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Climbing the Ladder: Explaining the Vertical Proliferation of Cruise Missiles

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Abstract

Why do some states possess more advanced military technologies than others? Our study explores the vertical proliferation of land-attack cruise missiles (LACMs), seeking to understand which demand- and supply-side factors best explain why some countries acquire more sophisticated LACMs. We theorize that states' security environments, regime types, possession of related strategic technologies, and membership in the Missile Technology Control Regime (MTCR) influence the possession of more sophisticated cruise missiles. Our analysis employs a unique new global dataset with granular data on every LACM national militaries have deployed. We use this dataset to evaluate the proliferation of LACMs across the international system from 1991–2015. Using a selection model that first controls for the horizontal proliferation of LACMs, we find that insecurity, scientific and technical expertise from related technologies, the possession of highly authoritarian and highly democratic regimes, and MTCR membership all have positive effects on the sophistication of LACM-possessors' arsenals.

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Introduction

What explains why some countries field more sophisticated military technologies than others?[1] Much of the literature on proliferation focuses on the horizontal proliferation of military capabilities, such as the spread of nuclear weapons or uninhabited aerial vehicles (e.g., Singh and Way 2004; Gartzke and Jo 2007; Fuhrmann and Horowitz 2017), as opposed to the vertical proliferation of military technologies, understood as the development of more sophisticated arsenals of a particular technology. While scholars have explored the number of nuclear delivery platforms states (Gartzke, Kaplow, and Mehta 2014; Terry and Cone 2020) and countries' aircraft capabilities (Saunders and Souva 2020a), much remains to be understood about what drives states to pursue more advanced military technologies.

This study explores why some countries have made more advancements in the sophistication of their land-attack cruise missile (LACMs) weapons systems. Cruise missiles have evolved from the slow, inaccurate, and largely ineffective versions used by Nazi Germany in World War II to become precise, lethal, supersonic weapons that project power for both tactical and strategic purposes. We advance the literature on the proliferation of military technology by explaining not only which countries obtain cruise missiles but also the factors that determine how sophisticated their LACM arsenals grow to become.

The proliferation of cruise missiles represents a salient issue for international security scholarship. Cruise missiles are an important element of short- and long-range conventional strike, giving countries the capacity to strike far beyond their national borders and the weapons platforms that launch them (i.e., planes and ships). Cruise missiles can also help states defend themselves, because being targeted by cruise missiles can complicate adversaries' efforts to project power (such as threatening aircraft carriers), making them potential weapons that influence the relative ability of major powers to succeed in executing coercion. Cruise missiles also have tactical utility on the battlefield, whether as precision strike weapons in offensive attacks or barrages in broader conventional campaigns. Finally, some cruise missiles have the capacity to deliver weapons of mass destruction (WMD). Technological sophistication accentuates the military capacity of cruise missiles. More sophisticated cruise missiles can travel farther, hit targets more precisely, and better avoid detection and countermeasures. States that invest in acquiring advanced cruise missile capabilities thus gain security advantages vis-à-vis other states, improving their performance in military operations and in enabling them to strike targets at a distance without having to first defeat their adversaries on the battlefield. Some U.S. policymakers have argued, for example, that recent advances made by Russia and China in developing hypersonic cruise missiles significantly imperil U.S. military forces and threaten strategic stability (Barnes and Sanger 2019). Cruise missiles are thus on the forefront of the military technologies defining states' modern military competition with one another.

Acquiring LACMs can also pay returns for states' security interests. Iran, a growing LACM power, has sought to maximize both the tactical and strategic capabilities of LACMs through strikes against Saudi Arabia and proliferating them to allied forces. Iranian cruise missiles have been used by Iran and its Houthi proxies in Yemen to strike Saudi oil facilities and other strategic sites (Iran Primer 2020). Allied groups from the Houthis, to Hezbollah, to militias in Iraq continue to benefit from an influx of Iranian produced LACMs, greatly increasing their military power (Katzman 2020). These factors make studying cruise missile proliferation an important topic for international relations.

The existing literature provides only limited guidance on the factors that drive the proliferation of cruise missiles (Betts 1981; Carus 1992; Gormley 2008). Gormley (2008) provides a strong descriptive overview of the factors that have contributed to cruise missile proliferation, but his analysis does not systematically evaluate a full range of explanations for the processes driving cruise missile proliferation (see also Gormley et al. 2014). Even within the policy community, cruise missile proliferation has often been overlooked. For example, the Missile Technology Control Regime (MTCR), an international export control regime, focused almost exclusively on ballistic missiles for many years and neglected the spread of cruise missiles (Mistry 2003). It was only in the early 2000s—15 years after the regime's creation—that the MTCR began to seriously address cruise missile proliferation threats by expressing concerns about cruise missile exports. Even so, the MTCR's focus on longer-range missiles (with ranges greater than 300 km) leaves even regime members with broad leeway in exporting many cruise missile systems and their associated advanced technological capabilities.

We seek to understand the myriad of factors that influence why some states obtain more sophisticated LACMs than their peers. That states have an interest in and invest in obtaining increasingly sophisticated cruise missile systems is well understood. The pace at which cruise missile technology advances and why some states lead while others follow, however, is not. We draw on several of the most prominent arguments from the international relations literature on the proliferation of military technologies to evaluate whether they can explain the vertical proliferation of LACMs. Our analysis explores the role the states' security environments, regime types, and the possession of related strategic technologies, such as ballistic missiles and nuclear capabilities, have on the sophistication of their LACMs. We also explore the role played by the MTCR in affecting the vertical proliferation of cruise missiles.

We test our hypotheses about vertical proliferation of LACMs with a quantitative analysis from 1991–2015 using the new National Cruise Missile (NCM) dataset.[2] Our study focuses on the post-Cold War era, given that it is when the lion's share of LACM proliferation has taken place and due to the rapid pace of advancements that has occurred. The NCM dataset we employ comprehensively lists all of the cruise missiles that states possess in their arsenals. It codes detailed information on LACMs' various attributes, including navigation systems, accuracy, range, cruising speed, payload, capacity for evasive maneuvers, terminal altitude, and terminal velocity. We use these attributes to construct a variable called the Cruise Missile Sophistication Score (CMSS) that provides a metric for comparing how advanced individual cruise missile systems are (Fahrenkopf 2018). The CMSS allows us to evaluate the factors that help explain variation in terms of the most sophisticated LACMs that states possess. Using both regression and selection models that allow us to account for the factors that first contribute to the horizontal proliferation of LACMs, we find strong evidence for our hypotheses about what determines the sophistication-level of states' LACMs. Our results show that the level of conflict experienced by states positively influences the sophistication of their LACMs. We also find that highly authoritarian and highly democratic governments tend to possess more sophisticated LACMs than anocracies. Countries' level of economic development and their possession of advanced ballistic missile capabilities positively contribute to LACM sophistication. Lastly, the results demonstrate that membership in the MTCR—which ostensibly exists to curb the horizontal proliferation of missiles—is strongly correlated with states' possession of more sophisticated LACMs.

Our findings offer new insights into how military technology proliferates vertically within the international system, helping to explain one of the foundational sources of international power. Whereas military power is central to many theories of international politics (e.g., Jervis 1978; Waltz 1971; Mearsheimer 2001), operationalizing how much of it states have has proven challenging to do with anything more than blunt indicators (Singer, Bremer, Stuckly 1972; Beckley 2018). Lobell (2018) argues, for example, that theories of balancing need to be more "targeted" in understanding which aspects of national military power states focus on. Future work can build off our study to gain more nuanced insights into how the distribution of military specific capabilities can contribute to interstate balancing. The ability to strike targets from a significant distance constitutes an important dimension of military power that shapes states conflict behavior (Schelling 1966; Mettler and Reiter 2013). Our study provides valuable insights into which factors empower and motivate states to invest in increasingly sophisticated power projection capabilities (see Fuhrmann and Horowitz 2017). Lastly, our findings can also provide policymakers with insights into understanding which states are most inclined to pursue more advanced cruise missile capabilities.

Why Cruise Missiles Matter for the International Security Environment

Since Germany employed the first cruise missile system during WWII, cruise missiles have spread widely throughout the international system. As of 2015, 34 countries possessed at least one variant of LACMs—doubling the number of states possessing them since 2007. Moreover, cruise missiles have grown substantially more sophisticated over the years. The proliferation of cruise missiles represents an enduring and growing security challenge (Betts 1981; Gormley 2008 and 2014).[3] Recent great power competition over hypersonic cruise missiles is only the most recent iteration of states' efforts at gaining a technological advantage over one another in this realm.

Existing research on the proliferation and diffusion of military technology, from nuclear weapons (Singh and Way 2004; Gartzke and Jo 2007; Gheorghe 2019; Mehta and Whitlark 2021) to unmanned aerial vehicles (Fuhrmann and Horowitz 2017) and battleships (Horowitz 2010) suggests that several factors may shape the probability that countries acquire new military technologies, or acquire more advanced versions of technologies, including security threats, domestic politics, and technical capacity.[4] To what extent are those factors generalizable to cruise missiles versus particular to those weapon systems?

Cruise missiles are versatile weapons systems that remain relatively affordable. They are one-time-use systems that rely on aerodynamic flight to deliver a payload to a target. Rather than following high-altitude, elliptical trajectories to their targets like ballistic missiles, cruise missiles employ horizontal, low-altitude flight patterns and remain self-guided and self-propelled all the way to their targets. Cruise missiles tend to be cheaper and easier to operate than ballistic missiles, giving them utility in a wide variety of military operations. The main attributes that make cruise missiles attractive weapons systems for many states include a track record of proven use, their affordability, their accuracy, and their ability to penetrate many missile defense systems (Feickert 2005: 3–4; Gormley 2008). Betts (1981: 6) argues that "The appeal of the cruise missile is its potential *combination* of high quality and quantity, with emphasis on the latter… the cruise missile's adaptability may make it better than other systems for rapid modernization of forces." Cruise missiles are versatile weapons systems that can accomplish a wide range of tactical and strategic objectives and can be launched from a wide variety of weapons platforms.

Given that cruise missiles are self-guided during flight, their navigation systems have always been a critical component of their design, making them amenable to improvements over time. More sophisticated navigation systems provide two major advantages: increasing their accuracy and survivability to reach their targets. Improved navigation systems provide cruise missiles with greater precision in reaching their intended targets before detonating their payloads. Improved navigation systems also allow cruise missiles to follow more efficient, stealthier flight paths (i.e., low altitude) and allow them to take a broader range of evasive maneuvers to ensure that they reach their targets without being destroyed. Investing in more sophisticated navigation technologies can dramatically increase the reliability and lethality of cruise missiles.

The investments that countries make in navigation systems also affect the operational range of their cruise missile systems. Cruise missile propulsion systems that extend range can also enhance their operational utility. Cruise missiles that possess greater ranges can strike distant targets while reducing the risk that a country's military personnel face. Versatility in the platforms that can be used to launch cruise missiles can also greatly affect their overarching range. For example, air-launched cruise missiles can be flown part of the way to their targets by plane before having to rely on their own propulsion systems. Substantial incentives thus exist for countries to invest in acquiring more sophisticated variants of cruise missiles to gain their benefits.

Cruise missiles have proliferated much more widely than ballistic missiles because there is a very active export market for these weapons systems, particularly for anti-ship cruise missiles. Many cruise missile variants also fall beneath MTCR restrictions or can be engineered to do so at the time of sale even if their ranges can readily be enhanced by customers later. The United States, France, China, and Russia, for example, have all been active exporters of anti-ship cruise missiles. Cruise missile systems have an additional advantage in that they are far cheaper for countries to purchase and reverse engineer than ballistic missiles (Dickey 2003: 156–157). According to estimates in 2002, a country could purchase 100 cruise missiles for the same price it would take to purchase 15 ballistic missiles and their launch platforms (Herbert 2002: 43). Given the competitive export market, defense manufacturers have incentives to continue innovating with the development of improved cruise missile systems. In Betts' (1981) view, the cost-effectiveness and flexibility in how militaries can use cruise missiles is a large part of why states have sought to acquire more sophisticated variants of cruise missiles.

At present, there is limited research on missile proliferation in general, and especially cruise missile proliferation. Barkely (2008), for example, found that regional arms race dynamics played a key role in motivating states to acquire ballistic missiles. Mettler and Reiter (2013) also find evidence of regional arms race dynamics, in addition to finding that states' level of economic development and whether they possess nuclear weapons increase their likelihood of possessing ballistic missiles. Research on both the horizontal and vertical diffusion of this military technology has been limited both by a lack of systematic theorizing about states' incentives to acquire cruise missiles and at what level of sophistication and the absence of detailed data on national cruise missile capabilities. We now address both issues.

Understanding the Vertical Proliferation of Military Technology

Our study's primary goal is to identify the factors that influence the sophistication of states' LACM arsenals, which we consider an important form of vertical proliferation. This differentiates our study from those that only analyze the horizontal proliferation of military technologies to new possessors. Our analysis takes into consideration, however, that accounting for which states obtain LACMs is important for understanding the ones that acquire the most sophisticated versions of the technology.

Previous works have emphasized that while the ability to purchase cruise missiles has given countries enhanced access to the missiles, states still require a reasonable degree of technological prowess to produce missiles and get more sophisticated missiles. Carus (1992) is more optimistic about the ability of countries in the developing world to master the technology associated with cruise missiles. He also argues that "[t]he technology needed to produce a cruise missile capable of reaching 1000 km is not inherently different from that required to produce a system with a arrange of only

150 km" (Carus 1992: 93). In contrast, Gormley (2008: 91–96) argues that highly specialized knowledge is required to make cruise missiles effective weapons systems. Gormley documents, for example, the challenges faced by Iraqi engineers in seeking to use reverse-engineering to create a longer-range LACM for its arsenals. He concludes that "Iraq's struggle with both cruise missile programs and manned aircraft conversion to RPVs [remotely piloted vehicles] stemmed largely from inadequacies in specialized know-how, not a shortage of component technology" (Gormley 2008: 96). These contrasting views suggest that much remains unclear about the role technological barriers play in shaping the proliferation of cruise missiles.

States that face a threatening or unstable external environment have powerful incentives to build up their armed forces and to acquire new or more sophisticated weapons systems. States arm when they have important conflicts of interest with other states and cannot completely observe the degree to which these rivals have invested in their military forces (Baliga and Sjöström 2008; Debs and Monteiro 2014; Meirowitz and Sartori 2008). Gartzke and Jo (2007), for example, find that conventional threats—defined as the relative power of rival states—increase the likelihood that a state will pursue nuclear weapons capability and will deploy nuclear weapons. A threatening environment also creates incentives to develop more capable and technologically sophisticated weapons systems. Gartzke, Kaplow, and Mehta (2014) find that the existence of rival states with nuclear weapons leads to an increase in the diversification of nuclear platforms, while Sechser and Saunders (2010) conclude that strategic threats shape the degree to which states invest in the mechanization of their militaries. We hypothesize that external threats also create incentives for states to invest developing more sophisticated cruise missile capabilities. External threats create incentives to increase military capabilities, such as through the acquisition of increasingly sophisticated LACMs. More advanced cruise missiles can deliver a payload over longer distances. Their guidance systems permit them to attack specific targets, such as an opposing state's naval vessels, military bases, or missile sites. This makes them suitable for both deterring attacks and for launching pre-emptive attacks against threatening rivals. The fact that sophisticated cruise missiles fly at high speeds, can take evasive maneuvers in flight, and fly low to the ground when approaching targets means that they are less vulnerable to interception than manned platforms such as bombers. The absence of an onboard crew also means that advanced cruise missiles do not require force protection while in flight. As such, cruise missiles with more sophisticated capabilities can effectively counter a potential opponent's material superiority in terms of military personnel and equipment.

> **Hypothesis 1:** State involvement in international conflict should increase cruise missile sophistication.

States' investments in advanced cruise missiles are also influenced by the broader portfolio of related strategic capabilities they possess. Possession of other types of long-range missiles or complementary weapons systems may increase states' ability to develop more sophisticated cruise missiles. This seems particularly likely for nuclear weapons and ballistic missiles. Some advanced cruise missiles can carry nuclear weapons, creating an alternative to the use of bombers and ballistic missiles as delivery systems. Some states with nuclear weapons seek to diversify their delivery platforms to ensure their survivability (Gartzke, Kaplow, and Mehta, 2014). LACMs can serve this objective as they are less vulnerable to anti-missile systems designed to counter ballistic missiles and can have advanced capabilities that allow them to avoid other forms of interception.

As has been found with respect to ballistic missiles, space launch capabilities, and nuclear proliferation (Early 2014; Early and Way 2017), experience researching and developing strategic technologies in one sector can lead to positive spillover in the development of capabilities in related sectors. States with long-range ballistic missiles have expertise developing and using guidance systems, aeronautical designs, and other elements that are similar across the two weapons systems. This includes scientific knowledge, a skilled workforce in the aerospace sector, and equipment than can be utilized for cruise missile development at a lower cost than is the case in countries without these capabilities. States that have advanced ballistic missiles programs also have a broader research infrastructure and testing facilities that can be leveraged in developing more advanced cruise missiles. Notably, almost all countries that have acquired long-range versions of ballistic missiles have done so via indigenous programs. With respect to nuclear weapons possessors, the convergent research and development infrastructure needed to create delivery systems for nuclear weapons could also motivate and enable governments to acquire more sophisticated cruise missiles. More broadly, research suggests that the overarching scientific and military industrial complexes developed by states to support nuclear and military rocketry programs can positively support one another (Early and Way 2017). Possessing scientific and technical knowledge and more advanced capabilities in related strategic technologies should thus enhance states' ability and interest in developing increasingly sophisticated cruise missiles.

> **Hypothesis 2:** Possessing greater capabilities and scientific and technical knowledge in related weapons systems (nuclear weapons and ballistic missiles) will positively contribute to states' cruise missile sophistication.

Regime type may also play a role in explaining cruise missile proliferation. Democratic states may have interest in pursuing capital-intensive solutions to military problems (Caverley 2009). Facing the loss of public support in wars where there are lots of casualties (Mueller 1971), democracies may favor the development of stand-off weapons that help them decrease the risks to their soldiers (Walsh and Schulzke, 2018). Cruise missiles, and especially longer range, more advanced missiles, may therefore be attractive for democratic states. The ability to launch these weapons and stand off from the conflict goes beyond the basic logic of democratic interest in capital-intensive militaries. Cruise missiles may therefore differ from tanks and fighter aircraft, which

Sechser and Saunders (2010) find democracies are not more likely to acquire. The experience of the United States may illustrate the potential democratic logic of cruise missile acquisition. From strikes in 1988 against a potential hideout of Osama bin Laden to the use of cruise missiles against Syria during the Trump administration, the United States has often turned to the use of cruise missiles when it needs to project power but does not want to put troops at risk. The success of open, democratic systems at producing technological innovation could also assist democracies in developing more sophisticated versions of LACM systems.

Alternatively, more autocratic states should have their own logic of cruise missile acquisition. Some research finds that personalist regimes are more likely to pursue nuclear weapons (Way and Weeks 2014), and to the extent that cruise missiles are potential delivery vehicles for nuclear weapons, they could be attractive for autocratic regimes as well. Moreover, autocracies, almost by definition, have low levels of trust in their militaries, because they have to protect against coups (Pilster and Böhmelt, 2011; Sudduth 2017). Autocratic leaders worry about powerful military leaders turning the elements of national power against them, especially when they involve large concentrations of highly trained troops (meaning this applies even when coup proofing does not undermine the capabilities of autocratic militaries, see Talmdage 2015). By reducing the need to rely on troops in the field, or armored troops with access to tanks and other vehicles that can easily be turned against the regime, autocratic regimes can use cruise missiles to centralize, relatively, their control over the use of military force.

Therefore, we expect a curvilinear relationship between regime type and the acquisition of cruise missiles, leading to our next hypothesis:

> **Hypothesis 3:** Both democracies and autocracies should be more likely to acquire more sophisticated cruise missiles than mixed regimes.

Another factor that could influence cruise missile proliferation is membership in the MTCR, the arms control regime that regulates the spread of cruise missiles. The MTCR is an export cartel founded in 1987 to limit the spread of missiles that could deliver weapons of mass destruction. Member states make commitments to restrict their missile exports. Previous studies have come to contrasting views about the role played by the MTCR in restricting the proliferation of ballistic missiles. Whereas Mistry (2003) concludes that the MTCR has played a valuable—but imperfect—role in preventing the proliferation of advanced missile systems, Mettler and Reiter's (2013) global analysis did not reveal any evidence that the MTCR had a significant impact on preventing ballistic missile proliferation. It is not clear whether similar or different dynamics affect cruise missile proliferation. The MTCR focused far more strongly on preventing the proliferation of ballistic missiles than cruise missiles for the first 15–20 years of its existence (McMahon and Gormley 2008). Given differences in their costs, capabilities, and the factors affecting how difficult they are to acquire, the attributes and incentives of the states that seek to acquire cruise missiles may be different than those seeking ballistic missiles—although there is likely to be overlap (McMahon and Gormley 2008: 1).

MTCR membership could make countries more capable of acquiring cruise missiles for two reasons—one a negative mechanism and one a positive mechanism. MTCR member states must commit to stringent rules concerning the export of advanced missile systems, especially aerospace weapons defined as Category I systems that can travel more than 300 km with a payload of 500 kg. MTCR member states are bound to impose a strong presumption of denial on exports of Category I systems. To the extent the MTCR succeeds, it should make longer range, more sophisticated missile proliferation to MTCR non-members less likely.

Second, to the extent that exports of systems or constituent technologies that meet MTCR thresholds (such as those listed in the MTCR's "Category II" Annex) occur, they should be more likely with partners the supplier can trust not to re-export the system or technology to a potentially dangerous actor. Thus, being part of the MTCR should relatively increase the probability that a state can acquire advanced cruise missiles or the technologies needed to produce them. Moreover, to the extent that MTCR member states may already possess advanced missile-related research and production capabilities to begin with, those capabilities should make them more capable of producing advanced cruise missiles themselves.

> **Hypothesis 4:** MTCR member states should be more likely to acquire more sophisticated cruise missiles.

Research Design

To evaluate our theoretical claims about factors that drive the vertical proliferation of cruise missile technology, we analyze how countries' cruise missile arsenals have grown more sophisticated from 1991–2015. During this period, cruise missiles became more widely available in the international system.[5] The ability to place cheap GPS guidance on what were originally anti-ship missiles, giving them a basic, yet reliable, land-attack capability, accelerated LACM proliferation. Anti-ship cruise missiles, such as the Ottomat Mk2 block 4, MM-40-3 Exocet, Naval Strike Missile, and RGM-84L Harpoon Block II, became new variants of land-attack cruise missiles. Though these weapons lack some of the survivability and advanced guidance capabilities of their more focused counterparts, they still have land-attack capabilities. Trends in the horizontal proliferation of LACMs are thus also linked to what we observe in terms of differences in their sophistication. To fully account for the sophistication of states' LACMs, we thus think it is also necessary to account for why they possess any form of the missile system.

Our time-series cross-sectional analysis allows us to evaluate why some countries possess more sophisticated LACMs in their arsenals than their peers. Given that we want to understand why countries acquire more sophisticated missile technologies, we focus on analyzing the determinants of the most sophisticated LACM systems states possess.[6] While we estimate our vertical proliferation model with OLS with panel corrected standard errors (PCSEs) as a reference point, our main analysis uses a Heckman Selection Model (Heckman 1979) that also accounts for the factors that influence whether countries possess LACMs. Our selection model first estimates the determinants of horizontal cruise missile proliferation before analyzing the factors that explain the vertical proliferation of LACM sophistication.

Our two-step analysis accounts for what are often interrelated yet distinct factors that contribute to acquisition of LACMs versus the sophistication of states' LACM arsenals. For example, security considerations likely play a role in both the acquisition and the sophistication of LACMs. The intensity of security concerns itself may play a distinct role in a state being either content with any LACM capability (horizontal proliferation) or being driven to acquire advanced LACMs that have greater strategic and/or tactical utility (vertical proliferation). While our selection model accounts for the fact that similar factors could be driving both the horizontal and vertical proliferation of cruise missiles, we expect that supply-side factors will play a larger role in shaping vertical proliferation. Highly sophisticated LACMs are not readily available to most countries for affordable purchase. States that cannot leverage such exports will need to rely on domestic production, which presents even greater supply-side obstacles—particularly those related to obtaining scientific and technical knowledge in the aerospace sector. Accounting for the factors that select countries into the pool of LACM possessors will allow our analyses to isolate the distinct effects our hypothesized variables have on determining which states pursue increasingly sophisticated LACM variants.

Coding the Dependent Variable

To capture the vertical proliferation of cruise missile technology, we employ the Cruise Missile Sophistication Score (CMSS) that ranks land-attack cruise missiles based on their technological capabilities using data from the NCM dataset (also, see: Fahrenkopf 2018). The NCM defines a cruise missile as "an unmanned, self-propelled, vehicle that sustains flight through the use of aerodynamic lift over most of its flight" (Carus 1992, 7–9).[7] The unit of analysis in the CMSS is the country-year. For each observation, we first record if the state possessed LACM or not. We use this variable to measure horizontal proliferation. The CMSS breaks down numerous identifiable technological capabilities that make LACMs more sophisticated and deadlier. The sophistication score, which we use to measure vertical proliferation, is not meant to provide a systems-level measure of the overall potency of individual missile systems, such as the combination of particular engine designs, radar guidance techniques, aerodynamics, and radar cross-sections. Such data would be technically challenging to produce and nearly impossible to acquire. Instead, the CMSS paints an essential portrait of how sophisticated individual missiles are based on their ability to marshal certain capabilities that have been found to play a role in making missiles more effective and technically challenging to produce.[8]

Table 1. Cruise Missile Sophistication Score Points.

First tier technologies (+1 Points)
Air launchable Submarine launchable Greater than 200-Kilogram payload
Second tier technologies (+2 points)
TerCoM terrain contour matching Electro-optical systems Imaging infrared guidance
Third tier technologies (+3 points)
Global positioning system (GPS) navigation Terrain hugging flight capabilities
Fourth tier technologies (+4 points)
Stealth Supersonic Digital scene matching area correlator (DSMAC)
Variable tier (+1 per level)
Range in kilometers (200+/500+/1000+)

Based on the technologies we identified, the CMSS has a possible range of 1–30. We operationalize the CMSS by identifying 12 distinct technological dimensions listed in Table 1. Drawing on our technical understanding of cruise missile technologies and the major advances that have contributed to significant increases in their sophistication, we have assigned points to each of the 12 technological dimensions we grade. Some of these measures are independent of one another, like the size of payload and whether the cruise missiles have stealth capabilities. Other categories, like the navigation systems employed by cruise missiles, have progressed over time. In those cases, the individual missile systems are coded by which specific navigation system they employ. Acknowledging that our scoring methodology only provides a proxy for individual cruise missile systems' sophistication, it should provide a way to assess the sophistication of the various cruise missiles possessed by states. We use this scoring system to rank the land-attack cruise missile systems possessed by states in their arsenals, and then code the CMSS of the most sophisticated missile in their arsenal as our dependent variable. We provide more detailed information on coding the CMSS in the Appendix.

Here is an example of how our scoring method works in practice. Built and introduced by Raytheon in 2004, the Tomahawk (TLAM-E) Block IV is one of the most advanced LACMs ever developed (U.S. Navy 2018). The TLAM-E boasts many of the same capabilities as previous variants such as, TerCoM, GPS and DSMAC guidance,

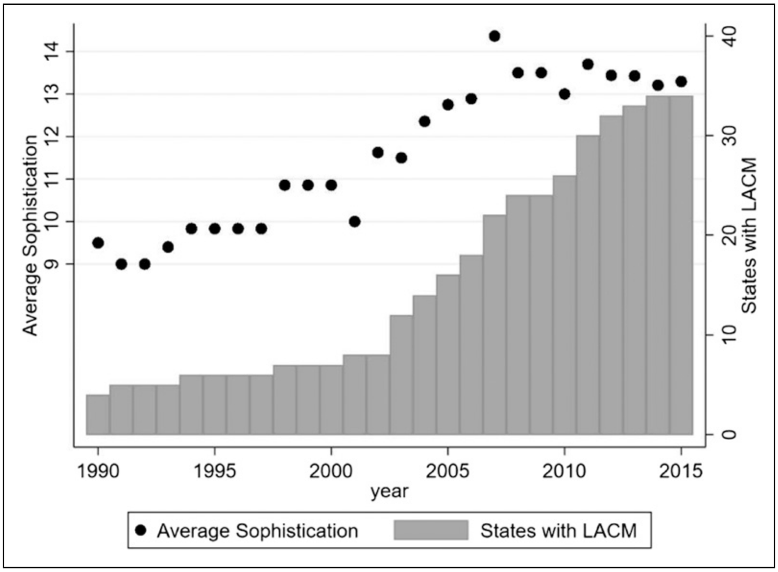

Figure 1. CMSS average and LACM proliferation, 1990–2015.

extensive range, a 450 kg warhead, an ability to be launched from submarines, and a low-flying altitude (U.S. Navy 2018; Hoehn 2019; Missile Threat 2019). However, the TLAM-E also boasts an electro-optical guidance system which grants additional capabilities, such as battle-damage assessments from previous strikes (U.S. Navy 2018). This gives the TLAM-E Block IV Tomahawk a score of 19, broken down as follows.

- The ability to be fired from submarines grants: +1 point
- A range of 1600 km fills all of the range thresholds (200, 500, and 1000 kms) granting: +3 points
- The 450 kg warhead fills the 200 kg warhead threshold granting: +1 point
- Terrain Contour Matching (TerCoM) guidance grants: +2 points
- Electro-Optical guidance grants: +2 points
- GPS guidance grants: +3 points
- Terrain hugging/low-altitude flight grants: +3 points
- DSMAC guidance grants: +4 points
- **CMSS Total Score: 19 points**

By coding the most sophisticated cruise missiles in countries' arsenals, we capture innovations and improvements in states' cruise missile arsenals across time and space. The variable allows us to capture significant changes in the technical sophistication of states' missiles as they add new capabilities reliant on considerable technological advances. It operationalizes vertical proliferation not just as a matter of the quantity of

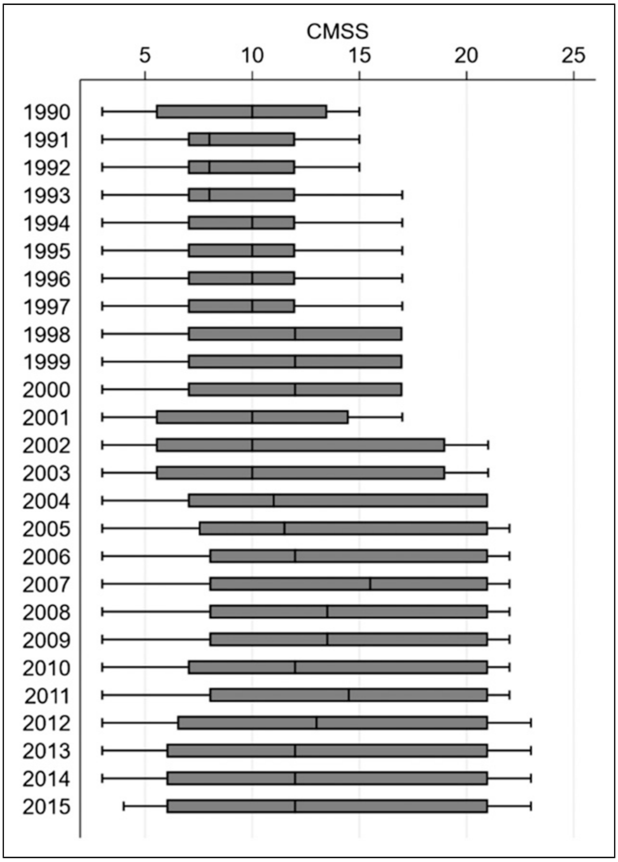

Figure 2. Box and whisk plot of CMSS values, 1990–2015.

the weapons a state possesses but rather their *quality*. Being able to understand the military utility and technological sophistication of weapons is an integral part of understanding how weapons affect the balance of power and is a crucial second stage of proliferation that is often overlooked. The exact substantive effects on the CMSS values from the dependent variables will differ depending on the state and missile system in question. Some more sophisticated missiles may lose traits (such as longer range and payload) and add more technically challenging ones, such as DSMAC guidance or supersonic speeds.

Our time-series cross-sectional data reveals that countries have steadily gained access to increasingly sophisticated land-attack cruise missiles. Figures 1 and 2 provide an illustration of how the average of countries' CMSS values changed from the start of our period of analysis in 1990–2015. Figure 1 displays the average CMSS values of deployed LACMs along with total possessor states from 1990 to 2015. Figure 2 is a box and whisker plot that displays the range of our CMSS variable for deployed LACMs, capturing the lowest and highest CMSS missiles as well as the general distribution of the CMSS values. The slight drops revealed in Figure 1 coincides with new states adopting less-sophisticated LACMs. Figure 2 reveals the variable in how dispersed the sophistication of LACM-possessors' capabilities have been across times. Both the horizontal proliferation of less-sophisticated LACMs and the introduction of new missile technologies appear linked with stronger concentrations of states at the lower- and higher-ends of our sophistication scores. This suggests that there is meaningful variation in states' missile capabilities cross-nationally and over time that needs to be explained.

We excluded the Cold War from our analysis because there were far fewer LACM possessors and the technology advanced slowly during that period (see the Appendix). The primary purpose of LACMs during the Cold War was for inaccurate nuclear delivery missions. Starting in the late 1970s, the United States sought to develop a new generation of LACMs with improved capabilities across the board, but, namely, in guidance and propulsion technology. These improvements laid the foundation for the drastic increase in the sophistication and possession of LACMs in the post-Cold War era.

Independent Variables

Our model includes key variables identified by our hypotheses in addition to several other potentially salient controls. To operationalize our hypothesis related to states' insecurity, we employ the average number of international conflicts that a state has been involved in over the past five years (*UCDP Conflict*) using data from UCDP/PRIO Armed Conflict Dataset (Pettersson and Öberg 2020). This variable captures if states have security concerns that would motivate their acquisition of more sophisticated military capabilities, such as cruise missile systems. We expect that higher levels of conflict will be associated with higher values in states' CMSS.

To test our hypotheses related to regime type, we employ the Polity2 variable from the Polity IV Project (Marshall, Gurr, and Jaggers 2018), coded on a −10 (most authoritarian) to +10 (most democratic). To account for the hypothesized curvilinear relationship between regime type and CMSS, we include Polity2 Squared as well. We hypothesize that highly authoritarian and highly democratic states will have invested in the acquisition of more sophisticated cruise missiles.

We account for the effects of possessing related scientific and technical knowledge and capabilities via two different variables. First, we code Maximum Ballistic Missile Capabilities as a five-point ordinal variable from (0–4), with 0 denoting no ballistic missiles, 1 denoting the possession of short-range ballistic missiles, 2 denoting medium range ones, 3 denoting intermediate range ballistic missiles, and 4 denoting intercontinental ballistic missiles using data from the National Space and Ballistic Missile Dataset (Early and Fahrenkopf 2017). This variable only provides a rough proxy of ballistic missiles' sophistication based on their range, but it offers significantly more information than only using a dichotomous measure of possession of any ballistic missiles. We expect this variable to have a positive relationship with CMSS. To account for how possessing nuclear weapons could influence states' interests and ability to acquire more sophisticated cruise missiles, we also account whether they possess nuclear weapons. We code Nuclear Weapons Possession as a binary variable using updated data from Singh and Way (2004).

To measure technological spread and state access to foreign sources of advanced aerospace technology, we include a systems-level count variable (*CM System Introduction*) for the number of years since 1944 when cruise missiles were first deployed by Nazi Germany. We code the dichotomous variable MTCR Membership for whether membership in that multilateral export control regime is positively correlated with the possession of more sophisticated cruise missiles.

We also control for the level of economic development, higher education, and military spending of states. We include GDP per capita because better developed countries should have access to more resources and technology that they could apply towards their cruise missile programs. GDP Per Capita is a logarithmically transformed variable using data from World Bank (2014). To account for states' general level of scientific and technical human capital, we follow Early (2014) in coding for the percentage of states' populations that have higher education degrees (Higher Education) using estimates from Barro and Lee (2010).[9] Lastly, we control for how much governments spend on their military forces (Military Spending) using data from the National Material Capabilities Dataset v.5.0 (Singer et al. 1972).

As an exogenous variable for inclusion in the horizontal proliferation portion of our selection model, we include a variable that should affect countries' security needs to acquire cruise missiles. We code DP with Great Power as a binary variable to account for whether a country has a defense pact with a great power state (Gibler 2009).[10] If a state possesses the patronage of a more powerful patron that likely already possesses the capacity to project power with missiles, then the state will have fewer incentives to potentially invest in acquiring its own cruise missiles.

Results

Table 2 depicts the results of our analysis using OLS with PCSEs in Models 1–2 and the Heckman Selection Model in Models 3–4. Our results illustrate some variation across our results when we account for selection effects. The rho value's statistical significance in Model 3–4 means that selection effects are having a meaningful impact and that the Heckman model should be preferred. Given selection models can be sensitive to specification, however, we think it is valuable to evaluate the findings within the context of the non-selection corrected models as well. Models 2 and 4 include Maximum Ballistic Missile Capabilities, while Models 1 and 3 exclude the variable to demonstrate the impact of its inclusion.

The selection model in Table 2 shows clear results regarding the correlates of cruise missile possession. We report these results independently to contrast them with our core

Table 2. Analyzing the Factors Impacting Cruise Missile Sophistication Scores.

Cruise missile sophistication models				
	Model 1	Model 2	Model 3	Model 4
UCDP conflict	0.104***	0.108***	0.151**	0.168**
	(0.03)	(0.03)	(0.07)	(0.07)
NWs possession	3.389***	2.082***	1.712***	−0.220
	(0.50)	(0.66)	(0.60)	(1.10)
Polity2	−0.055*	−0.035	−0.193***	−0.142**
	(0.03)	(0.03)	(0.05)	(0.06)
Polity2 squared	0.017**	0.015**	0.061***	0.060***
	(0.01)	(0.01)	(0.01)	(0.01)
MTCR membership	2.005***	1.932***	3.392***	2.935***
	(0.32)	(0.30)	(0.70)	(0.74)
CM system Introduction	0.149***	0.152***	0.053	0.047
	(0.03)	(0.03)	(0.06)	(0.06)
Maximum ballistic Missile capabilities		0.494***		0.794**
		(0.10)		(0.35)
GDP per capita	2.001***	2.018***	0.861***	0.973***
	(0.23)	(0.23)	(0.26)	(0.26)
Higher education	0.009	0.000	0.039	0.028
	(0.01)	(0.01)	(0.04)	(0.04)
Military spending	0.363***	0.313***	0.132	−0.189
	(0.12)	(0.12)	(0.27)	(0.27)
Constant	−25.268***	−24.929***	−4.536	−0.108
	(3.58)	(3.67)	(7.56)	(7.16)
Cruise Missile Possession Models				
			Model 3	Model 4
UCDP conflict –5 Year avg			0.048***	0.050***
			(0.01)	(0.01)
Defense pact with Great power			−0.195***	−0.211***
			(0.05)	(0.05)
Polity2			0.000	−0.000
			(0.01)	(0.01)
Polity2 squared			−0.005***	−0.005***
			(0.00)	(0.00)
GDP per capita			0.049	0.054
			(0.04)	(0.04)
Military spending			0.719***	0.722***
			(0.03)	(0.03)

(continued)

Table 2. (continued)

Cruise missile sophistication models				
	Model 1	Model 2	Model 3	Model 4
MTCR membership			−0.114	−0.111
			(0.14)	(0.14)
CM system			0.059***	0.058***
Introduction			(0.01)	(0.01)
Constant			−15.740***	−15.796***
			(0.83)	(0.82)
Rho			−0.830***	−0.906***
			(0.19)	(0.18)
N	380	380	3864	3864

Note: *,**,*** denote statistical significance at the 90%, 95%, and 99% levels using two-tailed tests. Standard errors are included in parentheses.

findings below on LACM sophistication. Security threats, military spending, and time since the beginning of the cruise missile era all make a state more likely to possess LACMs. Conversely, the number of defense pacts that a state has with great power states (DP with Great Powers) is negatively correlated with their possession of LACMs. Countries that have the protection of great powers may allow themselves to remain dependent upon their benefactors' more superior LACM arsenals as opposed to leveraging those relationships to acquire similarly capabilities. Our findings related to Polity2 offer interesting context for our subsequent findings in the sophistication model. The curvilinear relationship between Polity2 and cruise missile possession is negative, with highly authoritarian and highly democratic states being *less* likely to acquire LACMs than anocracies. Examining our cases more closely, anocracies appear to be most active in the buyers' markets for lower-end cruise missile systems available for export. Many of these anocracies, like Morocco and Egypt, purchased new models of anti-ship missiles that have added LACM capabilities through GPS guidance, which are generally cheaper and draw less attention than their traditional LACM counterparts. The selection models also indicate that MTCR Membership does not appear to affect whether states possess LACMs or not. This is not that surprising, though, given that the MTCR focuses only on restricting more advanced variants of cruise missiles with ranges of greater than 300 km and payloads larger than 500 kgs. These findings provide useful context for understanding what factors influence LACMs' vertical proliferation.

We now turn to the core focus of this paper, which is on the determinants of cruise missile sophistication. We find consistently strong positive effects for UCDP Conflict on CMSS across all four of our models, suggesting that countries experiencing higher levels of international conflict appear driven to acquire more sophisticated cruise missiles, conditional on the fact that they already possess them. On average and holding all other factors constant, a one-unit increase in UCDP Conflict is associated with an increase in a state's CMSS of 0.19 according to Model 4. Compared to other factors in or model, this finding suggests that individual conflicts have a smaller impact on the sophistication of LACM arsenals. Experiencing international conflicts drives states towards making significant advancements in their LACMs' sophistication when states are involved in many different ongoing conflicts. It is notable, though, that conflict-involvement maintained a distinct, significant effect on the vertical proliferation of LACM sophistication even after we accounted for its role encouraging the horizontal proliferation of LACMs. As a more general metric to capture states' level of regional security, we also used the proxy measure of the number of states they share a border with (e.g., Way and Weeks 2014). This method of operationalizing insecurity does a better job of capturing structural differences between states' security environments. Using states' shared borders (see the Appendix), we also find that the variable has a consistently positive effect on states' CMSS values across all the models.[11]

NWs Possession exerts a positive effect on CMSS in Models 1–3 but loses its significance in the selection model that includes the variable Maximum Ballistic Missile Capabilities. The latter variable is statistically significant in both Models 2 and 4. These findings broadly support our hypothesis that possessing related strategic technologies will increase states' interests and ability to acquire more sophisticated cruise missiles. Substantively, a one-unit increase in that variable is associated with an .817-unit increase in states' CMSS values. This would be roughly equivalent to a basic upgrade or partial upgrade of a more advanced technical capability in a state's most sophisticated LACM system, and suggests positive spillover of technological advancements made across states' ballistic missile and cruise missile programs. Russia, for example, has made significant investments in developing long-range ballistic missiles as a nuclear weapons-delivery platform and possesses a robust military rocketry research and development (R&D) sector. During our period of analysis, Russia's military introduced two new, highly advanced LACMs into its arsenal: the KH 101/102 (CMSS 23) and the series of 3M–14 Kalibr missiles (CMSS 12–14). While there are significant technological differences between ballistic and cruise missiles, there is enough of an overlap in which some technologies and the R&D infrastructure they rely on can carryover. This finding is bolstered by previous works that show similar spillover effects across civilian and military rocketry applications (Early 2014).

A potential explanation for why NWS Possession lost its significance in Model 4 is that, once selection effects are accounted for, the overlap in aerospace technologies between ballistic and cruise missiles exercised a more powerful effect on states' ability to develop more sophisticated LACMs. There is also a strong correlation between possessing long-range ballistic missiles and nuclear weapons. If the scientific and technical infrastructure and human capital associated with nuclear weapons programs rather than the need for more advanced nuclear weapons-delivery platforms is mainly driving the relationship with LACM sophistication, then advanced but non-weaponized nuclear capabilities should have similar effects. To test that interpretation, we substitute NWS Possession with a measure of nuclear latency status (Fuhrmann and Tkach 2015).[12] We re-estimate our models using this alternative measure and obtain similarly

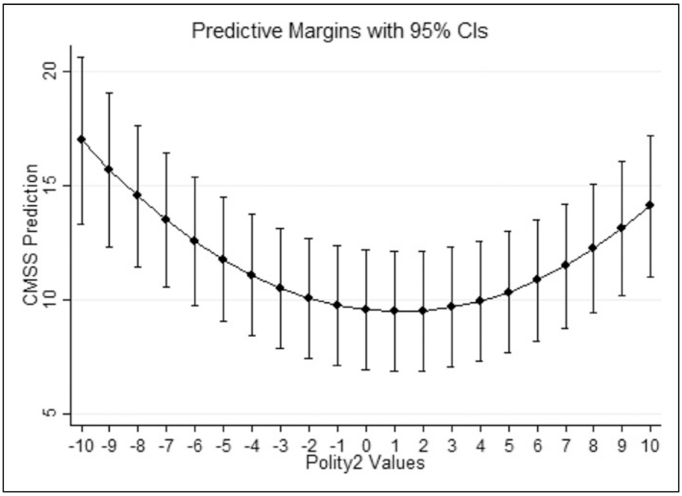

Figure 3. The predictive margins of Polity2 on CMSS. Note: Figure created using model 4.

positive results in Models 1–3 that also wash out in Model 4. Together, these findings suggest that possessing related strategic technological capabilities and expertise contribute to the acquisition of more advanced LACMs, but that capabilities in the most closely related sector (ballistic missiles) have a dominant impact.

The Polity2 regime type variables in our models demonstrate the curvilinear relationship that we hypothesized. This relationship is best observed graphically, not just from the positive and statistically significant value of Polity2 Squared term in the models. Figure 1 depicts the predicted margins with 95% confidence intervals using Model 4. Conditional upon states having cruise missiles, our model reveals that states with highly authoritarian governments and states with highly democratic governments will possess more sophisticated cruise missiles than states governed by anocracies. As Figure 1 illustrates, being a highly authoritarian (−10) or highly democratic state (+10) is associated with CMSS values that are respectively 8-points and 5-points higher compared to an anocracy with a Polity2 score of 0. Substantively, regime type appears associated with differences in possessors' most sophisticated LACMs that are equivalent of multiple advanced technological capabilities. This complements our findings from the selection analysis, where we observed that anocracies were most active in obtaining LACMs but that they appeared to be mostly acquiring lower-end LACM variants. As a robustness check, we replicated our analysis using the V-Dem v.11.1 Electoral Democracy Index variable (Pemstein et al. 2021). The results in our Appendix reveal a similar curvilinear relationship across the spectrum of authoritarian and democratic regimes as Figure 3.

Looking more closely at the data reveals that Saudi Arabia and the United Arab Emirates (UAE) represent two of the most authoritarian countries that possess advanced LACMs. Both imported the UK-French joint project Storm Shadow LACM (also known as the Black Shaheen) that received CMSS values of 21, which is one of the most sophisticated missile systems available for export. The UAE acquired the missiles in 2003, while Saudi Arabia acquired them in 2011. It is notable that the Storm Shadows were the first LACM system acquired by either country—and that both opted to start with one of the highest-end systems available for purchase. The 2003 export to UAE drew serious opposition from the United States, which cited concerns about the missiles' advanced nature and range (Lewis 2011). To provide more nuance to our findings about authoritarian states, we drew upon the Geddes, Wright, and Franz (2014) data on the varieties of authoritarian regimes. We replaced Polity2 with a categorical variable that instead accounted for whether states had Party, Personalist, Military, or Monarchical regimes, with democratic states serving as the baseline for comparison. The results in our Appendix reveal that possessing a monarchical regime, like the UAE and Saudi Arabia have, is associated with significantly higher CMSS values while possessing a personalist regime has a negative effect on CMSS values. While these findings are interesting, we are cautious about inferring too much from them because there are not that many cases of LACM possession across those four different authoritarian regime types.

With respect to democratic states, the U.S., United Kingdom, and France also possessed some of the most sophisticated LACM systems in our analysis. Our CMSS metric, for example, scored the U.S.'s TLAM-E Block IV Tomahawk as a 19, and the joint Anglo/French Strom Shadow (SCALP-EG) as a 21. Rather than importing these weapons, however, these states developed them on their own via indigenous R&D. The divergent examples involving both authoritarian and democratic states that possess highly advanced LACM systems suggest that additional qualitative research would be useful to analyze the different acquisition pathways employed by authoritarian versus democratic regimes.

MTCR Membership is associated with an increased CMSS level. On average and holding all other factors constant, shifting from being a non-member to an MTCR member is associated with predicted CMSS values that are 2.935 points higher in Model 4. Substantively, that is the equivalent to a state's most advanced LACM gaining a GPS navigation or terrain hugging flight capability via our method of coding CMSS values. Notably, the magnitudes of MTCR Membership's effects are larger in selection models that control for membership's effects on which countries acquire cruise missile missiles (no clear effect). This finding has two interrelated explanations. The first is that the strategic trade control obligations of the MTCR make its members more effective at keeping advanced cruise missile technologies from proliferating to other states. A second, and complementary explanation, is that MTCR members are more inclined to share advanced cruise missile technologies with fellow members that they are not willing to share with non-members. Whether one or both explanations are at play, MTCR members have a significant advantage over non-members in terms of their LACMs' sophistication.

The variable Cruise Missile System Introduction is statistically significant in Models 1–2 but loses its significance in the selection models. As those models revealed, the longer that LACMs have been in the international system the more likely new countries are to obtain them. This factor thus appears to play a larger role in explaining the horizontal as opposed to vertical proliferation of LACMs.

Our models also reveal some nuance concerning the other national capacity-oriented factors. As expected, states' level of economic development (GDP Per Capita) has a positive effect on CMSS values in all four models. The variable Higher Education, however, did not have a positive effect in any models. GDP per capita is frequently used as a proxy for the degree of wealth and economic sophistication, whereas higher education has a more limited focus on states' general scientific and technical human capital (Early 2014). The variable Military Spending had a positive effect on CMSS values in Models 1–2, but the effect washed out in the selection models. Notably, Military Spending has a positive and statistically significant effect on whether states possess cruise missiles. The factor thus appears to play a stronger role in explaining the horizontal proliferation of LACMs rather than explaining advances in their sophistication. Higher levels of general economic development—and the corresponding ability to both buy and indigenously develop more advanced missile capabilities—better explain the patterns we observe with respect to which states obtain more sophisticated LACMs.

Lastly, we extended our analysis by exploring the ways in which cruise missile producers serve as the sources of technology transfers (see the Appendix). Using the NCM's data on national LACM production capabilities and data from Kinne (2020) on defense cooperation agreements (DCAs), we coded a count variable for how many DCAs (of any kind) that states had with cruise missile producers. The variable had a positive and statistically significant effect in the models that only examined sophistication scores, but the effects washed out in the selection models. We also coded a version that only capture having a DAC with the U.S. after it achieved producer status. The U.S. DAC variable was statistically significant in the sophistication-only models and yielded a weakly significant effect in the selection models. For both variables, having DCAs with cruise missile producers had strong positive effects on the possession of LACMs. The results suggests that having DCAs with cruise missile producers facilitates the horizontal proliferation of LACMs more than it does the vertical proliferation of sophisticated variants.

Conclusion

The quality and sophistication of military technology can matter as much as its quantity. The U.S. military, example, makes substantial investments in technological superiority. Understanding what factors motivate and empower states to obtain more sophisticated capabilities is thus essential to understanding security competition. We examine the determinants of vertical proliferation within the context of LACMs, a leading conventional and strategic military technology for projecting power. We evaluate the role of the security environment, regime type, the possession of scientific and technical expertise in related technologies, and membership in suppliers' regimes as leading potential explanations of differences in states' vertical proliferation of LACMs. Importantly, our analysis controls for the horizontal proliferation of those weapons systems across the world as well.

Our main findings suggest that both supply- and demand-side factors explain the variation we observed in how sophisticated countries' LACM arsenals are. The security environment influences which countries invest in more sophisticated LACMs, but it is not the most powerful determinant of the weapon system's vertical proliferation. We find that both highly democratic and highly authoritarian regimes are more driven to possess more sophisticated LACMs and that factor has a greater substantive impact on the sophistication of states' LACMs. On the supply-side, countries' possession of advanced ballistic missiles and nuclear capabilities are positively correlated with also possessing more sophisticated LACMs. Ballistic missiles had the more dominant impact, though. While both ballistic missiles and LACMs involve different technologies and operate differently, technical expertise and infrastructure related to the former can benefit the latter. States' level of economic development also appeared to be more strongly correlated with the sophistication of states' LACMs than individual measures of states' general technical prowess and military spending. Higher levels of military spending are positively associated with the possession of LACMs, however. Lastly, we found that states that are party to the MTCR tend to possess significantly more technologically advanced LACMs than states outside of it. Notably, membership or non-membership in the regime did not affect whether states possess LACMs at all.

Our findings contribute to broader efforts within the security studies and policy communities to understand interstate relations and national power. The vertical proliferation of military capabilities constitutes a critical lens for understanding sources of national power (Gartzke, Kaplow, and Mehta 2014), and a dimension that is increasingly important to account for given advancements being made in the ability to project power and engage in precision strikes. Our analysis reveals leading factors that account for why certain countries possess advantages in how sophisticated their LACMs are relative to their peers. While our approach for measuring the sophistication of military technologies was technically intensive to develop and highly-resource intensive to code globally, it can be applied to understand the vertical proliferation of other key military technologies as well (naval vessels, bombers, tanks, etc.).

Our results also have important policy implications. For example, they suggest that the MTCR can have success at excluding states from acquiring more sophisticated cruise missiles but is less likely to prevent their acquisition of LACMs in the first place. However, MTCR members are more capable of acquiring more sophisticated cruise missiles, which should shape how policymakers think about that regime.

Additionally, most of our results about cruise missile sophistication are consistent with findings from the nuclear weapons literature—economic development and security threats both influence patterns of proliferation, though economic development appears less related to nuclear weapons sophistication for some states (Miller and

Narang 2019). However, the role of regime type in influencing the horizontal and vertical proliferation of LACMs seems to be more complicated than research has revealed with respect to nuclear weapons. For example, we found evidence that democracies appeared more inclined to develop their own indigenous highly advanced LACMs, while authoritarian regimes seemed more likely to purchase them. More broadly, we think that future research should build on our study to explore differences in the ways states acquire their LACMs—through buying or building them.

Moreover, while it makes sense that policymakers often focus on weapons of mass destruction, the relevance of missiles for today's wars around the world should make this an area of emphasis moving forward. For example, uninhabited aerial vehicles, a closely related technology to cruise missiles, just played a critical role in Azerbaijan's military victory over Armenia during their 2020. Understanding not just which countries have a technology like UAVs (e.g., Fuhrmann and Horowitz 2017), but also which countries' arsenals are technologically superior can play a major role in understanding the outcomes of modern conflicts.

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Supplemental Material

Supplemental material for this article is available online.

Notes

1. Our replication materials are available at https://sites.google.com/site/bryanrearly/home/data-sets and the Harvard Dataverse.
2. See the online Appendix located in the replication materials for a detailed description of the NCM data set.
3. In general, states that have air superiority tend to win conflicts (Saunders and Souva 2020b).
4. The literature on proliferation has also been criticized for its American-bias (Braut-Hegghammer 2019).

5. There were far fewer LACM possessors and far less variation in possessors' capabilities to track in the preceding period (see the Appendix).
6. Focusing on states' most cutting-edge LACM system, instead of their arsenals' average sophistication, offers the best approach for capturing national efforts at acquiring increasingly sophisticated military technologies.
7. We exclude UAVs because of their ability to return home after a missile. We only code weapon delivery systems that destroy themselves in the process of the attack and also have "active" guidance systems.
8. As Terry and Cone (2020:75) discuss with respect to hypersonics, those types of missiles are comprised of a "class of related technologies that must be combined together to form an operationally useful system." The CMSS constitutes an effort to disaggregate and measure the individual sophistication of missiles various "related technologies" rather than assess their sophistication as a whole.
9. The Barro and Lee (2010) estimates are only available in 5-year increments, so we back and forward filled in the data surrounding the included values.
10. The Gibler (2009) alliance data only ran through 2012, so we forward coded 2013–2015 with the values from 2012 so we could include those observations in our main analysis.
11. Additionally, we analyzed whether having a rival with nuclear weapons drove countries to acquire more sophisticated LACMs. The variable has a positive effect in the sophistication-only models and a negative effect in the selection models (see the Appendix). We think the mixed results are due to the conventional applications of sophisticated LACMs driving larger numbers of countries seeking the weapons for non-strategic purposes.
12. For more on the effects of nuclear latency, see: Mehta and Whitlark 2017; Whitlark and Mehta 2019.

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