: Belin, 2002), 162.

Institute's work on the reactor-cum-plutonium factory that the regime had ordered it to design in 1955 did not get very far.

Supek's ability to resist the regime's nuclear direction was greatly strengthened by the alliances he had made in the European Atoms for Peace community, for instance with Victor Weisskopf, the famed director of CERN,[98] and with Paolo Budinich, whose project to create the UNESCO and IAEA-sponsored Trieste International Center for Theoretical Physics Supek strongly embraced.[99] The Pugwash conferences were another valuable forum for Supek to strengthen his international ties.[100] Such high-profile international connections made it difficult for the regime to muzzle him. Indeed, it was Supek's explicit strategy to use his "international fame" to "make it difficult for [FNEC President and Tito's secret police chief Aleksandar] Ranković to completely get rid of [him] from the whole enterprise."[101] Supek's strategy paid off: even after losing the directorship of Bošković in 1958 he was able to cling to his post on the FNEC Scientific Council, where he continued his campaign against the regime's nuclear plans until 1962. (His successor as Bošković's representative to the FNEC, Vladimir Knapp, also multiplied his international contacts through such organizations as Pugwash and persisted in the same political stances.)[102] Supek then found his way on to the Cultural and Educational Council of the Federal Yugoslav Assembly, which although a toothless body nonetheless gave him a platform to continue his nuclear activism. In 1966, after Tito's spectacular purge of Ranković, Supek found himself turned into a popular hero for his long opposition to the Ranković FNEC's vast misallocation of funds to the gigantic Kalna uranium mining and milling complex, a white elephant that had produced only pitifully small usable quantities of the mineral at enormous expense. Kalna was shut down that year, only three years after it had opened.[103] The indefatigable Supek was to continue complicating politicians' lives all the way up to his death in 2007.

Desperate Departures

Around 1958, the Yugoslav nuclear program started running into serious trouble. There was a fatal nuclear accident in the zero-power reactor at Vinča, and Ranković caused further organizational disarray by replacing the

[98] As noted in Weisskopf, letter to Willems, 11 December 1961.

[99] Alexis de Greiff, "The Tale of Two Peripheries: The Creation of the International Centre for Theoretical Physics in Trieste," *Historical Studies in the Physical and Biological Sciences* 33, pt. I (2002): 33–59.

[100] Supek interview in Ripka, *Vivre savant sous le Communisme*, 168.

[101] Supek, "Post-Scriptum," in *Opstati Usprkos*, 81–101.

[102] Vladimir Knapp interview in Ripka, *Vivre savant sous le Communisme*, 173–74.

[103] Note de l'Ambassadeur de France en Yougoslavie, Belgrade, à Monsieur le Ministre des Affaires Etrangères, Paris, 22 December 1966, archives of the Commissariat à l'Energie Atomique, Fontenay-aux-Roses, France, dossier 2006-119-260.

directors of all three main nuclear institutes.[104] Ranković kept pushing the institutes for results, but in 1961 a "highest-level order," apparently from Tito himself, abruptly halted the then-ongoing intensive discussions for a bomb-grade plutonium-producing reactor. [105] Yugoslavia's decision to withdraw from CERN in 1961 was also indicative of the regime's declining interest in nuclear physics. The nuclear program continued to receive big budgets during the early 1960s, but its future looked increasingly uncertain. In such a situation, naturally scientific workers began to look even more intensely for outside options.

Among the first of these "desperate departures" was a man at the very top. Slobodan Nakićenović, a close comrade of Tito's during the war, first served as director of Vinča from 1949–52 and later became Secretary of the FNEC, reporting directly to Ranković and in fact running the FNEC on a day-to-day basis. But understanding that the end was near, in 1964, Nakićenović parlayed the good relations he had made in Vienna as the longtime Yugoslav representative to the IAEA to jump over to that organization as its new IAEA director of safeguards. The reader will recall that another Yugoslav, Dragoslav Popović, had been serving in that post since 1961. In fact, due to the recent creation of the higher post of IAEA inspector general, as a mere director, Nakićenović's rank in the IAEA hierarchy was actually an entire rung lower than where Popović had been—even though Popović had earlier worked under Nakićenović at the FNEC. Normally this effective demotion would have mattered to Nakićenović; but at this point he just wanted to get out.[106] Nakićenović remained as IAEA director of safeguards until his retirement in 1977 and stayed on in Vienna even after that.

Nakićenović's departure was the canary in the coal mine. In 1966, right after Ranković's fall from power the nuclear program's funding was cut in half.[107] After these draconian cuts, scientific workers began leaving in droves. In the five-year period between 1968 and 1973, 1,384 scientists of all kinds left Yugoslavia, with approximately another 3,000 leaving during the next 10 years.[108] The more general opening of Yugoslavia's borders to emigration around 1965 certainly smoothed scientific workers' path toward the exits.[109]

---

[104] On the accident, see Milan Pešić, "Review of Accident Analyses of RB Experimental Reactor," *Nuclear Technology and Radiation Protection* 18, no. 1 (2003): 3–15.

[105] Interview with Dragoslav Popović, 22 January 2009.

[106] Interview with Nebojsa Nakićenović, son of Slobodan Nakićenović, Vienna, Austria, 4 October 2008.

[107] Anton Moljk, Jordan Pop-Jordanov, and Slavko Vrhovac, "The Bases of Future Work in Nuclear Energy," *Nuklearna Energija* no. 4 (1967); Joint Publications Research Service translation no. 44, 180 (30 January 1968): 3, available in Readex Microprint Corporation, *U.S. Government Publications (Non-Depository):* no. 1968-5208. Thanks to Molly Molloy and the Media and Microtext staff at Stanford University Library for their help in locating this document.

[108] Vera Rich, "Yugoslavia: Brain Drain," *Nature* 312, no. 29 (November 1984): 395.

[109] See Schierup, *Migration, Socialism, and the International Division of Labour*, 124–25.

But even after the country's borders had been flung wide open, the international connections scientific workers enjoyed thanks to Atoms for Peace still facilitated their exit by ensuring that they would not be trading their vocation of knowledge work—however constrained it was by low budgets and Kafkaesque bureaucracy—for the steering wheel of a German taxi cab. Indeed, often the first step out of Vinča was to do a visiting researcher stint in a nuclear program abroad, and from there to transit out to a permanent job in the host country. A French delegation to Vinča in 1968 reported that no less than 20 percent of the scientific staff on the books was in fact working abroad at that time.[110] As for those who remained inside the three nuclear institutes, many were "certainly not first-rate researchers," in the diplomatic phrase of the French CEA's Jacky Weill.[111] The mass departures of the mid-to-late 1960s completed the nuclear program's arc from (to borrow Ražem's phrase again) "Big Science" to "Nullity."

This article is focused primarily on how international civil nuclear cooperation helps or hampers developing countries' nuclear capacities, but it is also breaking new ground by highlighting the nonproliferation consequences of the brain drain, whatever its causes. Yugoslavia's nuclear ambitions suffered mightily not just from the brain drain out of the nuclear program per se, but also from the more general brain drain that affected related economic sectors. For instance, one of the keys to nuclear weapons development is metallurgical expertise, of which Yugoslav industry at one point had a great deal. But the opening of the Yugoslav economy in the mid-1960s allowed Western European companies to systematically recruit Yugoslav metallurgists for their own purposes. Indeed, Schierup writes that through these practices Yugoslavia was "virtually stripped" of its most highly qualified metallurgists, an astounding 34 percent of whom were working outside the country by 1970.[112] The mass brain drain experienced by the post-1965 liberalizing Yugoslavia puts a new twist on the pattern identified by Etel Solingen that the more internationally open a state becomes, the less likely its "nuclearization" becomes. Solingen's explanation for this pattern relies mainly on the demand-side variable of the incentive for liberalizing regime elites and their societal allies to respect nonproliferation norms in order to maintain good relations with the outside world.[113] But the example of the Yugoslav brain drain suggests a different, albeit potentially complementary, supply-side explanation for the pattern: the simple impossibility of building the bomb when the people needed for such a project are no longer working inside

---

[110] Report "Mission en Yougoslavie de MM. Debiesse, Doireau, Weill: 20–25 Septembre 1968," CEA Archives, Fontenay-aux-Roses, France, dossier 2006-119-73.

[111] Interview with Jacky Weill, Paris, 13 September 2008. Weill made several visits to Vinča on behalf of the French CEA over the course of the 1960s.

[112] Schierup, *Migration, Socialism, and the International Division of Labor*, 109.

[113] Etel Solingen, *Nuclear Logics: Contrasting Paths in East Asia and the Middle East* (Princeton: Princeton University Press, 2007), 43.

the country. Indeed, such supply-side factors are key to understanding what ultimately constrained Yugoslavia, since Tito actually did order his men to launch a dedicated nuclear weapons drive in 1974.[114]

From Tragedy to Farce: Tito's Nuclear Bomb Project, Part Deux

Despite the many problems the nuclear program had encountered over the years, Tito never entirely gave up on his original nuclear dream. A few weeks after India's nuclear test of 1974, he instructed the country's top military and scientific leaders—despite Yugoslavia's recent accession to the NPT—to go ahead and build the bomb.[115] Given the lamentable state of Yugoslavia's nuclear program at that time, Tito's order was simply astonishing to the scientists present at the meeting. Ivo Slaus, a Croatian physicist who attended the meeting in his capacity as acting director of the Rudjer Bošković Institute, considered Tito's order to be either a "megalomaniac idea" or, more likely, a diplomatic "bluff."[116] Slaus and his colleagues made a show of signing on to Tito's "bluff," but few actually devoted themselves to the revived bomb project.[117] Indeed, less than a month after receiving this supposedly transcendental assignment, Slaus packed his bags and left for a long-planned research stint at the Naval Research Laboratory in Washington. All in all, there was essentially no progress toward "Tito's bomb" up to the supreme leader's death in 1980.[118] After that, as Slaus notes, "the project essentially collapsed" despite the efforts of the secretary of defense, Admiral Branko Mamula, to keep it alive.[119] Yugoslavia itself was to collapse not long thereafter, leading to new worries about the potential theft or spontaneous combustion of the dangerous nuclear materials inside its dilapidated nuclear establishments.[120]

SUMMARY AND CONCLUSION

Many analysts have characterized aboveboard international civil nuclear cooperation—"Atoms for Peace"—as an unmitigated disaster for the cause of nonproliferation. Most of Atoms for Peace's dwindling band of supporters themselves no longer contest the idea that it has given dozens of developing countries the technical capacity to build nuclear weapons at a time of their

[114] Note that despite Tito's 1974 decision, Gaukhar Mukhatzhanova finds that Solingen's argument about the impact of liberalizing political coalition interests on regimes' nuclear intentions generally fits the Yugoslav case pretty well. See Mukhatzhanova, "Nuclear Weapons in the Balkans," esp. 213–15.

[115] Potter et al., "Tito's Nuclear Legacy."

[116] Email communication with Slaus, 6 October 2009.

[117] Email communication with Slaus, 13 October 2009.

[118] Potter et al., "Tito's Nuclear Legacy."

[119] Email communication with Slaus, 6 October 2009.

[120] See Philipp C. Bleek, "Project Vinca: Lessons for Securing Civil Nuclear Material Stockpiles," *Nonproliferation Review* 10, no. 3 (Fall-Winter 2003): 1–23.

choosing. Even such routine practices as the holding of international conferences and student exchange programs in the fields of nuclear science and engineering have come under fire.

In contrast to these general trends in the literature, this article has offered a more nuanced assessment of the effects of Atoms for Peace. The literature needs to abandon its outdated, oversimplified, techno-centric approach to the supply side of the proliferation equation. When we recognize that "technical" capacity has political foundations, the effects of Atoms for Peace on states' nuclear weapons capacity appear much different than the literature suggests. In particular, by changing the career opportunities available to the most talented and energetic among the small pool of competent scientific workers in developing country contexts, Atoms for Peace makes their choice for loyalty more complicated, their choice for voice less dangerous, and their choice for exit more feasible. Thus, Atoms for Peace can substantially retard or even reverse the growth of technical capacity to build the bomb, despite the transfer of hardware and know-how that it promotes.

The case study of Yugoslavia has substantiated the theorized nonproliferation-promoting effects of Atoms for Peace, even during the policy's most "naïve" nuclear promotion days of the 1950s and 1960s. As Yugoslavia represents a hard test for the theory presented here, the findings from this study should be given special heed. We should not be surprised that Atoms for Peace ended up undercutting the Tito regime's nuclear ambitions through such mechanisms as brain drain, since similar findings abound in the broader literature on international technology transfer, with which the proliferation literature needs to engage deeply.

This article is not claiming that Atoms for Peace was a silver bullet for nonproliferation in the case of Yugoslavia. Rather, the claim is that over the long run Atoms for Peace intensified and locked in the Yugoslav nuclear program's poor organizational performance, and accelerated the program's ultimate collapse. Some readers might be tempted to conclude that since poor organization and management were the root causes of Yugoslavia's nuclear woes, therefore the effects of Atoms for Peace were superfluous to the outcome. However, it would be wrong to ignore the Atoms for Peace variable simply because it did not singlehandedly prevent a Yugoslav nuclear bomb from coming into being. Recall that up until now, the literature has generally contended that Atoms for Peace helps states leapfrog over their organizational and resource limitations by handing them ready-made solutions to difficult technical problems. So it would already be a significant finding simply to show that Atoms for Peace, even in its heyday in the 1950s and 1960s, actually did not allow them to leapfrog those limitations. But in fact my finding is that Atoms for Peace greatly compounded those limitations, at least in the case of Yugoslavia. My finding turns standard thinking about this question on its head. This finding is not just interestingly counterintuitive; it also has important implications for United States and international

nonproliferation policy. Typical nonproliferation measures, such as export controls and technical safeguards, can hope to achieve little more than to restrain nuclear programs from moving forward; but I have shown that Atoms for Peace, especially by stimulating the brain drain, ultimately caused the Yugoslav nuclear program to stumble backward, and made it next to impossible for Belgrade to turn things around.

I should also underscore that this article is not claiming that Yugoslavia's experience with Atoms for Peace necessarily generalizes to every developing country. Some developing countries have been able to leverage civil nuclear cooperation to achieve nuclear weapons more quickly than they otherwise could have. India is often mentioned as a prime example of the danger that Atoms for Peace will unwittingly provide atoms for war. But this article's focus on Yugoslavia represents a necessary corrective to the literature's typical focus on proliferation headline-makers like India. Moreover, there are good theoretical reasons to think that the Yugoslav nuclear experience with Atoms for Peace may have been much more typical for developing countries than the Indian experience. First, as noted earlier in the article, the brain drain literature has singled out India as one of the handful of developing countries where the size and quality of the science and technology community are enough to allow it to absorb the hit of a substantial brain drain and yet still benefit through such compensating mechanisms as brain circulation, brain diaspora, and brain replacement.[121] Second, the literature on state capacity suggests that the bureaucratic "steel frame" inherited from the British colonial Indian Civil Service, though surely not problem-free, places India far above most other developing countries in terms of its level of state institutionalization.[122] Reflecting these general bureaucratic strengths of the Indian state, the Indian nuclear program was—despite some hiccups—quite well-organized and managed, and this substantially reduced the potential for India's participation in Atoms for Peace to cause it serious damage.[123] In short, India appears deductively to be a much more exceptional case in the developing world than Yugoslavia, although more in-depth case studies will be necessary before we can say for sure if Yugoslavia's experience with Atoms for Peace was truly typical or not.[124]

[121] Kapur and McHale, *Give Us Your Best and Brightest*, 178–79.

[122] See, for example, Martin Van Creveld, *The Rise and Decline of the State* (Cambridge, UK: Cambridge University Press, 1999), 330–31; Bimal Jalan, "Economics, Politics, and Governance" (convocation address to the Indian Institute of Management, 3 April 2004), in *India in a Globalising World: Some Aspects of Macroeconomy, Agriculture, and Poverty*, eds., R. Radhakrishna et al. (New Delhi: Academic Foundation, 2006), esp. 125–26.

[123] See George Perkovich, *India's Nuclear Bomb: The Impact on Global Proliferation* (Berkeley: University of California Press, 1999).

[124] An anonymous reviewer of this article suggested that we should consider whether, contrary to the general presumption of the proliferation literature, proliferant states often pare back their international civil nuclear cooperation efforts in order to avoid creating complications for their nuclear weapons

It might be that even if Yugoslavia's experience was typical for its time period, a reenergized Atoms for Peace policy would not have the same nonproliferation-promoting consequences in today's changed circumstances. But it is also possible to argue that an expanded commitment to overt international civil nuclear cooperation would have even stronger nonproliferation-promoting consequences in today's world. After all, the brain drain from the developing world (and post-Communist states) continues to be a major social fact in the contemporary international system. Although the United States demand for the services of developing-world scientists and engineers was already quite high during the 1950s and 1960s, it has become absolutely voracious in recent years. Between 1978 and 2008, the number of U.S. PhD recipients holding temporary visas jumped from 3,475 (11 percent of the total number of doctorates granted by American universities) to 15,246 (31 percent of the total). In the physical sciences, the increase was from 653 (16 percent) to 3,678 (45 percent). In engineering, the increase was from 781 (32 percent) to 4,486 (57 percent). Of these newly minted temporary visa-holding PhDs, in 2008 73.5 percent reported the intention to remain in the United States; this number was generally much higher among those PhDs who had come from developing and post-Communist countries. Meanwhile, the out-migration of the highly skilled is having dramatic consequences on the resource base of sending countries: for instance, 41 percent of all tertiary-educated Caribbeans have emigrated to developed countries; for West Africa the figure is 27 percent; and for East Africa it is 18.4 percent.[125] This massive brain drain is nothing to celebrate; it has caused major social ills in the developing world. But as an empirical matter brain drain is correlated with reduced technological potential, and when it comes to the narrow question of nuclear weapons development, reducing developing countries' technological potential is not necessarily a bad thing.

One could try to turn this argument around and contend that since the brain drain has become so massive, state policies can do little to encourage or discourage it anymore. But in fact the brain drain still depends crucially on facilitative state policies, especially those of the United States and other receiving countries.[126] In the nuclear area in particular, there is no guarantee that those facilitative policies will continue. As noted at the outset of this article, nonproliferation concerns have led the United States to reduce substantially the scope of its international civil nuclear cooperation programs over the past decades, and some nonproliferation advocates want to abolish them altogether. The recent U.S.-India civil nuclear cooperation agreement points in the opposite direction, but it is too soon to tell if the deal signals a

---

ambitions. This is an important question for further research. In the case of Yugoslavia the evidence for such behavior is mixed.

[125] Kapur and McHale, *Give Us Your Best and Brightest*, 2.

[126] Ibid., 179–88.

new American nuclear openness or merely a unique exception to the overall policy trend, based on India's strategic importance to the United States. Certainly on the burning contemporary case of Iran, the United States has engaged in an intense and sustained attempt to cut off Iranian scientists from the outside world.[127] The rationales for such restrictive policies need to be reexamined carefully. Indeed, with more research one might well end up concluding that it is such hard-nosed policies of enforced international isolation, not the "naïve" policies of Atoms for Peace, that are the greatest gift that the United States has to offer to the leadership of an aspiring nuclear weapons state.

[127] Yudhijit Bhattacharjee, "Prominent Iranian Scientist Blocked From Attending Physics Meeting," *Science* 327, no. 5968 (19 February 2010): 933; Yudhijit Bhattacharjee, "ACS [American Chemical Society] Drops Iranian Members, Citing Embargo," *Science* 315, no. 5820 (30 March 2007): 1,777; Yudhijit Bhattacharjee, "Society [American Institute of Aeronautics and Astronautics] Bars Papers from Iranian Authors," *Science* 308, no. 5729 (17 June 2005); and Yudhijit Bhattacharjee, "U.S. Trade Policy Creates Confusion over Co-Authorship," *Science* 304, no. 5676 (4 June 2004): 1,422.