1.5.2 International Relations and STI (Science, Technology, Innovation)

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First Published December 8, 2023 Final Updated December 8, 2023

Introduction

What is the relationship between international relations and science, technology and innovation (STI)? Do militarized conflicts and security alliances cause STI? Does STI cause conflict and alliances? With a better understanding of the relationship between international politics and domestic STI, we can devise better policies for both. This is especially important today, as great power rivalry increases and we enter the Fourth Industrial Revolution.

Keywords

Politics, power, security, war, threat, alliances, institutions, international organization, identity, norms, culture, science, technology, innovation, fourth industrial revolution, artificial intelligence

1 International Relations and STI

Science, technology, and innovation (STI) affect nearly every facet of modern political and economic relations, including a country's trade profile (Krugman 1986, 1991); financial flows (Strange 1986); economic growth (Solow 1957; Romer 1986); military might (Waltz 1979); defense technologies (Gilpin 1981); and identity (Wendt 1999, 2003). STI therefore plays an important role in a state's global standing, both in terms of its relative economic influence and its absolute strategic power (Cox 1981). That is, from security to institutions to identity, all major theories of international relations incorporate STI.

If theory does not convince, then history surely does: states that rapidly increase their STI experience a corresponding increase in prestige and power, as typified by Britain's rise during the First Industrial Revolution, the ascent of Germany and the United States during the Second Industrial Revolution, the Japanese miracle of the 20th century, and China's current reemergence on the global stage (Mokyr 1990, 1992; Taylor 2016). Conversely, countries that fail to achieve success in STI or maintain their place at its frontier wither from global influence: history is replete with examples of nations that concurrently declined

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in STI leadership and international stature, including Ming China, The Dutch Republic, Sweden, Portugal, and Russia (Kennedy 1987).

Indeed, human history can be understood as a sequence of STI-driven revolutions (White 1966) on the one hand and war-fighting and alliance-making on the other (Cohen 1996; Tilly 1975), as technologies and scientific breakthroughs not only shaped imperialist projects (Headrick 1981; Baber 1996; Yang 2011) but also facilitated and accelerated (Mayer, Carpes, and Knoblich 2014) the explosion of globalization, statehood, and contemporary cultures in both the Global North ("the haves") and South (Chandler 1977; T. Hughes 2004; Iwabuchi 2021).

Today, we are entering the Fourth Industrial Revolution (also sometimes referred to as Society 5.0 in Japan) driven by innovation in emerging science and technologies at a time of rising great power competition, the causes and effects of which will again shape the course of human history. Therefore, academics and policymakers alike are asking questions about and seeking answers to the relationship between international relations and STI.

2 IR Theory and STI

To begin with, it is important to note that International Relations (IR) scholars have studied in-depth how international security affects domestic institutions and policies. This includes how war and conflict can: lead to domestic revolution (Skocpol 1973, 1979), determine democratic or authoritarian political trajectories (Pollins 1992), foment citizen nationalism (Posen 1993), determine who are citizens and what are their rights (Tilly 1999), influence design of national tax policies (Scheve and Stasavage 2010, 2012), affect the degree of social welfare spending (Skocpol 1999), and incentivize the extension of civil rights to minorities (Dudziak 2011). All of these examples – revolution, government type, nationalism, rights, tax policy, spending – of how international security affects domestic outcomes, as well as many more (Grieco, Cheng, and Guzman 2014), are linked directly or indirectly to national science, technology and innovation performance (Brummer 2022). Thus, each major camp within international relation theory – Realism, Liberalism and Constructivism – specifically treats STI, albeit for different reasons (Krishna-Hensel 2010).

2.1 Realism

Realist scholars have been primarily concerned with the strategic implications and power-maximizing effects of STI, where security is a first order state interest in the "self help" anarchic world system. Balance of power (Morgenthau 1948) and balance of threat (Walt 1987) theories both incorporate STI advances into their understanding of state behavior, where innovations in capabilities necessarily come to bear on changes in balance, power, and threat. For example, Waltz (1979) observes the profound impact that technology can have in the transportation of capabilities across distances, where innovations from the carriage wheel to shipbuilding to railroad technology and beyond radically redefined both the power and reach of military might. Walt (1987) agrees and argues that these kinds of game-changing discoveries, of which nuclear power maintains a singular importance, can determine the particular direction of alliance formation, from balancing to bandwagoning. For Posen (1986), technology is a key driver of military doctrine itself, as it

shapes and influences the formation of grand strategy. And for Fearon (1997), technological innovation of offensive and defensive capabilities alters the very logics for engaging in conflict. Jervis (1978) and Van Evera (1999) have both illuminated how the balance of offensive and defensive weaponry can play critically into how states calculate their relationships with each other. In his exposition of the "security dilemma", Jervis (1978, 186) argues that security-seeking behavior of one state can pose a threat to the security of other states, who respond in turn. Thus, innovations of offensive and defensive technologies – for example, missiles and missile defense systems, respectively – occur in relation to each other. Additionally, he argues, security competition increases as technology reduces the costs associated with offensive operations. In short, how technology influences military prowess, alliance formation, and the logics of conflict and war are core to the paradigm. Weiss (2005, 308) sums the Realist position neatly when he notes that rationalists view "concepts [such] as power, security, and national interests as objective and real, and science and technology as an external influence on them."

2.2 Liberalism

Neoliberal scholars also consider technology to be vital to the study of nations but reach starkly different conclusions as to why and how. Liberalists generally champion the creation and/or influence of international organizations, conventions, and norms to address global-scale problems and manage crisis-prone interstate relations, and argue that new STI often serve as principal motives for the development of such international organizations, conventions, and norms. For example, Krasner (1983) points to how innovation's capacity to raise or lower the costs of war can affect the rational attractiveness of partaking in international regimes (Krasner does not identify himself as a Liberal). Similarly, in promoting international trade networks, openness, and transparency, technological innovation can result in complex interdependence and the cultivation of shared futures (Keohane and Nye 1977). Keohane (1984, 101) details how international regimes serve as "information-providing and transaction cost-reducing entities" that facilitate agreements; enhance the likelihood of cooperation; create the conditions for multilateral negotiations; legitimate and de-legitimate different types of state action; facilitate linkages among issues within regimes and between regimes; and help to enhance the quality of the information that governments receive. In as much as technology lowers the expenditure burden of these operations, increasing efficiency and effectiveness in facilitating negotiation and increasing cooperation, it can determine the very relevance and legitimacy of international institutions. Still other liberal institutionalists emphasize the idea that technological and economic interconnectivity between states foster a mutual interest in prosperity, and therefore a more peaceful world (Friedman 1999). And for some, like Ohmae (1990), the diffusion of technology will eventually create an evenly developed, "borderless world," completely reshaping the state-system as we know it. Finally, there is a long-running debate on the relationship between government type, STI, and interstate behavior. For example, democracies are often said to be more efficient and effective at STI (Acemoglu and Robinson 2012) and do not war with each other – known as the Democratic Peace Theory – compared to authoritarian regimes which are inefficient at STI and prone to conflict (Doyle 1983), a line of reasoning that is up for considerable debate today (Lind 2023).

2.3 Constructivism

In studying the relationship between STI and IR, Constructivists emphasize how developments in science and technology can affect culture, norms, and social practices, and how these in turn can serve as explanatory forces in interstate relations (E. Haas 1975; P. Haas 1992; Hopf 1998). For these scholars, STI regularly follows a course of development prescribed by social, scientific, and physical environments (Wendt 1999), and is integrated into the "cultural norms" of a community, which structure such factors as threat perceptions and national security concerns (Katzenstein 1996). Wendt's writing on the independent effects of material forces on international relations echoes the perspective of technological determinism (Bimber 1992), a cornerstone of social constructivism's treatment of international politics (Wendt 1999) and an underpinning logic of "why a world state is inevitable" (Wendt 2003). Indeed, technology, such as telecommunications and the internet, not only transforms society and vice-a-versa, it can also undermine established authority and traditional power centers altogether (Schwartzman 1989). Importantly, as Katzenstein (2003) shows in his study of Japanese technology and US-Japan relations, states can maintain a military alliance while also competing technologically. For all of these leading Constructivists, technology directly affects norms, culture, and identities, which in turn come to bear on international relations.

Table 1: Summary of IR Treatments of Science, Technology, Innovation

IR Camp	Representative Scholars	STI affects…
Realism	Gilpin; Morgenthau; Walt; Waltz	Power & position
Liberalism	Axelrod; Keohane; Krasner; Nye	International institutions & systems
Constructivism	Haas; Katzenstein; Wendt	Culture & norms & identity

2.4 Reversing the Causality of IR and STI

While most traditional scholarship in IR treats STI as an independent variable (i.e., the cause of international outcomes), several contemporary research programs have emerged that specifically treat the external environment as a primary explanatory variable to domestic STI.

Doner, Ritchie, and Slater (2005), comparing South Korea, Taiwan, and Singapore on the one hand and Malaysia, the Philippines, and Thailand on the other, offer a theory of why the former but not the latter adopted 'developmental state' models. They argue that a central variable driving shifts in technological upgrading in these countries is vulnerability derived from insecurity surrounding resource scarcity and strategic important dependency: threats of an international ilk. Mark Taylor (2012, 2016), following in Doner's (2005, 2009) footsteps, develops a theory called "creative insecurity" that describes 'the positive difference between threats of economic or military competition from abroad and the dangers of political-economic rivalries at home'; in other words, the perception that foreign-born threats outweigh domestic ones. Under such conditions, support will be high for Schumpeter's ([1942] 1976, 83) gale of creative destruction. Taylor tests his theory qualitatively on the four cases of Taiwan, Israel, Ireland, and Mexico.

Likewise, IR scholars have also examined the relationship between national security alliances and STI, especially how the signaling dimension of alliances can influence domestic economic outcomes and institutional development. For example, Biglaiser and DeRouen (2007) argue that the stationing of U.S.

military resources in a country is associated with increased FDI inflows due to increased investor confidence that such perceived political alignment brings. Li and Vashchilko (2010) argue that security alliances between countries are associated with increased bilateral trade, an important input to STI, as government and industry from each state feel increased trust in each other's political relations and thus are more willing to bear the risk associated with cross-border business. In a cross-country study of 89 countries spanning over 30 years, Schmid, Brummer, and Taylor (2017) find a positive, significant correlation between innovation and an array of alliance proxies, including joint military exercises, high-level state visits, and the presence of alliance pacts with the United States. And Callado-Munoz et al. (2022) find that the NATO alliance increases domestic STI in member countries through preferential high-technology arms transfers

3 Expose on Nuclear Science and Technology

A brief expose on nuclear technology intended to shed light on how the different International Relations camps treat a specific S&T and its innovation is provided in this sub-section. After the U.S. detonated the first atomic weapon during the final stages of WWII, the power of such STI became a central concern to scholars of IR (e.g., Brodie and Dunn 1946; Snyder 1965; Betts 1987). With the introduction of these weapons, especially, the global community also became concerned about nuclear technology in general (Nye 1987; R. Smith 1987). The concern is that while many applications are used for peaceful purposes (e.g., electricity generation, agricultural applications, industrial applications, medical applications, among others), it is difficult to prove that a country is not also using nuclear infrastructure toward nefarious ends, such as building a bomb (Sagan 1997; Kroenig 2009). Surveying the different camps within IR, we see that scholars have quite divergent perspectives when considering the relationship between nuclear science, technology and innovation on the one hand and the international system on the other.

3.1 Realism and Nuclear Science & Technology

Realists view states as primarily motived by a central goal: power. As Von Clausewitz (1976) writes, "The worst of all conditions in which a belligerent can find himself is to be utterly defenseless" (77). As such, realists expect that states will pursue nuclear weapons, especially when their adversaries pursue them or already possess them. Deterrence theory was developed to explain why states seek nuclear weapons and how such weapons influence a state's foreign policy (Schelling 1966). This theory line argues that opponents must be dissuaded from taking an action through the explicit use of threats of retaliation (Snyder and Diesing 1977). Modern deterrence theory largely argues that symmetrical nuclear arsenals and similar levels of capability reduce the likelihood of conflict (Bueno de Mesquita and Riker 1982; Kugler 1984; Asal and Beardsley 2007; Gartzke and Jo 2009; Rauchhaus 2009; Kroenig 2013). The Cold War provides an illustrative example of deterrence theory at work. The primary reason the Cold War remained "cold" (in other words, no nuclear weapons were detonated) was because of what became known as Mutually Assured Destruction (MAD), which served as a steep deterrent to both the U.S. and the Soviet Union in terms of engaging in direct conflict with each other (Betts 1987; Jervis 1978). The costs of retaliation were so sufficiently high that neither state was willing to incur them (Powell 1990). Supporters of deterrence theory

also highlight the observation that since nuclear weapons were introduced into the international system, there has only been one war between two states that both possessed such weapons: India and Pakistan in the 1999 Kargil War (Geller 2005). Some realists extend deterrence theory logic beyond this point and suggest that the spread of nuclear technology and even "controlled" nuclear weapons proliferation can help make the world a safer place, at least theoretically. Waltz (1981) writes, "Nuclear weapons have been the second force working for peace in the post-war world. They make the cost of war seem frighteningly high and thus discourage states from starting any wars that might lead to the use of such weapons" (3). Others argue from a military organization theory perspective that nuclear weapons are unlikely to ensure peace due to the inflexible, rigid nature of military organizations (Sagan 1994) and that faith in the value of nuclear weapons to ensure peace is critically flawed (Doyle 2013). A common thread running through all realist thought suggests that states who do not seek nuclear weapons will lose out in a nuclear international system. Thus, the incentive structure suggests that all states should be weaponizing or enhancing existing arsenals out of fear that their opponent is also doing the same. One alternative approach that "non-weapon" states may take is to ally with a major power that maintains a nuclear arsenal in order to ensure their own protection and survival (Horowitz 2010). This alternative approach to security can generate new alliance structures in the international system from balancing to bandwagoning (Waltz 1964; Walt 1985).

3.2 Liberalism and Nuclear Science & Technology

Liberal Internationalists believe that states can have diverse preferences (Axelrod 1980; Keohane 1988; J. Goldstein and Keohane 1993). Some states may seek absolute power while other states are considerably more "altruistic" peace-makers in the international system (Moravcsik 1997). As such, what we see today in the current international nuclear safeguards regime is largely a product of liberal internationalist thought (Ikenberry 2009). The Nuclear Nonproliferation Treaty (NPT) states that "nothing in this treaty shall be interpreted as affecting the inalienable right of all the Parties to the Treaty to develop research, production and use of nuclear energy for peaceful purposes" (Article IV, Paragraph 1 NPT). Therefore, it is a violation of international law to deny a state the right to pursue peaceful nuclear technology, even though it is exceptionally difficult to prove that this technology is indeed being used in a peaceful manner. To ensure that the non-weapon states are only pursuing peaceful applications and not weaponizing, the International Atomic Energy Agency (IAEA) serves under the auspices of the UN to verify nuclear activities across the globe (Deese and Nye 1981; R. Smith 1987). The IAEA sends teams of inspectors to nuclear facilities all over the world to ensure that all nuclear material is accounted for and not being diverted to clandestine weapons facilities, in order to produce a "security community" through the cooperation of sovereign states (Adler and Barnett 1998). As Keohane and Martin (1995) write, "institutions (such as the IAEA in this scenario) can provide information, reduce transaction costs, make commitments more credible, establish focal points for coordination, and in general facilitate the operation of reciprocity" (42). Beyond cooperation in safeguards commitments, there are several recent examples of states giving up nuclear weapons as a result of international pressure and domestic pressure (e.g., Libya in 2003, South Africa in 1989). Liberalists pivot away from realists to consider how a state's domestic conditions and political coalitions influence nuclear proliferation or restraint, rather than almost exclusively considering external forces (Solingen 1994,

2007). Liberalists view civil technology sharing, the emergence of international cooperative bodies (such as the IAEA), and the relinquishing of nuclear weapons as proof positive of how technology gives rise to networked and shared futures between state as well as the significance of international organizations in managing these dynamics, including regulating / limiting their proliferation.

3.3 Constructivism and Nuclear Science & Technology

Constructivists take a step back and consider from a broader perspective how states form identities and how these identities shape their preferences (Adler 1997). For these scholars, "anarchy is what states makes of it," (Wendt 1992) and nuclear weapons are no different: nuclear technology is given meaning in the context of constructed norms and culture surrounding its existence. In constructivist terms, the continued criticality of nuclear weapons and state-led dominance in the nuclear arena constitute social facts. These weapons demonstrate state adherence to their constructed social purpose, that is, maintaining prestige (i.e. identity) and dominance (i.e. interests) (van Wyk et al. 2007). Constructivists examine a number of dimensions to explain where a state's identity is formed. Domestic politics, international norms, international organizations, world order, historical experience, and a host of other factors can explain a state's identity and thus its behavior in nuclear science and technology (Barnett and Levy 1991; Buzan 1987). Constructivists working on the problem of nuclear proliferation largely seek to answer a central question: given that we observe patterns of behavior in proliferation or nonproliferation, 'to what extent is that caused by factors such as the international social environment?' (Rublee 2009). Rublee (2009) continues by explaining that in order to answer this central question, scholars must consider how beliefs are formed in the first place and how they transform over time, and how the technology of nuclear physics affects these believe systems. As an example of how beliefs and norms are formed by the advent of nuclear weapons, Tannenwald (1999) explores the concept of the "nuclear taboo," and argues how no such socially constructed belief existed before the U.S. dropped two nuclear bombs on Japan, thus enabling such an event to take place with support of public opinion. After the war, however, and as demonstrated by the non-use of nuclear weapons in the Korean War, a nuclear taboo took hold, constraining their deployment in conflict and war. In speaking to the realist line that nuclear increases stability, Hayes (2015) argues that it is how the public understands the significance of nuclear weapons that matters, not the brute nature of the weapons themselves. In other words, if nations are to accept disarmament, they must first address public perceptions that have grown around anxieties and habits as they relate to the technology. For constructivists, nuclear technology has shaped foreign policy and international diplomacy through its effect on belief systems and cultural norms.

3.4 Room for Research in IR and Nuclear (and STI)

As a final observation on this topic, the previous subsections have focused primarily on how nuclear has affected international relations; not on how international relations has affected nuclear. This is because the majority of academic literature treats the relationship in this manner. However, as many policymakers know well from practice, international relations clearly affects domestic nuclear (and STI)

programs. Liberalism is perhaps the most developed of the IR camps in this regard in that the scholarship treats the relationship as endogenous: nuclear technology affects the formation of international institutions, and international institutions affect nuclear technology. But the Realism and Constructivism literatures are less developed in this regard (for exceptions, see: Taylor 2012, 2016; Schmid et al. 2017; Brummer 2022; Brummer and Mita 2023). In this sense, there is room for debate and further study on how Realist and Constructivist theories can explain domestic nuclear programs (and STI more broadly). This is very important in the contemporary period, as we entered an era of new "promote and protect" industrial and trade regimes focused on high technologies such as chips and semiconductors. The US, Japan, and EU have all recently (as of March 2023) introduced such new strategic economic statecraft, and China is doing the same. There is significant research potential in describing and explaining these new developments in the international politics of STI.

4 US-China Rivalry and the Fourth Industrial Revolution

The theory, empirics, and expose on nuclear technology introduced in previous sections are currently be considered and reconsidered in the contemporary context of international relations and STI. This is taking place amidst structural changes at both the international system and STI levels, exemplified by strategic competition and great power rivalry between the US and China and the advent of a host of new science and technologies at the cusp of the Fourth Industrial Revolution (Schwab 2016). That is, most IR scholarship has focused on the STI inherent in the first, second, and third industrial revolutions; yet we are now entering the fourth.

How will the science, technologies and innovations associated with artificial intelligence, cyber-physical systems, the internet-of-things (IoT), 3D printing, biotechnology, big data, renewable energy storage and next-gen batteries affect international relations? And how will international relations, including alliances, threats, conflict and war affect the STI of the Fourth Industrial Revolution (or, Society 5.0 in Japan)?\

4.1 Artificial Intelligence, US-China Rivalry, and Policy Implications

Covering the breadth of all Fourth Industrial Revolution technologies in this Core Contents is not possible. Therefore, I focus on arguably the single most important one: AI. Likewise, directly covering all countries is not possible: therefore, I focus on arguably the most consequential for international relations: China and the United States. With this being said, the same types of questions and implication presented below can (and should) be extended to many other cutting-edge technologies and country comparisons.

International relations scholars have begun to debate AI's potential effect on military capabilities and power (Horowitz 2018; Jensen et al. 2020). This scholarship has tended to focus on applications (Johnson 2019), strategy (Ayoub and Payne 2016; Payne 2018), and ethics (Maas 2019a, 2019b; Morgan et al. 2020), as well as whether or not there is or will be an "AI arms race" (Roper 2020; Scharre 2021) or an "AI-Revolution in Military Affairs" (Raska 2021; Schmid 2022).

Answers to these questions will inform key policy and theoretical debates. First, which countries are able to rise to the top of the AI food chain has profound implications for the international state system. For

example, if China can innovate in AI and avoid the "middle income trap," it can rise to superpower status. Assuming continued political stability, China's ascent into the high-income category would make it by far the world's richest country. This has profound implications for the future of US-China relations and the balance of power (Beckley 2018; Brooks and Wohlforth 2016; 2015), and the character of international order (Rolland 2020; Mazarr, Heath, and Cevallos 2018; Foot and Walter 2010).

Second, if China can succeed at AI and innovation in the Fourth Industrial Revolution more broadly, it will challenge a prominent literature about domestic institutions and economic growth. Scholars argue that authoritarian regimes' "extractive" institutions inhibit innovation (Kroenig 2020; Acemoglu and Robinson 2012). Yet China's rise in AI may undercut this argument and support research in the authoritarian politics literature that points out the tremendous heterogeneity of such regimes, in both institutions and economic outcomes (Frantz 2018). Evidence that some types of authoritarian regimes can produce more rapid technological and economic growth would necessitate a full reexamination of a large IR literature that posits a "democratic difference" across a number of issues in both security and political economy (Brummer and Lind 2023 forthcoming; Lind 2024 forthcoming).

Third, as rivalry between the US and China increases, both countries have adopted more competitive policies, to the extent that many observers have proclaimed the dawn of a New Cold War (Charap and Shapiro 2015; Zhao 2019). Part of this includes a trend toward economic decoupling, in which increasing threat perception is leading countries to prioritize the security rather than economic efficiency of supply chains (Johnson and Gramer 2020; Wyne 2020; Bateman 2022). Yet the US and China are not only the world leaders in AI, they also are each other's closest collaborators in AI research (Brummer and Lind 2023). This suggests that such a potential decoupling would significantly reshape the global networks of knowledge and technical cooperation that underpins the Fourth Industrial Revolution (Tang el al. 2021).

5 Conclusion

No country will be spared the shifting sands of power and technology in the 21st century. Scholars and policymakers alike are now racing for answers for how best to understand and manage the relationship between international relations and STI in the New Cold War and Fourth Industrial Revolution. The implications of "getting it right" are profound: those countries who do will become powerful, and those that do not will fade away. How can countries design institutional and policy mixes to best compete and cooperate in this new world of STI and great power rivalry? This is one of the most consequential questions facing scholars and policymakers today.

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