The Correlates of Nuclear Proliferation

A QUANTITATIVE TEST

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Fears of rogue states, withdrawal of cold war–era security guarantees, a falling technological threshold, and availability to terrorist organizations ensure that nuclear weapons proliferation remains a central security issue and that developing an adequate theory of proliferation ranks high on the agenda. A data set on nuclear proliferation is constructed that identifies three different stages on the path to the weaponization of nuclear weapons technology. Hazard models and multinomial logit are used to test theories of nuclear proliferation. Results suggest that nuclear weapons proliferation is strongly associated with the level of economic development, the external threat environment, lack of great-power security guarantees, and a low level of integration in the world economy.

Keywords: *Nuclear weapons proliferation; security; economic development; great-power security guarantees; hazard models*

Since the advent of the atomic age, nuclear weapons proliferation has been one of the major security issues facing the world. After the end of the cold war, concerns about proliferation have grown rather than subsided: the withdrawal of superpower security guarantees has created incentives for smaller powers to acquire nuclear weapons, a handful of "rogue" states have sought nuclear arms, Pakistan and India have joined the ranks of overt nuclear powers, the technological threshold necessary to develop atomic weapons is in reach of ever more nations, and the possibility of new nuclear powers selling weapons to terrorist organizations has focused concerns. Controversy rages around the world over U.S. plans to build a national missile defense (NMD) system to fend off emerging nuclear threats, and scholars debate whether NMD will fan the fires of proliferation or reduce the incentive for more states to acquire nuclear

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weapons. Thus, more than a half century into the nuclear weapons era, the problem of proliferation is even more pressing than at the dawn of the atomic age.

This is troubling, given our lack of reliable knowledge about the determinants of nuclear proliferation. Although there is no shortage of academic theories to account for the spread of nuclear weapons, few agree on the validity or generalizability of the various alternatives. Policy makers and scholars of international relations suffer from an embarrassment of riches in the diverse attempts to explain decisions to acquire nuclear arms, matched by a corresponding poverty of consensus about the empirical support enjoyed by various perspectives. Authors frequently find existing explanations unable to account for the details of a case of particular interest and then seek to redress the shortcoming by offering yet another alternative. Even as explanations proliferate, we do not know which of these perspectives provides the best guide to understanding decisions to "go nuclear" and for forecasting potential future proliferators.

We enter the debate by suggesting that a quantitative test of theories of nuclear proliferation can provide a useful complement to the qualitative, comparative case study methods that predominate in this research agenda.[1] We highlight three reasons a quantitative test is an appropriate, and indeed perhaps necessary, supplement to the proliferation literature. First, by sampling on the dependent variable, most qualitative studies ignore or underemphasize the large number of countries that have never pursued nuclear weapons. Ignoring nonproliferators runs the risk of underestimating the strength of causal effects or, more rarely, erroneously accepting a relationship that does not hold up in a wider sample (Collier and Mahoney, 1996; Dion 1998; Geddes 1990; King, Keohane, and Verba 1994). For example, as Sagan (2000) points out, analysts can almost always identify an ex-ante security threat after the fact of a proliferation episode. Yet they often fail to acknowledge that security threats are ubiquitous by the rather elastic standards often employed by realists. In this situation, sampling on the dependent variable may create a bias toward overemphasizing the explanatory power of security threats. More prosaically, but equally important, sampling on the dependent variable simply discards much valuable information useful in drawing inferences about the correlates of proliferation. Quantitative analyses that include observations covering the full range of variance on both the dependent and independent variables can provide a useful complement to qualitative approaches that delve deeply into a limited number of cases.

Second, theories of nuclear weapons proliferation often offer, either explicitly or implicitly, probabilistic hypotheses, yet theories are frequently tested as if they make deterministic claims. For example, the simplest realist claim—that the more severe and immediate a security threat, the more likely a state is to pursue nuclear arms—is clearly based on a probabilistic logic. Yet studies of nuclear proliferation often find realism wanting by identifying one or a handful of cases that fail to conform to the realist logic. Statistical models based on a probabilistic logic of inference offer a better fit with theoretical logic than the deterministic logic associated with the Millian methods underpinning comparative case studies (Lieberson 1992, 1994).

1. Quantitative large-*n* studies of nuclear weapons proliferation have been scarce, with few following up on the early efforts of Kegley (1980) and Meyer (1984) to provide systematic studies.

Not only are hypotheses about nuclear weapons proliferation best thought of as probabilistic statements, but it is also likely that there are multiple determinants and combinations of factors responsible for decisions to pursue nuclear arms. Yet many studies implicitly rely on monocausal logics of inference, comparing competing explanations as if looking for the "magic bullet" that will, by itself, account for all proliferation decisions or setting up dueling explanations in a winner-take-all contest. When applying this univariate standard, implicit in the Millian methods that form the basis of many comparative case studies (Lieberson 1992), it is not surprising that existing explanations are repeatedly found inadequate when they fail to account for all observations or all nuances of particular cases. As an alternative, the multivariate logic of inference embodied in multivariate statistical approaches seems more plausible.

We complement qualitative analyses by providing systematic statistical tests of a number of prominent perspectives on nuclear proliferation against a data set that covers 154 countries between the years 1945 and 2000. We employ new data on key decisions along the path to nuclear weapons. Conceptually, we argue for viewing proliferation as a continuum instead of a dichotomy, defining four stages of proliferation: no noticeable interest in nuclear weapons, serious exploration of the weapons option, launch of a weapons program, and acquisition of nuclear weapons. With these data in hand, we use survival models and multinomial logistic regressions to test hypotheses derived from three broad approaches to nuclear weapons proliferation: (1) *technological determinants*, emphasizing the role of economic development and the declining costs of weapons; (2) *external determinants*, emphasizing incentives provided by the security environment; and (3) *internal determinants*, emphasizing a variety of domestic factors ranging from regime type to economic policies.

To preview our main findings, we conclude that contrary to the impression given by much of the recent proliferation literature, current approaches correctly identify several statistically significant and substantively important correlates of proliferation. The development threshold argument favored by technological determinists provides considerable leverage: the likelihood of proliferation rises sharply with growth at low levels of development but levels off and even declines at high levels after a threshold has been passed. Security factors play a powerful, perhaps central, role in explaining proliferation decisions. Participating in enduring rivalries or taking part in more frequent militarized disputes strongly increase the chances a state will pursue nuclear arms, but credible support from a great-power ally dampens the temptation. Finally, offering some support for more recent arguments, we find that domestic factors, such as more externally oriented economic policies, reduce the likelihood of proliferation, although regime type appears relatively unimportant. Thus, if we move beyond the search for a deterministic, univariate account of proliferation decisions, our conclusions about the current state of knowledge are considerably less pessimistic than those of many authors: the conventional wisdom takes us quite a ways toward understanding nuclear weapons proliferation.

The second section of the study outlines three perspectives on the causes of nuclear proliferation and reviews the relevant literature. The data on nuclear weapons proliferation and explanatory variables are introduced in the third section. We then analyze the data using survival models and report results in the fourth section. The final section discusses implications for policy and future research.

THREE PERSPECTIVES ON PROLIFERATION

Given the vast destructive power of nuclear weapons, it is not surprising that considerable scholarly attention has been focused on understanding states' decisions to pursue nuclear arms.[2] The rich literature on proliferation has not ignored this challenge: on the contrary, it offers a wide array of answers to these questions. We divide this diverse literature into three chief strands by focusing on the source of the impetus toward nuclear weapons: technological, external, or domestic determinants.

TECHNOLOGICAL DETERMINANTS

The essence of the technological determinist literature is its emphasis on technology as the driving force behind weapons development. Once a country acquires the latent capacity to develop nuclear weapons, it is only a matter of time until it is expected to do so. According to this literature, a country's latent capacity to acquire nuclear weapons is determined by economic prosperity, literacy levels, and scientific development: as it becomes easier and cheaper for a state to acquire nuclear weapons, it becomes more and more likely that it will do so. States may achieve the capability to assemble nuclear weapons by an explicit intentional effort or as an implicit by-product of economic and industrial development (Meyer 1984, Schroeer 1984). However they get there, once states cross the threshold that enables the development of nuclear weapons, "the universal appeal of nuclear arms and the inability of individuals and organizations to resist technological change" will eventually impel states to acquire these arms, regardless of their original intent (Lavoy 1993, 194). Moreover, as technological advances inexorably reduce the costs of acquiring nuclear weapons, eventually every state will find the costs of building nuclear weapons so low as to make the temptation irresistible.

This perspective has fuelled much pessimism about the possibility of limiting proliferation and proved influential with policy makers, but technological imperative arguments suffer from an obvious lack of empirical support, at least in their strong form. Indeed, there are numerous examples of states that have had the technical capacity to build nuclear arms for several decades but have never attempted to do so.[3] However, we argue that it is an important starting point because no nation can build nuclear weapons without attaining a minimal economic/technological capacity.[4] Therefore,

2. This literature on proliferation was not as vast and varied 10 or 15 years ago. There was a fairly broad consensus that the proliferation puzzle had an obvious answer: states that face a strong security threat will develop nuclear weapons. Explanations for proliferation and dissatisfaction with the commonsense answer have mushroomed over the past 15 years; Ogilvie-White (1996) provides a nice survey of the rich array of answers.

3. Examples include Italy, Japan, Belgium, Canada, and Germany.

4. They may, of course, attempt to buy them instead of developing the technology themselves, a path taken at various times by both Libya and Australia.

we expect this literature to play an important role in understanding the proliferation puzzle by emphasizing something akin to a necessary but insufficient condition for the pursuit of nuclear arms.

EXTERNAL DETERMINANTS

In contrast, what we call the *external determinants* literature emphasizes the willingness rather than the ability of states to build nuclear weapons. Although authors in the realist tradition have presented a variety of arguments, the literature emphasizes two factors: the presence (or absence) of a security threat and a security guarantee from a powerful alliance partner.

Realist explanations emphasize the *threat environment*: the probability of a state pursing nuclear arms increases with the severity of external security threats. States in a self-help system will feel pressure to balance against the nuclear capabilities of a rival state by developing a similar deterrent (Waltz 1979). In addition, states may exercise their nuclear option when confronted with a conventional threat from a powerful rival as a way of achieving effective parity against a stronger nation (Kapur 2001; Potter 1982; Quester 1973, 1977). Thus, realism explains nuclear proliferation as a response to external security threats, which are thought to be endemic to the international system due to the pervasive logic of the security dilemma.

However, despite the intuitive appeal of this argument, it cannot by itself explain satisfactorily the proliferation puzzle. Even though most states that have sought nuclear weapons have faced some sort of security threat, a large number of countries have not turned to nuclear force for their defense, despite security threats (Ogilvie-White 1996). Moreover, as Sagan (2000, 26) has emphasized, empirical research supporting this argument suffers from potential selection bias: observing a proliferation episode, researchers work backward to find the security threat that can rationalize the decision. Leaving aside qualms about evidence, the choice for nuclear weapons is also theoretically underdetermined. Even given a clear threat, acquiring nuclear weapons is not the only, or necessarily the best, strategy available to a state that is seeking security. A state has at least three potential choices in the face of a security threat by a powerful adversary. It can strive to develop its own nuclear ability, it can publicly refrain from making any efforts to acquire its own deterrent so as to reassure potential rivals of its benign intentions in the hope of taming the security dilemma, or it can forge an alliance with a powerful ally. Because states have multiple options in responding to security threats, such threats should be thought of as a probabilistic cause of proliferation. Although security threats almost surely increase the probability of pursuit of nuclear weapons, the “multiple-exit” problem familiar to international relations scholars means that they do not determine a state’s choice.

Another strand of realist thought argues that a credible *security guarantee* from a powerful state can dull the desire for nuclear weapons, even for a state facing a significant threat. In this view, the acquisition of nuclear weapons and the forging of alliances serve as substitutes in the quest for security (Betts 1993; Davis 1993; Thayer 1995). The supremacy of a superpower ally serves to deter attacks on its nonnuclear protégées, negating their need to pursue nuclear weapons. Building on this security guarantee argument, some have argued that bipolarity inhibits nuclear proliferation, whereas multipolarity induces proliferation (Frankel 1993; Mearsheimer 1990). Under bipolarity, states gravitate into two well-structured alliance systems anchored by the two dominant powers, which provide a security umbrella for the weaker states in their respective coalitions, obviating their need for nuclear weapons. However, as these security guarantees are withdrawn or rendered less credible in the post–cold war system, states are thought to face greater incentives to acquire nuclear weapons (Betts 1993).

DOMESTIC DETERMINANTS

A third strand of the literature shares the emphasis that the external determinants approach places on understanding the motives behind state actions, but it shifts the focus from external to *domestic determinants* of nuclear proliferation. Although analysts have described a range of potential domestic pro-proliferation forces, we focus on four domestic factors that may have an influence on the choice to pursue nuclear weapons: democracy, liberalizing governments, an autonomous domestic elite, and symbolic/status motivations.

Building on the democratic peace literature, some have argued that the pacifying effects of democracy and the complex interdependence between states will reduce the number of states that feel "fearful or ambitious enough" to pursue nuclear weapons (Chafetz 1993). Chafetz (1993), for example, divides the world into "core" and "periphery" states, emphasizing that in the current system, the core constitutes liberal democracies with shared norms and values, which foster international cooperation, tame the security dilemma, and dampen dangers of a nuclear arms race. In addition, democratic states on the periphery may no longer seek nuclear weapons because an increasing number of governments want to reap the benefits of full integration into the core economic-political system. Consequently, the spread of democracy reduces the likelihood that states will pursue nuclear weapons by enlarging a zone of peace.

In contrast, some have noted that the widespread popular support for nuclear weapons acquisition in India and Pakistan suggests that democratic governments may be tempted to pander to nationalist populations in an effort to boost their popularity and retain power (Perkovich 1999). These temptations may be greatest during periods of democratization as competing elites face incentives to stir up nationalism (Mansfield and Snyder 1995; Snyder 2000) and may seek to score a popular nationalist triumph by joining the nuclear club.

Turning from political regime type to economic policies switches the emphasis to the economic component of domestic liberalization in reducing the appeal of nuclear weapons. According to Solingen (1994, 1998), ruling coalitions pursuing liberal economic policies are more likely to join regional nuclear nonproliferation regimes than inward-looking nationalist and radical-confessional governments; liberalizing coalitions trade away the opportunity to make the bomb for the opportunity to make money, perceiving little benefit from maintaining an ambiguous stance. In a similar vein, Paul (2000) argues that as the benefits of economic integration and interdependence rise, states will forgo highly sensitive activities, such as nuclear acquisition, which might generate uncertainty, negative repercussions, and heightened international tensions. As the cost of placing trading and investment ties at risk increases, states will become more cautious about pursing nuclear weapons.

Yet another domestic-level argument highlights the degree of autonomy afforded the domestic elite in choosing to pursue nuclear arms. A state may seek nuclear weapons when the national elite, who may want to develop nuclear weapons for parochial reasons, publicizes the state's insecurity or its poor international standing to popularize the idea that nuclear weapons provide military security and political power (Lavoy 1993). Like other bureaucratic politics arguments, this argument emphasizes the ability of particularistic interests to use security concerns and nationalistic rhetoric to promote the need for a nuclear program for their own strategic, parochial gain (Elworthy 1986; Sagan 2000). It is only a short step further to conclude that elites will enjoy less autonomy and that debate will be more transparent in democracies than in nondemocracies. This generates another variant of regime-type arguments; this one suggests that democratization may foster restraint by reducing the authority and autonomy of elites who might otherwise pursue nuclear weapons for parochial reasons (Barletta 1999).

Possession of nuclear weapons can also play an important symbolic role in a state's self-image. Therefore, the decision to acquire nuclear weapons or to exercise restraint offers a state an important normative symbol of modernity (Sagan 2000). According to this perspective, much of a state's behavior is determined by shared beliefs and norms about conduct that is deemed appropriate and legitimate in international relations. The cold calculations of leaders about national security and parochial bureaucratic interests may be of less consequence than concerns with "nuclear symbolism." Nuclear weapons are often imagined as fulfilling functions similar to those of flags, airlines, and Olympic teams: they form part of what a number of states have believed they must possess to legitimize their status as modern states or to lay claim to a "great-power" role in international politics (Sagan 2000). From this perspective, states suffering from a perceived status inconsistency or those seeking validation as modern and powerful states are strong candidates to pursue nuclear arms.

PROLIFERATION DATA

DEPENDENT VARIABLE

At first it may appear that the choice between pursuing a nuclear weapons program and exercising nuclear restraint is a straightforward binary decision, but further reflection quickly reveals greater nuances. It can often be a long and winding road from initial effort to explosion of a nuclear device, and there are many different stopping points on the pathway to proliferation. Some states end up with nuclear weapons, some states have made (or are making) serious efforts to build nuclear weapons but never actually acquire them, and others seriously consider building nuclear weapons yet stop short of actually taking firm steps to do so. To be sensitive to these diverse stages and allow for robustness checks across indicators, we devised multilevel indicators of nuclear proliferation. Conceptually, rather than thinking of nuclear weapons status as a dichotomous variable, we conceive of "degrees of nuclearness" arrayed along a continuum, ranging from absolutely no effort or interest, at one end, to possession of a vast nuclear weapons arsenal, at the other end. Operationally, we divide this continuum into four stages: acquisition of weapon capability, substantial efforts to develop weapons, exploration of the possibility of developing/acquiring weapons, and no interest or effort whatsoever. (See the online appendix for sources used in coding each country.)

First explosion/assembly of weapons. This is the most reliable and accurate measure of nuclear proliferation. According to this indicator, every country that has ever exploded a nuclear device or assembled a nuclear weapon is coded as a nuclear proliferator from the year of its first explosion or possession of a functional nuclear weapon until the date that it abandons its program.[5] However, not all countries that pursue nuclear weapons have gone all the way to test or assemble nuclear devices. Therefore, we have devised two additional indicators of nuclear proliferation.

Pursuit of weapons. For various reasons, not all states that pursue nuclear weapons end up acquiring them. Accordingly, we count every country that has ever made an active effort to pursue nuclear weapons as a nuclear proliferator from the year of its first effort.[6] Thus, all countries with nuclear weapons programs, without regard to the size or stage of development, are coded as nuclear proliferators until the date that they abandon their efforts.[7] To warrant inclusion in this category, states have to do more than simply explore the possibility of a weapons program. They have to take additional further steps aimed at acquiring nuclear weapons, such as a political decision by cabinet-level officials,[8] movement toward weaponization, or development of single-use, dedicated technology. Thus, Sweden, for example, is excluded from this category despite serious exploration of the nuclear option over a number of years because it failed either to take an explicit political decision demonstrating a strong willingness to acquire weapons or to move beyond dual-use research that was necessary for atomic power but also useful for a potential weapons program (see sources for Sweden in the online appendix).

5. In practice, the distinction between assembly and explosion is important in four cases. South Africa assembled working nuclear devices but declined to test them. Pakistan is widely considered to have assembled ready-to-use nuclear devices long before finally testing them in 1998, resulting in two alternative codings: one for assembly and one for first tests. We follow a similar process of including two alternate codings with India, which, according to several sources, had weapons ready for quick assembly in 1988. We also code India as crossing this threshold twice: once with the test in 1974, after which we judge it to drop back down, and again in 1988. Clearly, consequential political decisions about crossing a significant threshold and opening up the country to criticism were entailed by both actions. Although the range of variation is narrow, there is some disagreement about when precisely Israel gained full-fledged weapons capability. In all cases, we assess sensitivity of our findings to the particular coding employed.

6. The Soviet successor states that inherited nuclear arms and ultimately renounced them are excluded from our analysis. They made no independent political decision to pursue nuclear weapons and therefore do not qualify as proliferators. In the conclusion, we discuss the desirability of studying two-way transitions, which would include these states' decisions to renounce their inherited arsenals.

7. Hence, this indicator includes countries that have ongoing nuclear programs but that have not tested weapons or prepared nuclear devices for quick assembly.

8. We also count the decisions of senior military leaders in the case of a military government.

Exploration of weapons. Casting the net even broader, we can include countries that seriously considered building nuclear weapons, even if they never took major steps toward that end. This final and most comprehensive indicator of nuclear proliferation codes every country as a nuclear proliferator from the year that it first considered building nuclear weapons, as demonstrated by political authorization to explore the option or by linking research to defense agencies that would oversee any potential weapons development. Therefore, this indicator includes all states covered by the first two indicators as well as all countries that considered developing nuclear weapons without following through with their plans and crossing the threshold to level 2. Taking Sweden as an example once again, we include it because (1) atomic research was conducted by a semipublic company explicitly linked to and reporting to the defense ministry, and (2) decisions were explicitly made by cabinet-level officials to develop dual-use technology with high potential utility for any future weapons program (see sources for Sweden in the country appendix).

For each country-year, every state in our sample is assigned to one of the four categories. States that clearly and convincingly renounce weapons or stop seriously considering them can move back down, from the exploration level to the no-interest level, for example. Thus, when Sweden ceases to seriously consider nuclear weapons, it drops back down to the no-interest category.

EXPLANATORY VARIABLES

We group proxy explanatory variables under the headings of the three types of explanations surveyed above. Table 1 summarizes the included variables and theoretical expectations.[9]

Technological Determinants

To assess a country's ability to develop and construct nuclear weapons, we employed several variables that tapped the level of economic and industrial development. We focus on indicators of the general level of economic and industrial development, eschewing those that are likely to be endogenous to an interest in nuclear weapons (such as number of nuclear scientists or metallurgists).[10]

Gross domestic product per capita. Gross domestic product (GDP) provides a rough and ready indicator of the level of economic development. Whereas aggregate economic size indicates total resources available, per capita GDP more accurately

9. We omit ratification of the Nuclear Nonproliferation Treaty (NPT) because of obvious and substantial endogeneity. Assessing the causal role of the NPT in affecting decisions toward nuclear weapons poses a host of complex problems that we plan to treat separately in a new study.

10. We also constructed a time series of known uranium deposits, reasoning that domestic availability of uranium is likely to decrease the difficulties of mounting a weapons program. However, in collecting these data, it became clear that uranium exploration is endogenous to interest in nuclear weapons. Superficially, it might appear that discovery of domestic sources of uranium spurs the start of a nuclear weapons program; closer examination of the cases reveals that an interest in nuclear weapons often spurs intensive uranium prospecting.

TABLE 1
Theoretical Expectations and Measures

Explanatory Variable	*Anticipated Direction of Effect*	*Operationalizations*
Technological determinism		
Level of development	Positive	Gross domestic product (GDP) per capita; energy consumption per capita
Industrial capacity	Positive	Index based on steel production and electrical-generating capacity; aggregate and per capita electricity and steel production
External determinants		
Security threat	Positive	Participation in enduring rivalry; frequency of militarized interstate dispute (MID) involvement
Security guarantee	Negative	Alliance with great power
Internal determinants		
Democracy	Negative	Polity IV democracy scale
Democratization	Uncertain	Change in Polity IV democracy scale (3-, 5-, and 10-year periods)
Global democracy	Negative	Percentage of democracies among states in system
Exposure to global economy	Negative	(Exports and imports)/GDP
Economic liberalization	Negative	Change in trade ratio (3-, 5-, and 10-year periods)
Dissatisfaction/symbolic motivations	Positive	S score or Tau-b with either global or regional hegemon

reflects level of economic development, which is most closely linked to the sophisticated technical, engineering, and manufacturing knowledge necessary for the development and construction of nuclear arms. Purchasing-power parity GDP data are taken from version 6.1 of the Penn World Tables (PTW) (Heston, Summers, and Aten 2002).[11] To allow for the possibility that the relationship between economic development and the pursuit of nuclear arms is curvilinear (e.g., because of a threshold effect whereby achieving moderate levels of development allows countries to act on latent nuclear ambitions, although additional increments of wealth are unlikely to increase the temptation), we also include a squared term.

Industrial capacity index. To tap the level of industrial capabilities useful for a nuclear weapons program, we created a dichotomous variable based on electricity generation and steel production. This variable takes on a value of 1 if a country both produces steel domestically and has installed electricity-generating capacity greater than 5,000 MW and 0 otherwise.[12]

11. For countries not covered by the Penn World Tables (PWT), we turned to Angus Maddison's (2002) data of purchasing-power parity gross domestic product (GDP) covering 124 countries from 1950 to 1998, converting his data from base year 1990 to 1996 for comparability with the PWT data. For countries still not covered, we drew on Gleditsch's (2002) expansion of the International Monetary Fund's (IMF's) GDP data.

12. To create the index, we used data on electricity-generating capacity from the United Nations (*Energy Statistics Yearbook*, various years; *Statistical Yearbook*, various years) and on steel production from

Energy, electricity, and steel production and consumption. To supplement the industrial capacity index, we used data on both aggregate and per capita energy consumption, electricity production and generating capacity, and steel production.[13]

EXTERNAL DETERMINANTS

Enduring rivalry. Although perceptions of security threats can vary substantially, participation in an enduring rivalry can be safely taken as an indicator of a significant security threat, especially because the vast majority of wars and militarized disputes occur in the context of enduring rivalries (Diehl 1998). Drawing on Bennett's (1998) coding for enduring rivalries and their dates, we create a dichotomous variable indicating whether a state was involved in one or more enduring rivalries in a given year.

Frequency of dispute involvement. As an alternate measure of the intensity of the security threat, we calculated the 5-year moving average of the number of militarized interstates per year in which a state is involved, drawing on version 3.0 of the militarized interstate dispute (MID) data set (Ghosn and Palmer 2003).

Security guarantee. The allure of nuclear weapons as an avenue to security may be attenuated by a security guarantee in the form of a defense pact from a nuclear-armed great power.[14] Drawing on Singer and Small's (1982) standard list of great powers, we count the United States, the Soviet Union/Russia, the United Kingdom (from 1952), France (from 1960), and China (from 1964) as nuclear-capable, great-power allies. Basing our coding on version 3.0 of the Correlates of War alliance data set (Gibler and Sarkees 2002), we count only defense pacts as providing a significant security guarantee, deeming ententes and neutrality treaties insufficiently reassuring to elide the temptation for an insecure state to pursue nuclear weapons.[15]

INTERNAL DETERMINANTS

Democracy and democratization. We use the Polity IV data (Jaggers and Gurr 1995) to create three different variables related to arguments about regime type and proliferation. One variable measures democracy for each country-year: we create a derived measure of the level of democracy within each state by combining the two

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the Correlates of War project's Composite Index of Capabilities (Singer, Bremer, and Stuckey 1972), extracted using EUGene (Bennett and Stam 2000) and updated through 2000, using the United Nations's *Statistical Yearbook*.

13. Energy consumption data are from the Correlates of War project's Composite Index of Capabilities (Singer, Bremer, and Stuckey 1972), extracted using EUGene (Bennett and Stam 2000). Population data covering the period from 1945 to 2000 were gathered from the Penn World Table 6.1 (Heston, Summers, and Aten 2002), the Correlates of War project, Maddison (2002), and the United Nations (*Statistical Yearbook*, various years).

14. Although many authors, building on this logic, have emphasized bipolarity, because bipolarity characterizes most of our time period, we focus on the presence or absence of an explicit bilateral security guarantee instead of systemic variables to assess arguments emphasizing great-power security assurances.

15. Alliance data were extracted using the EUGene software program (Bennett and Stam 2000).

separate 11-point scales for democracy and autocracy from Polity IV: $dem_i = democ_i - autoc_i$. However, periods of transition toward democracy may prove particularly volatile, making new or unconsolidated democracies more aggressive and war prone. To allow for this possibility, we create a democratization variable, $demch_t = democ_t - democ_{t-n}$, that measures movement toward democracy over time spans of 3, 5, and 10 years. Finally, as an indicator of the prevalence of democracies in the system, we create a variable that records the percentage of states each year that receive a score of 7 or higher on the democracy measure.[16]

Economic interdependence and liberalization. Among possible measures of exposure to the global economy—international capital mobility, volume of foreign direct investment, tariff and nontariff trade barriers, and so on—the trade ratio is the most straightforward and is available for the largest number of countries and years. Consequently, we use exports plus imports as a share of GDP as a measure of exposure to the international economy, drawing on data primarily from the PWT (version 6.1).[17] We also create a measure of trade liberalization analogous to our democratization variable by calculating the change in trade ratios over spans of 3, 5, and 10 years.

Status inconsistency/symbolic motivations. Operationalizing concepts, such as prestige deficit, status inconsistency, and symbolic motivations, for a data set that covers 154 countries poses nearly insurmountable difficulties. Nonetheless, we suspect that any country suffering a prestige deficit is likely to be dissatisfied with the international status quo established by the dominant power in the system and that their dissatisfaction should be observable in their chosen policy portfolio. As a proxy for dissatisfaction with the international status quo, we employ two variants of Bueno de Mesquita's (1975, 1981) measure of similarity between alliance portfolios and an alternate version proposed by Signorino and Ritter (1999). The first compares each country with the United States, taken to be the global hegemon throughout the period under consideration. However, because grievances may more often be regional than global for second- and third-tier powers, we also assess a measure that indicates similarity of each state's portfolio with that of the leading regional power.[18]

METHODS AND RESULTS

METHODS

We employ event history models, supplemented with multinomial logistic regressions, to test claims about the correlates of nuclear weapons proliferation. Event his-

16. To create this indicator and to determine eligibility for our data set in general, we draw on version 2002.1 of the Correlates of War state system membership data (Correlates of War Project 2003).

17. For countries not covered by the PWT project, we used data from the IMF, drawing on Gleditsch's (2002) extension of the data using AMELIA interpolation software.

18. Both versions of the global and regional indicators of the divergence of preferences are computed by the EUGene software program (Bennett and Stam 2000).

tory models—also called survival, hazard, or duration models—offer several advantages of particular relevance to our research question and data. We need a method that is both well suited to rare events and able to model the effects of time (e.g., duration dependence), providing estimates of the likelihood that a country begins an effort to pursue nuclear weapons given that it has not done so until that point in time. Moreover, because most countries never do pursue nuclear weapons, we need a method that accounts for this "right censoring" and thus avoids the selection bias resulting from excluding countries that never even seriously considered going nuclear. Finally, we need a model allowing us to include explanatory variables that change in value over the observation period. Several types of event history models are ideal for these needs.

Event history models provide estimates of the probability of an event occurring—in our case, a state going nuclear or starting down that path—at a particular time, given that it has not yet happened (Allison 1984; Box-Steffensmeier and Jones 1997). In the language of event history analysis, this probability is given by the hazard rate, which tells us the "risk" that a country will go nuclear. Event history models can be either parametric, requiring the specification of a particular distributional form (such as the Weibull, exponential, or Gompertz) for the baseline hazard function, or semi-parametric, allowing one to avoid making such assumptions when there is no strong a priori reason to favor one distributional form over another. To facilitate the inclusion of both time-invariant and time-varying variables, we estimate parametric discrete-time hazard models using a Weibull distribution to characterize the baseline hazard function.[19] The hazard rate is then given by

$$h(t|x_j) = pt^{p-1}\exp(\beta_0 + x_j B_x),$$

where $h(t)$ is the hazard rate, t is time, and $\beta_0 + x_j B_x$ are the estimated coefficients and variables. P is a shape parameter estimated from the data: when p equals 1, the baseline hazard is constant over time; if p is less than 1, it decreases monotonically; and if p is greater than 1, hazard increases with time at risk.

Because survival models are nonlinear, interpretation of coefficients is not straightforward. Unlike those in standard ordinary least squares (OLS) regression models, the beta coefficients do not represent the marginal effect on the dependent variable of a one-unit change in the independent variable. To ease interpretation, we estimate the models in both standard and log relative-hazard forms; in the latter case, the coefficient can be read as the number by which we would multiply the odds of, for example, the initiation of a nuclear weapons program for a one-unit increase in the independent variable. For example, a coefficient of 4 on the enduring rivalry dummy variable would imply a 300% increase in the likelihood of starting a nuclear weapons program (in other words, the chance is four times as great). In interpreting results, we present the standard coefficients and their standard errors in main tables but discuss these relative risks in the text to ease interpretation of the substantive meaning of the findings.

19. Because parametric models derived from contending distributions are nonnested, we used the Akaike information criteria to assess the relative appropriateness of models using exponential, Weibull, Gompertz, log-logistic, and log-normal distributions.

RESULTS

To investigate the correlates of nuclear weapons proliferation, we estimated a series of models employing each of the three dependent variables in turn.[20] For the hazard models, durations consist of strings of country-years. When a country crosses over the threshold in question for a given model, it exits the risk pool and thus the analysis. A country can, however, reenter the risk pool if it makes a clear and convincing renunciation of its previous nuclear ambitions: at this point, it is again deemed "at risk" and can choose to reignite its interest in nuclear weapons at any time. Sweden, for example, exits the risk pool for exploring nuclear weapons once it starts down that path but later reenters it after completely stopping serious consideration of the nuclear option. Similarly, South Africa actually acquires nuclear weapons but later reenters the risk pool after it destroys them along with all remnants of its program.

Table 2 presents the estimates of the hazard models featuring, in turn, each of the three outcomes of interest: exploring the option, pursuing weapons, and acquiring weapons. Starting with "level 1" proliferation—the decision to explore seriously the nuclear option[21]—as the dependent variable, model 1 reveals that GDP per capita and industrial capacity have strong and significant effects on the hazard rate.[22] The pattern of coefficients on GDP per capita supports the nuclear threshold interpretation of the technological determinism approach: at low levels of GDP, further economic growth steadily increases the likelihood that a country will explore the nuclear option; yet at high levels of development, the effect levels off and, in fact, reverses because very high levels of income are associated with a falling hazard rate.[23] This suggests that at low levels, greater development renders the acquisition of nuclear weapons more feasible, allowing countries to act on their previously latent ambitions. At higher levels of development, those that have not already initiated a program are unlikely to be swayed by the small marginal reduction in opportunity cost arising from further growth. The coefficient on the industrial capacity index indicates the importance of achieving a minimal level of industrial capacity in enabling nuclear weapons development in terms of relative risk ratios.

The next grouping of potential correlates of proliferation focuses on the external security environment. Participation in an ongoing enduring rivalry and the frequency

20. In survival analysis, identifying entry into the risk pool is important. Entry should be defined so that if two subjects have identical time at risk values, the risk they face would be identical if they had the same values on all of the explanatory variables. Given data limitations and the advent of the nuclear era, we set risk onset time zero as 1944 for all countries that were independent sovereign states at that time. For countries that gained their independence at later dates, we use their first year of existence, as identified by the Correlates of War Project (2003), as time zero.

21. We code 24 instances of countries crossing this first-level threshold at some time: Algeria, Argentina, Australia, Brazil, China, France, Iran, Iraq, India, Israel, Libya, North Korea, Pakistan, Romania, Russia/USSR, Sweden, Switzerland, South Africa, South Korea, Taiwan (twice), United Kingdom, United States, and Yugoslavia. See the online appendix for sources: http://falcon.arts.cornell.edu/crw12/.

22. The energy variables are highly collinear with the GDP variables; using either energy or GDP produces similar results.

23. The threshold occurs at about $7,700 per capita income in 1996 U.S. dollars. All else being equal, prior to that level, additional increments of income increase the hazard rate, although by smaller and smaller amounts as the inflection point is approached; after that level, additional increments of income decrease the hazard rate.

TABLE 2
The Correlates of Nuclear Weapons Proliferation

	Dependent Variable		
Independent Variable	*Explore*	*Pursue*	*Acquire*
Technological determinants			
GDP per capita	0.00052$^{.119}$	**0.001**$^{.017}$	0.0002$^{.378}$
	(0.0003)	(0.0004)	(0.0003)
GDP squared	**–3.66e-08**$^{.094}$	**–7.92e-08**$^{.017}$	**–2.36-08**$^{.100}$
	(2.19e-08)	(3.11e-08)	(1.43e-08)
Industrial capacity index	**1.89**$^{.016}$	**1.46**$^{.046}$	**3.19**$^{< .001}$
	(0.78)	(0.73)	(0.91)
External determinants			
Enduring rivalry	**1.57**$^{.002}$	**1.83**$^{.024}$	**2.13**$^{.076}$
	(0.50)	(0.81)	(1.77)
Dispute involvement	**0.17**$^{.010}$	**0.38**$^{< .001}$	**0.23**$^{.070}$
	(0.07)	(0.09)	(0.13)
Alliance	–0.67$^{.260}$	–0.83$^{.194}$	–1.01$^{.225}$
	(0.59)	(0.64)	(0.83)
Internal determinants			
Democracy	0.02$^{.525}$	**0.070**$^{.084}$	0.092$^{.123}$
	(0.038)	(0.038)	(0.059)
Democratization	–0.03$^{.578}$	–0.080$^{.323}$	0.016$^{.895}$
	(0.056)	(0.081)	(0.120)
Percentage of democracies	–0.05$^{.204}$	**–0.186**$^{.007}$	–0.094$^{.351}$
	(0.04)	(0.069)	(0.101)
Economic openness	–0.01$^{.235}$	–0.018$^{.112}$	0.0002$^{.989}$
	(0.01)	(0.012)	(0.015)
Economic liberalization	**–0.037**$^{.030}$	**0.35**$^{.010}$	–0.001$^{.963}$
	(0.017)	(0.014)	(0.018) '
Constant	**–4.66**$^{< .001}$	**–6.34**$^{.016}$	–7.52$^{.022}$
	(1.32)	(2.63)	(3.29)
Ancillary parameter (*p*)	0.55	1.42	1.04
Standard error (*p*)	0.113	0.48	0.36
Log likelihood	–56.12	–28.57	–19.61
Number of countries	149	149	149
Total observations	5,215	5,578	5,784

NOTE: Coefficients are estimates for parametric survival models with a Weibull distribution; robust standard errors, adjusted for clustering by country, are in parentheses. *p* values are superscripted and are for two-sided tests. Coefficients that are significant at better than the 10% level are bold. GDP = gross domestic product.

of militarized disputes over the past 5 years are statistically significant at better than the 1% level and are linked with higher hazard rates. In contrast, the coefficient on the alliance variable is negative, as anticipated, although it falls short of statistical significance, offering little support for the claim that great-power alliances provide threatened states with a substitute for nuclear arms.

The third grouping of explanatory variables taps internal determinants. The democratization and economic liberalization variables measure change over a 5-year period; in addition, variants measuring change over 1-, 3-, and 10-year periods were employed in other models. In addition, tau-b and S variables, proxying for satisfaction, relative to both the global hegemon (the United States) and the regional leader, were investigated in separate models.[24] Democracy or, more precisely, the degree of institutional constraints on executive power, which is what the Polity IV data aim to capture, has a positive coefficient, whereas democratization is negative, although neither approaches statistical significance. In contrast, the trade ratio variable and all variants of the trade liberalization variable are both negative. The liberalization variable crosses conventional thresholds of significance. Finally, level of satisfaction with either the regional or global leader, as proxied by policy affinity, has no discernible effect on propensity to explore nuclear weapons.

Do the same patterns hold not only for decisions to explore the nuclear option but also for the decision to launch a major effort to acquire these weapons? The models reported in the column headed "Pursue" address this question.[25] By and large, the answer is yes. Most of the same variables attain statistical significance, coefficients do not differ much in magnitude, and only one sign—on economic liberalization—flips. Variables suggested by the technological determinism approach still find significance and are of even greater substantive importance. The coefficient on great-power alliance is still not statistically significant by traditional criteria, but the sign remains negative, and the *p* value of .19 is suggestive. Enduring rivalry and dispute involvement are both substantively and statistically significant. Finally, the coefficient on economic openness—in terms of the trade ratio—is once again negative and now features a *p* value of .11, although economic liberalization now takes on a positive sign.

Turning to the final stage, we might expect the determinants of actual decisions to construct or deploy nuclear weapons to differ somewhat from those that shape decisions to explore the possibility.[26] The costs, in economic, security, and political terms, of dallying with the possibility of acquiring nuclear weapons are quite different from those entailed by an explosion or assembly of weapons. Moreover, the reduced number of positive instances makes finding significant results less likely.[27] With these considerations in mind, the final column of Table 2 presents the results of models that

24. The satisfaction variables were left out of models reported in Table 2 because their inclusion causes more than 1,000 observations to be dropped due to missing data.

25. We code 17 examples of countries crossing the level 2 threshold to sustained pursuit of a weapons option: Algeria, Argentina, Brazil, China, France, India (twice), Iran, Iraq, Israel, North Korea, Pakistan, Russia/USSR, South Africa, South Korea, United Kingdom, and United States.

26. The nature of the data and research question lends superficial appeal to ordered logit or bivariate probit models. However, ordered logit models are inappropriate because they do not allow the direction of effect to vary across levels; that is, they do allow for the possibility, for example, that democracy may have negative effects for exploration but positive effects for weaponization. We do explore multinomial logit models in the next section.

27. We code 10 instances of crossing the nuclear threshold. The countries are as follows: United States, Russia/Soviet Union, United Kingdom, France, China, Israel, South Africa, India (twice), and Pakistan. For India and Pakistan, the models reported use dates of first ready-to-assemble weapons (1988 and 1990, respectively) instead of the 1998 tests. Where using the test dates instead of weapons-readiness dates (or any other permutation for other countries) creates a difference from reported results, we note this in footnotes.

explore nuclear weapons acquisition. Sheer level of per capita income plays a somewhat smaller role here, which is not surprising when one recalls the low levels of income at which China, India, Pakistan, and the Soviet Union exploded their first weapons.[28] However, although GDP per capita is somewhat less important than in the preceding models,[29] the industrial capacity index looms large, with a very large coefficient and a vanishingly small *p* value.[30] Even in the face of this strong effect, variables tapping the security environment retain their power. Enduring rivalries are powerful spurs, not just to exploration and development but to testing and deployment as well. This is not surprising when one recalls that of the countries to acquire nuclear weapons, all but two (South Africa and France) are coded as participating in an enduring rivalry at the time of acquisition. By alternate but defensible coding rules, one could make the case that both of these exceptions were involved in enduring rivalries. Frequency of dispute involvement provides a more nuanced indicator because it actually varies over time, even within rivalries, and it proves both statistically and substantively significant once again. Clearly, not just the existence of a rivalry but also the ebb and flow of the hostility level also play an important role in pushing states over the nuclear threshold. Moreover a country with an alliance has a hazard rate that is a fraction of one without a great-power security guarantee, although it falls short of significance. Finally, the battery of internal determinants variables falls below significance in these models. The democracy variable, however, does approach significance in these models and with a positive coefficient.[31] Even controlling for level of income and economic development, countries that score high on the democracy scale are more likely to acquire nuclear weapons. Finally, economic openness loses its significance.[32]

Although many of the variables attain statistical significance, how significant are they substantively in shaping the likelihood that a country explores and acquires nuclear weapons capability? Drawing on relative risk ratios, Table 3 interprets the substantive role played by each variable for decisions to explore and acquire nuclear weapons. The entries represent the percentage change in the baseline hazard rate for a given change in the explanatory variable. For example, a country with a great-power military alliance has a hazard rate for exploring the nuclear option that is 49% lower than a similar country without an alliance, as well as a risk of acquiring weapons that is

28. In 1996 U.S. dollars, the average GDP per capita at which countries exploded/deployed nuclear weapons is $5,275. India, China, Pakistan, and (to a lesser degree) the Soviet Union were all considerably below that average. No country has ever gone nuclear when its GDP per capita was above the $11,000 threshold.

29. If the 1998 test dates are used as alternate codings for India and Pakistan, then GDP per capita and its square are significant at better than the 5% level.

30. Every country to acquire nuclear weapons, with the exception of Pakistan, was above the threshold embodied in the index.

31. When the explosion dates are used as an alternate coding for Pakistan and India, the coefficient on democratization falls below statistical significance.

32. We also ran models asking a slightly different and distinct but related question: given that a country has explored the nuclear option, what determines whether it exercises that option? This greatly reduces the number of durations for study. In our view, this makes it less useful and tractable than the approach followed here but yields some interesting results. Although development and security still play a role, most notable is that trade liberalization remains significant, whereas democracy continues to have no discernible effect. The multinomial logit models reported below allow us to deal with the kinds of issues raised by this multiple-step question, thus complementing the hazard models.

TABLE 3
Substantive Effects of the Explanatory Variables on the Likelihood of Exploring Nuclear Weapons

Variable	Percentage Change from Baseline Hazard Rate	
	Explore	*Acquire*
Great-power military alliance	–49	–64
Participation in ongoing enduring rivalry	+382	+743
Increase in frequency of MIDs (two more/year)	+38	+52
Industrial capacity threshold	+563	+2,340
Increase in trade openness	–72	–2
Increase in per capita GDP—$500 at very low level	+26	+12
Increase in per capita GDP—$500 at high level	–20	–17
Satisfaction	+40	–82
Increase in democracy	+25	+94

NOTE: MID = militarized interstate dispute; GDP = gross domestic product.

54% lower.[33] Even more striking, participation in an enduring rivalry increases the hazard rate nearly fourfold (382%) compared to a country not so engaged, and the effect for the actual acquisition of weapons is even greater (at 743%). Frequency of militarized dispute involvement also produces a powerful effect: increasing the 5-year moving average of the number of disputes per year by two yields a 52% increase in the likelihood that a country will go nuclear. Taken together, these three examples indicate that the security environment has not just a statistically significant but, more important, a substantively significant effect on decisions to explore nuclear weapons acquisition, as realists have long emphasized. Yet, the next four items remind us that economic factors also play a substantial role. Moreover, the process of economic liberalization is associated with a reduced likelihood of exploring nuclear weapons: a country that has expanded its openness by 20 points over the past half decade has a 72% lower hazard rate, although a level of economic openness 20 points higher reduces the predicted hazard of acquiring weapons by only 2%. The level of economic development plays an even larger role, although these effects are nonlinear over the level of GDP per capita. Two examples, chosen to reflect different ends of the spectrum where relatively small changes in per capita GDP yield relatively large effects, illustrate the relationship. At very low levels of GDP, increasing per capita national income by $500 produces a fairly dramatic rise in the hazard rate for exploration, by 26% (and 12% for acquisition).[34] However, once a country is already very wealthy, further increments of income only reduce the hazard; the same increase now yields a

33. In other words, the likelihood that it explores nuclear weapons is about 51% that of a similar country without an alliance.

34. This example corresponds roughly to the change in India's per capita GDP from 1958 to about 1983.

20% drop in the hazard for exploration (and 17% for acquisition).[35] Crossing a minimum industrial threshold greatly increases the likelihood of exploring the nuclear option (an increase of 563%) and has a simply massive effect on the likelihood of actually acquiring weapons.

MULTINOMIAL LOGIT MODELS

To supplement hazard/survival methods, we reestimated the models, using multinomial logistic regressions. Hazard models are very good at dealing with problems of temporal dependence and duration dependence, but they do not allow us to assess the contingent nature of successive steps along the proliferation path: given that a country explores nuclear weapons, how far do they go? Although they are imperfect for our purposes, multinomial logit models are valuable when the dependent variable has several possible outcomes[36] and when explanatory variables may not affect the likelihood of each outcome in the same fashion. Moreover, with multinomial logits, a country does not simply exit the analysis when it crosses a threshold as it does in the hazard models; instead, we can allow it to move up and down different levels across time.

Table 4 presents the results using multinomial regression models. Multinomial logit models estimate the likelihood that the independent variable takes on one of several possible discrete outcomes (in our case, four), given the values of the explanatory variables, with the coefficients representing effects relative to a reference category. Accordingly, we now have three separate coefficients for each variable, one representing the marginal effect of that variable to the likelihood of each of the three outcomes (relative to no interest in nuclear weapons at all, the reference category).[37] In general, the results accord well with those of the hazard models, and many of the variables attain very high levels of significance across all three levels. As in the hazard models, the economic development variables have strong and consistent effects across all three thresholds, and these effects are both substantively and statistically significant. Among the security variables, participation in an enduring rivalry and frequent dispute involvement have strong effects across all three levels, whereas alliance with a nuclear armed power has negative effects on levels 1 and 3 but a much weaker effect at level 2.

Thus far, the results strongly parallel those of the hazard models; however, things change somewhat when we turn to internal determinants. Democracies are again significantly more likely to acquire nuclear weapons, although they appear less likely to

35. This example corresponds roughly to the change in Sweden's per capita GDP from 1968 to 1972.

36. Ordered logit is not appropriate here because of the possibility that variables have different effects across different levels of proliferation. Multinomial logit is a flexible tool that allows us to assess separately the influence of an explanatory variable on both the exploration of nuclear weapons and the subsequent steps up the proliferation ladder.

37. Interpretation of results from multinomial logit models is not straightforward because of their multiple-equation nature. To understand the full direct effect of a variable on, for example, the second outcome, one has to take into account its effect both on the conditional likelihood of that outcome and on other categories. Most of the time, the direction will be the same as indicated by the coefficient, but occasional surprises are possible. Here we are interested mainly in significance levels and compatibility of findings with the hazard models.

TABLE 4
Pathways to Proliferation: Multinomial Logit Models

	Level		
Independent Variable	*1 (Explore)*	*2 (Pursue)*	*3 (Acquire)*
Technological determinism			
GDP per capita	**0.0003**$^{< .001}$	**0.0005**$^{< .001}$	**0.0004**$^{< .001}$
	(0.00005)	(0.0001)	(0.0001)
GDP squared	**–1.55e-08**$^{< .001}$	**–4.36e-08**$^{< .001}$	**–1.00e-08**$^{< .001}$
	(2.73e-09)	(7.86e-09)	(1.80e-09)
Industrial capacity index	**2.88**$^{< .001}$	**2.41**$^{< .001}$	**22.59**$^{< .001}$
	(0.270)	(0.280)	(0.664)
External determinants			
Enduring rivalry	**0.43**$^{.017}$	**0.67**$^{.003}$	**1.61**$^{< .001}$
	(0.179)	(0.221)	(0.240)
Dispute involvement	**0.31**$^{.002}$	**0.77**$^{< .001}$	**0.86**$^{< .001}$
	(0.099)	(0.105)	(0.119)
Alliance	**–1.24**$^{< .001}$	–0.22$^{.205}$	**–1.25**$^{< .001}$
	(0.19)	(0.18)	(0.18)
Internal determinants			
Democracy	**0.020**$^{.073}$	**–0.027**$^{.055}$	**0.029**$^{.018}$
	(0.011)	(0.014)	(0.012)
Democratization	–0.005$^{.790}$	0.003$^{.937}$	–0.023$^{.334}$
	(0.020)	(0.032)	(0.024)
Percentage of democracies	**–0.122**$^{< .001}$	0.017$^{.390}$	**0.036**$^{.066}$
	(0.017)	(0.019)	(0.019)
Economic openness	**–0.028**$^{< .001}$	**–0.012**$^{.001}$	**–0.027**$^{< .001}$
	(0.003)	(0.003)	(0.003)
Economic liberalization	0.002$^{.917}$	–0.007$^{.299}$	0.003$^{.675}$
	(0.009)	(0.007)	(0.007)
Constant	**–1.47**$^{.006}$	**–6.95**$^{< .001}$	**–28.31**$^{< .001}$
	(0.538)	(0.745)	(0.339)

NOTE: Log pseudo-likelihood = –1874; pseudo-R^2 = 0.39; total observations = 6,125. The reference category is no steps to pursue nuclear weapons. Coefficients are estimates for multinomial logit regression models, with robust standard errors in parentheses. *p* values are superscripted and are for two-sided tests. Coefficients that are significant at better than the 10% level are in bold. GDP = gross domestic product.

pursue them seriously (level 2). Economic openness now has a statistically significant negative effect across all three levels of proliferation. Neither democratization nor economic liberalization has any discernible effect in the multinomial logit models; in contrast, the hazard models suggest that economic liberalization dampened the risk of going to level 1. Finally, both satisfaction with the system leader and the percentage of democracies among all states in the system have different effects across different levels. The percentage of democracies is associated with a reduced likelihood of crossing to level 1 but an increased likelihood of reaching level 3.[38] Overall, however, the

38. In models including satisfaction with the regional leader, the S score has a positive but insignificant coefficient for levels 1 and 2; but a strongly negative coefficient for level 3.

multinomial logit models produce results quite similar to the survival models, although offering greater support for variables associated with internal determinants perspectives, enhancing our confidence in the findings.

PUZZLING MISSES

These results suggest that, contrary to what some scholars have argued, existing arguments about the determinants of nuclear weapons proliferation do a reasonable job of accounting for the data. One further way of seeing this is to examine instances when the models miss by a fairly wide margin: that is, which countries *did not* explore the nuclear option, although the models suggest they should have, and which countries *did* explore the option, even though the model produces relatively low predicted hazards.

To this end, Table 5 lists the countries that had a high predicted hazard for several years, yet never (to the best of our knowledge) seriously explored the nuclear option. It is reassuring that the list corresponds with the countries that analysts often identify as puzzling nonproliferators. Saudi Arabia's presence may surprise some, but its combination of a high threat environment, substantial wealth, and minimally sufficient economic and scientific infrastructure make it a likely suspect.[39] Still, our coding of security guarantees is based on formal alliances and thus probably overstates the temptation facing Saudi Arabia. Although it enjoys no formal alliance with the United States, the fact that Saudi Arabia has (at least until recently) a de facto security guarantee was amply demonstrated in 1990 and 1991. In a similar vein, Syria's inclusion may surprise some due to its low level of economic development, but our analyses suggest that its frequent dispute involvement, participation in an enduring rivalry, relatively low economic interdependence, and (barely) adequate level of economic development made it a strong candidate for nuclear weapons proliferation.[40] Japan and Germany's presence comes as no surprise: they are widely seen as powerful, economically developed states facing strong security threats that only foreswore nuclear weapons under duress and with the reassurance of a highly credible American security guarantee.[41] Although lacking the same level of industrial/scientific development, Italy and Spain are similar cases; moreover, rumors of interest in nuclear weapons have swirled around both countries at times.[42] Egypt's challenging security environment provides strong incentives counterbalanced by relatively low levels of economic development. Bulgaria is more of a surprise, but its status as a relatively developed economy on the front lines of the cold war gave it a combination of strong incentives and sufficient

39. Contrary to widely held images, Saudi Arabia produces steel domestically (since 1976, and in fairly large quantities since 1984), has a large and modern electrical-generating capacity (well over the 10,000 MW threshold since 1983), and has a well-educated upper tier of researchers.

40. Indeed, Syria is also a "near miss" in our coding of proliferators. Despite some suggestive evidence, we ultimately decided that there is not enough firm interest in serious or sustained exploration of the nuclear option to code Syria as a level 1 proliferator.

41. Among other economically advanced Western countries not on this list, Finland provides the biggest outlier but is not a surprising miss for fairly obvious reasons.

42. However, the evidence was too slim or the level of interest too ephemeral to warrant coding as level 1 proliferators.

TABLE 5
Dogs That Didn't Bark? Countries That Did Not Seriously Explore the Nuclear Option . . . but Should Have

Country	*Years of Maximum Predicted Hazard*
Saudi Arabia	Mid-1980s to mid-1990s
West Germany	Mid-1950s to early 1960s
Japan	Mid-1950s to 1960s
Turkey	Late 1960s to 2000
Bulgaria	1950s
Spain	1960s to early 1970s
Greece	1960s and 1980s
Italy	1950s to early 1960s
Syria	Various

ability that led to a strong predicted hazard, despite the Soviet alliance.[43] Turkey and Greece are obvious, if not frequently mentioned, possibilities.

If we turn the question around to ask who sought nuclear weapons but should not have, the list is quite short, simply because our model attributes a relatively high hazard to nearly every state that pursued nuclear arms. Libya, Brazil, Algeria, and Pakistan had relatively low predicted hazards at the time they began seriously exploring the nuclear option. Of these, Algeria and Libya provide perhaps the biggest surprise because both feature relatively infrequent (though not inconsequential) MID involvement with a moderate to low level of economic development, rendering them somewhat unlikely proliferators.[44] Pakistan is primarily a surprise because of the remarkably low level of economic development at which it began exploring the nuclear option, and to this day, it stands out as the least developed country to pursue and acquire nuclear arms.[45] Brazil provides another minor surprise; although its relationship with Argentina often rendered its security environment less than benign, it has not faced a high-intensity threat environment compared to most other proliferators. Argentina, by contrast, does not appear as an outlier because of its more perilous security situation (tensions with Chile as well as Brazil, not to mention the United Kingdom) and higher level of economic development. Interestingly, the "Australian surprise" (Walsh 1997) is not much of a surprise to our model, which predicts a comparatively high hazard for Australia in the 1950s and 1960s, precisely when it secretly pursued the atomic option.

43. Ties to the Soviet Union were not sufficient to render a country immune from the nuclear temptation, as Romania's flirtation with indigenous nuclear arms in the 1980s indicates.

44. However, it is worth noting that both also share a number of unresolved border disputes.

45. China's per capita GDP, in 1996 U.S. dollars at purchasing-power parity exchange rates, was lower, but it had a large domestic steel industry and a much more extensive electricity industry than did Pakistan.

ROBUSTNESS CHECKS

Special attention to the robustness of the estimates of the coefficients and their variances is warranted because of the relatively small number of proliferators and due to disagreements about coding of the dependent variables for several countries. To assess the influence of particular countries, we ran a series of models sequentially, deleting in turn each case that features a positive outcome on the dependent variable. This procedure revealed no strongly influential cases, although a few slight sensitivities are worth noting. Deleting China and/or India strengthens the importance of economic development variables, whose estimated effects are clearly attenuated by the (successful) efforts of two of the world's poorer countries to develop nuclear weapons. Finally, omitting India and/or Pakistan elides the effect of the enduring rivalry variable somewhat.

Our second robustness check was to experiment with alternate coding of the dependent variables for countries where there is some disagreement among sources about the timing of key events and decisions. Although for most countries, there is surprising convergence from credible sources on factual accounts and assessments, some codings are based on more divergent and difficult-to-reconcile sources and evaluations, forcing us to make a judgment call. North Korea provides an extreme case, with both its decisions to explore nuclear options and dates of first serious efforts at a weapons program shrouded in secrecy and controversy. Iran provides another example; although there is broad agreement within a 5- or 10-year range, choosing a precise year for program initiation is more controversial. In these cases, we created alternate versions of the dependent variables, using years across the temporal range of estimates in turn. Running dozens of models based on these variants reveals that the results are not sensitive to codings that differ by up to 10 years for the contentious cases.

CONCLUSION

Fears of rogue states, withdrawal of cold war–era security guarantees, a falling technological threshold, and concerns that new nuclear powers will provide weapons to terrorists all ensure that nuclear weapons proliferation remains a central security issue and that developing an adequate understanding of the correlates of proliferation ranks high on the agenda of international relations scholars. Yet, although scholars have offered an abundance of explanations for proliferation decisions, little consensus exists on the adequacy of various theories or whether we even possess a theory of nuclear proliferation (Ogilvie-White 1996). We argue that this unsatisfactory state of affairs derives at least partly from a mismatch between theoretical arguments, which tend to make probabilistic claims and envision multiple causal variables, and the predominant empirical methodology in the area, which tends toward case studies that implicitly apply deterministic standards based on an (often implicit) univariate logic of inference and samples on the dependent variable. Seeking to complement existing research, we constructed a new data set on nuclear weapons proliferation and used hazard models to test theories of nuclear proliferation. The data analysis suggests that existing theories deserve more credit than they are frequently given: nuclear weapons proliferation is reasonably well accounted for by the level of economic development and the external threat environment.

Although the inevitable uncertainty entailed in coding cases of nuclear weapons proliferation makes us cautious about drawing sweeping conclusions, the findings clearly suggest several implications for policy and future research. Starting with policy, one of our more surprising findings offers some, albeit limited, support for the emphasis placed on economic interdependence and (less so) liberalization in recent work on proliferation (Paul 2000; Solingen 1994, 1998). This empirical link between involvement in the world economy and nuclear abstinence seems to bolster the case of those arguing for a strategy aimed at tying down potentially troublesome states in a mutually beneficial web of economic interdependence. Yet the causal linkage remains somewhat opaque and unpersuasive: the direct economic costs and foregone economic opportunities of pursuing or even acquiring nuclear weapons do not seem prohibitive, as the relatively mild and short-lived sanctions levied against India and Pakistan demonstrate. Adding nonproliferation to the list of putative benefits of economic integration is premature without firmer theoretical and empirical knowledge about the causal mechanism that produces this relationship. Parsing out this linkage both theoretically and empirically thus poses an important task for future research and points to the possibility of synergies between qualitative and quantitative methods in exploring this relationship.

Our findings about the centrality of perceived threats in proliferation decisions have implications for debates about the proposed U.S. national missile defense program (NMD). Whether NMD fans or dampens the fires of proliferation depends largely on how other states perceive it. If a U.S. missile defense is viewed as an implicit security guarantee by countries under its umbrella, then it should function like an alliance, substituting for home-grown security measures and reducing the incentive to acquire nuclear arms as a deterrent. However, if some states view NMD as threatening because it neutralizes their own nuclear deterrents or allows the United States to intervene wherever it chooses with virtual impunity, then it may spur them to acquire larger nuclear arsenals, rush to acquire nuclear weapons before a defense can be deployed, or develop alternative delivery systems. As Paul (2000) has persuasively argued, when it comes to nuclear weapons, the security dilemma seems to operate with a vengeance because attempts by rivals to bolster nuclear arsenals or build defense are often viewed with great alarm and met with forceful responses. The question of the influence of NMD on proliferation may thus be one of net effect: states under its umbrella face reduced incentives to acquire their own deterrents, whereas states outside its reach are likely to feel their security reduced and face heightened incentives to bolster or assemble nuclear arsenals.

These findings also offer considerable support for the commonsense theory of nuclear proliferation, in which states go nuclear "when they face a significant military threat to their security that cannot be met through other means" (Sagan 2000). In fact, there are no cases of the determined pursuit of nuclear weapons by countries not experiencing a subjectively threatening security environment. Given this fact, one has to question the wisdom of policies aimed at countering proliferation that may well increase the subjective insecurity of incipient proliferators. To be sure, one would not want to reward proliferation by lavishing resources on countries that pursue nuclear weapons, yet nothing in our analysis suggests that policies that produce a higher level of security threat can be anything but counterproductive to the aim of discouraging the pursuit of nuclear weapons. Policies aimed at a graduated reduction of threat would seem to be more productive. A straightforward reading of our results suggests that actions aimed at the following would reduce a country's temptation to pursue nuclear arms: reduce the threat posed by its external environment, accelerate economic growth so that it moves well beyond the threshold of temptation and onto the decreasing hazard portion of the relationship between development and risks of proliferation, encourage integration into the world economy, and encourage a defensive alliance with a great power. Arguably, current American policies toward proliferators have exactly the opposite effects. In the context of our model, they would probably result in an increasing predicted hazard rate.

Although we have filled one lacuna in the proliferation literature by providing a contemporary quantitative test, we have not explored interaction effects between variables or various causal combinations of variables. As always in the social sciences, many arguments in the proliferation literature are implicitly or potentially conditional. One can easily imagine that the effects of an enduring rivalry might be dampened by the presence of a great-power alliance, that the effects of economic interdependence might rest conditional on regime type, or that democratization spurs aggressive nationalism (and thus potential proliferation) only in the context of an enduring rivalry. In a similar vein, we have ignored the decision of states to give up nuclear weapons (Ukraine, for example, is not included in our analysis) or to abandon programs short of weaponization. However, any comprehensive theory of proliferation must account for decisions both to pursue weapons and to abandon them (Goldstein 1993). Two-way transition models can help investigate this additional nuance of the proliferation puzzle. Thus, although we have broken new ground in bringing state-of-the-art statistical methods and new data to bear on proliferation research, we have just opened the toolbox: exploring interactions, conditional relationships, and two-way transition models are additional tools that must be brought out of the box in the future.

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