Article

cmps

Conflict Management and Peace Science
2015, Vol. 32(4) 443–461

DOI: 10.1177/0738894214559672
cmp.sagepub.com
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Almost nuclear: Introducing the Nuclear Latency dataset

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Abstract
The capacity to build nuclear weapons—known as "nuclear latency"—is widely believed to be important in world politics. Yet scholarly research on this topic remains limited. This paper introduces a new dataset on nuclear latency from 1939 to 2012. It discusses coding procedures, describes global trends, and compares the dataset with earlier efforts to measure nuclear latency. We show that nuclear latency is far more common than nuclear proliferation: 31 countries developed the capacity to build nuclear bombs from 1939 to 2012, and only 10 of those states went on to acquire atomic arsenals. This paper provides one empirical application of the dataset, showing how the study of nuclear latency can contribute to our understanding of international conflict. We provide preliminary evidence that nuclear latency reduces the likelihood of being targeted in militarized disputes. Having the capacity to build nuclear weapons, therefore, may provide deterrence benefits that we usually associate with possessing a nuclear arsenal.

Keywords
International conflict, nuclear latency, nuclear proliferation

Introduction

Only 10 countries have built nuclear weapons to date. Yet many others have the technical capacity to proliferate if they so desired. States that could assemble an arsenal relatively quickly in the event of a crisis, like Japan, possess nuclear latency. Latent nuclear powers, it is sometimes said, are "a screwdriver's turn away" from making a nuclear bomb (e.g. Sanger and Parker, 2012).

Nuclear latency is potentially consequential for world politics. First, the spread of latent nuclear capabilities could influence international conflict. According to an emerging wisdom,

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nuclear latency can deter military attacks (Horowitz, 2013; Levite, 2002/2003; Paul, 2000). However, a state's capacity to assemble a nuclear arsenal in short order can also trigger conflict, as underscored by the ongoing crisis over Iran's nuclear program. Although it remains to be seen whether Tehran will build nuclear weapons, the mere possibility that it could expeditiously assemble a nuclear bomb in the future has led some officials in Israel and the USA to call for preventive military action against Iran. Second, having the capacity to build nuclear weapons could provide states with political leverage—even if they never assemble an arsenal (Volpe, 2013). Henry Kissinger (2012) suggested, for example, that Iran's nuclear latency enhances its influence in the Middle East: its latent capacity, he argued, will "lead many of Iran's neighbors to reorient their political alignment toward Tehran". Third, nuclear latency could foment nuclear proliferation by triggering the global diffusion of advanced nuclear technology. For instance, Iran's nuclear program might compel some Arab states to become latent nuclear powers, potentially putting them months away from nuclear arsenals.

Scholarly understanding of nuclear proliferation has increased tremendously over the last decade. Recent studies have examined why countries build nuclear weapons (e.g. Fuhrmann, 2009a, 2012a; Horowitz, 2010; Hymans, 2006; Miller, 2014; Solingen, 2007), and how nuclear arsenals influence international conflict (e.g. Fuhrmann and Sechser, 2014; Gartzke and Jo, 2009; Narang, 2014) and crisis bargaining (e.g. Beardsley and Asal, 2009b; Sechser and Fuhrmann, 2013). Other work analyzes the diffusion of nuclear power plants and related dual-use technologies (e.g. Fuhrmann, 2008, 2009b, 2012b). Yet we still know surprisingly little about nuclear latency in political science. As Scott Sagan (2010: 80) writes, nuclear latency is "poorly understood" despite being "exceedingly important". We currently lack clear answers to the most basic questions. How common is nuclear latency? Why do countries develop latent nuclear capabilities? Why do some latent nuclear powers go on to build nuclear weapons, while others are satisfied with just having the technological capacity to make bombs? What are the political effects of nuclear latency?

Our understanding of these issues remains limited, in part, because of data unavailability. Scholars have assembled numerous datasets that make it possible to conduct quantitative analyses of nuclear politics. For example, we now have datasets on nuclear weapons programs (Jo and Gartzke, 2007; Singh and Way, 2004), nuclear postures (Gartzke et al., 2014; Narang, 2014), foreign nuclear deployments (Fuhrmann and Sechser, 2014), and nuclear assistance (Fuhrmann, 2012a; Kroenig, 2009). Yet we do not yet have an off-the-shelf dataset that provides a fully accurate picture of nuclear latency in international politics.[1]

This paper introduces a dataset designed to help scholars obtain a deeper appreciation of nuclear latency. The Nuclear Latency (NL) dataset provides detailed information on the global spread of latent nuclear capabilities from 1939 to 2012. The dataset focuses on the development of enrichment and reprocessing (hereafter ENR) facilities. These nuclear plants provide countries with the ability to produce fissile material—weapons-grade highly enriched uranium or plutonium—and acquiring this material is the most difficult step in making nuclear bombs.[2] It is widely believed, therefore, that possessing ENR technology is the most important feature of nuclear latency (e.g. Sagan, 2010). The NL dataset indicates that 31 countries developed latent nuclear capabilities over the last 70 years. Nuclear latency, is thus three times more common than nuclear proliferation. In total, our dataset contains 241 ENR facilities built during the nuclear age. We provide information on the operational history, size, and purpose (whether it served civilian or military functions) of each plant. The dataset also reveals whether facilities were subjected to safeguards administered by the

International Atomic Energy Agency (IAEA), and whether they were built covertly or with foreign assistance.

Scholars could use the NL dataset to examine a host of questions related to the causes and effects of nuclear latency. This paper provides one empirical application of the dataset, showing how the study of nuclear latency can contribute to our understanding of international conflict dynamics. We provide preliminary evidence that nuclear latency reduces the likelihood of being targeted in militarized disputes. Having the capacity to build nuclear weapons, therefore, may provide deterrence benefits that we usually associate with possessing a nuclear arsenal. This finding has implications for the growing literature on the deterrent effects of nuclear weapons (e.g. Beardsley and Asal, 2009a; Bell and Miller, 2014; Gartzke and Jo, 2009; Horowitz, 2009; Narang, 2013, 2014; Sobek et al., 2012).[3]

We proceed in five main parts. First, we discuss existing attempts to measure nuclear latency, and explain why a new approach is useful. Second, we describe the NL dataset in greater detail. This section explains what information is contained in the dataset and how we collected it. The third section discusses global trends in ENR development, drawing on information contained in the NL dataset. Fourth, we present the empirical application of the dataset. The final section concludes with a brief discussion of research areas on nuclear latency.

Prior attempts to measure nuclear latency

Nuclear latency is frequently discussed in the literature on nuclear proliferation, but assessments of how many countries possess latent nuclear capabilities vary widely. Frank Barnaby (2004: 68) implies that any state with a civil nuclear program, which could include as many as 69 countries, has nuclear latency. Jacques Hymans (2006) and Richard Stoll (1996) place this figure in the high 40s. Mohamed ElBaradei, IAEA Director General from 1997 to 2009, said in 2004 that there were fewer latent nuclear states: in his view, 40 countries were nuclear weapons capable (see Sagan, 2010: 82). A lower estimate still comes from Stephen Meyer (1984), who stated that 34 states were latent nuclear powers—but the data used to generate this figure are now 30 years old.

These figures are all over the map, in part, because analysts use different metrics to define nuclear latency. Political scientists typically code latency based on a series of technical and industrial variables—but the metrics judged to be important often differ. Meyer's (1984) measure of nuclear latency is based on 10 variables: national mining activity, domestic uranium reserves, metallurgists, steel production, construction work force, chemical engineers, nitric acid production, electrical production capacity, nuclear engineers, physicists, chemists, and explosive and electronics specialists. Stoll (1992) updated Meyer's data, but excluded the uranium requirement, leading to a sharp increase in the number of nuclear-capable states. Dong-Joon Jo and Erik Gartzke (2007) further modified Meyer's approach, dropping three of the original indicators.[4]

Existing nuclear latency measures from political science have some key limitations (Sagan, 2010). The biggest shortcoming is that they do not account for a country's ENR capabilities. Meyer, Stoll and Jo/Gartzke use "surrogate indicators" for a state's capacity to build ENR plants—for example, whether a state has operated a research reactor for three or more years—but they do not directly measure whether a country operates facilities capable of producing plutonium or weapons-grade highly enriched uranium (see Meyer, 1984: 173–193).

As a result, existing datasets provide useful proxies for a state's latent nuclear weapons production capability, but they do not necessarily allow us to distinguish states that could assemble a nuclear bomb relatively quickly from other countries. Based on Jo and Gartzke's eight-point composite indicator, for instance, Columbia, Peru, Thailand and Venezuela had the highest possible degree of nuclear latency in 2001. These countries operated research reactors, but they did not possess more advanced nuclear facilities, like nuclear power plants, nor did they have the human capital needed to construct bomb-related infrastructure indigenously. To be sure, they lacked the capacity to make fissile material, the key ingredient for producing atomic weapons. Most analysts, therefore, would not characterize countries such as Colombia as having the latent capacity to produce nuclear weapons.

Nuclear assistance datasets, both the military and civilian varieties, usefully account for the transfer of ENR technologies (Fuhrmann, 2012a; Kroenig, 2009). However, these datasets only capture ENR capabilities acquired from foreign sources, excluding indigenously built plants. Because many ENR plants are built without foreign aid, as we will discuss in a subsequent section, nuclear assistance datasets provide an incomplete picture of nuclear latency.

In the technical literature (e.g. Mozley, 1998), an ENR capability is widely viewed as the most important indicator of a state's potential to build nuclear weapons. It is therefore not surprising that research by nuclear engineers generally does a better job of accounting for a state's ability to produce fissile material. For example, Nelson and Sprecher (2010) define nuclear latency based on whether non-nuclear weapons states have the ability to make nuclear fuel in large-scale production plants. However, their definition excludes numerous countries, like South Africa, that have the capacity to make fissile material for bombs on a smaller scale. Only Argentina, Brazil, Canada, Japan, and the Netherlands satisfy Nelson and Sprecher's key criterion. Moreover, the Nelson and Sprecher measure provides a snapshot of nuclear latency at a single point in time; it does not provide a sense of how patterns of nuclear latency changed throughout the nuclear era. Zenter et al. (2005) identify states that sought ENR capabilities in a study designed to examine how long it takes states to master bomb-related technology. Yet their study does not provide complete details about the number of ENR plants built by each country, nor does it supply important facility-specific information, such as whether a plant was intended for civilian or military purposes or whether it was under international safeguards.

The NL dataset addresses the limitations of existing datasets. Following the advice of Sagan (2010, 2011), we measure nuclear latency based on states' ENR capabilities, whether they are acquired indigenously or from foreign sources. The dataset is also presented as a time series, providing information about every state's nuclear capabilities during 73 years of the nuclear age. It gives details about each ENR plant, allowing researchers to identify latent nuclear powers according to different criteria, based on the particular characteristics of a state's facilities. All of these improvements lead to a more accurate depiction of nuclear latency in world politics.

Our approach: the Nuclear Latency dataset

The NL dataset identifies all ENR facilities built in the world from 1939 to 2012. All of the plants in our dataset could, in theory, be used to produce fissile material for nuclear weapons. We therefore classify every country in the NL dataset has having latent nuclear capabilities. However, there is significant variation in the bomb-making capabilities of latent nuclear powers. Some countries—such as Russia and the USA—built more than a dozen ENR facilities and produced enough fissile material to make tens of thousands of nuclear weapons. Others—such as Algeria and Romania—acquired just one facility. We design the NL dataset so that researchers can account for this variation when measuring nuclear latency if they so desire. One could measure nuclear latency based on the presence of a single ENR plant or the number of ENR facilities a country operates. Analysts could also code latency based on certain facility traits. For instance, one might argue that Yugoslavia was not really a latent nuclear power because its ENR plants could only produce small amounts of plutonium on a laboratory scale. This concern is easy to address: analysts could simply exclude Yugoslavia, and all other states that had only laboratory ENR capabilities, from their measures of nuclear latency.

When describing the dataset and global trends in this paper, and when conducting the empirical application, we take a broad approach to nuclear latency, assuming that any state with at least one operational ENR plant has the capacity to build nuclear weapons. We recognize, however, that some may view this as a fairly strong assumption. As we mention later in the article, future research could extend our initial analysis to examine how varying degrees of nuclear latency may influence international conflict dynamics.

Unit of observation and coding rules

The unit of observation in the dataset is the ENR facility: we compiled facility-specific information on the operational history, size, and purpose of each plant constructed in the nuclear age.[5] Many countries possess multiple ENR facilities that vary in terms of their characteristics. Our approach—as opposed to one that uses the country as the unit of observation—allows us to capture this variation.

Our research strategy for identifying ENR plants consisted of three main steps. First, we established which countries had the technical, financial, and political capacity to develop ENR technology. We defined such countries as those that operated at least one research reactor. This is a fairly low technological threshold: many developing countries, including Jamaica, operate research reactors. Without a research reactor in operation, therefore, it is exceedingly unlikely that a state would build ENR facilities. Yet if such a country managed to do so, its ENR activity would not be included in the NL dataset. Second, for all 69 countries that built a research reactor, we created "coding sheets" to record all of the relevant information, including our sources.[6] Third, we scoured the open-source record for information on ENR development, focusing on one country at a time.

Finding verifiable information on each facility was not always an easy task owing to the national security implications of ENR technology. We cannot be certain that our dataset contains all ENR plants, since some facilities may remain covert. However, the media has a fairly good track record of identifying previously covert facilities.[7] If secret facilities remain, they were most likely built in recent years by a state suspected of pursuing ENR technology for military purposes. It is possible, for instance, that Iran has ENR plants under construction or in operation that are not included in the NL dataset.

To identify ENR facilities, we consulted a variety of primary and secondary sources, including trade journals such as *Nuclear Fuel, Nucleonics Week*, and *Bulletin of the Atomic Scientists*. The IAEA's *Nuclear Fuel Cycle Information System* was also a useful source, although it excludes information on many ENR plants used for military purposes. In order for a facility to be entered into the dataset, we required a minimum of two independent sources verifying its existence, although in most cases we identified five or more sources.[8] When searching for ENR facilities, we were aware that absence of evidence is not necessarily evidence of absence. We ruled out the possibility that a state developed ENR technologies if we found evidence from at least five sources indicating that a state never pursued such facilities. About half (38 of 69) of the countries on which we collected information fall into this category.

A few additional points are worth clarifying. First, the NL dataset includes any ENR facility on which construction started. A facility does not need to successfully operate in order to be included. It turns out, however, that most facilities in the dataset are ultimately finished.[9] Second, countries may use multiple technologies at the same geographic location. At Oak Ridge National Laboratory, where the uranium was produced for the Hiroshima bomb, the USA operated both diffusion and electromagnetic isotope separation enrichment facilities. We treat these plants as distinct. Another case in point is Russia's Siberian Chemical Combine, which began as a gaseous diffusion plant but was converted to a centrifuge facility in the early 1970s. This one location constitutes two separate facilities in the NL dataset. Identifying facilities based on technologies, instead of just location, provides a more accurate measure of a state's ENR capability. Third, if a state moves a facility, we code the new location as a separate ENR plant. For example, in the early 2000s Iran moved its uranium enrichment activities from the Kalaye Electric Company, located in Tehran, to Natanz. These ENR plants represent distinct facilities in the NL dataset.

Variables

For each ENR plant in the NL dataset, we code the following variables:

- *Construction and operation dates*—the dataset identifies the years when construction started and the duration of operation for each ENR facility.
- *Facility size*—ENR facilities can vary greatly in terms of their size and scope. The dataset classifies each facility into one of three categories, based on the classification scheme used by the IAEA: laboratory, pilot and commercial.[10] Commercial technologies are used on an industrial scale, while pilot plants usually precede extensive enrichment or reprocessing. Laboratory facilities, the smallest of the three, are typically intended to demonstrate the feasibility of a technology.
- *Facility type*—the dataset identifies whether a facility employed reprocessing or enrichment technology. In the case of enrichment plants, it indicates the method used to increase the concentration of U-235 relative to U-238. The main enrichment methods can be grouped into several categories: (1) diffusion, (2) centrifugation, (3) electromagnetic isotope separation, (4) laser, (5) aerodynamic, (6) chemical and ion exchange, and (7) pyrometallurgical.[11]
- *Military applications*—we identify whether an ENR facility was part of a military complex. The dataset codes facilities as serving a military purpose if at least one of the following conditions are met: (1) primary or secondary sources explicitly indicate that a plant was part of a nuclear weapons program; (2) a plant produced, or was intended to produce, fissile material for nuclear bombs; or (3) the military was involved in the construction or operation of a plant.[12] Some facilities serve weapon-related functions throughout their lifespans, while others shift between military and civilian

applications over time. ENR technologies can also serve both functions simultaneously, as in the case of some French plants.

- *Covert*—some ENR plants are initially constructed in secret, while the existence of others is publicly known from the beginning. The dataset identifies whether work on a plant began covertly. We code facilities as covert if a facility existed unbeknownst to the international community, based on open-source records. A facility is coded 1 if built in secret and 0 otherwise.
- *Safeguards*—we identify whether a facility is under IAEA or regional safeguards. We code IAEA safeguards based on the Agency's list of safeguarded facilities. Note, however, that some facilities on this list are not actually inspected. For example, owing to budget constraints, the IAEA does not typically conduct on-site inspections of US ENR plants. There are two regional safeguard agreements included in our dataset: the European Atomic Energy Community (Euratom) and the Brazilian–Argentine Agency for Accounting and Control of Nuclear Materials (ABACC).[13] These two agreements cover all non-military facilities in the respective countries. Both IAEA and regional safeguards can apply to inactive sites; facilities can go offline and continue to be under safeguards.
- *Foreign assistance*—the dataset indicates whether a facility was built with foreign assistance.[14] Foreign assistance is the state-sanctioned transfer of key components or technology necessary for the design, construction, or operation of an ENR facility. Pakistan's transfer of centrifuge components to Iran through the A.Q. Khan network, for example, represents one high-profile example of foreign ENR assistance. We exclude transfers that are not supported by the state. For example, a private firm's sale of ENR-related equipment without authorization from the government would not count as foreign assistance, according to our definition. This variable also does not capture transfers of nuclear materials; providing uranium that is eventually used in a centrifuge plant would not be classified as foreign assistance.
- *Multinational*—we indicate whether a facility is multinational, that is, owned by more than one country or a conglomerate. Urenco, a nuclear fuel supply company owned by the British and Dutch governments and German utilities, operates the most well-known multinational ENR plants.

Global trends in ENR development

The NL dataset contains 241 ENR facilities built from 1939 to 2012. Figure 1 illustrates the frequency of ENR development over time. The number of ENR plants in operation increased steadily throughout the Cold War. However, the collapse of the Soviet Union led to a sharp decrease in the number of plants, as Moscow and Washington dismantled a large portion of their nuclear weapons-related infrastructures. The number of states with ENR capabilities followed a similar, albeit less dramatic, trend: since the early 1970s, the number of ENR states has been relatively constant. The peak year for global ENR development was 1987, when 22 countries operated a total of 99 plants globally.

Table 1 lists the countries that built at least one ENR facility, along with the years that a plant operated. As the table shows, our dataset indicates that 31 countries were ENR-capable during the nuclear age.[15] When measuring nuclear latency based on an ENR capability, therefore, there are fewer latent nuclear powers than prior efforts would lead us to believe

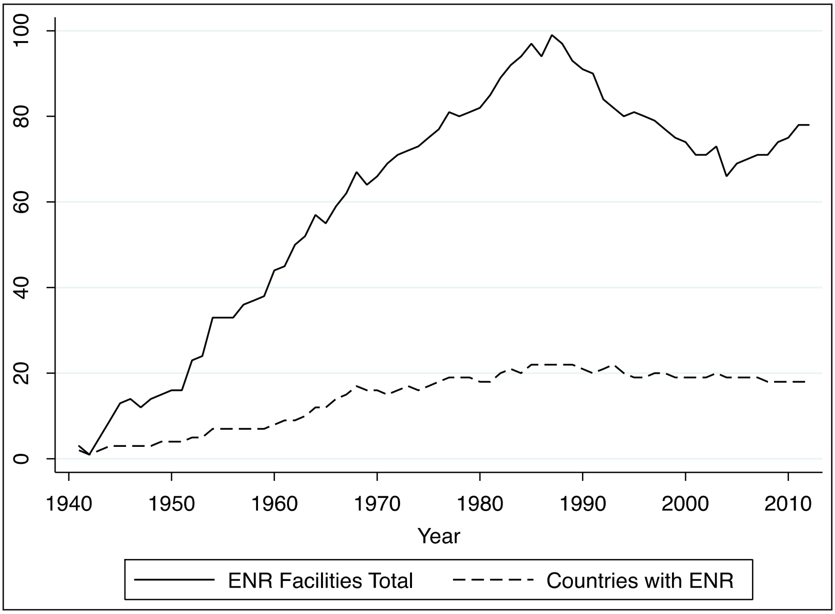

Figure 1. Number of ENR facilities and ENR countries over time.

(Barnaby, 2004; Hymans, 2006; Jo and Gartzke, 2007; Stoll, 1996). Still, as noted previously, ENR development is three times more common than nuclear proliferation. The list of ENR states is remarkably diverse: it contains countries from six continents; democracies and authoritarian regimes; wealthy states and relatively poor ones; US allies and US enemies; "rogue" regimes and champions of international norms.

All ENR states do not possess the same degree of nuclear latency. ENR capabilities vary based on the number of plants a state possesses and the size of those facilities. As shown in Figure 2, some countries—namely, China, France, India, Iran, Russia, the UK, and the USA—built 10 or more ENR plants. Fifty percent of all ENR countries, however, built five or fewer plants, and six states—about 19% of all ENR countries—built just one facility. The number of ENR plants, however, does not always correlate with a state's capacity to produce plutonium or highly enriched uranium. It is theoretically possible—depending on the size of a facility—for a country to produce enough fissile material for a modestly sized nuclear arsenal with a small number of plants.

In terms of size, laboratory facilities are the most common (40%), followed by commercial (30%), and pilot plants (30%). States that operate commercial ENR facilities—such as Brazil, Japan and the Netherlands—generally have the potential to produce the most fissile material, all else being equal. Yet, as the cases of Israel and North Korea indicate, countries do not need commercial ENR plants to produce sufficient fissile material for nuclear bombs. Laboratory facilities, from a nonproliferation standpoint, can be a major concern. Officials in the USA and elsewhere, for instance, worried about Italy's sale of a laboratory-scale reprocessing facility to Iraq in the late 1970s, arguing that it would allow Saddam Hussein to make nuclear weapons.

Table 1. Countries with ENR facilities, 1939–2012

Country	ENR plant operation years
Algeria	1992–2012
Argentina	1968–1973, 1983–1989, 1993–1994
Australia	1972–1983, 1992–2007
Belgium	1966–1974
Brazil	1979–2012
Canada	1944–1976, 1990–1993
China	1960–2012
Czech Republic (Czechoslovakia)	1977–1998
Egypt	1982–2012
France	1949–2012
Germany (West Germany)	1964–2012
India	1964–1973, 1977–2012
Iran	1974–1979, 1985–2012
Iraq	1983–1991
Israel	1963–2012
Italy	1966–1990
Japan	1968–2012
Libya	1982–2003
The Netherlands	1973–2012
North Korea	1975–1993, 2003–2012
Norway	1961–1968
Pakistan	1973–2012
Romania	1985–1989
Russia (Soviet Union)	1941–2012
South Africa	1967–2012
South Korea	1979–1982, 1997–2012
Sweden	1954–1972
Taiwan	1976–1978
UK	1952–2012
USA	1941–2012
Yugoslavia	1954–1978

ENR facilities also vary in their purpose. Roughly 40% of plants served exclusively civilian purposes—usually making fuel for nuclear reactors—while the other 60% had military applications. Twenty-two states developed ENR for military purposes, meaning that 71% of all countries that built enrichment or reprocessing plants did so, at least in part, to have a bomb-making capacity. Some countries, like Japan, may have developed ENR to keep the bomb option open, a strategy known as "nuclear hedging" (Levite, 2002/2003). However, these cases are not classified as military because ENR development was not part of an ongoing nuclear weapons program. Not surprisingly, Russia and the USA built far more military ENR plants than other states. Those two countries together accounted for nearly 40% of all military ENR development.

Some facilities are initially built in secret, as we noted above. Sixty-eight percent of the countries that built at least one ENR facility (21 of 31) constructed a covert plant. All of the states that pursued an ENR capability secretly arguably had dedicated nuclear weapons programs, although the degree to which some of these countries wanted the bomb is still

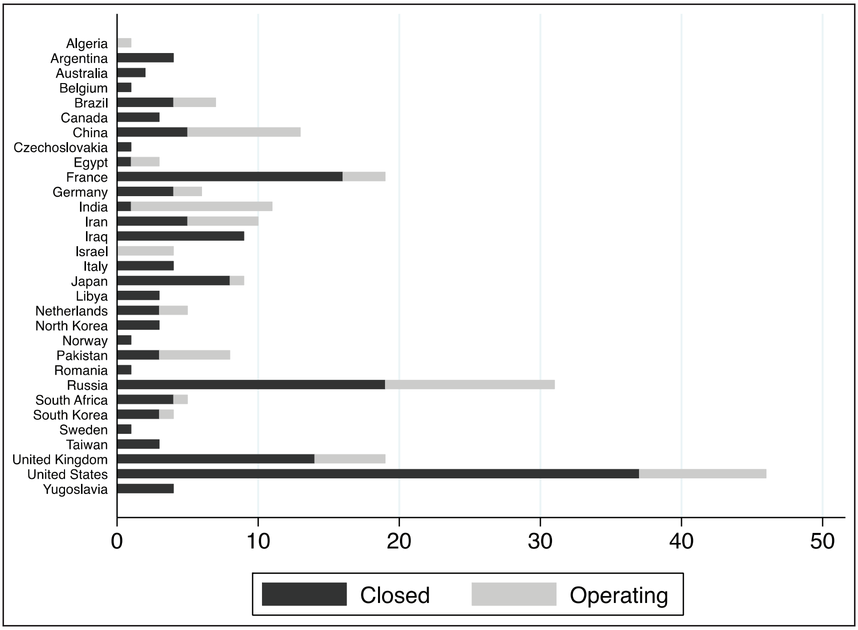

Figure 2. Number of ENR facilities by country.

debated. Facilities that serve exclusively civilian purposes—such as those in the Netherlands—tend to be overt from the beginning.

The number of plants under IAEA safeguards has steadily increased since 1970, when the nuclear Nonproliferation Treaty entered into force. The percentage of safeguarded plants remained low from 1970 to 1990, but IAEA safeguards were relatively more common after the Cold War, owing to the closure of several unsafeguarded ENR plants. At the end of 2012, about 50% of all ENR facilities globally were under international safeguards.

Foreign assistance in building ENR facilities is fairly common: 70 plants were constructed with some foreign aid. Twenty-seven countries built at least one ENR facility with foreign nuclear assistance, indicating that about 85% of all latent nuclear powers received some external aid.[16] Joint ownership is another potential way in which international collaboration in ENR development can occur. Yet relatively few ENR plants in the NL dataset are owned by more than one country. Multinational ventures are largely a European endeavor: 16 of the 20 ENR plants under joint ownership are either based in Europe or operated by Urenco.[17]

Empirical application: nuclear latency and international conflict

This section provides an empirical application of the NL dataset. We analyze the relationship between nuclear latency and international conflict. Does nuclear latency influence the likelihood of being targeted in military disputes? As we noted earlier in the paper, an emerging wisdom suggests that nuclear latency deters international conflict. It is also possible, however, that latency increases the risk that states will be targeted in disputes. We conduct some preliminary analysis to determine if latent nuclear capabilities have any effect on deterring military conflict. Before doing so, we further develop two competing arguments on the deterrent effects of nuclear latency.

Theoretical expectations

There is a voluminous literature on the political effects of nuclear weapons. Much of the research in this vein focuses on the bomb's utility for deterrence.[18]A prominent argument holds that nuclear weapons reduce the risk of conflict, especially major war (e.g. Jervis, 1989; Waltz, 1981). The reason is simple: countries that possess atomic weapons can threaten nuclear escalation if they are attacked. The possibility of nuclear use dramatically increases the costs of war and thus makes conflict less likely.[19]

Could nuclear latency provide states with similar deterrence benefits? If so, why might that be the case?

The existing literature is mostly silent on these questions. However, it is plausible that nuclear latency reduces the likelihood of military conflict (e.g. Horowitz, 2013; Levite, 2002/2003). Latency may allow states to pursue what T.V. Paul (2000: 59) calls a "virtual deterrence strategy". Latent nuclear powers could not launch an immediate nuclear strike following an attack, but they could potentially assemble a rudimentary nuclear arsenal in short order. If a dispute persists for an extended duration, then the nuclear option could be on the table. Based on this line of thinking, the prospect of nuclear punishment could deter potential aggressors even if the target does not possess a nuclear arsenal at the onset of a dispute.[20]

Nuclear latency may provide deterrence benefits even if there is little chance of nuclear use in the short term. A state with latency may decide, following an episode of military conflict, that it needs an arsenal of atomic weapons to ward off threats that could emerge in the future. Potential attackers presumably understand that latent nuclear powers could build nuclear bombs relatively quickly if their security environment deteriorates. Given that states generally want to avoid fomenting the spread of nuclear weapons, they may think twice before initiating military disputes against states with nuclear latency. Thus, latent nuclear powers may be able to deter conflict by (implicitly) threatening to "go nuclear" following an attack. To illustrate, imagine that *Potential Attacker* and *Latent Nuclear Power* are in the midst of a political disagreement. *Potential Attacker* has incentives to avoid actions that leave *Latent Nuclear Power* feeling highly threatened. Attacking *Latent Nuclear Power* could push that country to weaponize its nuclear program, thereby undermining *Potential Attacker's* security. *Potential Attacker* therefore might try harder than it otherwise would if it were dealing with a state that lacked nuclear latency to peacefully resolve its dispute with *Latent Nuclear Power*. This leads to the following hypothesis:

Hypothesis 1: Having nuclear latency reduces the likelihood of being targeted in a militarized interstate dispute.

Nuclear latency may also breed insecurity. Others might perceive a state's development of advanced nuclear capabilities as a signal that it intends to build nuclear weapons. If states come to believe that nuclear proliferation will occur in the absence of external intervention, they might use preventive military force to forestall a large shift in the balance of power (Debs and Monteiro, 2014). For example, Israel bombed Iraq (1981) and Syria (2007) to eliminate facilities that could have been used to build nuclear bombs (Fuhrmann and Kreps, 2010; Reiter, 2006). Even if states do not believe that nuclear proliferation is imminent, they may worry that their nuclear-capable rivals will eventually build nuclear weapons. In that case, putting pressure on the latent nuclear power—by issuing military threats, displaying force, or launching attacks—may be preferable to more peaceful strategies. Having nuclear latency, therefore, may actually make a state more susceptible to military conflict.

> **Hypothesis 1A**: Having nuclear latency increases the likelihood of being targeted in a militarized interstate dispute.

It is also possible, of course, that nuclear latency has nothing to do with international conflict. We will test the above predictions against the null hypothesis that there is no relationship between these two phenomena.

Empirical analysis and findings

To test the above hypotheses, we build on an existing study that examines the relationship between nuclear weapons and military conflict (Gartzke and Jo, 2009). We follow Gartzke and Jo's (2009) empirical procedures, adding latency-related variables to their model as appropriate. Mirroring their approach, we use a standard time-series cross-sectional dataset that covers the period from 1945 to 2000. The unit of observation is the directed-dyad-year, which allows us to distinguish between challengers and targets of military disputes. The dependent variable comes from the Correlates of War Militarized Interstate Dispute dataset (Ghosn et al., 2004). *MID Initiation* is coded 1 if the potential challenger initiates a militarized dispute against the target and 0 otherwise.[21] The independent variables from Gartzke and Jo's (2009) model, all of which are included in our analysis, are described in the Appendix.

Our primary independent variable of interest (*Nuclear Latency B*) measures whether the potential target in a militarized dispute has latent nuclear capabilities in a given year. This variable is coded 1 if the target has nuclear latency and 0 otherwise; nuclear powers are coded 0 beginning in the first year that they assemble an arsenal. We operationalize latency based on a lenient criterion: any non-nuclear weapons state that has an ENR plant in operation is classified as a latent nuclear power. Future research could extend our study to examine how different degrees of latency influence international conflict dynamics.

Our analysis also accounts for the latency status of the challenger with the variable *Nuclear Latency A*. Some have argued that nuclear weapons make countries more aggressive (Kapur, 2007), while others posit that having an atomic arsenal induces caution (Waltz, 1981). Nuclear latency might similarly embolden states to take greater risks or, alternatively, encourage self-restraint when it comes to dispute initiation.

Table 2 displays the results of probit regressions with standard errors clustered by directed dyad. Model 1 is a replication of Gartzke and Jo's (2009: 220) model.[22] Our findings confirm their results. Model 2 adds the variables *Nuclear Latency A* and *Nuclear Latency B*. The coefficient on *Nuclear Latency B* is negative and statistically significant, indicating that nuclear latency is associated with a lower risk of being targeted in military disputes. This relationship is substantively meaningful: increasing *Nuclear Latency B* from 0 to 1 while holding all other variables constant at their mean values reduces the probability of experiencing a dispute by nearly 40%.

Some states with ENR facilities actively pursued nuclear weapons (e.g. Iraq prior to the 1991 Persian Gulf War). Other latent nuclear powers have yet to show serious interest in nuclear bombs (e.g. the Netherlands). It is worthwhile to distinguish the effects of nuclear latency from the presence of a nuclear weapons program. To do so, model 3 adds variables that measure whether the challenger and target have active bomb programs (*Nuclear Weapons Pursuit A* and *Nuclear Weapons Pursuit B*).[23] *Nuclear Latency B* remains negative and statistically significant, suggesting that nuclear weapons programs do not drive our initial findings. Nuclear latency appears to provide states with deterrence-related benefits that are distinct from actively pursuing nuclear bombs. By contrast, the target's pursuit of nuclear weapons is statistically unrelated to conflict. Bomb programs therefore do not appear to suppress military disputes independently from nuclear latency.

These results support Hypothesis 1, but they do not necessarily imply that nuclear latency is always a source of peace. Although latency reduces the risk of being targeted in disputes, it may increase the likelihood of conflict initiation. The coefficient on *Nuclear Latency A* is statistically significant and positive in model 2. Based on the estimates from model 2, challengers with nuclear latency are 77% more likely to initiate disputes than challengers without latency. However, the statistical significance of *Nuclear Latency A* washes away once we account for the challenger's pursuit of nuclear weapons (model 3). We therefore do not find robust evidence of a relationship between a challenger's nuclear latency and international conflict. Bomb programs themselves, though, are associated with an increased risk of dispute initiation, as indicated by the coefficient on *Nuclear Weapons Pursuit A*.

In terms of the other variables, Gartzke and Jo's (2009) initial findings are stable across models 1–3. Accounting for nuclear latency and nuclear weapons programs, therefore, does not overturn their main results. Variables that were statistically significant in their model continue to be significant in our models; those that were insignificant remain so.

Our findings are far from definitive. They do suggest, however, that there may be a relationship between nuclear latency and international conflict. This relationship has been underappreciated in the conflict literature to date, and it is worthy of further scholarly examination.

Conclusion

Scholars and policy-makers have long recognized that nuclear latency is important. The current Iranian nuclear crisis, for example, underscores the significance of nuclear latency for international conflict and nuclear proliferation. Yet political scientists have yet to devote much attention to the causes and political effects of nuclear latency. This paper introduced a new dataset that provides a comprehensive measure of nuclear latency, based on the diffusion of ENR capabilities. It discussed the features of the dataset, identified key trends, and provided an illustration of the type of analysis that one could conduct using these data. We presented initial evidence that nuclear latency is associated with a reduced risk of being targeted in military disputes. Thus, having the capacity to build nuclear weapons, like possessing an atomic arsenal, may bolster deterrence.

This paper raises a number of topics for future research on nuclear latency. First, it would be fruitful to further explore the deterrent effects of nuclear latency. Knowing more about *why* latency appears to reduce the risk of being targeted in military disputes would be especially useful. We conjectured that latency provides a valuable deterrent because states can threaten to "go nuclear" if they are attacked. However, nuclear latency could be associated

Table 2. Probit analysis of militarized conflict

	(1) Gartzke and Jo (2009)	(2) Latency added	(3) Pursuit added
Nuclear Latency A		0.151**	0.072
		(0.049)	(0.053)
Nuclear Latency B		−0.133**	−0.148**
		(0.044)	(0.052)
Nuclear Weapons Pursuit A			0.182**
			(0.061)
Nuclear Weapons Pursuit B			0.040
			(0.068)
Nuclear Weapons A	0.260**	0.316**	0.333**
	(0.070)	(0.071)	(0.069)
Nuclear Weapons B	−0.001	−0.053	−0.049
	(0.077)	(0.082)	(0.082)
Nuke A × Nuke B	−0.212	−0.210	−0.204
	(0.135)	(0.136)	(0.138)
Democracy A	0.023**	0.020**	0.021**
	(0.006)	(0.006)	(0.006)
Democracy B	0.041**	0.043**	0.043**
	(0.006)	(0.006)	(0.006)
Democracy A × Democracy B	−0.005**	−0.005**	−0.005**
	(0.001)	(0.001)	(0.001)
Rivalry Status A	0.293**	0.286**	0.277**
	(0.032)	(0.032)	(0.031)
Rivalry Status B	0.157**	0.162**	0.160**
	(0.030)	(0.030)	(0.030)
Dyadic Rivalry	1.113**	1.116**	1.109**
	(0.051)	(0.051)	(0.051)
Contiguity	−0.137**	−0.137**	−0.139**
	(0.044)	(0.044)	(0.044)
Distance (ln)	−0.050†	−0.050†	−0.049†
	(0.026)	(0.026)	(0.026)
Alliance	0.043	0.044	0.045
	(0.040)	(0.040)	(0.040)
CINC A	0.778	0.398	0.265
	(0.707)	(0.724)	(0.708)
CINC B	1.589†	1.972*	1.923*
	(0.829)	(0.864)	(0.862)
CINC A × CINC B	0.207	0.064	0.395
	(15.833)	(16.132)	(16.164)
Peace Years	−0.062**	−0.061**	−0.061**
	(0.008)	(0.008)	(0.008)
Spline 1	−0.000**	−0.000**	−0.000**
	(0.000)	(0.000)	(0.000)
Spline 2	0.000**	0.000**	0.000**
	(0.000)	(0.000)	(0.000)
Spline 3	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
Constant	−2.308**	−2.314**	−2.315**
	(0.081)	(0.080)	(0.080)
N	1,051,218	1,051,218	1,051,218

Notes: Standard errors in parentheses; $^{\dagger}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, two-tailed tests.

with international conflict for other reasons. More theorizing about this relationship, combined with qualitative analysis of key cases, might illuminate other causal mechanisms. Related to this, future empirical work might assess whether nuclear latency *causes*, or is merely associated with, a reduced risk of international conflict. We have shown that there is a correlation between these two variables, but more work is needed to understand whether this is a causal relationship.[24]

Second, our preliminary analysis provided some evidence that states with nuclear latency are more likely to initiate disputes. But we do not yet understand why this might be the case. A rich literature focuses on how nuclear weapons influence the likelihood that states will instigate conflict. Scholars might build on this research to explore the possible emboldening (or restraining) effects of nuclear latency.

Third, it would also be worthwhile to explore the variety of other ways in which latency might influence world politics. Does the capacity to build nuclear weapons, for instance, provide states with greater coercive bargaining leverage? Many have argued that nuclear weapons increase states' bargaining power in crises, allowing them to extract concessions with greater ease (e.g. Beardsley and Asal, 2009b). Others question whether the bomb has political value beyond deterrence (e.g. Sechser and Fuhrmann, 2013). Future work could contribute to this ongoing debate by exploring the coercive effects of nuclear latency. Important research along these lines is already underway (Volpe, 2013), but we do not yet fully understand how and why nuclear latency might carry political leverage.

Finally, the study of nuclear latency is relevant for scholarship on the causes of nuclear proliferation. The decision to obtain latent nuclear capabilities is a key part of the proliferation process. Indeed, as we noted throughout this article, no country can build nuclear bombs without first acquiring the requisite nuclear technology. Analyzing why states obtain latent nuclear capabilities, then, could help us more fully appreciate the demand for nuclear weapons in world politics.[25] There is also a methodological reason to account for latency in research on how and why nuclear weapons spread: three times as many states developed latent nuclear capabilities as built nuclear weapons. This provides greater variation to exploit in the dependent variable, just as studying less severe but more frequent episodes of international conflict may give us additional insights into the causes of war.

Funding

This research is part of the "Correlates of Sensitive Technologies" project, funded by the USA Department of Energy, Nuclear Energy University Programs (NEUP 3149). We thank Paul Nelson, Garill Coles, and Valerie Lewis, our collaborators on the COST project, as well as William Boettcher, Jeff Colgan, Bryan Early, Erik Gartzke, Llewelyn Hughes, Mark Nance, Glenn Palmer, Robert Reardon, Adam Stulberg, participants in the International Studies Association workshop "A New Security Dilemma? Politics and Policy at the Energy-Security Nexus", and anonymous reviewers for helpful feedback on this paper. Molly Berkemeier, Miguel Contreras, and Josiah Barrett provided helpful research assistance.

Notes

1. Scholars have devoted some attention to the measurement of nuclear latency, but existing datasets have some limitations, which we address later in the paper.
2. ENR facilities also have a civilian application: making fuel for nuclear power plants or research reactors.
3. For seminal earlier work on this issue see Jervis (1989) and Sagan and Waltz (2002).

4. Jo and Gartzke exclude construction workforce, steel production, and national mining activity.
5. There must be an attempt to enrich uranium or separate plutonium at a facility for it to be included in our dataset. Plants that manufacture ENR components are excluded, unless uranium is enriched or plutonium is reprocessed at those sites. A testing facility that spins centrifuges without introducing uranium hexafluoride, for instance, would not count as an ENR plant.
6. The coding sheets will be made publicly available on publication of this article at http://www.matthewfuhrmann.com.
7. The NL dataset contains more than 100 ENR plants that were initially built in secret.
8. Two sources are considered independent when they rely on unique information to substantiate claims about ENR facilities. To illustrate, consider a stylized example. Source A asserts that an enrichment plant exists in North Korea. Source B makes a similar claim, and substantiates this on the basis of Source A only. Source C also provides evidence of an enrichment facility, based on Source D. Based on our criterion, Source A and Source C are independent but Source A and Source B are not.
9. Only 20 of the 241 (8%) facilities fail to become operational. Note that some of these facilities will probably begin operating in the future while construction on others has permanently ceased.
10. We followed the IAEA's Nuclear Fuel Cycle Information System guidelines for coding facility capacity.
11. There are distinct reprocessing techniques (e.g. PUREX, Thorex, and bismuth phosphate), but the dataset does not distinguish between them.
12. In theory, the third condition could be met even if a plant was not part of a nuclear weapons program. For example, the military could be involved in an ENR plant that was intended to produce fuel for nuclear submarines. In practice, however, most military-supported facilities are part of a nuclear weapons program.
13. Euratom was founded in 1952 and ABACC emerged in 1991 with the signing of the Guadaljara Agreement for the Exclusively Peaceful Use of Nuclear Energy.
14. In some instances, sources indicate that a foreign country helped to build an ENR plant without providing the name of the facility. In those cases, we conducted further research to determine which facilities were built with foreign assistance.
15. This number is greater than the maximum number of ENR states depicted in Figure 1 because all of the states listed in Table 1 did not possess latent nuclear capabilities at the same time.
16. Kroenig's (2009) dataset on sensitive nuclear assistance indicates that 12 countries received ENR assistance. We identify more cases of foreign aid, in part, because of differences in coding rules. In particular, Kroenig excludes ENR-related assistance to states with the indigenous capacity to construct facilities on their own. For example, he excludes French assistance in constructing a Japanese commercial reprocessing plant in the 2000s (he includes earlier French assistance to Japan for a pilot plant in the 1970s). In contrast, we include all ENR transfers, regardless of the recipient's domestic capabilities.
17. In most of these cases, facilities were multinational from the beginning. However, in two instances—Russia's Angarsk Electrochemical and Norway's Kjeller Pilot Uranium Plant—joint ownership occurred after the start of facility operation.
18. The compellent effects of nuclear weapons are more controversial (e.g. Beardsley and Asal, 2009b; Gartzke and Jo, 2009; Sechser and Fuhrmann, 2013).
19. Empirical support for this argument remains mixed (e.g. Bell and Miller, 2014; Fuhrmann and Sechser, 2014; Gartzke and Jo, 2009; Huth and Russett, 1984; Narang, 2014; Rauchhaus, 2009).
20. This logic is most applicable to highly industrialized states with the most advanced civilian nuclear capabilities, like Germany and Japan (Paul, 2000: 59).
21. Gartzke and Jo (2009) measure this variable in year $t+1$.
22. When examining the relationship between nuclear weapons and international conflict, it is important to control for the dispute history in a dyad (Bell and Miller, 2014). We added a variable measuring the number of prior disputes two countries experienced, and the main findings were similar.

23. These variables are coded based on Jo and Gartzke (2007).
24. On the challenges associated with making causal inferences using observational data, see, for example Imai et al. (2011).
25. This is particularly true since countries may "hedge" when they have an interest in building nuclear bombs—that is, states might develop latent nuclear capabilities but refrain from taking the final step towards weaponization, knowing that they could do so quickly in the event of a crisis. Yet it is also possible that fears of nuclear hedging are overblown and that states develop advanced nuclear technologies for reasons that have little to do with augmenting military power. Scholars could assess this possibility by systematically analyzing the causes of nuclear latency.

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Appendix

This Appendix briefly describes the independent variables in Gartzke and Jo's (2009) model of international conflict. For further details, see Gartzke and Jo (2009: 218–220).

- *Nuclear Weapons A*. A dichotomous variable indicating whether the challenger possesses a nuclear arsenal.
- *Nuclear Weapons B*. A dichotomous variable indicating whether the target possesses a nuclear arsenal.
- *Nuke A* × *Nuke B*. An multiplicative interaction between *Nuclear Weapons A* and *Nuclear Weapons B*.
- *Democracy A*. A measure of the challenger's level of democracy based on an 11-point scale, ranging from 0 to 10.
- *Democracy B*. A measure of the target's level of democracy based on an 11-point scale, ranging from 0 to 10.
- *Democracy A* × *Democracy B*. A multiplicative interaction term between *Democracy A* and *Democracy B*.
- *Rivalry Status A*. A dichotomous variable indicating whether the challenger is party to at least one interstate rivalry.
- *Rivalry Status B*. A dichotomous variable indicating whether the target is party to at least one interstate rivalry.
- *Dyadic Rivalry*. A dichotomous variable indicating whether the challenger and the target are rivals.
- *Contiguity*. The geographic proximity between the challenger and the target based on a six-point scale.
- *Distance (LN)*. The logged great circle distance between the capital cities of the challenger and the target.
- *Alliance*. A dummy variable indicating whether the challenger and the target are military allies.
- *CINC A*. The challenger's military power based on the Correlates of War Composite Indicator of National Capabilities (CINC) index.
- *CINC B*. The target's military power based on the CINC index.
- *CINC A* × *CINC B*. A multiplicative interaction term between *CINC A* and *CINC B*.
- *Peace Years, Spline 1, Spline 2* and *Spline 3*. Standard controls for time dependence recommended by Beck et al. (1998).