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State Technological Power and Interstate Trade Relations and Conflict

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State Technological Power and Interstate Trade Relations and Conflict

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ABSTRACT

This dissertation examines roles of state technology capacity in determining national power, whether and in what ways international trade affects between-state tech power transition, as well as how state tech power position influences their trade policy. This research argues that technology is an increasingly important component of national power in the modern era; state trade dependence on another is likely to cause unfavorable tech power transition; states tend to initiate trade conflict against its trade partner that is technologically catching up toward it, attempting to prevent further dyadic tech power convergence or even surpassing. A variety of analytical methods, including statistics, case studies, formal theory, and network analysis, are employed in this research, and the empirical findings appear supportive of the propositions.

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PART I

INTRODUCTION

Modern global politics can be characterized by two realities. First, states become more and more reliant on technology rather than material resources to build power. State possession of cutting-edge technology is a cornerstone of its power, given that technology strengthens material production, military might, and state overseas influence; national innovative capacity, from the realist perspective, therefore plays a critical role in underpinning national security. A growing number of power measures have involved state tech capacity as necessary ingredients of national power (e.g., Krahmann 1927; Saaty and Khouja 1976). I hence postulate that contemporary states are badly concerned about their technological capacity distribution, and tech catching-up between states, according to the power transition theory, should intensify struggles for tech power, cause belligerent foreign policy, and escalate interstate tensions in multiple spheres. The tech-race-driven economic and civil isolationism during the Cold War and the recent US-China tech-related trade frictions serve as prominent cases testifying to this conjecture.

The second trend is that the postwar period has witnessed remarkably falling odds of using conventional war to resolve interstate disputes, while interstate tech-economy competition has been persisting and even intensifying throughout the modern era. Constraints to conducting interstate warfare may include nuclear proliferation and existence of credible alliances like the NATO, which have enhanced mutually assured destruction (MAD) and effective deterrence; or the rarity of interstate war can be ascribed to postwar tides of democratization and globalization, which might cause liberal peace. This research points out that to address tech competition, nonmilitary measures such as trade restrictions may be more effective and efficient than militarized action, which may both result from and contribute to the shifting of interstate conflict from military to nonmilitary arenas.

To explore the new patterns of global political economy, this dissertation examines how technology determines national power and state foreign strategies, whether and in what ways interstate trade affects between-state tech power transition, as well as how state tech power positions influence their trade policy. Specifically, this research argues that technology is an increasingly important component of national power in the modern era; state trade dependence on another will cause unfavorable tech power transition, but it is less likely to realize a tech power surpassing; states tend to initiate trade conflict against the trade partner that is technologically catching up toward it, as a way to prevent further dyadic tech convergence or even surpassing. In the related empirical investigations, a variety of analytical methods, such as statistics, case study, game theory, network analysis, are employed, and the findings are supportive of the propositions.

The following part of this dissertation explains why technological capacity has been crucial in shaping national power. To this end, it reviews literature about national power and reveals several shortcomings of conventional measures of national power; then, it highlights the important and probably independent role that state technological capacity plays in explaining and predicting state foreign behavior. Specifically, I demonstrate the close associations between state tech capacity and domestic production levels, military strength, as well state global influences respectively, in order to uncover the pivotal role of state tech capacity in determining national power. I point out that components of national powers may not be scalars but rather vectors that probably lead states to resort to different strategies realms, and thus, under some conditions, a comprehensive measure of national power may be inappropriate in international relations (IR) analysis. Particularly, state material power contest is likely to cause militarized actions, while a technical competition may tend to breed non-violent conflict.

The concept, **national power**, serves as one of analytical bases for studying international relations. Most theorists regard national power as highly correlated to resources at a state's disposal, including material wealth and military assets (Kennedy 1987; Mearsheimer 2001; Tellis et al. 2001). In practice, most studies measure state power in terms of several material indicators, such as territorial area, population, human capital, gross domestic product (GDP), GDP per capita, military spending and personnel, and so forth. Singer et al (1972) proposed the Composite Index of National Capabilities (CINC) as an index for national power, which has been widely adopted in IR studies. The CINC is computed as a combination of six indicators: military expenditures, military personnel, steel production, energy consumption, and urban and total populations; some studies also consider nonmaterial factors such as moral and prestige when measuring national power.

In the modern era, technology has risen to become the pivotal part of national power (Krahmann 1927; Gilpin 1987), as states have been growing reliant on technology rather than materials to build power and maintain security. Several realities account for this trend. First, ingredients of technology can be either material or ideational, in forms of facilities, personnel, ideas, knowledge, and skills. Material components of technology are necessarily a kind of material resources that contribute to national power, and disembodied information itself is an important strategic asset as well. Second, technological capacity exerts positive impacts on productivity (Abernathy and Townsend 1975), which is crucial for domestic economic growth. Besides, in the global market, innovative advantages lend competitiveness and bargaining leverage to oligopolistic firms, which thereby exploitingly gain excessive profits (Prebisch 1962).

National technical advancements therefore promise long-lasting economic prosperity. Third, technology has long been major components of military strength alongside manpower and natural resources, and the contemporarily merging techniques, such as artificial intelligence, Big Data, drones, and Robotics, even make manpower trivial in combats. Modern tech advancements also explore virtual battlefronts. A great amount of national security problems arises from cyberspace (Reveron 2012), highly demanding latest techniques to deal with competitions and conflicts revolving around information on the internets. National defense capability has become heavily dependent on keeping leading in and effectively protecting technical innovations in these fields (Hoadley and Lucas 2018). Fourth, Technology helps states project global power. States can exchange technology abroad for political rewards, such as cementing an alliance or politically exploiting a backward state by monopolizing its tech supplies; technological capacity confers on a state a decent position in setting international industrial standards; technologies also contribute a lot to a country's soft power by globally demonstrating its success in innovation.

In practice, a host of theorists already incorporate technological capacity into the assessment of national power. For example, theorists like Luttwak (1990) point out that spending on research and development (R&D) and education should be considered when measuring national power; Porter (1998) measures state competitiveness based on five factor groupings, one of which is knowledge resources.

I point out that there is an unwarranted assumption that states in face of similar interstate structures of material powers and of technological powers will take similar maneuvers to deal with each. Undoubtedly, national material accruement can be effectively deterred by foreign military invasion. By contrast, information and skills seem not to be readily eradicated by physical smashes. State technological capacity sometimes is more of an idea than a material; in face of tech catching-up, the state under threat is assumed to primarily consider civil or/and economic tactics rather than violent means, since the former is expected to create fewer costs and more efficacies than the latter. In sum, this research argues that technological capacity should be deemed as a factor that is probably able to affect foreign policies independently of and differently from other material components of national power.

Part III is devoted to investigating how interstate trade affects between-state gaps in tech capacity. **State technological capacity** (i.e., state tech strength or power) consists of the quality and amount of national-possessed knowledge and skills as well as national abilities to create, apply, and store knowledge; ingredients of technology can be either material or ideational, in forms of facilities, personnel, formulas, or skills. Previous research on state-level innovative achievement concentrates largely on the debate over an array of endogenous and exogenous determinants of state tech procurement and whether there exists general tech-economy convergence between the backward and the advanced blocs, lacking attention to the dynamics of between-state tech power relativeness or gaps, which greatly interest IR students and practitioners. Comparativists who are concerned about the innovative variation among states have uncovered the effects of policy designs and institutional configurations on state innovative capacities (Nelson 1993; Storper 1995; Hollingsworth 2000). Classical international economics identifies integration into the global economy as a positive exogenous factor for domestic tech-economy growth, given the downward knowledge diffusion alongside cross-border exchanges (Grossman and Helpman 1991; Keller 1998). Yet critical theorists stress hierarchical and politicized characters of global production networks and the function of global capitalism in assisting powerful states to project clout beyond borders and explore plus profits through exploiting subordinate states and prohibiting them from upgrading (Love 1990; Hills 1994; Muzaka and Bishop 2015).

Since the end of the Cold War, interstate tech-economy competition has persisted, and global tech power distribution patterns have kept changing due to varied outcomes of developmental policies and sporadic global shocks (Storper 1995; Gabriele 2002). The contest has been intensified greatly presently due to increasingly complex geopolitical realities. Previous International Political Economy (IPE) research on state-level innovative growth concentrates largely on external and internal physical or/and institutional conditions for technical growth, state strategic activism (Weiss 2005; Bell and Feng 2007), as well as global or regional tech-economy convergence (Findlay 1978; Barro and Salai-Martin 2014). As aforementioned, a loose end rests in the fact that former research on state-level innovation has paid insufficient attention to between-state tech power gaps, which are exceptionally critical in assessing national security conditions and guiding foreign tactics amid power competition. To bridge this gap, this research examines the association between dyadic trade relations and technical power transition. Particularly, I contend that a state's **trade dependence** on another one causes unfavorable technological power transition, and nevertheless trade dependence solely is less likely to realize tech power surpassing. As another theoretical innovation, I stress that state trade dependence on another can stimulate corporate incentives to explore profits by sharing or investing techniques alongside outsourcing and reduce state negotiation leverages in tech-related issues, both of which lead to unfavorable tech power transition. By shifting the focus from trade volumes, contents, or structure to trade dependence, this research helps settle the debate between macroeconomists and critical theorists revolving around trade-driven tech growth. A large-*N* state-level empirical analysis is conducted, which provides strong evidence.

The fourth part of this dissertation is dedicated to exploring association between interstate technological strength relativeness and initiation of bilateral trade conflict. Specifically, I theorize that a state tends to trigger trade conflict against a technologically ascending trade partner as a preventive strategy, and as the partner rises to lead ahead in the tech realm, the state becomes less likely to launch trade conflict against it. According to the power transition theory, since states are assumed to care about their tech power distribution, they shall have motives to prevent a tech power competitor from further ascending; considering that cross-border trade may facilitate downward tech transfer, and opening domestic market to a competitive partner may involuntarily financially or/and materially support its tech growth, states are bound to consider implementing trade restrictions to prevent worrisome tech convergence and power transition. By contrast, preventing a leading-ahead power from further growth is not as urgent as deterring a rising challenger, so states may not have as much interest in hindering a technically leading-ahead state as deterring a power chaser. More importantly, a backward state cannot effectively attack a more advanced partner by trade cutting, since the latter can readily resume lower-level production, outputs of which can replace secondary import goods, while the technically lagging state often has more difficulties in producing substitutes or finding alternative supplies for tech products from the more advanced partner. Therefore, the relationship between a state's tech position relative to another and its incentives to initiate trade conflict against the other is supposed to be quadratic.

This proposition advances the power transition theory by adapting it to the modern context — Power parity's association with interstate all-out militarized confrontations has declined; states increasingly rely on technological rather than material resources to build power and maintain security, and their tech power competition may tend to breed economic conflict. Another novel point is that it systemically examines **initiation of trade conflict**.

This research identifies trade sanctions, state withdrawal from free trade agreements, the triggering of trade disputes under the WTO agreement as proxies for state initiation of trade conflict. Particularly, I point out the *alternate utilities* of economic sanctions—Sanctions may give the sender direct (i.e., not reliant on the target's concession) political rewards, which may have to be in a cloak of convicting the target for its wrongdoing, because they are not as legitimate as what senders overtly request; when such political gains are greater, the state is more likely to resort to the sanction; the sender uses sanctions rather than corresponding economic policies that can render the same political outcomes because it wants to avoid loss of reputation or/and lack of legitimacy, or use sanctions as focal points to mobilize collective action. That is, trade sanctions can serve realist purposes; they can be used to deter a tech competitor.

I develop hypotheses for the three types of events following the main proposition. As State A is technically catching up to State B, State B is more likely to make trade sanctions against the former, withdraw from an existing preferential trade agreement (PTA), with, and trigger a dispute filed under the WTO agreement by State A. However, if A technically leads ahead of B, as A keeps rising, State B becomes less likely to send trade sanctions against the former, withdraw a trade treaty with, or be complained by State A under the WTO agreement.

Through analyzing the three types of events based on a longitudinal state-level data set that covers a period from 1980 through up to 2018, I find evidence supportive of the claim. I also investigate two recent trade conflict cases to provide more evidence. This theoretical proposition helps understand the conflict between Japan and South Koreas since 2019. Though many analysts interpret Japanese implementation of a trade sanction after South Korean courts convicted several Japanese corporations for forcing Koreans to work during the war as a racial or social conflict, the Japanese government justified its action as a punishment for South Korean breach of export multilateral control regimes by transferring strategic goods to prohibited zones. I point out that this trade sanction is quite likely to come out from the purpose of addressing the pressure imposed by South Korea's reaching parity in terms of tech power. I also investigate the historical trade conflict against People's Republic of China (P.R. China). When this state was relatively underdeveloped during Mao's reign, a number of developing states followed the US trade sanction against China; yet they did neither initiate nor follow any trade conflict against China since 1985, even after the brutal suppression of Tiananmen protests. Recently, the US launched another round of trade sanctions against China, because this country has kept technically rising, which has been posing threats to the US leading position and national security.

PART II

STATE TECHNOLOGICAL CAPACITY AND NATIONAL POWER

II.i Introduction

On 1st October 2019, a showing-off military parade for the 70th anniversary of the P.R. China was held in front of the Tiananmen, in which China's most advanced weaponry was exhibited in formation. It manifested China's special capability of effectively attacking the US homeland, fighting an American carrier strike group, and raiding Taiwan, considering that the demonstrated weapons include fifth-generation stealth aircrafts (J-20), hypersonic ballistic missiles (DF-17), ship-targeting bombers (H-6N), state-of-the-art unmanned aerial vehicles (sharp sword drone), as well as intercontinental, multiple-warheads-carried missiles (DF-41). In addition to the inroads it had made in armament fields that had long been dominated by the US or/and other advanced states, China also showed its ambitions to take over leaderships in civilian high-tech domains, as it has taken the lead in 5th generation (5G) of mobile access technologies[1], commercial drones[2] , and supercomputers[3], and it has made steady progress in aerospace by successfully setting up its own space station (Tiangong program), launching lunar orbiters (Chang'e) and rover (Yuetu), and sending a Mars probe (Tianwen-1). Meanwhile, China has been concentrating governmental as well as private investments on aviation, robotics, 3D printing, artificial intelligence (AI), electric car, and autonomous driving techniques; it also staked out long-term plans to weed out

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[1] Huawei, a Chinese telecom giant, which was one of the pioneering 5G developers and attempted to make 5G global standards, has been reportedly favored by Chinese mercantilist policies to seize global market share (Brake 2018).

[2] The largest commercial drone manufacturer in China, DJI, has been enjoying a global market share more than 50% since 2016.

[3] The Sunway TaihuLight supercomputer developed in China has been the fastest supercomputer in the world.

foreign monopoly of high-performance chips and engines, in terms of which it lags far behind and is vulnerably dependent on more advanced states, and technologies of which are extremely sophisticated and impossible to procure except with substantial, long-term investments. In response to the threat that China poses to the US tech leadership and national security, American government has added a multitude of China's high-tech-related persons, corporations, and institutions on the Entity List, individuals and entities on which are subject to specific license requirements for exporting to or/and importing specific items from the US.[4] In April 2021, the *Endless Frontier Act* was introduced in the US Senate, with a goal of "strengthening of U.S. leadership in critical technologies through basic research in key technology focus areas"[5]. As a counterpart, China enacts the *Plan for Strengthening Basic Academic Disciplines* to support domestic first-tier universities to recruit talented students in several critical disciplines, including mathematics, physics, mechanics, nuclear engineering, bioscience, and the like, and its aim is to "cultivate talents who can serve national strategies"[6]. Without a doubt, the US and China have been locked in a series of ongoing technological contests, which is anything but new, given that a tech race alike occurred a half century ago between the US and Soviet Union (e.g., Kevles 1990).

Previous theoretical studies of international relations sometimes have one eye on state tech strength and thereof geopolitical implications, which, however, are far from adequate,

[4] Here is the source for the description of the Entity List: https://www.bis.doc.gov/index.php/policy-guidance/lists-of-parties-of-concern/entity-list

[5] The key technology focus areas include artificial intelligence and machine learning (AIML); high performance computing, semiconductors, and advanced computer hardware; quantum computing and information systems; Robotics, automation, and advanced manufacturing; natural or anthropogenic disaster prevention; advanced communications technology; biotechnology, genomics, and synthetic biology; cybersecurity, data storage, and data management technologies; advanced energy; materials science, engineering, and relevant exploration relevant.

[6] See the official file issued by Ministry of Education of the P.R.China in January 2021: http://www.moe.gov.cn/srcsite/A15/moe_776/s3258/202001/t20200115_415589.html

especially compared to policymakers' vast interest in international tech competition. Thus, this part is devoted to addressing a query of the essence underlying tech races—*How important is state tech capacity's role in shaping national power?* I discuss the roles that national power plays in international relations and in what ways it is aptly conceptualized. Then, a diversity of operationalization methods for national power are reviewed, and I make synopses and parses of a myriad of existing measures of national power to disclose their patterns and limitations. I contend that in some contexts, it may be improper to analyze international affairs based on a synthetic measurement of national power that is constructed by embodying everything related to a state. The following two sections are dedicated to showing that state technological capacity is an increasingly important component of national power. Technology is closely related to national economic growth, military might, and a state's global influence, and historical innovative surges always ushered in global power reshuffling. Then, I summarize existing gauges of state tech capacity. After uncovering the shortcomings of a composite index of state technical strength, I stipulate two qualifications for choosing proxies for state tech capacity and thereby propose several tech proxies for this research. In the last section, I point out that different components of national power might be not scalars but rather vectors that can lead states to resort to different strategies realms; specifically, this research asserts that a material power race is likely to cause militarized action, whereas a technical competition may tend to breed economic conflict.

II.ii. National Power and International Relations

The concept, **national power**, serves as a practical, analytical, and theoretical cornerstone of international relations. Students of IR, and especially realists, have been making substantial effort to construct an epistemological architecture of IR by linking state behavior to national power. Classic realists claim that states seek survival in the dangerous anarchic world by building and grabbing power; since power is something limited, the zero-sum power game enmeshes states into never-ending conflict (e.g., Morgenthau 1948). Defensive neorealists assert that global or regional power structures shape interstate interactions; under a given setting of between-state power distribution, states select allies to amalgamate collective power and sustain a balance of power, as a way to achieve survival (e.g., Waltz 1979). Some realists emphasize effects of concentration levels of global power distribution on war and peace, though they may hold divergent viewpoints regarding which kind of power structure is most stable and peace-making (e.g., Singer et al. 1972; Waltz 1979; Mearsheimer 2001)[7]. Offensive realists contend that states have incentives by nature to vie for hegemonic power, which is believed to be able to guarantee long-term security (e.g., Mearsheimer 2001). Transitionists posit that a stable unipolar structure facilitates the enforcement of international rules and provides a basis of world peace, and an abrupt power transition is supposed to be associated with a high likelihood of war (e.g., Organski and Kugler 1980).

In all, national power, from a realist prism, is in a high relation to state security; it therefore straightforwardly or indirectly impacts a wide range of foreign policy. Smith (1937) shares a realist account of national economy in *Wealth of Nations* by asserting that "the great object of the political economy of every country is to increase the riches and power of that country" (352). To further this postulation, Hirschman (1945) inquired political implications of cross-border trade and point out that interstate trade, if wisely managed, can boost national

[7] Waltz (1979) and Mearsheimer (2001) think of a power structure of few powers is more stable than a multipower structure in that information is too diffusive and dynamic to attain and process under a structure with multiple big powers, while Singer et al. (1972) contends that a more decentralized system can be more stable.

power by supplying strategic resources and increasing coercive power over partners based on the *influence effect of trade*. States are found inclined to trade with their allies rather than potential rivals, given the concern that international trade can lend opportunities to partners to grow defensive or aggressive military power, which concern exacerbates the prisoner dilemma when trading with adversaries (Gowa and Mansfield 1993). As to nuclear policy, Monteiro and Debs (2014) find that states of great power or endorsed by powerful allies, and under significant external threat are most likely to develop nuclear power projects. Gunitsky (2017) discovers the causal connection between hegemonic shock or superpower competition and a wave of world-wide promotion of certain political institutions; likewise, Simmons et al. (2006) conclude that coercion through economic power or physical control serves as a main mechanism for the diffusion of liberal policies. Apart from institutionalist emphasis of the positive roles that international organizations (IOs) play in reducing transaction costs of international cooperation, raising the costs of violation, and thereby furthering harmonious interests among states (e.g., Keohane 2005), realists conceive of IOs as primarily reflecting powerful states' wills and serve as platforms for power politics (e.g., Strange 1982; Mearsheimer 1994). In the similar vein, realists believe that national power shapes international laws (e.g., Vagts and Vagts 1979; Mearsheimer 1994). In all, the presence of many influential research works referring to national power suggest that this concept is a basis for many analytical frameworks that aim to explain or predict IR events and foreign policy.

II.iii. The Conceptualization of National Power

Dahl's (1957) "intuitive idea of power" is that A has power over B if the probability of B doing something is conditioned on A's preferences, and the gap between the probabilities of B doing something with and without A’s attempt to get B to do it can help measure the size of A’s power over B. The excise of power is often discerned in collective decision making. Polsby (1963) asserts that power can be conceived of “as the capacity of one actor to do something affecting another actor, which changes the probable pattern of specified future events. This can be envisaged most easily in a decision-making situation” (3-4). In international relations, researchers largely focus on state-level power, which is normally called national power and “typically defined as the ability of a country to shape world politics in line with its interest” (Beckley 2018: 8) and is normally “estimated by comparing the capabilities of a number of units” (Waltz 1979: 98), including economic, military, and other capabilities. From the prim of realism, between-state power distribution, or capability parity/disparity, influences state perception of security conditions, strategy spaces, as well as the payoffs of strategy profiles in their interactions, and thereby impact their behavior.

Suppose there are two players, State A and State B, and presumably, they have common, complete information (i.e., they need to make estimations) on the strategy space, each one’s capability, and payoffs for strategy profiles. Suppose State A has grown unsatisfied with the current distribution of a certain amount of benefit between itself and State B, and it may signal a resolve to change the *status quo* in its favor through initiating a crisis bargaining (i.e., compellence), or it chooses to make no aggression. State B can undertake a military deterrent against A prior to or as a response to State A’s aggression, starting an interstate militarized conflict. It may make a concession voluntarily after communication with A or under A’s compellence, through ceding a portion of what it possesses to A and peacefully resolve the tension. The last alternative strategy for B is to simply neglect A’s coercive diplomacy and run the risk of war.

In the game matrix displayed in Table 2.1, x_a and x_b denote current benefits States A and B have respectively, c ($\in \mathbb{R}^{+}$) the cost of a war; p ($\in \mathbb{R}^{+}$) represents state capabilities, κ the quantity of benefits that State A demands from State B. The most basic element of conceptualized national power is a state's capability to win a potential war; and some theorists even regard national power parallel to *war potential* (Knorr 1956). Though the definition of war victory has long been theoretically debatable and practically controversial, public and professional perception of victory is normally positively associated with small war costs and achievement of a large number of stated objectives (O'Connor 1969; O'DRISCOLL 2015). Therefore, it is reasonable to assume that *the postwar distribution of benefits shall be proportional to their capabilities*, and the side with *more capabilities of a war is assumed to receive a lower war cost*. Thus, the postwar benefit State A has will be $p_a\left(x_a + x_b - c_a - c_b\right)/\left(p_a + p_b\right) - c_a$. Similarly, the postwar benefits State B possesses will be $p_b\left(x_a + x_b - c_a - c_b\right)/\left(p_a + p_b\right) - c_b$. Since capability is negatively associated with war cost, we have $c_a \propto p_a^{-1}$. Let y denote stochastic, perceived version of $p_a\left(x_a + x_b - c_a - c_b\right)/\left(p_a + p_b\right) - c_a$, and $y \sim N\left(\frac{p_a}{p_a + p_b}\left(x_a + x_b - c_a - c_b\right) - c_a, \sigma^2\right)$; since in reality states rely on estimations to make strategies, and then we have $\Pr\left(y > x_a\right) = \int_{x_a}^{\infty} \frac{1}{\sigma} \varphi\left(\frac{y - E\left(y \middle| p_b, x_a, x_b, c_a, c\right)}{\sigma}\right) dy \propto p_a$. Similarly, assume $E\left(z\right) = \frac{p_b}{p_a + p_b}\left(x_a + x_b - c_a - c_b\right) - c_b$, and $z \sim N\left(E\left(z\right), \sigma^2\right)$, and then we get

$$\Pr\left(z_a < x_b - \kappa\right) = \int_{-\infty}^{x_b - \kappa} \frac{1}{\sigma} \varphi\left(\frac{z - E\left(z \middle| p_b, x_a, x_b, c_a, c_b, \kappa\right)}{\sigma}\right) dz \propto p_a .$$

Table 2.1. The Game of Compellence

<table>
<tr><td></td><td></td><td colspan="3">B</td></tr>
<tr><td></td><td></td><td>Deterrence</td><td>Concession</td><td>No response</td></tr>
<tr><td rowspan="2">A</td><td>Compellence</td><td>$\frac{p_a}{p_a+p_b}(x_a+x_b-c_a-c_b)-c_a$;
$\frac{p_b}{p_a+p_b}(x_a+x_b-c_a-c_b)-c_b$</td><td>$x_a+\kappa$;
$x_b-\kappa$</td><td>$\frac{p_a}{p_a+p_b}(x_a+x_b-c_a-c_b)-c_a$;
$\frac{p_b}{p_a+p_b}(x_a+x_b-c_a-c_b)-c_b$</td></tr>
<tr><td>No aggression</td><td>$\frac{p_a}{p_a+p_b}(x_a+x_b-c_a-c_b)-c_a$;
$\frac{p_b}{p_a+p_b}(x_a+x_b-c_a-c_b)-c_b$</td><td>$x_a+\kappa$;
$x_b-\kappa$</td><td>x_a; x_b</td></tr>
</table>

In other words, as State A's power increases, it is more likely to be assertive and make a compellence, and State B is more likely to make concessions; this change is in line with A's interests. By contrast, if A's power is not great enough, the *status quo* may remain a Nash equilibrium for the players, or State B can expect a marginal gain from a war against A and confidently makes a military deterrence. In all, the exemplary game demonstrates how national power and power structures dictate rational states to behave in certain ways.

Both realists and institutionalists believe that states are rational and pursue interests (e.g., Waltz 1979; Keohane 2005). Realists stress *statism*, highlighting the predominant role sovereign states play in offering security to people (e.g., Morgenthau 1948). They argue that the core interest of a state is to by any means survive the anarchic world (Morgenthau 1948; Waltz 1979; Mearsheimer 2001). Based on the realist assumptions, states may have uniform and mostly mutually competing interests—security; in the zero-sum game over state survival, greater national power offers a state more chance of prevailing.

Several IR theorists point out that it is not valid to formulate the ontology of national power through referring to physical and intangible resources a state possesses, because only perceived power can take real effect, which *de facto* hinges on political actors' subjective cognition and psychologic attributes. Or. from a constructive perspective, national power may be a collectively or socially constructed notion. Nevertheless, researchers find that individual actors' perception of national power is highly correlated to national material wealth and spiritual assets (e.g., Alcock and Newcome 1970; Caro 2000)[8].

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[8] Alcock and Newcome (1970) find that perception of national power is a function of GNP and military expenditure. Caro (2000) conducted a survey of French defense industry experts to establish the perception scheme for national power and find that power is related to GNP, technology, nuclear capacity, and defense expenditure.

II.iv. The Operationalization of National Power

National power is a basic concept for international relations such that IR is supposed to rely on the quantitative measure of national power to be a coherent discipline (Alcock and Newcome 1970). So far, substantial attentiveness and efforts have indeed been made to operationalize national power, which is defined in the preceding section as a state's capability that can influence international events in its favor. This capability is conventionally supposed to be highly correlated to resources at a state's disposal, in forms of geopolitical endowments, material wealth, military might, or some intangible attributes such as prestige or culture (e.g., Morgenthau 1948; Waltz 1979; Kennedy 1987; Mearsheimer 2001; Tellis et al. 2001).

Morgenthau (1948) enumerates major components of national power: military preparedness, geography, population, natural resources, industrial capacity, national character, national morale, and the quality of diplomacy; Waltz (1979: 131) later added political stability and competence to the list. In general, most studies measure national power in terms of several material indicators, including territorial area, human capital, national or individual income (e.g., GDP, NGP, or GDP *per capita*), strategic assets, military spending and personnel, and so forth. Singer et al. (1972) proposed the Composite Index of National Capabilities (CINC) as an index for national power, which has been widely adopted in IR studies. It is computed by combining six indicators: military expenditures, military personnel, steel production, energy consumption, and urban and total populations, which had been conceived of as key components of national power by some scholars even prior to the emergence of CINC (Wallace 1971). In addition to hard power indicators, some surveys also encompass immaterial factors such as moral, prestige, or culture.

Several prominent measures of national power are presented in Table 2.2, by which most other national power formulas are inspired. They cover varying ranges of variables. In addition, Höhn (2011) provides a more extensive sample of national power measures initiated or developed by 2010. From the table and Höhn's (2011) list, one can get some information on different popularities of potential components of national power among existing measurements. First, they demonstrate that *national income* or *production, population* or *demographic power*, and *military strength* are most frequently referred to by measurers, though these state attributes may be represented by different variables. Many other factors may be mentioned as well with varying frequencies. In Höhn's (2011) list of formulas, *territory*, *technology* and *science*, as well as *energy supply* or *consumption* are included in more than twenty formulas. some coding methodologies also regard culture, education, foreign trade, social structure, political stability, information or communications systems, diplomatic capacity, foreign strategy, and so forth as ingredients of national power.

By analyzing the formulas samples, we can discern several patterns. First, consistency and variation coexist in measuring national power. On one hand, several indicators, such as population or manpower, national income or production, military strength or nuclear power, as well as area of territory, remain at the core across power surveys; on the other hand, later approaches tend to appeal to a longer array of variables indicative of an assortment of aspects of national power and propose more sophisticated algorithms by assigning variables perplexing weights compared to earlier methodologies. Second, recent formulas have more interest in soft powers like prestige, culture, tourism, or movies, suggesting the growing influences of spiritual assets on international affairs.

Table 2.2. The List of Several Major Indexes or Formulas for National Power

Name	Developer	Methodology
	German (1960)	$Pow = N(L+P+I+M)$, where *Pow*=national power; *N*=nuclear capability; *L*=land; *P*=population; *I*= industrialization base; and *M*= military size.
	Fucks (1965)	$Pow = \frac{E \times P^{1/3} + S \times P^{1/3}}{2}$, where *Pow* =national power; *P*=population; *E*=energy; *S*=steel production.
	Cline (1975; 1993)	$Pow = (C+E+M)\times(S+W)$, where *Pow*= perceived power; *C*= population+terriory+strategic location bonus; *E*=economic capacity, including income, energy, mineral, manufacture, food, and foreign trade; *M*=military capability, including nuclear force and conventional force; *S*=strategic purpose[a]; *W*= national will[b].
Composite Index of National Capabilities (CINC)	The Correlates of War (Singer et al. 1972)	$CINC = \frac{\%ME + \%MP + \%IS + \%NRG + \%UP + \%TP}{6}$, where *%ME* denotes ratio of *national military expenditures* to world total; *%MP* denotes *military personnel* ratio; *%IS* is iron production ratio, applied for 1816-1895, and *steel production* ratio, applied for the period from 1896 to present; *%NRG* represents *energy consumption* ratio; *%UP* denotes *urban population* ratio, and *%TP* indicates *total population* ratio.
	Organski and Kugler (1980); Kugler and Domke (1986)	$P = (GNP + F) \times \frac{E_a}{E_e}$, where *P*=national power; $GNP \equiv$ gross national products; *F*=foreign aid; E_a=actual extraction; E_e=expected extraction. Particularly, the term, E_a / E_e, indicates state's relative political capacity.
	Beckman (1984)	$Pow = Steel + \frac{Pop + PoliStab}{2}$, where Steel=percentage of world steel production; Pop=population; PoliStab=political stability.
Elcano Global Presence Index (EGPI)	The Elcano Royal Institute (Olivié and Santos 2020)	*Economic presence*: *energy* (8%), *primary goods* (6%), *manufactures* (8%), *services* (9%), and *investment* (10%); *Military presence*: *troops* (10%), and *military equipment* (13%); *Soft presence*: *migration* (4%), *tourism* (4%), *sports* (3%), *culture* (4%), *information* (4%), *technology* (5%), *science* (4%), *education* (4%), and *development cooperation* (4%).

Table 2.2 Continued

Name	Developer	Methodology
Comprehensive National Power (CNP)	Chinese Academy of Social Sciences (CASS; Wang 1996)	The index involves *natural resources* (8%), *economic capability* (28%), *foreign economic activities* (13%); *science and technology* (15%); *social development* (10%); *military capability* (10%); *government capability* (8%), and *foreign affairs capability* (8%).
ISA Country Power Rankings	International Strategic Analysis	The index involves *economic power* (25%), *demographic power* (15%), *military power* (15%), *political power* (10%), *environmental and natural resource power* (15%), *technological power* (10%), and *cultural power* (10%).
National Power Ranking	Powermetric Research Network (Białoskórski et al. 2019)	$EP = GDP^{0.652} \times L^{0.217} \times a^{0.109}; MP = MEX^{0.652} \times S^{0.217} \times a^{0.109}; GP = \frac{EP + (2 \times MP)}{3}$, where *EP*=economic power; *MP*=military power; *GDP*=gross domestic product; *L*=population; *a*=territory; *MEX*=military expenditures; *S*=active soldiers.
Audit of Geopolitical Capability (AGC)	Henry Jackson Society Rogers (2019)	The index involves *national wealth* (10%), *national spread* (3%), *resource self-sufficiency* (1%), *national income* (10%), *corporate size* (2%), *financial control* (1%), *commercial reach* (1%), *knowledge base* (4%), *infrastructure* (3%), *research outlay* (1%), *innovativeness* (1%), *health* (1%), *freedom to create* (10%), *discursive dominance* (2%), *national appeal* (1%), *sporting attainment* (1%), *economic allure* (1%), *overseas missions* (6%), *diplomatic centrality* (3%), *organizational penetration* (3%), *developmental capacity* (1.5%), *passport power* (1.5%), *defense spending* (6%), *nuclear arsenal* (3%), *projection forces* (3%), *military-Industrial base* (1.5%), *global reach* (1.5%), *government efficacy* (7%), *economic resolve* (1%), *strategic resolve* (1%), and *altruistic resolve* (1%).

Note: a. Cline (1993) defines strategic purpose as "the part of the political decision-making process that conceptualizes and establishes goals and objectives designed to protect and enhance interests in the international environment."

b. National will here refers to the degree to which citizens can be mobilized to support defense policies.

A minority of power measures involve at least one variable belonging to the category named "technology or science"; in other words, a state's technical capacities have been recognized by, albeit not many, scholars as an integral part of national power. Interestingly, Chinese and Japanese raters normally stress technology's role in determining national power (e.g., Saaty and Khouja 1976; EPA 1987; Huang 1992; Wang 1996). It is probably partly because that the two countries experienced unprecedented invasion by Western countries in the 19th century, and then, both attributed the loss of autonomy to their immense tech gaps with the Western invaders'[9]. Further, they ascribed the stunning technical backwardness to the failure of their traditional political institutions[10]. Since its seizure of governing power, the Chinese Communist Party has been sticking with the doctrine of materialism and constantly pursuing high levels of both national production and technical capacity, though some radical policies like the *Great Leap* were so unrealistic that they performed counterproductively. As a fledging communist state, P.R. China initially mobilized substantial resources and effectively took advantage of the Soviet tech aids to successfully acquire critical strategic powers like nuclear bombs, missiles, and satellites. After assuming power, Deng Xiaoping launched profound economic and social reforms in China and redressed former radicalism. In 1978, he visited Japan,

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[9] For example, right after the defeat in the second Opium War, a group of Chinese intellectuals and politicians pointed out the necessities of attaining Western knowledge and developing modern industries for resisting foreign invasion; they launched the *Self-Strengthening Movement* in the early of 1900s, aiming to "learn foreign technologies and employ them to subdue foreign countries".

[10] After noticing the exigency of political reforms, Japanese military government made a series of institutional reforms named as the Meiji Restoration in 1860s, including transforming feudal domains to political units, eliminating hereditary fiefs, ending samurai privileges, and vesting all executive power in the emperor. The Qing rulers of China followed suit and promised to establish a constitutional monarchy by transferring most power to a republican government, but the new constitution issued in 1908 was more of a placebo for dissidents than an operative reform scheme.

aiming to draw lessons from the advanced neighbor about "how to grow to be a technically powerful nation". Deng proposed the notion of "*science and technology are the first productivity*" in 1988 when he met the Czechoslovakian communist party secretary; since then, this tenet has become one of the principles that have firmly rooted in Chinese mind and guided this country's growth. Therefore, it is understandable that most Chinese measurers deem state tech capacity as an important ingredient of national power. Besides, it is noteworthy that the formulas that do not encompass a variable subsumed under the category of "technology" or "science" may refer to some factors which are highly interrelated with state technological capacity, such as education, literacy, communications system, trade, or foreign investments.

This research recommends that *when conducting IR analysis, it is perhaps better to find appropriate proxies for national power that best fit issues at hand than use a synthetic power index*, given that a number of challenges exist in formulating a reliable composite power index. The first concern rests in the problematic lack of common standards for selecting and weighting variables, which jeopardizes the external *consistency* and *reliability* of the comprehensive measurement of national power; internal inconsistency of measuring is also significant given that many scholars incrementally advance or sometimes even fundamentally revise their past formulas. Likewise, national power measures can be easily manipulated to reflect personal knowledge and predispositions, as well as national interests. For instance, measurers from countries of a small territory but a great economy may tend to highlight economic power and exclude geographical factors like population or territorial area (e.g., Shimbori et al. 1963). Scholars dwelling in authoritarian states or identifying with a nation of ingrained authoritarian culture are more likely to involve "political capability", which normally stands for the capability that a state has of extracting or mobilizing resources within its sovereignty, into formulas than are those originating from democracies (e.g., Wang 1996; Zhu and Xiao 1999; Hu and Men 2002; Chinese Academy of Science 2003; Wang 2006). Sometimes measures of national power are also suspected of serving national strategies. For instance, China's Comprehensive National Power (CNP) has tended to assign a low rating to China[11] relative to the US, Russia, Japan, Germany, and Britain, in accordance with its policy of "*Tao Guang Yang Hui*"[12]; by contrast, American raters like to give a top rank to recent China, either purposely or unintendedly legitimize the US deterrence measures against China's rise.

Second, synthetic measures for national power, especially when including many variables, are susceptible to high levels of *intercorrelation* and *multicollinearity*; the issue of *double counting* would therefore be severe if all power-related factors are put together into one formula. For example, several core components of national power, such as gross domestic production, population, area of territory, and military spending, are subject to high levels of collinearity. Common wisdom suggests that a country of a larger territory is more likely to have a larger population, and a larger population often leads to a larger number of troops and higher domestic production. In the similar vein, a state that has a great economy normally enjoys a great deal of cultural power, and more broadly, hard power often acts as the basis of soft power. These intercorrelations result in severe double-counting issue in measuring state power by unduly exaggerating certain factors' magnitudes and marginalizing some relatively isolated but important factors like technology, which inexorably compromises the explanatory power of national power when using such an index. For example, even though China had the highest 2021

[11] Chinese scholars and organizations seldom ranked China among five-top powerful countries, even though China has been among the top five in CINC rankings since 1860. Examples include Yu and Wang (1989), Zhu and Xiao (1999), and Wang (2006).

[12] Tao Guang Yang Hui means hiding one's strength and pretending to be weak. It is a strategy to avoid preventive actions from powerful rivals.

CINC score, quite few if any analysts would believe that China had overtaken the US and been capable of winning a *vis-à-vis* war with the latter. Since China has a significantly large population, it tends to have a large quantity of gross domestic product, steel production, military personnel, and energy consumption. That is, its demographic advantage in manpower is repeatedly counted in its CINC score through influencing a number of intercorrelated variables, overblowing its national power index. Had more power components that are not related to population, such as state technological capacity, the quality of GDP, and state-of-the -art military apparatuses, been taken into account, China would not have been assigned a power rank above the US.

Quite a few measures of national power select variable schemes unarbitrarily. Some of them conducted perception surveys and regressions. However, since there exists significant cross-sample and temporal variation in knowledge, cognitive habit, and psychological state, this method may lead to a low level of external validity and reliability. Some researchers choose to conduct regression analyses over a list of potential power variables and compare their performance in explanation and extrapolation of IR events; based on statistic outputs, they select variables and decide on their weights. Yet this approach tacitly assumes that national power is essentially equivalent to a particular political event like war victory, which may be conceptually and ontologically untenable given that national power primarily influences state behavior by providing an *ex ante* perception and estimates; meanwhile, this regression-based survey tends to be subject to selection bias, considering that national power can affect whether a state decides to engage in a war in the first place. Moreover, external validity of variable schemes selected this way will be compromised by their lack of theoretical grounds for justifying the selection process.

Lastly, these measures have an implicit assumption that different power components always lead states to behave in same courses; in the language of math, they are presumed to be scalars rather than a set of vectors. National power will lose much explanatory power if this presumption unfortunately fails to hold. States may undertake different strategies to deal with different dimensions of national power competition or conflict. For instance, a state's rise in military strength is usually bound to incur militarized deterrence from the challenged dominant power, while its acquisition of nuclear weapons may bring about a peaceful talk between them. In a later section, I will introduce the argument that economic means are supposed to be more effective and efficient than military action in addressing interstate technical competition. Therefore, in some analytical contexts, it is probably better for us to rely on proxies for national power that best fit the issue at hand than a synthetic power index that embraces everything.

II.v. State Technological Capacity and National Power

Among several potential proxies, state tech capacity may be the paramount one contemporarily. First, technology directly greatly influence other conventional components of national power, such as national production, military strength, and soft power. Second, among major power components, state tech strengths appear to have significant explanatory power for some IR events like trade conflict, especially when applied to the modern times, which will be elaborated on in Part IV at large. Third, policymakers, especially those of modern generations, have been placing technology at the core of national security, and their perception can profoundly impact foreign policy.

State tech capacity consists of the *quality* and *amount* of national-possessed knowledge and skills as well as national abilities to *create, apply,* and *store* knowledge; ingredients of technology can be either *material* or *ideational*, in forms of *facilities, personnel, formulas,* or *skills*. Technological capacity *per se* is a straightforward part of national power. On one hand, material components of technology, such as labs, researchers, technicians, information systems, satellites, supercomputers, and the like, are tangible resources that directly contribute to national hard and soft power, though their utility is often greatly conditioned on other resources like innovative capability and management as well as their effective interplays. On the other hand, well-protected ideational aspects of technology accord competitive advantages to a state in that information itself is important national strategic assets. Nevertheless, state tech capacity contributes to national power mainly by its tight bonds with national income, militarized defense and offense, and global influence.

II.v(i) Technology and National Income

According to the endogenous growth theory, R&D is one of determinants of domestic productivity (Abernathy and Townsend 1975), which is crucial for promoting production and sustaining economic growth[13]. National income, often indicated by domestic product, is a widely recognized component of national power (e.g., Davis 1954; Casetti 2003), in the sense that most existing power formulas involve it. Some researchers like Davis (1954) even employ national income as the single proxy of national power. On one hand, through directly enhancing domestic production activity, technological capacity furthers national material power. On the other hand,

[13] In some economic research works, technology is assumed to be highly positively correlated with, or even conceptually equivalent to, total factor productivity (TFP), which indicates the rate of converting inputs and capitals into total outputs, or a more efficient production (e.g., Cobb and Douglas 1928; Caves et al. 1982). Specifically, the Cobb-Douglas function: $Y = AL^{\alpha}K^{\beta}$, $\alpha + \beta = 1$, and $TFP = \frac{Y}{L^{\alpha}K^{\beta}}$, where *Y* is output, *K* capital stock, *L* labor or employment, and *A* an index of productivity (Cobb and Douglas 1928).

innovative advantages lend competitive edges, in the manner of monopolizing global markets for tech-related products, to oligopolistic firms and help them exploitingly gain excessive profits from joining global production and distribution (Prebisch 1962). Through highlighting technology's vital roles in global political economy, Gilpin (1987) redefines the dependency system this way: "The core is characterized principally by its more advanced levels of technology and economic development; the periphery is, at least initially, dependent on the core as a market for its commodity exports and as a source of productive techniques" (20). In short, tech repertoires assist states to extract wealth from economic globalization, which, in combination with their contribution to domestic productivity, serve as a firm basis of a long-lasting economic prosperity. Fagerberg (1988) investigates twenty-seven developed or semi-industrialized countries in a period over 1973-1983 and finds a strong positive association between growth of technological activity and national economy. Again, since economic achievements are a major part of national power, technology is germane to national power through enhancing economy.

In the following figures, year-country observations are plotted against national income, which is indicated by gross domestic product, as well as three proxies of state tech capacity, which have been transformed logarithmically, respectively. The data are drawn from the World Bank database, and more information about the variables can be found in Section II.vii. Figure 2.1 demonstrates a strong, positive association between national income and nationally received payments for intellectual property (IP). Similar patterns can be discerned in Figures 2.2 and 2.3, in which national income is significantly positively correlated with annual patent applications and high-tech exports.

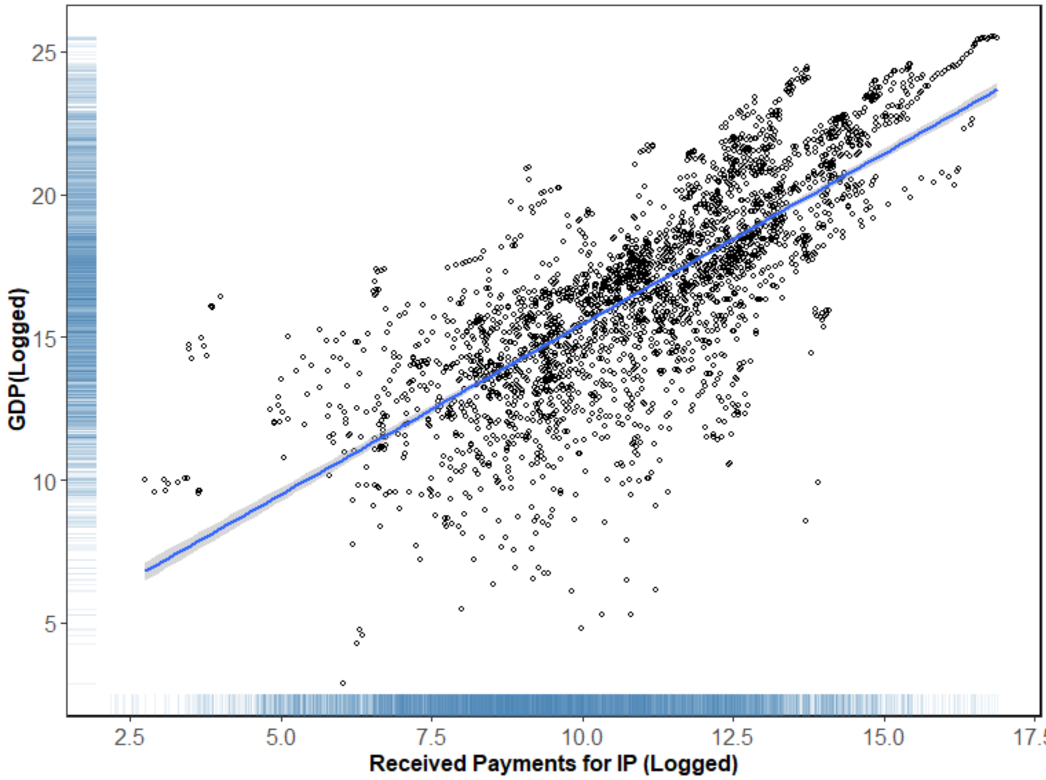

Figure 2.1. The Plot of Gross Domestic Product against Nationally Received Payments for Intellectual Property

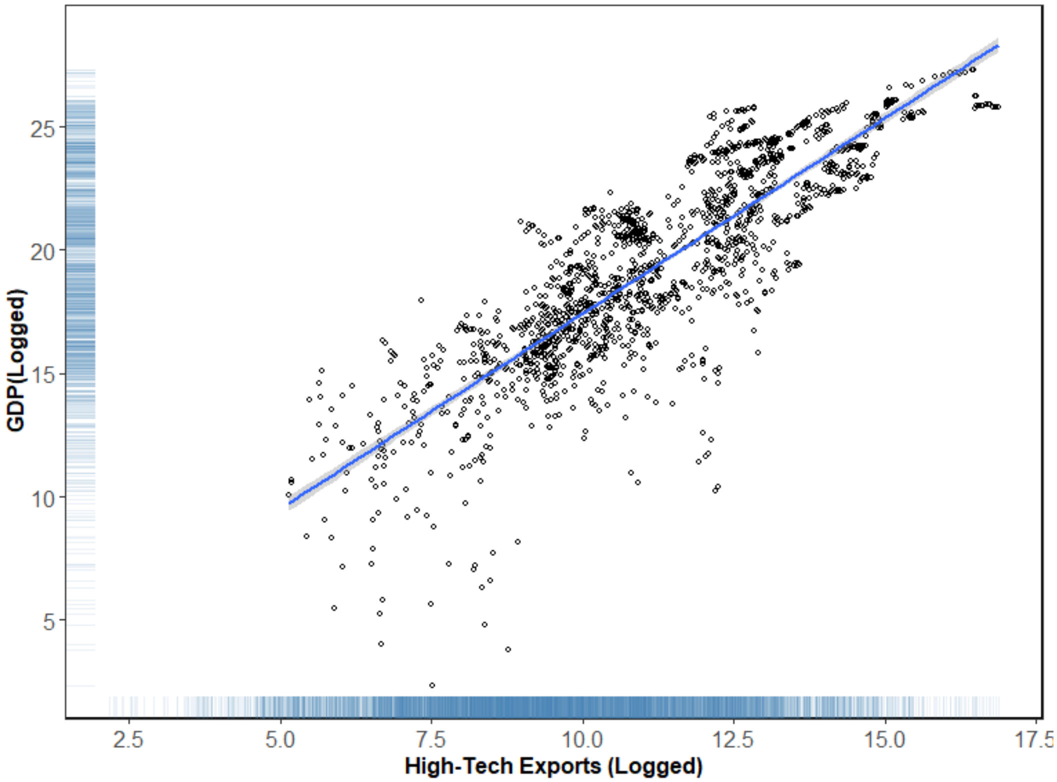

Figure 2.2. The Plot of Gross Domestic Product against State High-Tech Export

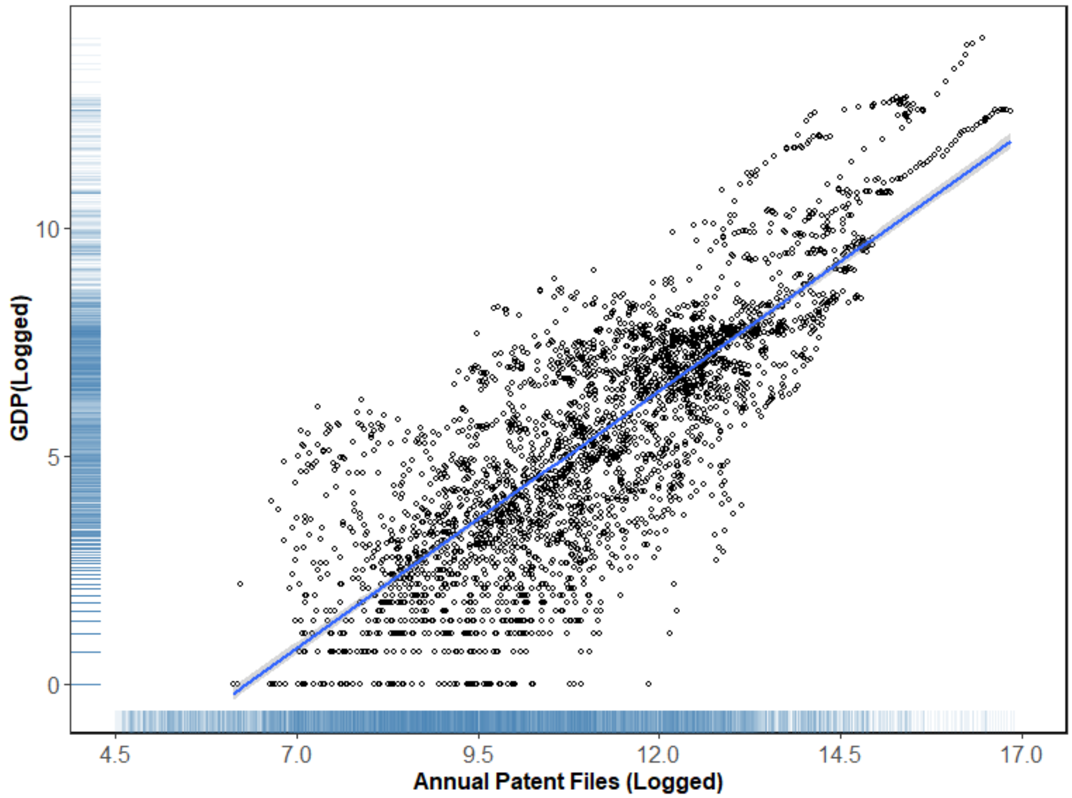

Figure 2.3. The Plot of Gross Domestic Product against Annual National Patent Files

Additionally, as with general informational assets, the cost that it takes to hide, move, store, and replicate disembodied components of technology is relatively small, and technology is therefore expected to have great capability to be immune to or recuperate from exogenous shocks. Therefore, the states that possess a larger number of advanced technologies are supposed to be more self-sufficient and resilient to a global economic, natural, or violent crisis (e.g., Bristow and Healy 2018). In other words, technological capacity contributes to state risk-resisting capability and economic resilience.

II.v(ii). Technology and War

Technology is major components of military strength. A tenet for conventional war is that all else being equal, the side carrying more advanced arms should have the upper hand in battlegrounds. In white arm wars, impregnable fortresses, impenetrable armors, rugged boats, and high-quality blades were vital in increasing combat effectiveness, which relied heavily on contemporarily consummate craftsmen and technology. Since the 14th century, weaponry progress went into the phase of "*mechanization*". At the early age of discovery, firearms had been advanced such that they were easy to carry and operate and allowed for remote, precise killing; rifles and muskets lent overwhelming edges to European expeditioners and immigrants over native sword warriors, spearmen, and archers residing in explored lands, propelling the colonizing process (Black 2013). The mechanization since then continued to advance, and the two world wars epitomized its prowess. Tanks, radars, propeller or jet bombers and fighters, electric telegraphy, machine guns, aircraft carriers, lethal gases, and nuclear fissions were used (Hacker 2005), accounting largely for innumerable mass killings in battles and among civilians in the wars. This was a function of the fact that the belligerents put enormous efforts and passed war pressures on to domestic scientific and technical innovations (e.g., Growther and Whiddington 1947). In the postwar period, interstate militarized conflict has taken on upgraded forms like high levels of automation, cyberspace battlefronts, and potential biological warfare.

Technology can promote the automation of military weapons and thereby increase the efficiency and effectiveness of military attacks and defenses. Unmanned weaponry made its debut in the Second World War, in forms of American installation of Norden Bombsight, an automatic bombsight, on bombers, and German use of V-1 buzz bomb, a precursor of ballistic missiles. Since then, unmanned arms have been ceaselessly progressing, and tele-control aircrafts, cannons, missiles, and submarine objects have kept coming out. In 1955, for containing the communist spread in Indochina from the north, the US began to get mired into the Vietnam war. One decade after that, as more than ten thousand warriors died, American morale and public confidence in the war had significantly been worn out. Domestic surges of anti-war sentiments and protests eventually culminated in the *Paris Peace Accords* of 1973 that arranged the US retreat from Southeastern Asia in 1975, when the prolonged war already generated more than 40,000 casualties of American combatants. By contrast, the US-led coalition concluded the Gulf War of 1991 in merely one month, with a land-sliding, decisive victory and impressively few causalities that are lower than one hundred and fifty. American painlessness of this war should largely be credited to its deployment and employment of many cutting-edge technologies that allowed for a high level of autonomous operations or remote control of weaponry, which enormously increased the effectiveness of attacks and defenses and reduced the exposure of combatants within enemies' firing ranges. The high-tech apparatuses ranged from precision-guided weapons, reliable anti-ballistic missile systems, to drones, which were assisted by the global positioning system (GPS) and satellite communication systems. Contemporarily, some merging techniques like AI and robotics, coupled with sophisticated warfare algorithms, can elevate arms' automation to such a high degree that they make human intervention nearly trivial; highly autonomous weapons have displayed in many scenarios their appalling efficiency and reliability in execution. On 3rd January 2020, the US sent a drone strike at Baghdad and killed Soleimani, an Iranian military officer, on his way to meet Iraqi prime minister in Baghdad. Likewise, Fakhrizadeh, an Iranian nuclear scientist and politician, got assassinated on 27th November 2020 in Tehran, reportedly by an automatic gun equipped with AI and facial recognition and controlled by satellites, and "the gun was so accurate that not a single bullet struck his wife, who was seated next to him" (Shahla and Motevalli 2020). In addition to smart drones and autonomous machine guns, many other robots can alter war patterns as well. Tiny espionage robots can sneak into spaces where impossible for humans to reach; robotic birds that carry venom or germ can make a biological or chemical attack anywhere surreptitiously; military actions will be more maneuverable if letting robotic dogs lift heavy munitions and walk on foot through rugged terrains like dense jungles that do not allow a wheeled vehicle to pass.

Since the advent of the Web in early 1990s, people have reaped immense tech welfare by using the internet, which has however engendered severe security issues. A large portion of national security problems have been arising from cyberspace (Reveron 2012)[14], and state governments have been in high demand of advanced techniques to ward off cyber invasion and protect the information linked to networks. Virtual offenses and defenses have been explored as auxiliary militarized campaigns, in which informational techniques play the pivotal role. In times

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[14] According to the information provided by the Dyadic Cyber Incident and Dispute Dataset (Maness et al. 2019), a dozen states have been detected to be conducting cross-border cyber-attacks. China has been reported to make state-sponsored cyber espionage targeting foreign commercial, political, military institutions (Lindsay et al. 2015).

of militarized disputes, cyberattacks have potentials to paralyze the telecontrol networks and automation process that are critical to enemies' national defense or specific military action. For instance, in September 2007, Israeli armies penetrated in Syrian radar networks and changed thereon real-time radar images, making its jet raid in Syria undetected (Singer and Friedman 2014). Beyond wartime, cyber invasions can threaten national security by sending blackmails, virus, and disinformation, as well as facilitating espionage. Under cyberattacks, military, political, commercial, or other sealed information become subject to exposure to foreign forces, except if the target is equipped with effective cyber safeguards. In this regard, in addition to advanced informational know-hows, AI can make both cyber defense and offense more efficient and effective, by relying on deep learning programs and big data analysis to automatically detect susceptible cyber dynamics and monitoring weaknesses of networks (Hoadley and Lucas 2018).

Moreover, growing biotechnology may break another ground for war. In history, spreading infectious disease had sporadically been used along with violent disputes. After the first world war, despite the items of the *Geneva Protocol* of 1925 that stipulate no first use of bioweapons, developing and preserving biological munition were not prohibited by any international agreements; biological armaments that were more destructive than chemical weapons were greatly appreciated by and developed in France, the UK, the US, and Japan (Guillemin 2004). Nevertheless, only Japan rendered biological warfare a reality. Japanese Unit 731 and its affiliates assaulted Chinese civilians by disbursing plague-infected fleas through airplanes, poisoning water, and spreading germ-carrying bodies, resulting in approximately 580,000 casualties (Barenblatt 2004). During the Cold War, the US and USSR foresaw bioweapons more destructive than nuclear weapons, and both removed restrictions on offensive use of bioweapons and overtly spent substantial resources developing their own bioarms programs (Guillemin 2004) until 1975 when the *Biological Weapons Convention* signed by the superpowers went into force, which banned all offensive bioweapons. Regardless, biological warfare has still been lingering around the world. Several Chinese officials have even envisioned "specific ethnic genetic attacks" in their strategic reports (e.g., Zhang 2017). Initiation of such warfare is supposed to hinge on national technical and political capability of collecting gene information and cultivating ethnic-specific targeting disease agents; some techniques beyond biotechnology such as AI and facial/gesture recognition can greatly expedite the process. It is highly doubtful that international regimes of scientific ethics are capable of effectively preventing so-far-imaginary genetic warfare from eventual occurrence, considering that some cases of collecting gene information on specific ethnic groups have been disclosed. For instance, China has been reported to screen and analyze its citizens' genetic data, especially those of Uighurs, an ethnic minority in China, to allegedly "infer geographic origins of suspects" (Wee 2019). Though its key purpose so far seems to reinforce within-state suppressive ruling, the techniques can, to be sure, be used to target external races in similar ways. Furthermore, some radical research like gene editing can provoke the idea of so-called "racial improvement" that fascists were indulging in and aggravate the ethnic account of international conflict and competition. Though gene editing has been strictly prohibited by world-wide ethic rules, clandestine research may be encouraged by unconstrained totalitarian authorities and ongoing under sovereignty's shelter. For example, a Chinese scientist suddenly claimed that he bred two genetically edited babies in early 2019, shocking the entire biological academia, though he subsequently was sentenced by Chinese courts to jail for three years[15].

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[15] Here is the news source from New York Times: https://www.nytimes.com/2019/01/28/opinion/crispr-genes-babies.html. Here is the source from the Xinhuanet: http://www.xinhuanet.com/english/2019-12/30/c_138666754.htm.

In history, many cases testify to technology's critical roles in determining a waring state's fate. As an example, China had the largest population and GDP, as well as a large territory, in the time of the official boycott of British opium in 1839. Yet its material might did not take effect in the subsequent two Opium Wars, both of which ended with humiliating treaties that expanded colonial privileges and advanced foreign interests in China. Similarly, even though China was far more materially powerful than was Japan during the first Sino-Japanese War in 1894, its fleets were wiped out quickly by the Japanese navy, and then it was forced to cede a part of Shandong to Japan. In reality, owing to the *Meiji Restoration* beginning in 1868, Japan had industrialized and become technically powerful in the late 19th century (Yamamura 2017). Meanwhile, the Manchu rulers in China were reluctant to take substantive reforms toward industrialization and free markets, which, as a big concern to them, might empower the majority Han people and thereby put an end to the already-faltering regime. Another exemplary case is the series of Arab-Israeli conflicts. Though Israel has never been the most powerful Middle Eastern state in terms of major material power indicators like population, GDP, area of territory, or troops, it nearly won all the Arab-Israeli wars, or at least has never been defeated by its more materially powerful neighbors, since 1947. Most credits should be given to Israeli high levels of education, morale, and innovative capability, as well as Western assistance, especially from the US. All the factors have constituted a high level of technological strength of Israel, offsetting its material deficiency relative to its Middle Eastern rivals.[16] Amid the wars, the Israeli armies employed imported advanced missiles and aircrafts and domestic-made high-quality arms like Merkava tanks, Spike systems, and Tavor rifles, and it also conducted high-tech-supported surveillance and espionage.

[16] Archibugi and Coco (2005) find that by 2004 the ranking mean of Israel among the latest four measures of technological capacity is 12.3, while Egypt's ranking mean is 43.3. Other Middle Eastern states had such insignificant technical capacity that they are not included in the analysis.

II.v(iii). Technology and Global Influence

Technologies sometimes are directly traded by states for political benefits. For example, in the late phase of the COVID pandemic, the US and China, managed to donate their vaccinations to certain states to reinforce alliance, gain overseas political support, or/and release a good national image.[17] It is also quite normal that a technologically powerful state transfers technologies or state-of-the-art products to their allies. For instance, since its formation, P.R. China kept receiving expertise assistance from the Soviets, which vastly helped with China's infrastructural, industrial, and ammunition progress. Contemporarily, ZTE and Huawei, two of China's telecom manufacturers, were accused by the US of underground supplying equipment that contains US-made semiconductors to Iran, violating the US embargos policy. Trade between technology and political goods sometimes is implicit. States conventionally restrict or even ban foreign direct investment's (FDI) entry to strategic industries, and many conduct mercantilist campaigns like *import substitution industries* (ISI) to realize tech and economic autarky. However, tech-intensive products and services tend to have the capacity of overcoming such policy hurdles, especially when their oversea purchasers find these imported high-tech capitals economically or physically non-substitutable in boosting domestic economy and stabilizing society. Such a unilaterally technically dependent relationship can be easily converted to transboundary political hierarchy, as the less advanced side must, sooner or later, find itself in difficulties to pursue national interests, except if they are compatible with those of its advanced partners. In words, it

[17] For example, the US donated 2.5 million doses of vaccines to Taiwan (Martina et al. 2021), which was expected to consolidate their political bonds and stabilize Taiwan's democratic regime in the crisis. On 24th June 2021, Ukraine decided to withdraw from a joint statement at the UN Human Rights Council that was discussing human rights issues in China. Anonymous Ukrainian diplomats divulged that China threatened to withhold vaccines that were planned to ship to Ukraine except if it pulled out of the statement. (Keaten 2021).

must surrender some policy autonomy in order to ensure sustainable supplies of critical technologies that have been embedded in its domestic economy. Furthermore, such tech-related trade and investment, and especially those accompanied by collateral loans, may lead to transfer of possession of strategic assets, in forms of harbors, railroads, airports, and the like, from a technically weak state to its advanced partners, reinforcing the latter's global power by accommodating their overseas deployment of military forces, facilitating manipulate international commercial activity, or helping collect global data.

Great tech capacity allows a state to take a high position in setting international standards. Global markets, and especially cross-border high-tech products transactions, are based on standards. Although standards are mostly formally set by private enterprises associations, state governments often play influential, and sometimes predominant, roles in nongovernmental standards entities, whose decisions therefore *de facto* reflect state preferences (e.g., Drezner 2004). A state that possesses a big economy and cutting-edge technology has much chance of being involved in formulating transboundary standards (Mattli and Büthe 2003). Standardization activity furthers major participants' global power, in the sense that standards can be manipulated to act as barriers against particular products, shaping production patterns and trade behaviors. As China's innovative capacity grows, utilizing the tech leverage to govern global technical communities has become an imperative, which serves as part of China's long-term strategy for expanding global influence. Chinese innovative firms have been engaging in improving domestic tech standards, and they have increased their presence in major standard-setting organizations like the *Third Generation Partnership Project* (3GPP) and *International Telecommunication Union* (ITU). The Chinese government made overseas investment plans like the *Silk and Road Initiative* to project its economic power abroad, and by marketing its high-tech products and services like high-speed rails and telecommunications systems in target states, its standards are supposed to have more chance of being externalized.[18]

Moreover, technology contributes a lot to a country's soft power. A unit of technical inputs generally endows products with additional quality, greater utility, and lower price *per* unit; tech-intensive commodities therefore normally enjoy high levels of competitiveness in global markets. Along with the vast outflows of appealing tech products, technology can confer on exporters advantages to effectively disseminate their norms, values, or/and ideologies. According to the *liberalism diffusion theory*, people are assumed to reckon whether and to what extent liberal policy is correlated to national economic success, through observing other states' experiences, and then decide whether to adopt such policy (Simmons et al. 2006; Miller 2016). Thus, a reasonable corollary is that people should be more likely to follow ideas advocated by a technically successful state than by a less advanced one. Briefly, the higher a state tech capability, the more prevailing its ideas.

II.v(v). Global Technological Transition and Power Shift

Human history has witnessed several waves of technological breakthroughs (i.e., positive technology shocks), each of which, except for the ongoing one that has not reached a conclusion, brought about reshuffling of international power distribution. In the time of the industrial revolution between 1760s and 1820s, the emergence of the Watt steam engine that could output

[18] On 22nd December 2017, China's Standardization Administration Published "The Operational Plan for Homogenizing Standards and Co-building the 'One Belt One Road' (2018-2020) ". here is a PDF source: http://www.srcic.com/upload/newsletter/16/pdf_zh/5bfd0ba90de69.pdf. Here is the news on one-belt-one-road net, "Make China's Standards to be the Foundations of the 'One Belt One Road' Constructions". http://ydyl.china.com.cn/2020-10/16/content_76812178.htm?f=pad&a=true.

great motions stimulated a variety of innovations, which immensely promoted productivity and living standards. Britain, the homeland for most major developers of efficient steam engines, then rose to be the most advanced state, and its supremacy in tech buttressed its one hundred years of hegemonic power. Between the late 19th century and the 1950s, combustion-engine-driven automobiles and electro-magnetic communication became frontier technologies. Through actively participating in this innovation movement, America, Germany, and France grew to bereave British of its preponderance. Consequently, Germany became the most powerful state in Europe and developed impetuses to revise the world rules that were favoring Britain and France. For decades after WWII, superpower armament races centered on developing thermonuclear weapons, advancing warheads delivery systems, and exploring space. Meanwhile, semiconductors-based digital technology grew swiftly and profoundly influenced human lives. Partly owing to their mercantilist, corporatist, and export-oriented-industries policies, several East Asian countries, such as Japan and South Korea, successfully took advantage of this window of opportunity for industrial upgrading and grew to be technically powerful states. In the new millennium, many long-existing technologies further evolved and broke new grounds that are unprecedentedly challenging; this ongoing campaign, or the "fourth industrial revolution" as President Biden of the US called when issuing "*Interim National Security Strategic Guidance March 2021*"[19], has become a battlefield for the US-China tech competition. The "frontier technologies" enumerated by United Nations Conference on Trade and Development currently in its "*Technology and Innovation Report 2021*" consist of 3D printing, gene editing, nanotechnology, blockchain, drones, solar PV, Big Data, robotics, AI, 5G, and the Internet of

[19] Here is an online source for the guidance: https://www.whitehouse.gov/wp-content/uploads/2021/03/NSC-1v2.pdf

Things (IoTs). Questions of most interest are about whether, in what ways, and to what extent this ongoing so-called fourth technology revolution is going to alter world power structure.

II.vi. Measures of State Technological Capacity

In modern eras, technologies have been rising as the most important productive forces that remarkably impact national wealth and security, which has been discussed in detail in Section II.v. As a theoretical response to this reality, a growing number of measures of national power have involved state technological capacity (e.g., Krahmann 1927; Saaty and Khouja 1976; Orłowski 2007). To gauge technological capacity, they normally resort to quantities or ratios regarding R&D spending, patents, tertiary education, the penetration rate of computers, or technical and scientific personnel. For instance, Hu and Men (2002) estimate state competitiveness based on five groups of factors: human resources, physical resources, knowledge resources, capital resources, and infrastructures; particularly, the knowledge resources group embraces the numbers of personal computers, internet users, scientific and technological journal articles, R&D spending, and patent applications filed by domestic residents. Among the power surveys that do not contain a factor or factor category named technology or/and science, many in effect refer to some factors correlated to technical capacity. For instance, Luttwak (1990) points out that expenditures on R&D and education should be considered when measuring national power, though not broadly identifying scientific or technical capacity as part of national power.

It is noteworthy that it may be not valid for some works such as Nye (2004) to subsume technologic capacity under the category of “soft power”, since technology can be “hard”—Technological capacity itself can be tangibles, taking on forms of personnel or machinery;

moreover, some intangible technology can be real-timely converted to productivity or fighting forces and thereby change international interactions quasi-physically.

According to the conclusion reached by Eaton and Kortum (1996), the indicators that are most often referred to when measuring technological capacity include research, productivity, and patents. Some macroeconomists use total factor productivity (TFP) as a proxy for technology, which is computed by making aggregate outputs divided by aggregate inputs (e.g., Keller 2002b; Crespo et al. 2002). Though state tech stocks are supposed to be positively related to national productivity, they are not same thing ontologically. Besides, in practice, using productivity to explain national material incomes tends to engender a tautology, considering that the former is calculated based on the latter— They are based on the Cobb-Douglas function:

$Y = AL^{\alpha}K^{\beta}$, $\alpha + \beta = 1$, and $TFP = \frac{Y}{L^{\alpha}K^{\beta}}$, where Y is output, K capital stock, L labor or employment, and A an index of productivity (Cobb and Douglas 1928) (More details can be found in Part III).

By contrast, many measures of state tech power resort to specific factors instead of nation-level productivity. There have existed several projects that engage in assessing state technological capacity (see Table 2.3), which implicitly assume that state technological capacity can influence policy and state strategy independently of other attributes of a state. The majority projects embody at least one of the following indicators: patent, education, numbers of technicians, scientific personnel, and the establishment of information or communications systems; some of them involve R&D spending. Other factors mentioned in these formulas cover royalty receipts, high-tech exports, scientific articles, capitals, political environment, and so forth. Here I point out some shortcomings in these measures.

Table 2.3. The List of Measures of State Technological Capacity

Indicator	Developer	Patent	R&D spending	Education	Information or Communication System	Energy	Researchers, Scientists, or Engineers	Others
Technology Achievement Index	Desai et al. (2002)	✓		✓	✓	✓		Receipts of royalty; high-tech exports.
Indicator of Technological Capabilities	Archibugi and Coco (2004)	✓		✓	✓			Scientific articles; FDI; Technology import; high-tech exports.
Industrial-cum-Technology Advance Index	The United Nations Industrial Development Organization (UNIDO) UNIDO (2005)							High-tech exports and added value share in high-tech industries.
Innovation Capability Index	United Nations Conference on Trade and Development (UNCTAD) Barnard and Cantwell (2007)	✓		✓			✓	Scientific publication
Science and Technology Capacity Index	Rand Corporation Wagner et al. (2004)	✓	✓	✓			✓	
Knowledge Economic Index	The World Bank	✓		✓	✓		✓	Scientific articles
Summary Innovation Index	European Commission (2021)	✓	✓	✓	✓		✓	Employment in high-tech services and venture capital.
Global Innovation Index	World Intellectual Property Organization (WIPO) Wunsch-Vincent et al. (2015)		✓	✓	✓		✓	Political environment, regulatory environment, online creativity, intangible assets, etc.

First, any effort, willingness, or policy to make technical and scientific progress is something different from technical capability *per se*, which should be able to be utilized to advance national interests in international interactions immediately. Factors like FDI inflows, R&D spending, political or regulatory environment, and education may bring about future's technological progress, but they are not a straightforward part of state tech capacity, since they cannot deliver a direct threat to a rival state.

Second, these measures pay more attention to quantity of technologies than their quality, which may reduce their content validity, given that the definition of state tech capacity refers to both quantity and quality of technology. For example, though many surveys think highly of and incorporate national-level numbers of patents or patent applications, they seldom take the quality of patent into account, which however is in conjunction with national stockpiles of *effective* techniques. Since 2019, China has been ranked first in annual patent applications under the *Patent Cooperation Treaty* (PCT), but it is doubtful that China's innovative capacity has systemically outperformed the US and some other advanced states. The incompatibility between the patent indicator's suggestion and the reality that we perceive probably results from the overlook of patent value.

Third, in these projects, arbitrary weights are imposed on a variety of indicators related to innovation, inventiveness, technology, and the like. Even though some data techniques, such as the Bayesian factor analysis with the MCMC method, may help researchers find objective weights for selected variables (Quinn 2004), these processes of selecting and weighting candidate variables still lack theoretical justifications. As a result, the issues like double counting, overrating, or underrating tend to arise in formulating a composite index.

Therefore, I raise two points concerning measuring of state tech power. First, using different proxies for tech power are preferred to a comprehensive measure. Second, several indicators have been frequently used to evaluate state technical richness, including numbers of patent application files, spending on R&Ds, numbers of scientists and researchers *per* one million citizens, rewards from possessed intellectual properties, and so forth, but not all of them meet the two qualifications I stress: First. it represents a state's possession of applicable technologies rather than its efforts or willingness to develop technology or make innovation; second, both quantity and quality of national technologic assets are taken into account.

According to the two rules, some indicators like the spending on R&D and the number of researchers *per* one million citizens cannot be appropriate proxies of technological capacity, given that they stand for states' efforts in developing technology but cannot directly reflect their possession of applicable technology.

Many research works have used patents as a proxy of technologies (e.g., Fagerberg 1988; Frame 1991; Eaton and Kortum 1999), but as aforementioned, there is great variation in quality of patents. To incorporate patent quality into the gauging of technical levels, Pakes (1986) appeal to renewal fees paid by each patent; Harhoff and Reitzig (2004) use numbers of citations of each patent in subsequent patent applications to weight them; Gambardella (2008) analyzes the data on patent quality gathered *via* the PatVal-EU s survey. These methods, however, still have shortcomings. To keep a good performance record, patent owners may have impetuses to renew their patents, even when their quality is not good enough to guarantee a royalty return higher than the renewal fee.[20] Nor can citation numbers be a good representation of patent quality. First,

[20] For example, in China, many public or private organizations regard patent portfolios as key tokens of private or organizational research achievements and link them to career promotions

any time intervals used for counting patent citations can render biasness, since an average patent's influence may grow and ebb in ways that vary across regions (Bacchiocchi and Montobbio 2010) and across fields (Jaffe and Trajtenberg 1996).[21] Second, applicants are socialized, and their applications tend to refer to their own and domestic peers' past patents (Bacchiocchi and Montobbio 2010). The weakness of assessing patent quality based on surveys is evident, as most inventers tend to overestimate their own innovations.

In this research, I use state annual number of patent files, which can show a state's innovative capacity and possession of latest techniques, annual volumes of high-tech exports, as well as annual received royalties of intellectual properties as proxies for state tech capacity; the first one is used as the baseline measure, which does not take IP's quality into account, and the latter two are able to reflect both national technical hoards and their qualities. The assumption underlying the use of receipts of royalties is that the quality of proprietary assets is closely positively associated with their price and sales. Likewise, it is assumed that IP's quantity and quality mostly equally make major contribution to the volume of high-tech exports.

Three proxies for state technological gaps, $\text{Relaive\_tech}_{ji,t}^{(\mathbf{1})}$, $\text{Relaive\_tech}_{ji,t}^{(\mathbf{2})}$, and $\text{Relaive\_tech}_{ji,t}^{(\mathbf{3})}$, are used to measure dyadic interstate parity/disparity in terms of technological capacity, which are computed based on the following algorithms respectively.

$$\text{Relaive\_tech}_{ji,t}^{(\mathbf{1})} = \ln\left(\frac{patent\_appls_{j,t}}{patent\_appls_{i,t}}\right),$$

and fund offers, which partly accounts for Chinese explosions of patent applications in recent two decades.

[21] A patent's influence is temporally dynamic, and it is modeled as a combination of the knowledge diffusion and the process of obsolescence (Jaffe and Trajtenberg 1996).

$$\text{Relaive\_tech}^{(2)}_{ji,t} = \ln\left(\frac{IP\_receive_{j,t}}{IP\_receive_{i,t}}\right),$$

$$\text{Relaive\_tech}^{(3)}_{ji,t} = \ln\left(\frac{hitech\_export_{j,t}}{hitech\_export_{i,t}}\right).$$

The data about the variables, $patent\_appls_{i,t}$, $IP\_receive_{i,t}$, and $hitech\_export_{i,t}$, are drawn from the World Bank's database of World Development Indicators. In the following parts of this dissertation, these proxies of technical gaps will be utilized to analyze the relationships between interstate trade and technical gaps, as well as how technical catchng-up alters the course of between-state trade interactions. The variable, $patent\_appls$, stands for the number of patent applications that are filed by the residents of state *i* in year *t*. $IP\_receive_{i,t}$ denotes the charges for the use of intellectual property that are received by the nationals of state *i* in year *t*. $hitech\_export_{i,t}$ indicates the high-tech exports state *i* makes in year *t*. According to the Word Bank's description about its methodology for the measurement, the high-tech products classification is based *on SITC Rev. 3* and is taken from Table 4 of Annex 2 of Hatzichronoglou's (1997) working paper, and the measurers determine high-tech products based on R&D intensity on products from several advanced states, including Germany, Italy, Japan, the Netherlands, Sweden, and the United States. High-tech products in this survey include aerospace, computers, pharmaceuticals, scientific instruments, electrical machinery, and so forth.

II.vii. State Technologic Capacity and Non-Militarized Conflict

Based on the presumption of a high intercorrelation between national power and war potential, neorealists put forth a series of theories about relationships between interstate power structure and state strategic behavior, such as the balance of power, deterrence war, and preventive action.

In the last part of Section II.iii, it is mentioned that the assumption, underlying existing measures of national power, that different components of national power are scalars rather than vectors and always lead states to behave in same courses is basically unwarranted. Disparate from this assumption, I posit that *states in face of similar interstate structures of material powers and of technological powers tend to take different maneuvers to deal with each*. From a realist prism, realism purveys crucial contexts for all kinds of interstate interaction, given that state behavior in any arenas ought to be compatible with the anarchic settings like uniform interests of security and aim of survival. Aim may be uniform, but national strategy can be diverse. Foreign strategy spaces have multiple dimensions: militarized conflict and peace processes, economic interactions, as well as a set of other domains that demand international cooperation such as environment and human rights protection. Here I assert that *while all militarized, economic, and other non-militarized conflict or cooperation can be triggered by various common factors, they are qualitatively different policy options, and their efficiency and effectiveness in addressing situations are different*.

Undoubtedly, national material accruement can be effectively deterred by successful military invasion. In addition to material costs directly incurred by a war, in forms of combatant and civilian deaths as well as war-torn houses, villages, and cities, a military defeat is generally followed by a cession of territory or colonial interest, pecuniary reparations, forced disarmament, or other post-war penalties inflicted on the loser, which exacerbates its loss of material wealth. In contrast, information and skills cannot be readily eradicated by physical attacks. For example, after its surrender in 1918 to the *Entente*, Germany was deprived by the *Versailles Treaty* of a lot of domestic and overseas strategic material possessions, which sapped its economy and bogged down its military strength badly. Nevertheless, German technologies and innovative capability remained nearly intact, given that the war itself and post-war punishments it received could not effectively vanish German stocks of skills and knowledge. Partly owing to its intelligent legacy, despite under stringent, humiliating post-war constraints, Germany revitalized its domestic production and survived the 1930s recession, and its military power accrued swiftly by the eve of WWII. Similar phenomena can be discerned in post-WWII Germany and Japan. Considering that technologies are often more disembodied than material, and militarized actions are therefore not able to destroy or effectively and efficiently impede another state's technological progress, a state amid international tech competition is assumed to primarily consider undertaking some non-militarized tactics like trade policies to deal with the tournament, which supposedly incur fewer costs and more efficacies than do military actions.

Furthermore, it is relatively difficult to legitimize military attacks on a technological competitor on the ground of national security. Compared to some material power build-ups that exhibit disturbing aggression directly, technologies, except for those in shapes of weapons or military facilities, appear benign, progressive, and mostly friendly to global customers, and thus they are not conventionally regarded as a direct threat to another state's security. Accordingly, militarized actions against a tech power challenger can hardly be legitimized by invoking national security. By contrast, non-militarized actions such as economic sanctions can be readily justified in guise of reasonable punishments legitimized by convictions of the target, hiding or disacknowledging the true purpose of tackling intense tech competition from the domestic audiences and international communities.

Hence, this research contends that as the foremost component of national power contemporarily, *state technological capacity may be deemed as a factor that affects foreign policies independently of and differently from other material components of national power*.

Specifically, this research proposes that amid interstate material power struggles, in forms of scrambling to expand territory, arsenal, or domestic production, states under threat are likely to carry out militarized deterrence; in contrast, interstate technical competition tends to lead to non-violent deterrence, including cyber warfare or protectionism in economic and civilian contact.

The first World War can be largely explained by German remarkable rise in material power. In 1870, Germany and France had populations, territory areas, and domestic productions of roughly equal size, and both their populations and economies were significantly smaller than Britain's; this tripartite material power structure had changed in 1990 when Germany had the largest population and GDP in Europe. The transition theory asserts that "the international system is usually hierarchically ordered with a dominant power at the top that creates and sustains the international order; ... the risk of war is highest in a situation when a dissatisfied rising power has reached parity or even overtaken the declining dominant power" (Lemke 2004: 55)[22]. According to the transitional approach, a material power shift from Britain to Germany may help explain the breakout of WWI[23].

By contrast, the Cold War during the second half of the 20th century is largely shaped by technological races and non-militarized interstate conflict. Right after WWII, the extremely high levels of uncertainty due to their separations and power parity basically discouraged an all-out war initiation between the US and USSR, who inexorably fell into a security dilemma. To get the

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[22] For more original works about the power transition theory, see Organski (1968) and Organski and Kugler (1980).

[23] Most transitional theorists regard power transition as a material power catch-up. Organski and Kugler measure national power based on population, economic size, and efficacy of political structure. (Organski 1968; Organski and Kugler 1980). Efird et al. (2003) analyze war from the transitional perspective, using GDP and military strength to indicate power. Likewise, Rapkin and Thompson examine the globally political significance of China's growth in national income and military power.

upper hand in the escalated tension and thereby shore up national security, both states got obsessed with expanding their stockpiles of atomic bombs and chemical weapons, developing missiles of a larger range and advanced aircraft carriers (e.g., Nimitz class), and producing high-performance aircrafts (e.g., Antonov An-124 Ruslan), submarines (e.g., Typhoon), and fleets. In the meanwhile, they were engaged in a space race, by sending more and more objects and astronauts into space, and these expensive projects squandered a lot of resources. The arms and space races were in fact the embodiments of a technical contest, as they heavily relied on national capability of making innovations and technical progress. Military actions were not an optimal, realistic way of winning or ending the technical competition at that time, and for tackling the bitter technical race, the US and Soviet explored conflict fronts in civil, economic and intelligence realms. Amid the Cold War, the US and the USSR built their own trade zones, and the two blocs had little economic contact with each other, even though trading with all possible partners would be more efficient and beneficial. It is partly due to their unwillingness to have bilateral trade materially empower their rival. Another concern lies in the fact that economic contact would lead to technical information leakage in many ways, including facilitating already-out-of-control espionage activity.

Similarly, the US-China competition that emerged at the beginning of the new millennium is also mainly characterized by technical competition, which will be introduced in Part IV. All the above cases delineate critical evolutions of power struggles. First, since the inception of mutually assured destruction backed by nuclear weapons, power catching-up or parity's association with interstate war has declined. Second, states not merely care about material power transition but are also, or even more, concerned about their technical power distribution, and they evidently recognize technology's pivotal roles in enhancing national security. Third, apart from material power shifting, which tends to be closely associated with militarized confrontations, technical power races may engender non-militarized conflict; this distinction supports the previously raised proposition that state technological capacity is a factor that may affect international interactions independently of and differently from the material segments of national power.

II.viii. Conclusion

National power is a basic concept in international relations that almost bolsters the entire realist analytical frameworks and shapes IR practices. This research maintains that state tech capacity directly contributes to national power in many ways, such as promoting national production, military strengths, and global influence, and the historical surges of innovations were always followed by a profound alteration in global power distribution. These facts suggest that the operationalization process of national power is ought to be subject to continual updating for adapting to a rapidly evolving political world. By disclosing the weaknesses in existing composite measures of national power, I posit that using issue-relevant national power proxies to analyze IR events might be preferred to a synthetic power index in some analytical contexts. As to the measure of state tech strength, it is recommended that a composite technical index appears not an optimal choice, and we can use indicators that embrace both quantities and qualities of technologies to represent state tech capacity. Furthermore, it is argued that different aspects of national power can be vectors that may lead to state resort to different policy domains. For example, interstate competition in technology is supposed to affect state non-militarized policies than to trigger militarized actions, while some non-militarized policies like trade restrictions or civil isolations are probably more efficient than physical attacks in deterring a worrying growth in intangible assets in other states. Besides, technologies are not conventionally regarded as a direct threat to another state's security, and hence militarized actions against a technological challenger can hardly be domestically and internationally legitimized.

PART III

CROSSBORDER TECHNOLOGICAL POWER TRANSFER: INTERSTATE TRADE DEPENDENCE AND TECH POWER TRANSITION

III.i. Introduction

The critical roles that *state technological capacity* plays in shaping national power has been systematically discussed in the preceding part. The following query of great relevance is what factors determine a state's tech capacity. Without a doubt, a wide range of endogenous conditions, such as political institutions, economic scales, production structure, demographic settings, and cultures, should exert impacts to some extent on technological progress. Likewise, crossborder interpersonal or interfirm contact, in any forms, should have potentials to stimulate indigenous tech procurement, through either providing access to global free-to-use knowledge pools, promoting transnational joint innovative ventures, or transactions concerning privatized foreign technologies or tech-related intermediates or commodities. This part concentrates on international trade and technological diffusion; in particular, it manifests how a state's *trade dependence* on its partner paves the path for unfavorable between-state tech power transition—It causes an advanced state to fail to prevent its knowledges and innovations from outflowing toward its lagging partners; simultaneously, it can lead to fewer opportunities for a less advanced state to develop indigenous technical systems.

Orthodox macroeconomics contends that states can significantly improve their economy by joining global production networks. Some political economists assert that crossborder trade can serve as sources of strategic resources for states and provide them with coercive power over partners (e.g., Hirschman 1945). That is, trade is supposed to economically empower a participatory state and give it more room for raising military might. In the similar vein, technological liberals optimistically predict that once other things being equal, states can gain technical strength from knowledge transfer alongside crossborder economic activity (e.g., Grossman and Helpman 1991). However, adherents to the *dependency theory* who focus much more on bilateral economic interactions and power distribution hold opposite viewpoints; they insist that economic globalization is innately hierarchical and politicized, in which powerful states project and expand their influences, through preventing subordinate states from developing indigenous technical systems and competitive industries. Apart from the existing debates on globalization's impacts on domestic technical progress or global/regional tech convergence, this research has a particular focus on how bilateral trade activity influences two participants' *dyadic* tech power relativeness, which is supposed to be of more interest to IR practitioners.

In the first section, the nature of technological diffusion is investigated, in which economics of learning knowledge, often-taken means of obtaining and utilizing knowledge, as well as conventional, and especially political, barriers for technology transfer are presented. Following this, a causal relationship between foreign technology influx and state technical growth is constructed. Specifically, I will show how alien knowledge directly, through learning-by-doing processes, or/and through boosting strategic efficiency, contribute to state tech power growth. After that, the mechanisms through which interstate trade brings about crossborder technology transfer are specified. First, technically backward states can exchange their labor-intensive goods or raw materials for tech-intensive commodities through integration into global production networks, and then they can receive and absorb knowledge from advanced imports. Second, the spillover effect of trade is part of FDI's externalities, given that FDI promotes cross-border flows of complementary or intermediate high-tech goods and thereby facilitates knowledge diffusion. Unlike liberals' optimistic attitudes toward the impact of trade on backward countries' technical progress, dependency theorists cast doubt on it, based on facts that high-tech firms and technically leading states normally have monopoly power and great bargaining leverage in global markets, which allow them to make rules in their favor and prohibit technological catching-up from less-advanced states. I uncover the past significant variation in correlations between a backward state's commercial contact with its more advanced partner and its relative technical achievements; this puzzling fact necessitates an alternative explanation beyond existing liberal and dependency approaches. In the following section, I point out that it is state trade dependence, and especially import dependence, on another that acts as the major dynamics for state tech power transition. A utility model is formulated to manifest how a higher level of trade dependence leads to more concessions in technology protection, as a way for IP holders to exploit global supply chains most efficiently, and gives the depended state more bargaining leverage in transnational negotiation around technology. In the similar vein, if a less advanced state is heavily dependent on tech-related imports from its advanced partner, it is inevitably enmeshed in the latter's great economic, technological, and political power and falls short of capability to promote autonomous technical progress. Furthermore, I put forth another conjecture, which is also crucial for IR analysis, that trade dependence solely is less likely to realize between-state technological power surpassing. The remainders of this part are dedicated to empirical investigations, and a large-*N* state-level analysis is reported, and what I find is basically supportive of the arguments.

III.ii. Technology Diffusion

Technology is "always inherently intelligent enough either to function, to be used to function, to be imbued with, or to be interpreted as having a function that only intelligent beings have the ability to comprehend;…[it can be] something devised, designed, or discovered that serves a particular purpose … [, or] a significant beneficiary of rationally-derived knowledge that is 'used for' a purpose, without itself necessarily being translated into something physical or material that 'does'" (Carroll 2017: 18). According to this comprehensive definition of technology, technology can either take shape or be intangible; specifically, it can be embodied by formulas, designs, equipment, facilities, processes, biological organisms, personnel, and so forth. Though innovations are mostly developed by talented or inspired individuals or private corporations for profit or nonprofit reasons, certain R&D enterprises may either straightforwardly or indirectly be encouraged, funded, and controlled by public organizations for political purposes.

Orthodox economists conventionally assume humans to be innately rational or boundedly rational actors who seek to explore greatest satisfaction under budget or resource constraints. Mostly, they can approach this goal by wisely diversifying investments or consumptions across available different resources. Likewise, following the *rational choice approach*, people shall be fully incentivized to manage to comprehend and perform as many of the new technologies that they can touch as possible; this is because each technology normally returns to owners a fixed additional utility each time it is used, and in the long run, the fixed cost of learning a technology becomes negligible relative to its numerous accumulative rewards. Therefore, though techniques are initially developed and utilized by different groups of humans and in different locations, they presumptively comply with the rule of *increasing entropy* by irreversibly diffusing among people who communicate with one another.

Free dissemination and convergence of technology, however, are anything but a reality, since there always exist either visible or invisible tough hands holding back the absorbing process of alien knowledge. These obstacles probably take on forms like property rights policy, administrative orders, geographic barriers, cultural conservativeness, low levels of domestic R&D, complexity of cutting-edge technologies, and so forth.

Sovereign states are the most powerful entities presently on the planet, in the sense that they are *de jure*, and mostly *de facto*, in possession of mutually acknowledged autonomy against external influence and the entirety of authority within their claimed territories. According to the previous analyses of state technological capacity, states, as rational actors who, from the realist prim, urge for power in an anarchic world, ought to be motivated to acquire foreign technology as a way to accumulate state tech power, and simultaneously attempt to prevent domestic critical technology from outflowing for purposes like preserving domestic jobs, avoiding fostering a potential competitor, or forestalling potential foreign threats to national security, especially when such political costs are significant. Besides, borders of states commonly reflect natural, physical barriers of mobility. In all, one has reasons to expect states to be the principal actors that disrupt the diffusion of knowledge, and sovereignized clusters of technology are supposed to exist. In this regard, this research focuses on state-level technological diffusion and tech competition, and it shall bear great importance.

In all, there coexist both positive factors that pave a way for and antagonizing forces that act as obstacles to cross-border tech spillovers. The next section introduces ways in which technologies may transfer; specifically, it reveals characteristics of technology and makes a synopsis of methods of or/and conditions for knowledge diffusion. Then, it concentrates on several channels through which transferred-in technology helps shore up state tech capacity, including directly expanding and elevating the stock of high-tech final goods, providing opportunity for learning, inspiring second innovations, as well as directing politicized R&D activity.

III.iii. Technology Input and State Technological Growth

This section is devoted to illustrating whether and how foreign technology inflows contribute to domestic technological growth. A host of economists have made positive assertions about this relationship. For example, Findlay (1978) conceptually divides the world into the advanced and backward regions and establishes a model to show that the tech growth rate of the backward one "is an increasing function of the relative extent to which the activities of foreign firms with their superior technology pervade the local economy" (5) [24]. In this section, a systemic analysis of an exogenous growth model for state tech power will be introduced.

III.iii(i). Direct Knowledge Inflows

Technology can permeate state borders. A large portion of technology exists as public goods, which are non-rivalrous, nonexclusive, and always accessible. Mostly, the use of knowledge is not rivalrous given that consumption of certain information by one actor does not diminish the quantity available for others to consume, and this nonrivalry feature of many technologies makes their spatial diffusion or spillovers possible. Meanwhile, disembodied knowledge can be adopted and exercised across a variety of practices at different places simultaneously; that is, it cannot be exclusive (Romer 1990). Though non-rivalrous and nonexclusive, many technologies are not accessible or available for free.

Technology can be privatized. First, the technologies incarnated in concrete matters like instruments, personnel, or materials can be rivalrous and exclusive, given that they normally

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[24] Findlay's (1978) model for technological growth rate is $\dot{B}/B = f(x, y)$, with $\partial f/\partial x < 0$ and $\partial f/\partial y > 0$, where $x \equiv B(t)/A(t)$, and $y \equiv K_f(t)/K_d(t)$; K_f and K_d denote state *i*'s foreign and domestic capital stocks, *A(t)* and *B(t)* the technical efficiencies of the advanced and backward regions respectively, and *t* the time.

have a limited quantity and a discount rate for use. Likewise, tech-intensive intermediate or final goods are private goods, even though their consumers may not really comprehend the know-hows embedded in them. Trading private technological goods is common and of great relevance in international relations, given that states may import advanced weapons or receive them as aids from their allies, which can substantively upgrade their arsenal and increases their military power and presence. This kind of technology transfer has significant limitations: tangible technological products will not be replicated if their owners cannot decipher and master the critical information within it. Possessing and operating imported tech goods may facilitate learning by doing and help develop secondary innovations, and these activities may substantively increase domestic technological levels, which will be elaborated in the following sections; however, the foreign-tech-driven learning processes and making of secondary innovation heavily rely on many preconditions, so importing tangible high-tech goods solely does not guarantee a perpetual increase in state tech capacity.

Second, technology which is intangible and innately nonexclusive can be converted to proprietaries through legally recognizing pecuniary rewardableness of novelty and effectively monitoring and penalizing their free use. The intellectual property protection systems confer on innovators the rights to keep the profitable use of their inventions excludable unless the rights expire or are renounced by owners. First, some technologies may remain classified and thoroughly at owners' private disposal, and their owners have the right to prevent their hidden technical information from being pried or disclosed, which is normally protected by civil, and often specifically IP, laws. Second, innovators may have incentives to publish their innovations to claim originality and proprietary based on the novelty, and the authorities that are delegated to enact and enforce patent or copyright terms grant intellectual properties to inventors and punish unfranchised commercial use of patented assets. Such publishing activities engender great positive side effects on knowledge diffusion and global R&D. Therefore, privatized technology can be legally transferred or unlawfully used.

Figure 3.1 sketches the conventional processes for technology transfer. As it displays, most technologies are nonrivalrous, nonexclusive, and nearly available for free. Some technologies, normally in forms of patents, classified information held by private companies, or encrypted R&D conducted by government-sponsored enterprises, remain secret or publicized but protected by laws against free use. Owners of secret technologies may like to share their covert intelligence with certain people; if that happens, hidden technologies are legitimately transferred. Others may seek confidential knowledge by stealing and committing infringement of the owners' intellectual property rights. Patented technologies and creative works that reserve copyright preclude their unlicensed use, except for some noncommercial purposes like education or further R&D. Piracy activities, which employ patented knowledge without franchise agreements and royalty payments, are subject to charges for abusing of intellectual property rights. Some knowledge is embodied and embedded in tangible goods, and it therefore is rivalrous and exclusive. The major way of transferring such a kind of technology is selling and purchasing tech-intensive final goods; sanctioned firms or states may get embargoed technical goods through smuggling. It is noteworthy that all patented innovations shall eventually become public goods when their patents expire; in comparison, though there rarely exist terms of validity for intellectual secrets, they usually become public knowledge as well; owners choose to publicize them probably because the technology has become obsolete and nearly profitless, or they aim to encourage certain R&D.

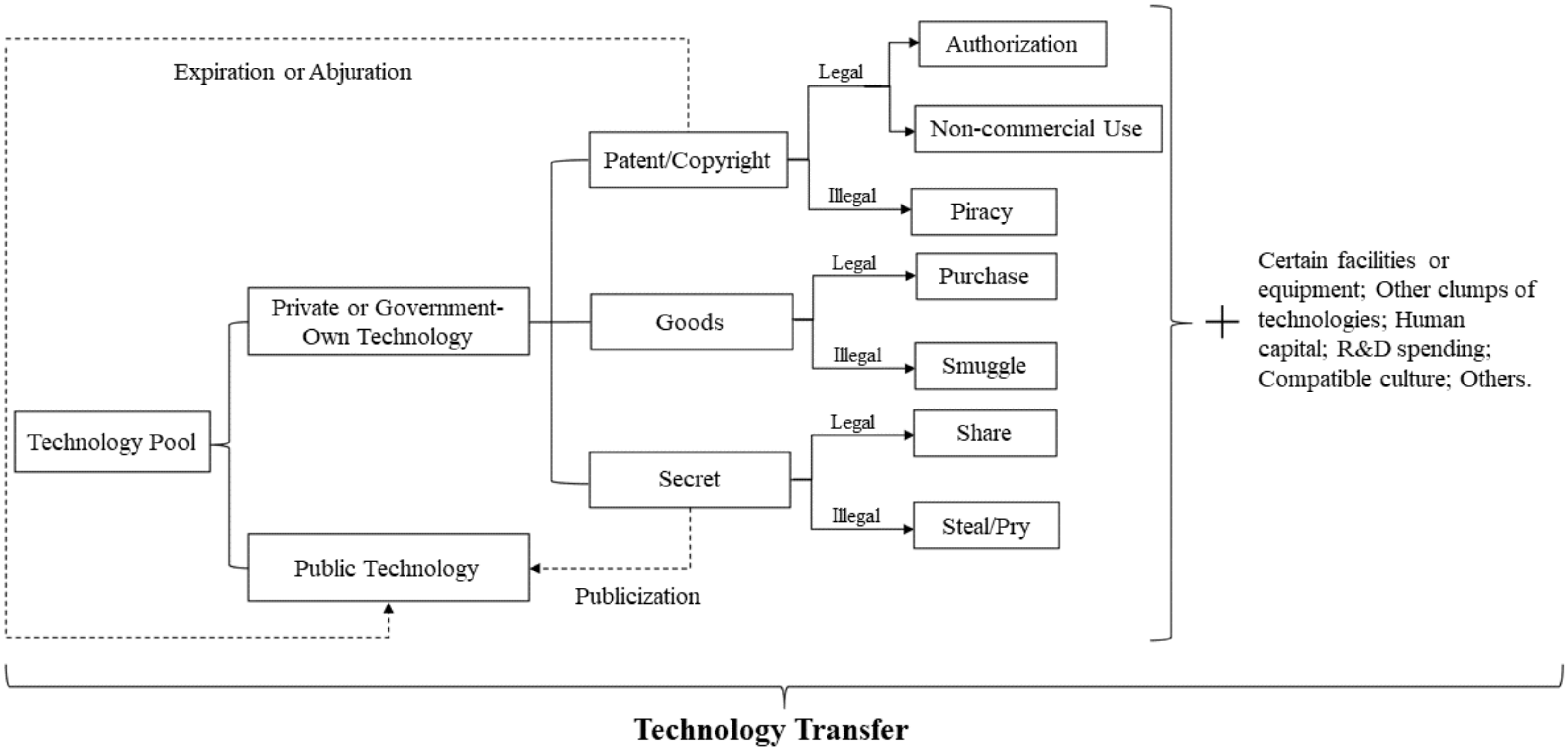

Figure 3.1. Direct Technology Transfer

A common false presumption is that potential recipients of cross-border technology transfers are always ready to import, adapt to, and apply new knowledge and skills. In fact, the effectiveness of technology diffusion is normally conditional on an array of prerequisites.

Interstate geographical proximity has a positive impact on cross-border technology transfer because short distances help reduce the cost of communication (Keller 2002a). By contrast, technical proximities across different tech fields are supposed to negatively affect technological diffusion by shrinking the spillover pool (Jaffe 1986; Branstetter 2001; Griffith et al. 2003). Specifically, Jaffe (1986) and Branstetter (2001) measure a technology spillover pool between two firms as the sum of R&Ds which are weighted by technological distances between the two firms.[25] Grossman and Helpman (1991) presume open communication channels between countries to exist, in which scenario knowledge is public goods that are nonrival, freely disposal, and accessible to every producer; then they formulate a function that links world innovative growth rates to cross-border research differences, based on which it is argued that the larger the overlap between two states in terms of R&D, the lower the common innovation growth rate in both.[26] Similarly, at the regional level, Findlay (1978) assumptively divides the world into the

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[25] Specifically, the technological proximity between two firms *i* and *j* is represented by T_{ij}, which is expressed as $T_{ij} = \frac{F_i F_i'}{\left[\left(F_i F_i'\right)\left(F_j F_j'\right)\right]^{1/2}}$, and $F_i = \left(f_i \cdots f_k\right)$, where f_k designates firm *i*'s technological capacity in the *k*th tech field.

[26] Grossman and Helpman (1991) first suppose a fraction of new products developed in state B have been available in country A. The equation for the growth rate of innovations in either one of two states is $g = \frac{L^A + \psi L^B}{a\left(1-\alpha\right)^{-1}} - \alpha\rho$, where *g* denotes the innovation growth rate, *L* the size of labor force, $\left(1-\alpha\right)^{-1}$ the elasticity of components, ρ the subjective discount rate, and *a* the constant (240-242). According to the model, a larger ψ designates a smaller overlap, which results in a greater growth rate.

advanced and backward regions and establishes a model for the tech growth rate of the backward one, showing that it “is an increasing function of the relative extent to which the activities of foreign firms with their superior technology pervade the local economy” (5).[27]

Economists assert that the effectiveness of converting transferred-in technologies to domestic tech growth is reliant on the availability of other resources of relevance, such as R&D stocks, human capital, and public spending. At the firm level, the effective absorption of advanced knowledge and skills is supposed to entail certain prerequisite abilities, including firm-level capabilities to well train employees and foster creativity (Lall 2000). In the similar vein, Crespo et al. (2002) maintain that the effect of international technological spillovers on domestic technical growth is conditional on domestic stocks of knowledge, which is determined by human capital and R&D capital stocks.[28] Multiple economists point out the *two faces* of R&D—it directly generates new knowledge or/and establishes *a prior* capability of learning and absorbing available technology of more complexity; some empirical findings show that firms invest in R&D to increase its capability of assimilating external technologies (e.g., Tilton 1971; Cohen and Levinthal 1989). Griffith et al. (2003) even think of R&D as a straightforward indicator of absorptive capacity, which plays a crucial role in facilitating the transfer of technology. A few research works empirically test the preconditional roles human capitals play in technology

[27] Findlay’s (1978) model for technological growth rate is $\dot{B}/B = f(x, y)$, with $\partial f/\partial x < 0$ and $\partial f/\partial y > 0$, where $x \equiv B(t)/A(t)$, and $y \equiv K_f(t)/K_d(t)$; K_f and K_d denote state *i*’s foreign and domestic capital stocks, *A(t)* and *B(t)* the technical efficiencies of the advanced and backward regions respectively, and *t* the time.

[28] Their model for TFP growth is $\Delta \log A_{it} = \delta + \varphi \cdot T_{it} + \mu \cdot T_{it} \cdot S_{it} + \varepsilon_{it}$, and $T_{it} = 0.398 \cdot H_{it} + 0.917 \cdot RDK_{it}$, where *T* denotes domestic stock of technological knowledge, *S* the international technological spillover, *H* the human capital stock per employed divided by mean, and *RDK* the R&D capital stock *per* employee divided by mean.

transfer. Nelson and Phelps (1966) develop models that describe a process in which education speeds up technological diffusion and argue that "society should build more human capital relative to tangible capital the more dynamic is the technology" (75). Benhabib and Spiegel's (1994) empirical analyses evidence that the growth rate of TFP is positively associated with a nation's human capital stocks. Relatedly, Xu (2000) probes R&D transfers created by the multinational enterprises (MNEs) from the US and observes that they are more likely to occur in developed countries (DCs) than in less-developed countries (LDCs), suggesting that potential recipients of exogenous technology should possess a minimum stock of human capital in pursuit of an effective conversion of FDI inflows from the US to productivity growth. In addition, state capability of providing public goods such as social orders, public educational systems, physical infrastructures, property rights protections, dynamic and competitive markets, and so forth, is supposed to facilitate international technological convergence (Desai et al. 2002). Moreover, Parente and Prescott (1994) resort to social and political factors and assert that the growth variations across developing states can be accounted for by their disparity in barriers to technology adoption, such as legal constraints, corrupt bureaucrats, violence, and strikes.

III.iii(ii). Technology Inflows and Secondary Innovation

An indirect technology spillover can be achieved through learning by doing, referring to a phenomenon in which innovations originating in one place are found to perform upgraded functions in another location (Rosenberg 1982). Technology influx may offer opportunities for further inventive exploration, actualization, or realization of its potentials, in the sense that major technical breakthroughs can drive a series of minor technical innovations (Young 1991: 372). Specifically, Aghion et al. (1998) distinguish fundamental technology, which purveys a basis for future development, and secondary R&D, which utilizes pre-existing, often critical, technology and thereby makes new innovations; they contend that domestic accumulation of technology depends on both genres of innovation. In general, any technology can serve as both. At the state level, emergence of some profound inventions within one state may make certain secondary R&D possible or relevant research more efficient in another state; in so doing, transferred-in knowledge promotes the latter's technology accumulation. For instance, though no Chinese firms have successfully developed high-performance chips, some Chinese tech giants have made leading R&D in certain frontier fields like the 5G based on the imported chips. More broadly, by joining the global R&D networks, every firm engages in internal R&D based on exogenous knowledge.

It is noteworthy that even though states can benefit from secondary innovation, the primary innovations remain pivotal in state technological capacity. That is, the learning-by-doing process may contribute to domestic tech growth but hardly lead to a significant leap in national tech power.

III.iii(iii). Foreign Technology and Strategic Technological Development

Obtaining external technology information, especially from competitive or adversary states, is crucial in international interactions as it provides states with opportunities to devise strategic schema. Through investigating the up-to-date technology that another state possesses, states can precisely comparatively assess the capacities of itself and the other, even though it may not be able to thoroughly comprehend and master the observed technology. This kind of practice mitigates information asymmetry and helps states avoid unnecessary costly conflicts due to misperception or misinformation. Besides, exogenous technical information allows states to develop efficient and effective countermeasures, in forms of certain military tactics or techniques, targeting the discovered limitations and weaknesses of the technology a rival state is dictating. Such strategic R&D will generate high returns in terms of state tech capacity, provided that these innovations precisely target disturbing or threatening foreign technologies and therefore straightforwardly and effectively enhance national security by lending the state the upper hand in interstate military conflict or races.

Therefore, states are fully incentivized to seek latest technology information from rival states. For example, in May 2020, Libyan Government of National Accord seized the Russian Pantsir-S1 missile system that Libyan national Army possessed before, and then, its ally, US, acquired it to examine and develop a better understanding of the system's capability [29]. Similarly, in 2009, the US bought two Sukhoi Su-27 jets from Ukraine, reportedly aiming to train its air force to deal with the threat posed by Russian 4th-generation aircraft [30].

III.iv. Interstate Trade and Technology Transfer

Does trade facilitate technology transfer? Some existing research confirms this idea theoretically and empirically. For instance, Grossman and Helpman (1991) assume in *Innovation and Growth in the Global Economy* that "international trade in tangible commodities facilitates the exchange of intangible ideas" (166), and enumerate several channels through which technological diffusion may occur— International trade will increase cross-border personal contact, which will raise information exchange; firms are able to gain technology by inspecting imported intermediates

[29] Here is a source from Forbes for the event: https://www.forbes.com/sites/pauliddon/2021/01/31/that-pantsir-s1-it-acquired-from-libya-isnt-the-first-russian-missile-system-the-us-has-gotten-its-hands-on/?sh=113cc17b371a

[30] Here is a source for the news: https://www.unian.info/world/220084-us-buys-su-27-fighters-from-ukraine.html

that contain technologies not available domestically; when firms export products, their foreign purchasers may tell what they should do with the products to guarantee a minimum standard of quality. Xu and Wang (1999) identify two types of R&D spillovers—Some technology is transmitted in disembodied form like scientific publication, academic conference, patenting, and the like; some are embodied in trade flows and transferred. Keller (2010) posits that the diffusion of technology involves market transactions and externalities, and both are related to trade and FDI. This study shows that trade can facilitate technology diffusion by providing opportunities for purchasing foreign technology and utilizing tech-intensive intermediate, as well as exchanging local endowments for technology investment.

III.iv(i). Importation of Goods and Services and Technology Transfer

Less advanced countries normally have comparative advantages in primary industries; they can join in the global production networks and sell raw resources, agricultural goods, manufacturing, and labor-intensive commodities to earn foreign currencies; for keeping a balance of payments, the foreign currencies will be spent on importing foreign R&D in the form of service and high-tech products or/and making outward FDI or M&As that target foreign tech companies. Since contacting external technology paves the way for directly learning alien knowledge and making secondary innovations, importing and utilizing tech-intensive goods and intellectual properties are supposed to straightforwardly or indirectly increase state tech capacity. Likewise, annexing foreign high-tech firms or making joint ventures is an effective way of acquiring intellectual assets in forms of either patents or classified knowledge. In all, international trade makes possible a knowledge flow from a state with abundant R&D capability to a state of other geographic endowments.

Specifically, trade provides states of technical backwardness with opportunities to exchange their primary products for external technology in global markets. For example, in 2020, (Mainland) China had a merchandise trade surplus of approximately $551 billion and a services trade deficit of $145 billion; while the US had a deficit in merchandise trade and a surplus in service trade [31]. Figure 3.2 displays the yearly balances of merchandise trade (red) and services (blue) in the US (left-hand) and China (right-hand) over the period from 2005 through 2020. As it demonstrates, the merchandise trade balance in the US has been positive over the period, whereas it has long had a surplus in the service balance. By contrast, China had an increasing surplus in yearly merchandise trade balance and deficit in its service balance. That is, this country has had a trade structure that focuses on producing and exporting labor-intensive manufacturing products and buying services including technology from the global market, whereas the US has tended to export intellectual proprietaries for primary or intermediate imports. China's merchandise import structure also reflects its reliance on purchasing of foreign tech-intensive products. For example, since 1998, this country's largest goods import has been electronic equipment.[32] Generally speaking, through communicating with overseas suppliers of high-tech services, firms have opportunities to learn about the procedures and ideas revolving around their partners' job. Besides, obtaining licensed use of foreign technology helps owners make secondary R&D.

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[31] According to the OECD's definition of trade in services, services include transport (both freight and passengers), travel, communications services (postal, telephone, satellite, etc.), construction services, insurance and financial services, computer and information services, royalties and license fees, other business services (merchanting, operational leasing, technical and professional services, etc.), cultural and recreational services, and government services not included in the list above.

[32] The largest goods import was textile before 1998. See detailed information on China's goods import structure in the United Nations COMTRADE database.

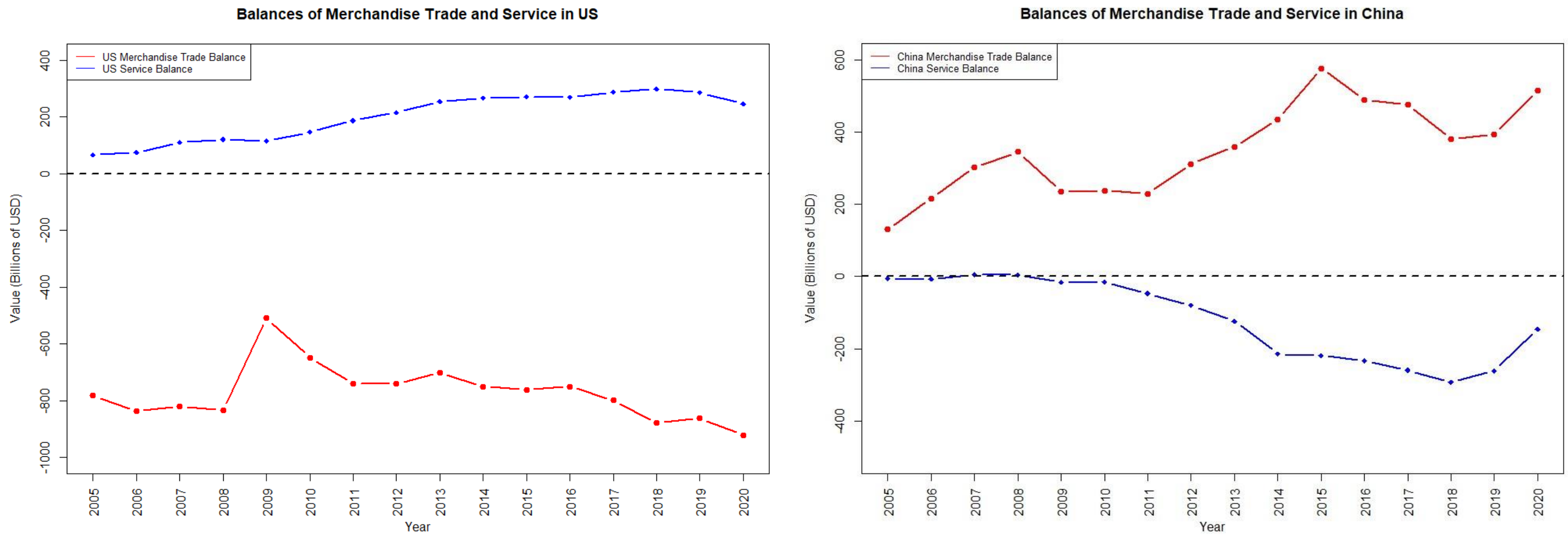

Figure 3.2. Yearly Balances of Merchandise Trade and Services in the US and China between 2005 and 2020

Note: 1 The data come from the IMF database, and here is the online source: https://data.imf.org/regular.aspx?key=62805740.
2. I do not demonstrate their yearly investment balances because there is a lack of data for China's investment liabilities.

Second, under-developed states can purchase intermediate or final tangible goods of high technology *via* interstate trade, which may directly serve as a part of domestic stocks of technology, though this improvement cannot be permanent if importers are not able to decipher, comprehend, and replicate the sophisticated techniques embedded in these imports. Meanwhile, contacting and investigating intermediates that embody unfamiliar, more advanced technology make possible learning and making secondary innovation; these activities can help acquire or/and generate perpetual, albeit probably still heavily reliant on foreign basic know-hows, technical advancement. Moreover, downstream firms of supply chains are incentivized to have intermediate parts produced or/and assembled overseas and ship them back home or to other markets, for reducing costs of labor, transportation, or the like. They therefore need to invest or share information on products with suppliers of intermediates such that they optimize cross-border division and specification while guaranteeing the minimum standard of quality, which activities greatly contribute to technology flows from downstream to upstream. This phenomenon will be discussed in detail in the following section.

In many growth models, importing high-tech goods that involve foreign R&D increases backward states' domestic total factor productivity, which indicates the conversion efficiency from aggregate inputs to aggregate outputs and has been often used as a measure of technology level in growth theories. Grossman and Helpman (1991) develop a model in which domestic stocks of knowledge capital is a function of trade: $K_n = n\boldsymbol{\Psi}(T/n)$, and $\boldsymbol{\Psi}(\cdot) \equiv G\left[1, T(t)/n(t)\right]$, where K denotes knowledge stock, T the cumulative volume of trade, and n a variety of intermediate; $G(\cdot)$ is homogeneous function of degree 1. Madsen (2007) tests a dataset for 16

OECD countries over the past 135 years and finds that imports of high-tech goods significantly positively impact TFP growth.[33]

To evidence the significant roles that imported high-tech intermediates play in domestic TFP growth, Coe and Helpman (1995) examine 21 OECD countries plus Israel during the period 1971-90, which confirms that domestic productivity is a beneficiary of foreign R&D, and this association hinges on foreign trade. Likewise, Keller (2002b) conducts an empirical analysis on whether foreign R&D activity affects domestic productivity *via* trade flows by testing a linear model, in which TFP in country *c* industry *i* is regressed with respect to imported intermediates.[34] His positivist investigation based on a dataset of eight OECD countries shows that foreign R&D inflows from same or other sectors have a positive association with a state's domestic productivity. Hakura and Jaumotte (1999) analyze 87 countries, including some LDCs

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[33] Madsen (2007) measures country *i*'s imports of knowledge using the formula: $S_{it}^{fL-F} = \sum_{j=1}^{21} \frac{M_{ijt}^{\lambda}}{Y_{jt}^{n}} S_{jt}^{d},\ i \neq j$, where M_{ijt}^{λ} denotes the nominal imports of goods of high-tech products from country *j* to country *i*, Y_{jt}^{n} the nominal income of country *j*, S_{jt}^{d} the stock of country *j*'s domestic knowledge. There are 21 countries used to construct S_{it}^{fL-F}.

[34] Keller (2002b) defines TFP as $F \equiv An^{e} = \frac{z}{l^{\alpha}\tilde{k}^{1-\alpha}},\ 0 < \alpha < 1$, where *A* denotes a positive constant, *l* labor services, n^{e} the range of intermediate inputs which are employed, *k* the cumulative stock of capital. Then he expresses productivity in country *c* industry *i* as follows.

$$F_{ci} = \mathbf{\Psi}\left(n_{ci}, n_{ck}, n_{hi}, n_{hk}, \ldots\right),\ \forall c, i, k \neq j, h \neq i,$$

where *ci* denotes domestic intermediates from an industry, *ck* domestic intermediates from other industries, *hi* foreign intermediates from the same industry, and *hk* foreign intermediates from other industries; $\mathbf{\Psi}(\cdot)$ is unknow function. Based on them, the model for trade-driven tech transfer is $\log F_{ci} = \log A_{ci} + \beta_1 \log\left(S_{ci} + \beta_2 S_{ci}^{io} + \beta_3 S_{ci}^{f} + \beta_4 S_{ci}^{f,io}\right),\ \forall c, i$, in which S_{ci} is the effect from domestic intermediates from the same industry, S_{ci}^{io} is the technology effect though intermediates from other domestic industries, S_{ci}^{f} is the effect from foreign intermediates of the same industry, and $S_{ci}^{f,io}$ is the effect from foreign intermediates from other industries.

and twenty-four OECD countries, and find that imports from advanced states positively affect developing states' domestic TFP growth rate; in particular, intra-industry trade is more effective than is inter-industry trade.[35] Xu and Wang (1999) investigated the OECD countries between 1983 and 1990 and find that capital goods trade serves as a more significant conduit for R&D than non-capital goods trade.

III.iv(ii). Spillover Effects of Trade as A Part of FDI-Related Externalities

Firms choose to form multinational companies (MNCs) and make FDI only when they want to reserve and exclusively practice their intangible, intellectual assets.[36] Nevertheless, FDI is conceived of by a group of economists as a channel for transborder technology spillovers (e.g., Blomström and Kokko 1998; Liu 2008; Clark et al. 2011). The chief reason is that MNCs train local employees in abroad affiliates, and then, the trained workers, once moving into indigenous enterprises, diffuse their gained knowledge domestically (e.g., Fosfuri et al 2001; Glass and Saggi 2002). Another key aspect of FDI related to technology diffusion is that FDI spurs trade; though parents' exports and their affiliates' sales of final goods are likely to be substitutes, parents' exports of auxiliaries or intermediates and their subsidiary branches' sales tend to be

[35] Hakura and Jaumottee's (1999) model for growth rate is

$$g_i = c + \alpha \cdot g_l + \left[\beta \cdot \sum_{s \in IR} \frac{m_{ils}}{y_i} + \gamma \cdot \sum_{s \in IA} \frac{m_{ils}}{y_i} \right] \cdot \ln \frac{TFP_l}{TFP_i} + \varepsilon_i$$

, where l denotes the more technologically advanced country, i the importing country, g TFP growth rate, m imports, y output, IR the set of interindustry trade sectors, and IA the set of intra-industry trade sectors.

[36] According to the *Ownership, Location, and Internalization* (OLI) paradigms (Dunning 1993), there exist three premises for investors to make foreign direct investment (FDI) rather than portfolio investments, trade, or licensing. First, they have ownership-specific advantages (i.e., proprietary assets like intellectual properties or managerial advantages). Second, abroad production has low costs relative to domestic production and exportation. Lastly, they have incentives to internalize its ownership-specific advantages.

complements (Blonigen 2001). Horizontally, overseas production may help parents promote exports of complementary goods to host countries (Brainard 1993). Vertically, affiliates of MNCs may send intermediate or final goods back to their home country or third countries; they can also import capital goods or differentiated products from their parents. Namely, "complement exports as shipments of inputs and final products tend to follow FDI" (Clark et al. 2011: 4). As aforementioned, there exist trade-driven intentional technical flows from downstream to upstream alongside supply chains, and thus, the resulting trade of FDI should be able to bring about technical spillovers. Javorcik (2004) finds that technology spillovers driven by FDI are more likely to take place from multinational buyers to domestic producers of intermediates. Tian (2007) investigates China's firms between 1996 and 1999 and reveals that technology spillovers from foreign-invested firms to domestic firms occur through tangible rather than intangible assets.

III.v. The Critical School

Unlike classical international economics, theorists like Prebisch (1962) observed that trade's hypothetical positive effect on a state's development could be insignificant, if the state has a subordinate position in the global network of production and distribution. The principal assertion that features the dependency theory is that core states prevent peripheries from achieving autonomy and competitiveness, in either economic, technological, or political spheres (Santos 1970; Love 1990). Its structuralist strain contends that core states can achieve this objective by acquiring innovation and advanced production and meanwhile restricting poor states to engaging in primary production.[37] Markets for such high-level industries are mostly monopolized by oligopolistic giants and thereby create excessive profits. Even if export-oriented industries in peripheries may overcome their rat race through agglomerating, core states can quickly develop substitutes to break the fixed price. Therefore, to move away from the unfavorable situation, backward states must lay out well-designed schema for economic upgrading (Gereffi 2014; Lombardozzi 2021).

Likewise, trade's effects on domestic technical progress and industrial advancement are reasonably suspicious. Worries root in the following facts. First, high-tech companies can easily crowd out foreign infant competitors. Specifically, if LDCs manage to export their own tech-intensive goods, the MNCs can lower their price and swiftly cause the demise of vulnerable competitors. Second, even though globalization may bring about technological progress in LDCs, powerful states possess predominant positions in production networks, and liberal rules can be dismissed when not serving their interests (Hills 1994; Muzaka and Bishop 2015). Developed states subsidize certain R&D or/and develop dual-use innovations and thereby accumulate strategic technology; they can implement restrictive policy on exports of strategic products, preventing critical techniques from leaking out; they may tend to withdraw from international institutions which are not supportive of their interests. Moreover, high levels of complexity and sophistication of advanced technology tend to act as another obstacle in the process of learning and imitating (e.g., Blomström and Sjöholm 1999).

[37] In their view, there exist three levels of industries—Agriculture and resources mining, which entail few technology and human capital inputs, belong to the primary industries; manufacturing industries are the secondary; the tertiary and highest industries refer to services, which focus on practicing knowledge.

Accordingly, strategic governmental intervention, market protection, and industrial policy have widely been recognized as necessary for technological development. The potential trade, financial, and fiscal policy spaces cover a range from subsidizing high-tech industries, expanding public R&D spending, erecting barriers against high-tech imports, limiting foreign ownership of MNCs, to forcing foreign firms to transfer technology, though they prove to have mixed outcomes due to varied constraints facing states which come from balancing of protection and efficiency (e.g., Storper 1995). Besides, due to their mercantilist feature, these policies tend to incur trade retaliation. As an example, as Brazil undertook an informatics strategy, aiming to protect and develop domestic telecommunications systems and computer industries during the 1970s, the US government, in response, launched investigations of this project, accusing the restrictive policies of violating the liberal terms of GATT (Schoonmaker 2002).

Despite critical pessimism concerning global tech convergence, there exist significant cross-country and temporal variations in association between a state's integration in global economy and its domestic tech growth. Figure 3.3 displays the respective differences between each of several major Eastern Asian and Latin American states and the US in terms of annual patent files from 1980 through 2014. The data come from the World Bank database. It suggests that Japan had kept leading ahead of the US by 2012, and its leading position had been rising until 1987. China had been catching up to and began to outstrip the US in 2008. By contrast, the two Latin American states, Brazil and Argentina, have been lagging behind the US, with gaps kept getting widened. To help explain these variations, I re-construct the ontology of *state trade position* by shifting the focus from levels or contents of a state's domestic production and exportation to between-state trade dependence.

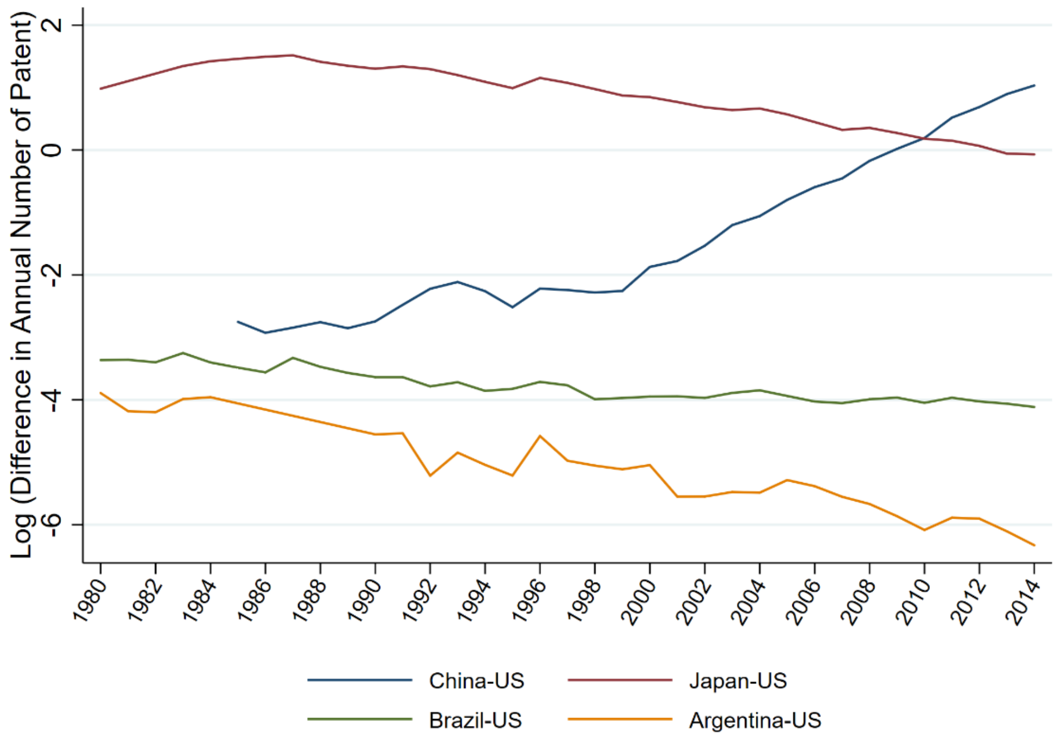

Figure 3.3. Differences in Annual Numbers of Patents Between States

Note: For more information on the data, see the following table.

III.vi. Trade Dependence and Dyadic Technological Power Transition

As discussed previously, classic international economics has theoretically and empirically investigated the diffusional effects of external R&D on domestic productivity or technical growth *via* trade (e.g., Keller 2002b; Hakura and Jaumottee 1999). Some research has even empirically examined trade flows' direct relationship with state technical growth. For example, Young (1991) develops several models to show that under free trade the LDCs have a rate of technical progress less than or at most equal to the rate under autarky, whereas DCs would enjoy a higher growth rate under liberalism than protectionism. Based on the diffusion model, have emerged research works probing international technical convergence, focusing on regional or global trade intensity and variation or heterogeneity in tech levels among state. However, the existing research pays little attention to the question of more relevance in international relations—Whether and in what ways trade affects between-state tech power distribution. As aforementioned, the dependency theorists hold negative attitudes toward a dyadic tech convergence between states by trade; however, it cannot well account for a remarkable variation in association between a state's trade with more advanced partners and domestic technical growth. This study bridges these gaps by focusing on interstate trade activity and tech power transition and pointing out that a state' *trade dependence* on its partner may act as a factor reducing its dyadically relative tech power.

Liberals contend that economic interdependence decreases the likelihood of war in the sense that the costs of war are great for interdependent states (Keohane and Nye 1973). By contrast, realists assert that states are concerned about the vulnerability due to interdependence, which compels them to initiate war to seek a complete control of the sources, as a means of lessening their dependence (Waltz 1979). As economic interdependence increases, the US and

China have not yet engaged in *vis-à-vis* militarized conflicts; nor have they been in a peaceful relationship, given that they have made confrontations in economic frontiers. I argue that trade dependence of advanced states on their backward partners narrows their technological capacity discrepancy. A technical gap shrinkage tends to intensify interstate competitions in technical areas, which is likely to trigger economic conflict.

Technological firms join the global network of production in order to take advantage of low costs of labor or transportation; for increasing the efficiency of overseas production, they are willing to equip their trade partners with certain know-hows. Specifically, downstream firms of supply chains have intermediate goods produced overseas when upper-stream partners are well endowed with the factors of which the intermediates are primarily made; it allows them to enjoy low costs and high profits for final outputs. In this process, "multinationals have no incentive to prevent technology diffusion to upstream sectors, as they may benefit from improved performance of intermediate input suppliers" (Javorcik 2004: 607-608).

This study asserts that, under certain conditions, the greater the production capacity of foreign suppliers of intermediates, the greater incentives the parent firms have to share or invest technology in the outsourcing process, as a way to optimize the production. A lower level of production costs promises a lower price for intermediates, which, however, is also indicative of an under-efficient labor force. The laborer is less efficient perhaps mainly because they are neither well trained nor assisted by high levels of technological capitals. Aghion et al. (1998) formulate models to show that "[intermediate goods'] quality improvements come at a rate equal to the flow of secondary innovations across the whole economy" (176). Likewise, Eaton and Kortum (1996) treat the rise of quality of inputs as a function of inventions. Therefore, to guarantee the quality of intermediates, parent or downstream firms have to transfer certain technology to their abroad intermediate suppliers. They need to make a trade-off between shifting intermediate production to another country and technology preservation to maximize profits.

Proposition 3.1. *As a state has a greater trade dependence, especially import dependence, on its less advanced partner, the technological power cleavage will shrink, as its partner has a dyadic relative technological growth, ceteris paribus.* The reasoning at the firm level is as follows. Suppose the utility function for outsourcing (i.e., a firm seeking intermediate productions overseas) is expressed as $U = (B - C)Q - \tilde{T}$. *B* here denotes the revenue that a firm gains from its final outputs that involve overseas produced intermediates, *C* the input price which is positively correlated with the production cost in the host country, *Q* the quantity of final outputs based on the total supply of the intermediates from the host country, and $\tilde{T}$ the technology transferred to its abroad intermediate goods suppliers; all the variables are nonnegative. Production cost is assumed to be positively associated with proficiency and productivity of the labor. Therefore, the quality constraint equation is $h \equiv f\left(C, \tilde{T}\right)$, where *h* is the minimum standard of quality for intermediates. This equation indicates the substituting relationship between the costs of technology transfer and labor if the quality of intermediates is guaranteed. We have $\frac{\partial f}{\partial C} > 0$ and $\frac{\partial f}{\partial \tilde{T}} > 0$. The relationships can be expressed as

$$f\left(C, \tilde{T}\right) \propto \tilde{T}^{\alpha} C^{\beta},\ \alpha > 1, \beta > 1.$$

Considering that $\frac{\partial U}{\partial C} < 0$ and $\frac{\partial U}{\partial \tilde{T}} < 0$, *U* has a maximum value when subject to the quality constraint $f\left(C, \tilde{T}\right) = h$ (see Figure 3.4).

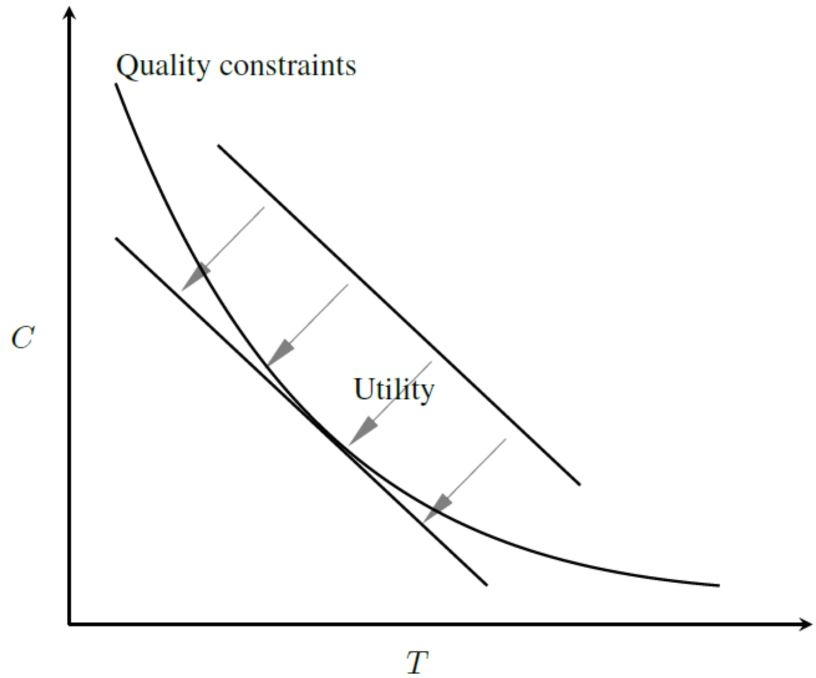

Figure 3.4. The Utility Function and Quality Constraint

Lemma. The larger the potential output of intermediates that an overseas supplier can make, the more willing foreign firms or MNCs are to transfer technology to this producer through sharing or investing certain intellectual properties in order to compensate for the labor inefficiency, realize optimal production, and maximize utilities.

Proof:

Firms wish to maximize the following utility for outsourcing

$$U = (B - C)Q - \tilde{T},$$

which is subject to the quality constraint

$$f(C, \tilde{T}) = h.$$

Using the method of Lagrange multiplier, we need to find C and $\tilde{T}$ such that

$$\nabla U = \lambda \nabla f,$$

and $f(C, \tilde{T}) = h$. We then have the following equations

$$\frac{\partial U}{\partial C} = \lambda \frac{\partial f}{\partial C}$$

$$\frac{\partial U}{\partial \tilde{T}} = \lambda \frac{\partial f}{\partial \tilde{T}},$$

which become

$$-Q = \lambda \beta \tilde{T}^{\alpha} C^{\beta-1}$$

$$-1 = \lambda \alpha \tilde{T}^{\alpha-1} C^{\beta}.$$

After solving the above equations with $f(C, \tilde{T}) = h$, we can get

$$\tilde{T}^{\alpha+\beta} = \frac{Q^{\beta} h \alpha^{\beta}}{\beta^{\beta}}.$$

Given that $\alpha > 1$, $\beta > 1$, and h is positive, a firm's willingness to transfer technology shall be positively associated with the intermediates' supplier's production capacity when all other conditions are given.

End.

At the state level, when a series of productions in State A is highly reliant on intermediates from State B which possesses low production costs and immense production capability, A's firms are little likely to have outside options for supplies. Likewise, if State B has a large market, it can serve as one of best destinations for A's exports. In both cases, State B's governments can wield substantial bargaining leverage to realize forced technology transfer (FTT) from State A. Forced technology transfer, broadly defined, refers to "foreign operators are directly or indirectly forced to share their innovation and technology with the state or with domestic operators".[38] Specifically, exporters can be compelled to disclose certain technology information to firms or governments of State A in exchange for the approval for specific investments or/and a lower or the removal of duties on supplies productions or barriers against their final products (e.g., Prud'homme et al. 2018; Qin 2019). Though legal scholars tend to examine FTT through a legality or normative lens, intellectual assets holders choose to comply with the administrative request for information disclosure in hopes of achieving multidimensional optimization regarding returns. It is noteworthy that several significant cases have shown that forced transfers are more likely to relate to intermediates. For instance, so far, the four US trade Representative's Section 301 lists of China's products, on which special tariffs

[38] The definition of forced technology transfer comes from *The European Commission, WTO–EU's Proposals on WTO Modernization*: https://trade.ec.europa.eu/doclib/docs/2018/september/tradoc_157331.pdf

are imposed due to target states' unfair trade practices like subsidies or FTT, focus largely on intermediate goods from China.[39]

Proposition 3.2. *As a state has a greater trade dependence, especially import dependence, on its more advanced partner, the technological power cleavage will be enlarged, ceteris paribus.* This proposition basically conforms to claims made by the *Dependence theory* and advances them by stressing that it is trade dependence of a less advanced country on its more advanced trade partners that holds back its endeavoring to catch up. The reasoning is that once a less advanced country heavily relies on external supplies of consumer goods, which are mostly tech-related, its partners can easily exert their substantial monopoly powers to deter its efforts to construct import-substituting, independent, and potentially competing industries. Besides, a technologically backward country normally lacks requisite knowledge for learning and adapting to advanced tech; therefore, it is hard for them to absorb technologies involved in their imports.

Combining the first two propositions, I put forth the following hypothesis about how a state's trade dependence on another one influences their between-state technological power gaps.

Hypothesis 3.1: *A state's trade dependence on another will change the dyadic technological capacity gap in ways that are unfavorable for the former, ceteris paribus.*

Proposition 3.3. *A state's trade dependence on its less advanced partner is less likely not make the latter technologically transcend the former, ceteris paribus.* A common assumption is that there exists a diminishing return in the learning-by-doing process (e.g., Young 1991); specifically, if there were no continual influxes of innovations to be exploited, the point would eventually be reached where there was nothing more to learn. It is noteworthy that though states

[39] Here is the source for the four Section 301 lists of China's products: https://ustr.gov/issue-areas/enforcement/section-301-investigations/section-301-china/300-billion-trade-action

may develop technology by their means rather than concentrate on exploring transferred-in knowledge, this kind of activity is not directly influenced by trade. Grossman and Helpman (1991: 168-169) develop a model to demonstrate the process of international knowledge flows and find that if $\alpha(1-\alpha)^{-1} > \beta$, where $(1-\alpha)^{-1}$ denote the elasticity of demand for every component and β the aggregate cost share of intermediates, international trade will make a contribution to domestic accumulation of knowledge, while this contribution will decline and diminish in the long run. In contrast, if $\alpha(1-\alpha)^{-1} < \beta$, the technology gained from trade continues to drive tech growth. Considering that a later tech variety, except for certain strategic techniques for national security, is usually less likely to be part of living necessities or traditional production and therefore normally has a high level of demand elasticity, according to the Crossman-Helpman model, trade's contribution to domestic tech capacity tends to be finite.

In light of the Veblen-Gerschenkron effect (Gerschenkron 1962), Nelson (1968) and Findlay (1978) formulate a model that describes the process of productivity or technology diffusion between "backward" and "advanced" entities as follows.

$$\frac{dB}{dt} = \lambda\left[A_0 e^{nt} - B(t)\right],$$

where *B* denotes technological efficiency in the backward entity and *t* the time; in particular, $A_0 e^{nt}$ is the expression of the advanced entity's technological level, which increases at a rate *n*. Then we will have the following equations.

$$\frac{B(t)}{A(t)} = \frac{\lambda}{n+\lambda} + \frac{(n+\lambda)B_0 - \lambda A_0}{(n+\lambda)A_0 e^{(n+\lambda)t}},$$

$$\lim_{t\to\infty}\frac{B}{A} = \frac{\lambda}{n+\lambda}.$$

That is, as time elapses, the lagging one can catch up with the advanced one through technological transfer but is never going to reverse the tech power difference except if the latter has a negative *n*, which is hardly possible.

III.vii. Empirical Analysis

The empirical analysis is based on a time-series cross-sectional state-level data for 217 countries covering the period from 1980 through 2014. The study uses three indicators of technological gaps as explanatory variables. In addition to the three key explanatory variables, trade dependence, import dependence, and export dependence, I include polity, FDI flows, alliances, and interstate militarized conflict as potential confounding factors to control for.

III.Vii(i). Data

Dependent Variables

As consistent with the former analysis about measuring state technological capacity, I propose three proxies for state tech capacity, the annual number of patent applications, the annually received payments for national-own intellectual properties, and the annual volume of high-tech exports, which are denoted by $patent\_appls_{i,t}$, $IP\_receive_{i,t}$, and $hitech\_export_{i,t}$ respectively.[40] Based on the three proxies, I develop three indicators of between-state technological gaps, which are represented by $\text{Relaive\_tech}^{(\mathbf{1})}_{ji,t}$, $\text{Relaive\_tech}^{(\mathbf{2})}_{ji,t}$, and

[40] As introduced in Part II, the variable, $patent\_appls_{i,t}$, stands for the number of patent applications that are filed by the residents of state *i* in year *t*. $IP\_receive_{i,t}$ represents the charges for the use of intellectual property that are received by the nationals of state *i* in year *t*. $hitech\_export_{i,t}$ designates the high-tech exports state *i* makes in year *t*; high-technology-intensive exports are products with high R&D intensity. The data about the three proxies drawn from the World Bank's database of World Development Indicators.

$\text{Relaive\_tech}^{(3)}_{ji,t}$, to be the dependent variables, and the algorithms for computing them are as follows.

$$\text{Relaive\_tech}^{(1)}_{ji,t} = \ln\left(\frac{patent\_appls_{j,t}}{patent\_appls_{i,t}}\right),$$

$$\text{Relaive\_tech}^{(2)}_{ji,t} = \ln\left(\frac{IP\_receive_{j,t}}{IP\_receive_{i,t}}\right),$$

$$\text{Relaive\_tech}^{(3)}_{ji,t} = \ln\left(\frac{hitech\_export_{j,t}}{hitech\_export_{i,t}}\right).$$

In the formulas, *i* and *j* designate states *i* and *j* respectively, and *ji* stands for a tech gap computed by *j*'s tech capacity minus state *i*'s, and *t* denotes year *t*. It is noteworthy that the distributions of the three tech power proxies are highly skewed, and I therefore use the difference of their natural logarithms to represent between-state tech gaps.

Explanatory Variables

I follow the conventional approach to compute trade dependence of state *j*'s on state *i*, by dividing the sum of the volume of state *j*'s exports to and imports from state *i* by its GDP. It is postulated that import dependence contributes more to technological catching-up than export dependence, so I include import and export dependences as alternative explanatory variables for testing. The three explanatory variables of interest are expressed as follows.

$$\text{Trade\_dep}_{ji,t} = \frac{import_{ji,t} + export_{ji,t}}{GDP_{j,t}}$$

$$\text{Import\_dep}_{ji,t} = \frac{import_{ji,t}}{GDP_{j,t}}$$

$$\text{Export\_dep}_{ji,t} = \frac{import_{ji,t}}{GDP_{j,t}}$$

I draw the bilateral trade data from the COW Project's Trade (v4.0) (Barbieri et al. 2009), and the GDP data come from the World Bank's database. To scale down the three variables, GDP here is in billions of current USD. The distributions of the three variables are too skewed, and I use their logarithmic versions in regression models.

.

Control Variables

FDI has long been considered as an important channel for technological transfers, and some research has found evidence for this FDI-driven technological diffusion (e.g., Blomström and Kokko 1998; Liu 2008). However, some empirical investigations reveal an adverse effect of FDI inflows on domestic productivity growth (e.g., Aitken and Harrison 1999) or find little evidence for FDI technology transfers (e.g., Hanousek et al. 2011). Some scholars maintain that there exist factors, like recipients' absorptive capacity that exert conditional effects on the FDI-driven transfer process (e.g., Xu 2000; Nicolini and Resmini 2010). Simultaneously, as aforementioned, FDI is also closely connected with international trade, and thus, I include FDI flows between states *i* and *j* into regressions as confounders to control for. The variable, $\mathrm{FDI}_{ij,t}$, denotes the FDI from state *i* to state *j* in year *t*, and $\mathrm{FDI}_{ji,t}$ the other way around. The data for bilateral FDI flows come from UNCTAD's (2017) database.

Normative and institutional explanations of observed democratic peace assert that since democracies share similar liberal thoughts and norms, they have low levels of transaction costs for cooperation and low likelihood of lethal conflict (e.g., Maoz and Russett 1993; Rosato 2003). Likewise, Peceny et al. (2002) detect a peace among dictatorial states, implying that states of similar regimes are likely to share identity and cooperate. One can therefore expect that dyadic polity features are likely to influence bilateral trade and technological transfer simultaneously. In regression models, dyadic polity structure is a categorical variable, $\text{Polity type}_{ji,t}$, which consists of four categories: A) authoritarian state *j* and democratic state *i*; B) authoritarian *j* and authoritarian *i*; C) democratic *j* and authoritarian *i*; D) democratic *j* and democratic *i*. The data for polity come from the Polity2 data, compiled by the Polity V project (Marshall et al. 2019), which indicates the democratic degree of political institutions. The index ranges from -10 (most autocratic state) to 10 (most democratic state). In particular, if a state has a Polity2 Score greater than 5, it is deemed as democratic, and authoritarian otherwise.

States establish linkages between economic and security issues to enhance their cooperation (e.g., Axelrod and Keohane 1985; Koremenos et al. 2001). Following the rationale, powerful states are supposed to be willing to directly transfer technologies to or/and actively engage in joint R&D with their allies to empower them and cement the alliances. Therefore, I regard alliance as a confounder for the association between trade interactions and technology transfer; in practice, the binary variable, $\text{Alliance}_{ij,t}$, that takes the value of one if states *i* and *j* are formally allied and zero otherwise is involved. The data for alliance come from the COW Project's Formal Alliances (v4.1) dataset.

Two states being amid militarized conflict are supposed to purposely avoid bilateral cooperation in economic and technological arenas, and sanctions are quite likely to be sent against one another. Thus, I adopt the militarized interstate dispute (MID) data from the COW Project (Maoz et al. 2019) and involve the dummy variable, MID_{ij}, into models to control for, which is assigned one if there is ongoing MID between the two states and zero otherwise. The summary of the dataset is exhibited in Table 3.1.

Table 3.1. Statistics Summary of the Sample

Variable	Label	Period	*N*	Mean	Sd.	Min.	Max.
$\text{Tech\_gap}^{(1)}_{ji,t}$	$\ln\left(\frac{patent\_appls_{j,t}}{patent\_appls_{i,t}}\right)$	1980-2014[a]	298,108	0	3.911	-14.147	14.147
$\text{Tech\_gap}^{(2)}_{ji,t}$	$\ln\left(\frac{IP\_receive_{j,t}}{IP\_receive_{i,t}}\right)$	1980-2014[a]	230,936	0	5.369	-22.631	22.631
$\text{Tech\_gap}^{(3)}_{ji,t}$	$\ln\left(\frac{hitech\_export_{j,t}}{hitech\_export_{i,t}}\right)$	1980-2014[a]	196,424	0	5.817	-24.904	24.904
$\text{Trade\_dep}_{ji,t}$	$\frac{import_{ji,t}+export_{ji,t}}{GDP_{j,t}}$; GDP in billions of current USD. [b]	1980-2014	754,902	.004	.027	0	3.808
$\text{Import\_dep}_{ji,t}$	$\frac{import_{ji,t}}{GDP_{j,t}}$; GDP in billions of current USD. [b]	1980-2014	783,079	.002	.020	0	3.808
$\text{Export\_dep}_{ji,t}$	$\frac{export_{ji,t}}{GDP_{j,t}}$; GDP in billions of current USD. [b]	1980-2014	781,956	.001	.011	0	1.034
$\text{Export}_{ij,t}$	Source: the COW Project, Trade (v4.0); Barbieri et al. (2009).	1980-2014	880,587	.282	3.557	0	472.525
$\text{FDI}_{ij,t}$	UNCTAD's (2017) database	1990-2014	25,790	.478	3.053	0	206.671
$\text{Polity type}_{ji,t}$	A: democratic *j* and democratic *i*, B: democratic *j* and authoritarian *i*, C: authoritarian *j* and democratic *i*, D: authoritarian *j* and authoritarian *i*. Source: Polity V. [c]	1980-2014	221,125 255,334 221,125 224,258				
$\text{Alliance}_{ij,t}$	Source: the COW Project, Formal Alliances (v4.1); Singer and Small (1966).	1980-2012	1,546,776	.047	.212	0	1
$\text{MID}_{ij,t}$	Source: the COW Project; Maoz et al. (2019).	1980-2014	1,640,520	.002	.045	0	1

Note: a. The three technology gap variables data cover a period between 1980 and 2015 for the surpassing analysis.
b. Trade data source: the COW Project, Trade (v4.0); Barbieri et al. (2009). GDP source: the World Bank.
c. If a state has a Polity2 Score greater than 5, it is deemed as democratic, and it is authoritarian otherwise.

I also present the levels of collinearity between the variables in Figure 3.5. In this figure, A denotes $\text{Tech\_gap}_{ji,t}^{(1)}$, B $\text{Tech\_gap}_{ji,t}^{(2)}$, C $\text{Tech\_gap}_{ji,t}^{(3)}$, D $\log\left(\text{Trade\_dep}_{ji,t}\right)$, E $\log\left(\text{Import\_dep}_{ji,t}\right)$, F $\log\left(\text{Export\_dep}_{ji,t}\right)$, G $\log\left(\text{Export}_{ij,t}\right)$, H $\log\left(\text{Export}_{ji,t}\right)$, I $\log\left(\text{FDI}_{ij,t}\right)$, J $\log\left(\text{FDI}_{ij,t}\right)$, K $\text{Alliance}_{ij,t}$, L $\text{Polity type}_{ji,t}$, and M $\text{MID}_{ij,t}$. The respective associations between the dependent variables and the three explanatory variables are observed in the plotting graphs within the blue rectangular. The dependent variables appear not correlated with any of the control variables (see the graphs circled by red rectangular). The trade dependence variables have some association with the volumes of bilateral trade flow (see the graphs within the orange area), and the correlation coefficients ranges from 0.395 to 0.817. To attenuate effects of a possible collinearity (see Figure 3.5), I will test models that exclude $\text{Export}_{ij,t}$ and $\text{Export}_{ji,t}$. There is no visible correlation between the three explanatory variables with other control variables like FDI, alliance, regime type, and MID respectively. Between-state relative economic strength indicators such as GDP differences are not included in models, given that according to the domestic growth model, economic size is supposed to be a function of domestic stocks of technology, and they therefore cannot confound the relationship between trade dependence and technological gaps.

III.vii(ii). Models

Three sets of full regression models that test effects of trade dependence, import, and export dependence respectively on each of the three variables indicative of between-state technology gaps are formulated as follows; the method of OLS for estimating the parameters will be employed. In the first group of models, the key explanatory variable is trade dependence,

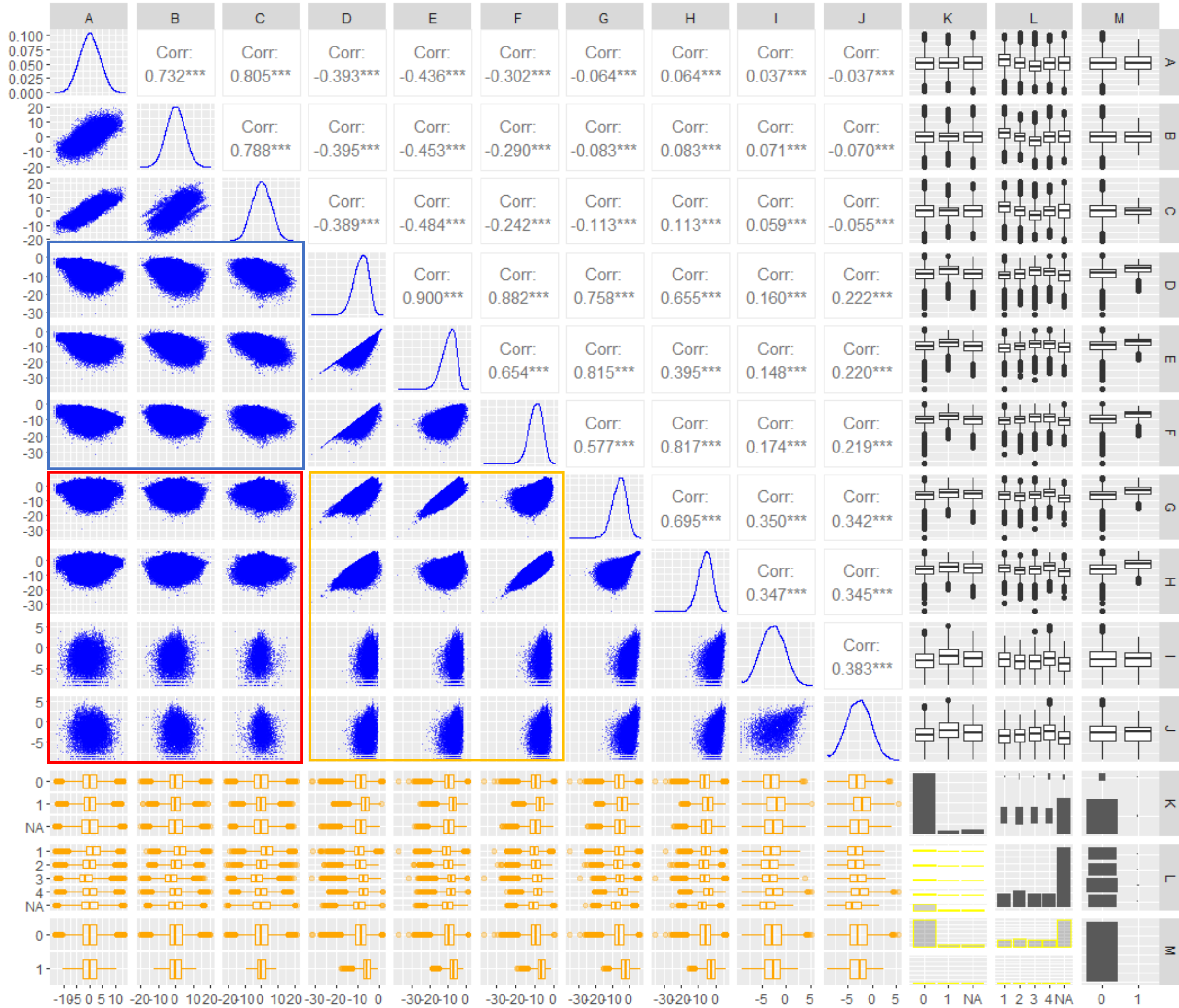

Figure 3.5. The Matrix for the Correlation Coefficients and Two-Way Plots for the Variables

whereas the rest two have import and export dependences as the independent variables of interest respectively. According to the *two faces* of R&D, technology accumulation can act as absorptive capacity for further assimilation of external knowledge, and therefore the OLS models' error structure therefore might be heteroskedastic and perhaps autocorrelated. To address this issue, I test Newey-West standard errors for coefficients (Newey and West 1986)[41]; specifically, the maximum lag order of autocorrelation is set as four[42]. Meanwhile, to tackle potential error covariance between equations of different states, fixed effect and random effects models will be examined; particularly, the dependent variable with a one-year lag is involved in random effect models to control for potential autoregression. Besides, considering that there is a collinearity between trade dependence and trade volumes, bilateral trade flows, in forms of either import or export, are not involved in the models. A baseline model that excludes all control variables except for technology gaps with a one-year lag will be tested in the first place. Considering that the periods that the FDI and alliance data cover are shorter than are others, models that exclude these variables for achieving a large sample size will be tested along with full models.

$$\begin{aligned}\text{Relaive\_tech}_{ji,t}^{(\mathbf{1,2,3})} &= \beta_0^T + \sum_{k=1}^{n}\beta_k^T \cdot \text{Relaive\_tech}_{ji,t-k}^{(\mathbf{1,2,3})} + \beta_{n+1}^T \cdot \log\left(\text{Trade\_dep.}_{ji,t-1}\right) + \beta_{n+2}^T \cdot \text{Polity\_type}_{ji,t-1} \\ &+ \beta_{n+3}^T \cdot \text{Alliance}_{ij,t-1} + \beta_{n+4}^T \cdot \text{MID}_{ij,t-1} + \beta_{n+5}^T \cdot \log\left(\text{FDI}_{ij,t-1}\right) + \beta_{n+6}^T \cdot \log\left(\text{FDI}_{ji,t-1}\right) \\ &+ \varepsilon_{j(-i),t-1}^T + \gamma_{i(-j),t-1}^T + \lambda_{j,t-1}^T + \sigma_{i,t-1}^T + \mu_{ij,t-1}^T\end{aligned}$$

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[41] The Newey-West estimation of variance for coefficients is expressed as the following formulas. $\text{Var} = \left(\mathbf{X'X}\right)^{-1}\mathbf{X'\Omega X}\left(\mathbf{X'X}\right)^{-1}$, and $\mathbf{X'\Omega X} = \dfrac{n}{n-k}\sum_{i=1}^{n}\hat{e}_i^2\mathbf{x}_i'\mathbf{x}_i + \dfrac{n}{n-k}\sum_{c=1}^{m}\left(1-\dfrac{c}{m+1}\right)\sum_{t=c+1}^{n}\hat{e}_t\hat{e}_{t-c}\left(\mathbf{x}_t'\mathbf{x}_{t-c} + \mathbf{x}_{t-c}'\mathbf{x}_t\right)$.

In the formulations, *n* denotes the number of observations, *k* the number of independent variables, *m* the maximum lag, $\mathbf{x}_i$ the *i*th row of $\mathbf{X}$, and $\mathbf{x}_t$ the *t*th row of $\mathbf{X}$ observed at time *t*.

[42] I test Newey-West models with different maximum lags during analysis and find little difference in estimates among those with a maximum lag equal to or greater than four.

$$\text{Relaive\_tech}^{(\mathbf{1,2,3})}_{ji,t} = \beta_0^I + \sum_{k=1}^{n} \beta_k^I \cdot \text{Relaive\_tech}^{(\mathbf{1,2,3})}_{ji,t-k} + \beta_{n+1}^I \cdot \log\left(\text{Import\_dep.}_{ji,t-1}\right) + \beta_{n+2}^I \cdot \text{Polity\_type}_{ji,t-1}$$
$$+ \beta_{n+3}^I \cdot \text{Alliance}_{ij,t-1} + \beta_{n+4}^I \cdot \text{MID}_{ij,t-1} + \beta_{n+5}^I \cdot \log\left(\text{FDI}_{ij,t-1}\right) + \beta_{n+6}^I \cdot \log\left(\text{FDI}_{ji,t-1}\right)$$
$$+ \varepsilon^I_{j(-i),t-1} + \gamma^I_{i(-j),t-1} + \lambda^I_{j,t-1} + \sigma^I_{i,t-1} + \mu^I_{ij,t-1}$$

$$\text{Relaive\_tech}^{(\mathbf{1,2,3})}_{ji,t} = \beta_0^E + \sum_{k=1}^{n} \beta_k^E \cdot \text{Relaive\_tech}^{(\mathbf{1,2,3})}_{ji,t-k} + \beta_{n+1}^E \cdot \log\left(\text{Export\_dep.}_{ji,t-1}\right) + \beta_{n+2}^E \cdot \text{Polity\_type}_{ji,t-1}$$
$$+ \beta_{n+3}^E \cdot \text{Alliance}_{ij,t-1} + \beta_{n+4}^E \cdot \text{MID}_{ij,t-1} + \beta_{n+5}^E \cdot \log\left(\text{FDI}_{ij,t-1}\right) + \beta_{n+6}^E \cdot \log\left(\text{FDI}_{ji,t-1}\right)$$
$$+ \varepsilon^E_{j(-i),t-1} + \gamma^E_{i(-j),t-1} + \lambda^E_{j,t-1} + \sigma^E_{i,t-1} + \mu^E_{ij,t-1}$$

In the above models, $\varepsilon_{j(-i),t-1}$ ($\gamma_{i(-j),t-1}$) represents variations brought about by state *j*'s (state *i*'s) interactions with the states other than state *i* (state *j*); $\lambda_{j,t-1}$ and $\sigma_{i,t-1}$ designate deviations caused by states *j* and *i*'s unilateral factors; $\mu_{ij,t-1}$ denotes the part of between-state tech gaps that can be accounted for by other bilateral factors. In all, these factors are viewed as making contributions to the errors in a random manner.

III.vii(iii). Descriptive Analysis

In Figure 3.6, the sample is plotted with regression lines in nine two-dimensional spaces, the axes of which indicate one of dependent variables and one of explanatory variables respectively. In particular, the regression lines are derived from the baseline models without control variables. As the figure presents, between-state technology gaps appear negatively associated with trade dependence, and this correlation is stronger for trade and import dependence than for export dependence, which meets the expectation of the hypothesis. Heteroskedasticity exists in the monotonic, linear regressions, but this issue is not that significant, and generally, the residuals conform to linearity and normality.

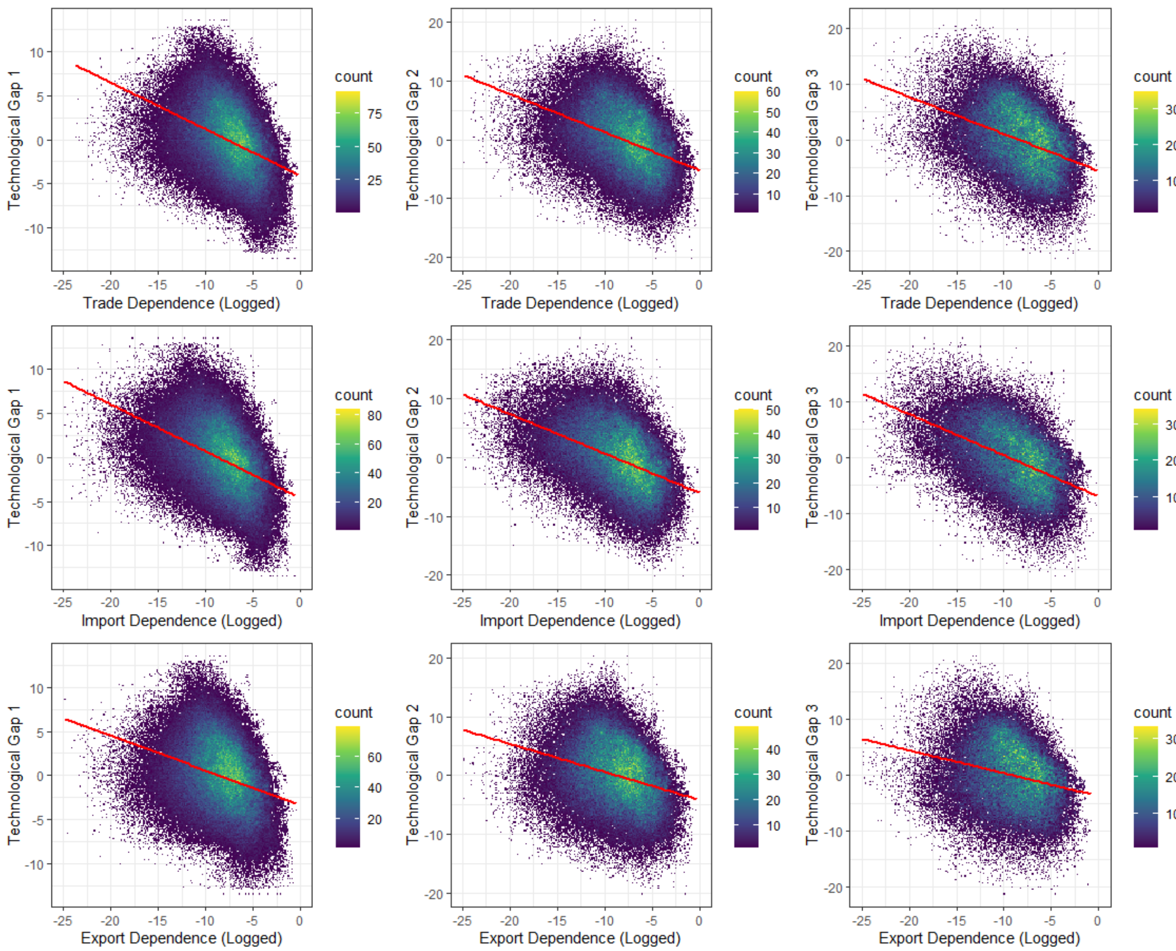

Figure 3.6. The Plots of the Sample against Alternative Explanatory and Dependent Variables

III.vii(iv). Regression Results

The regression results demonstrated in Tables 3.2-3.4 strongly support the hypothesis that the greater a state's trade dependence on another state, the higher the latter's relative technological growth. The estimates of the coefficient of trade dependence in all the models for all the three alternative technological gaps variables, only except for the fixed effect Model 3.2(8), are negative and statistically significant at the 99% confidence level. There is variation in its magnitude, in the sense that the coefficient appears relatively small (e.g., -0.02 in Model 3.1(3)) in several fixed effect and random effect models. The insignificance of fixed effect models may be explained by the fact that variables' variation in each dyad is not large enough.

Polity structures have identifiable association with tech gaps from the regressions, which however is inconsistent, as it is positive in some models and negative in others. Alliances appear positively associated with technology gaps, which meets common sense, though the estimates of the coefficients are not statistically significant in several models. The association between interstate militarized conflicts and technological power gaps is not strongly supported by the statistics, as it appears positive and significant in several models but negative in others. Annual FDI flows from state *i* to state *j* seems negatively associated with tech gaps, though the estimates of the coefficient are not statistically significant in Models 3.2(8) and 3.3(8) and become positive in Models 3.4(8) and 3.4(9). What is more at odds with theoretically expectation is that annual FDI made by state *j* in state *i* does demonstrate a neither consistent nor generally statistically significant effect on their tech gaps. One of possible reasons for this issue is that there is too much missing data for FDI flows. In all, according to the regression results, trade dependence appears to be the only one independent variable that demonstrates consistently and significantly association with technology gaps.

Table 3.2. Regressions of Technological Gap One with Respect to Trade Dependence

	3.1(1)	**3.1(2)**	**3.1(3)**	**3.1(4)**	**3.1(5)**	**3.1(6)**	**3.1(7)**	**3.1(8)**	**3.1(9)**
$\text{Relaive\_tech}^{(1)}_{ji,t}$									
$\log\left(\text{Trade\_dep}_{ji,t-1}\right)$	**-0.531***	**-0.504***	**-0.0200***	**-0.0424***	**-0.535***	**-1.422***	**-1.470***	**-0.373***	**-0.612***
	(-102.16)	(-90.37)	(-9.23)	(-19.77)	(-88.38)	(-46.44)	(-46.73)	(-13.02)	(-23.08)
$\text{Relaive\_tech}^{(1)}_{ji,t-1}$				0.0000111					0.0000470
				(1.50)					(0.85)
$\text{Polity type}_{ji,t-1}$: A		0.696***	0.167***	0.178***	0.765***	-2.962***	-3.558***	-0.00657	-0.0548
		(13.48)	(12.19)	(13.00)	(14.52)	(-7.23)	(-8.87)	(-0.07)	(-0.54)
$\text{Polity type}_{ji,t-1}$: B		1.480***	0.222***	0.265***	1.659***	-2.746***	-3.025***	0.366***	0.341***
		(26.57)	(15.82)	(18.84)	(28.85)	(-5.86)	(-6.54)	(3.82)	(3.44)
$\text{Polity type}_{ji,t-1}$: C		-0.950***	0.0110	-0.0219	-0.802***	-2.077***	-2.496***	-0.348***	-0.368***
		(-17.39)	(0.79)	(-1.57)	(-14.24)	(-4.63)	(-5.63)	(-3.65)	(-3.73)
$\text{Alliance}_{ij,t-1}$					1.091***		0.713***	0.148	0.273**
					(22.72)		(5.70)	(0.87)	(2.10)
$\text{MID}_{ij,t-1}$					0.971***		0.776**	-0.00601	-0.0101
					(5.53)		(2.51)	(-0.09)	(-0.15)
$\log\left(\text{FDI}_{ij,t-1}\right)$						0.0224	0.0141	0.00236	0.00543
						(1.25)	(0.77)	(0.69)	(1.51)
$\log\left(\text{FDI}_{ji,t-1}\right)$						0.185***	0.166***	0.0100***	0.0149***
						(9.80)	(8.66)	(2.93)	(4.17)
Constant	-4.117***	-4.305***	-0.300***	-0.484***	-4.766***	-2.916***	-2.907***	-1.622***	-2.869***
	(-96.34)	(-65.74)	(-14.46)	(-12.44)	(-67.08)	(-7.08)	(-7.17)	(-9.19)	(-15.19)
	Newey	Newey	FE	RE	Newey	Newey	Newey	FE	RE
N	198,906	181,260	181,260	181,260	163,052	4,777	4,272	4,272	4,272
R^2			0.00277					0.0652	
χ^2				991.3					601.0

t statistics in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$

Table 3.3. Regressions of Technological Gap Two with Respect to Trade Dependence

	3.2(1)	3.2(2)	3.2(3)	3.2(4)	3.2(5)	3.2(6)	3.2(7)	3.2(8)	3.2(9)
$\text{Relaive\_tech}^{(2)}_{ji,t}$									
$\log\left(\text{Trade\_dep}_{ji,t-1}\right)$	**-0.651*****	**-0.586*****	**-0.0311*****	**-0.122*****	**-0.628*****	**-1.392*****	**-1.447*****	**0.0190**	**-1.025*****
	(-91.16)	(-75.40)	(-5.69)	(-23.78)	(-73.28)	(-29.04)	(-28.32)	(0.16)	(-16.41)
$\text{Relaive\_tech}^{(2)}_{ji,t-1}$				0.0000345**					0.000135
				(2.07)					(0.83)
$\text{Polity type}_{ji,t-1}$: A		0.789***	-0.00124	0.0411	0.786***	-3.557***	-3.839***	-0.00368	-0.653*
		(8.19)	(-0.03)	(0.93)	(7.75)	(-5.70)	(-5.64)	(-0.01)	(-1.67)
$\text{Polity type}_{ji,t-1}$: B		2.830***	-0.396***	-0.0939**	2.859***	-1.150*	-1.284*	-0.107	-0.132
		(27.39)	(-8.79)	(-2.11)	(26.25)	(-1.79)	(-1.82)	(-0.27)	(-0.34)
$\text{Polity type}_{ji,t-1}$: C		-2.296***	0.404***	0.148***	-2.135***	-4.580***	-4.626***	0.120	-0.680*
		(-22.25)	(8.96)	(3.33)	(-19.67)	(-7.25)	(-6.70)	(0.30)	(-1.76)
$\text{Alliance}_{ij,t-1}$					1.461***		0.672***	-0.00303	0.594**
					(18.30)		(3.65)	(-0.00)	(2.41)
$\text{MID}_{ij,t-1}$					1.494***		0.686	-0.00354	-0.0214
					(4.84)		(1.50)	(-0.01)	(-0.08)
$\log\left(\text{FDI}_{ij,t-1}\right)$						-0.0344	-0.0401	-0.000775	0.00524
						(-1.31)	(-1.41)	(-0.06)	(0.38)
$\log\left(\text{FDI}_{ji,t-1}\right)$						0.243***	0.225***	-0.00380	0.0269**
						(9.56)	(8.15)	(-0.28)	(1.97)
Constant	-5.250***	-5.134***	-0.226***	-1.059***	-5.630***	-2.197***	-2.495***	0.104	-4.324***
	(-84.24)	(-45.54)	(-3.77)	(-14.34)	(-46.03)	(-3.48)	(-3.64)	(0.13)	(-9.02)
	Newey	Newey	FE	RE	Newey	Newey	Newey	FE	RE
N	140,244	121,732	121,732	121,732	105,516	4,150	3,672	3,672	3,672
R^2			0.00453					0.000184	
χ^2				605.6					275.3

t statistics in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$

Table 3.4. Regressions of Technological Gap Three with Respect to Trade Dependence

	3.3(1)	**3.3(2)**	**3.3(3)**	**3.3(4)**	**3.3(5)**	**3.3(6)**	**3.3(7)**	**3.3(8)**	**3.3(9)**
$\text{Relaive\_tech}^{(3)}_{ji,t}$									
$\log\left(\text{Trade\_dep}_{ji,t-1}\right)$	**-0.662*****	**-0.570*****	**-0.0134*****	**-0.0965*****	**-0.605*****	**-0.954*****	**-1.014*****	**-0.262*****	**-0.604*****
	(-73.45)	(-62.03)	(-2.75)	(-20.83)	(-54.53)	(-19.16)	(-18.39)	(-5.11)	(-14.12)
$\text{Relaive\_tech}^{(3)}_{ji,t-1}$				0.0000117					-0.0000272
				(1.07)					(-1.39)
$\text{Polity type}_{ji,t-1}$: A		0.696***	-0.00106	0.0117	0.759***	-0.842	-1.104	-0.200	-0.244
		(6.10)	(-0.02)	(0.24)	(5.63)	(-1.29)	(-1.49)	(-0.91)	(-1.22)
$\text{Polity type}_{ji,t-1}$: B		2.759***	0.0558	0.404***	3.081***	-0.281	-0.174	-0.0344	0.0942
		(22.67)	(1.13)	(8.39)	(21.31)	(-0.40)	(-0.22)	(-0.20)	(0.56)
$\text{Polity type}_{ji,t-1}$: C		-2.445***	-0.0573	-0.395***	-2.463***	-0.703	-0.982	-0.0295	-0.226
		(-19.94)	(-1.15)	(-8.19)	(-16.81)	(-0.97)	(-1.18)	(-0.17)	(-1.33)
$\text{Alliance}_{ij,t-1}$					1.547***		0.607***	0	0.348
					(15.40)		(3.55)	(.)	(1.48)
$\text{MID}_{ij,t-1}$					1.570***		0.0999	-0.00487	-0.0108
					(3.51)		(0.19)	(-0.07)	(-0.16)
$\log\left(\text{FDI}_{ij,t-1}\right)$						-0.0378	-0.0559*	0.00649	0.00880**
						(-1.45)	(-1.89)	(1.53)	(2.00)
$\log\left(\text{FDI}_{ji,t-1}\right)$						0.179***	0.166***	-0.00376	0.362+e6
						(6.62)	(5.46)	(-0.89)	(0.00)
Constant	-5.590***	-5.138***	-0.105*	-0.844***	-5.669***	-3.216***	-3.552***	-0.964***	-2.729***
	(-70.07)	(-37.27)	(-1.81)	(-11.98)	(-33.58)	(-4.93)	(-4.64)	(-3.28)	(-9.23)
	Newey	Newey	FE	RE	Newey	Newey	Newey	FE	RE
N	91,384	79,654	79,654	79,654	54,686	2,212	1,708	1,708	1,708
R^2			0.000205					0.0291	
χ^2				759.0					204.7

t statistics in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$

This study postulates that import dependence on another state generates unfavorable tech power transition more than export dependence. Table 3.5 represents the regression results of the second set of models (see Appendices III.A1-III.A3 and III.B1-III.B3 for the results for full specifications), in which import and export dependences serve as the key explanatory variable respectively. Compared to export dependence, import dependence's negative association with tech gaps proves bigger, more consistent, and more statistically significant across a variety of models. This is supportive of the anticipation.

Figure 3.7 illustrates the magnitudes of potential effects of trade, import, and export dependences on tech power transition. It seems that as trade dependence with a one-year lag in the sample increases from its minimum to its maximum, the logarithm of the predicted technological gap falls from 15 to nearly -5, by a rate of 133%, which range covers almost all tech gaps. For the majority dependence data between 19 and -1, the largest effect is 10. Import dependence contributes most to the effect of trade dependence on gaps transition, as its effect size appears as large as trade dependence. By contrast, export dependence's potential impact on technological power gaps is relatively small, as it can reduce predicted technology gaps by approximately 7 at most for the majority degrees of dependence. Besides, its effect is not consistent as it turns positive in several models.

IIIvii(v). Trade Dependence and Tech Power Surpassing

The last proposition of this study contends that trade dependence is not able to bring about the overturning of a dyadic tech power structure, other things being equal. To provide some empirical evidence for this proposition, I select two categories of cases to make comparison. The first group of cases is called a continuous dyad, in which the past technically leading side

Table 3.5. Regressions of Technological Gap with Respect to Import and Export Dependences

	$\text{Relaive\_tech}^{(1)}_{ji,t}$				$\text{Relaive\_tech}^{(2)}_{ji,t}$				$\text{Relaive\_tech}^{(3)}_{ji,t}$			
	Coef.	Std. Err.	*P*-value	*N*	Coef.	Std. Err.	*P*-value	*N*	Coef.	Std. Err.	*P*-value	*N*
$\log\left(\text{Import dep.}_{ji,t-1}\right)$												
No controls												
Newey-West	-.536	.004	<.001	190,969	-.674	.006	<.001	132,937	-.739	.007	<.001	85,837
No FDI ,alliance, and MID												
Newey-West	-.499	.004	<.001	174,572	-.597	006	<.001	116,611	-.638	.007	<.001	75,449
FE	-.043	.001	<.001	174,572	-.049	.004	<.001	116,611	.01	.004	.012	75,449
RE	-.063	.001	<.001	174,572	-.146	.004	<.001	116,611	-.087	.004	<.001	75,449
Without FDI												
Newey-West	-.525	.005	<.001	157,075	-.628	.007	<.001	101,128	-.669	.009	<.001	51,905
Without Alliance and MID												
Newey-West	-1.356	.03	<.001	4,777	-1.271	.048	<.001	4,150	-.922	.045	<.001	2,212
With all controls												
Newey-West	-1.404	.031	<.001	4,272	-1.319	.051	<.001	3,672	-.978	.05	<.001	1,708
FE	-.215	.026	<.001	4,272	-.017	.108	.871	3,672	-.038	.047	.417	1,708
RE	-.457	.024	<.001	4,272	-.902	.058	<.001	3,672	-.419	.04	<.001	1,708
$\log\left(\text{Export dep.}_{ji,t-1}\right)$												
No controls												
Newey-West	-.397	.005	<.001	190,800	-.487	.007	<.001	132,912	-.414	.009	<.001	85,821
No FDI , alliance and MID												
Newey-West	-.377	.005	<.001	174,413	-.434	.008	<.001	116,605	-.355	.009	<.001	75,436
FE	.014	.001	<.001	174,413	.004	.004	.336	116,605	-.029	.004	<.001	75,436
RE	.002	.001	.128	174,413	-.038	.004	<.001	116,605	-.058	.003	<.001	75,436
Without FDI												
Newey-West	-.401	.005	<.001	156,916	-.471	.008	<.001	101,122	-.379	.011	<.001	51892
Without Alliance and MID												
Newey-West	-1.288	.032	<.001	4,777	-1.291	.047	<.001	4,150	-.822	.051	<.001	2,212
With all controls												
OLS	-1.339	.031	<.001	4,272	-1.342	.049	<.001	3,672	-.884	.054	<.001	1,708
FE	-.344	.024	<.001	4,272	.033	.098	.735	3,672	-.329	.041	<.001	1,708
RE	-.493	.022	<.001	4,272	-.807	.058	<.001	3,672	-.529	.036	<.001	1,708

Note: See Appendices III.A1- III.A3 and III.B1- III.B3 for the results for full specifications.

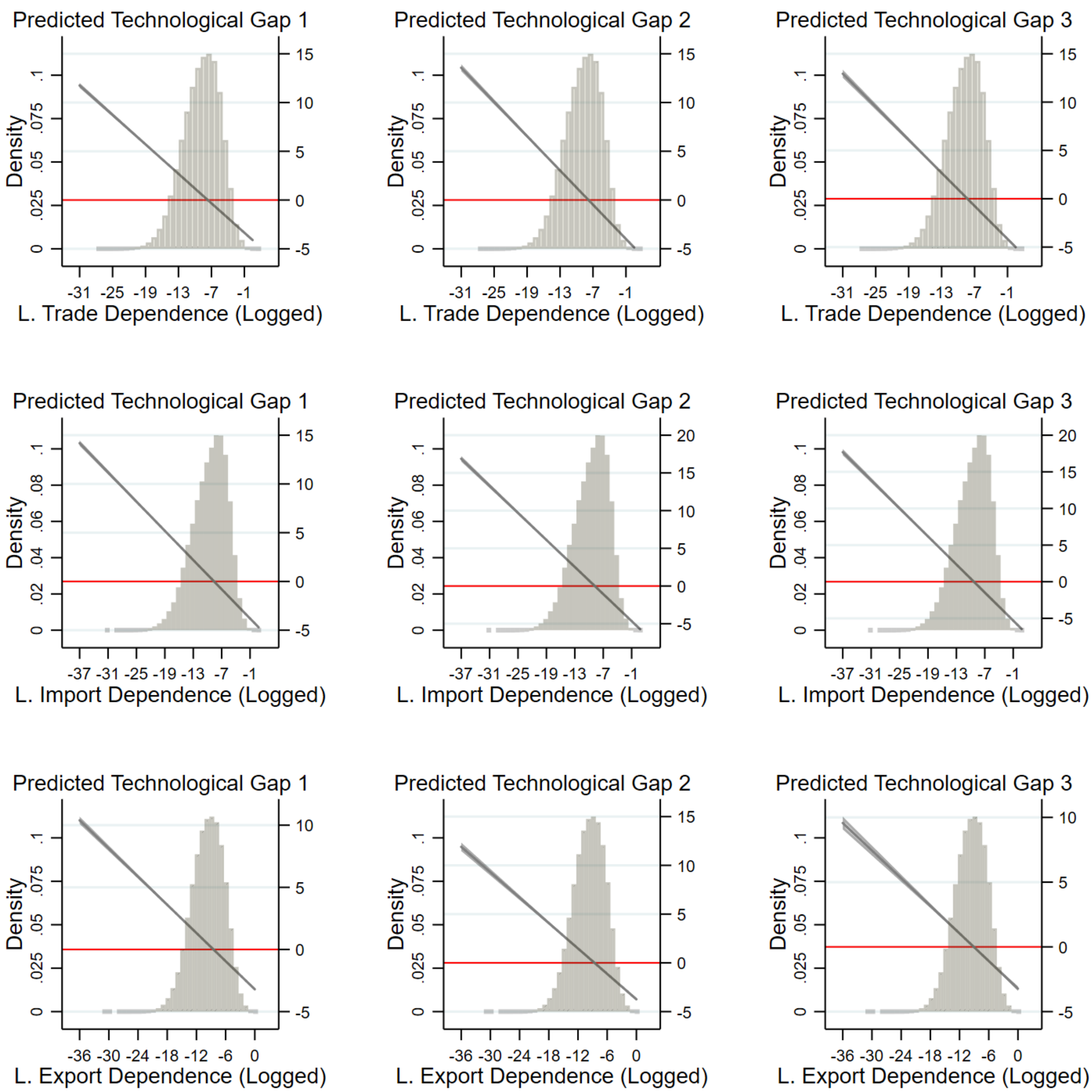

Figure 3.7. Trade, Import, and Export Dependences and Predicted Technology Gaps

Note: 1. The graphs are based on Models 3.1(2), 3.2(2), 3.3(2), A.1(2), A.2(2), A.3(2), B.1(2), B.2(2), and B.3(2).
2. 95% confidence intervals of predictions are displayed in the subgraphs.
3. All the control variables have their mean values in the prediction.

continues to be the bellwether; in contrast, some cases are deemed as reversal cases, in which the formerly leading state has become lagging behind, and this reversed between-state tech power relativeness persists for a while. I rely on an indicator function to define a dummy variable, *reversal*, and elaborate the selection process. I establish a function from the set of technology gaps to the set of reversal (=1) and being continuous (i.e., reversal=0) based on a four-year window: $\mathbf{1}:\mathbf{X}\longrightarrow\{0,1\}$, which is defined as

$$\mathbf{1}\left(\text{Relaive\_tech}_{ji,t-2},\text{Relaive\_tech}_{ji,t-1},\text{Relaive\_tech}_{ji,t},\text{Relaive\_tech}_{ji,t+1}\right)\equiv$$
$$\begin{cases}0 & \text{if Relaive\_tech}_{ji,t-2}>0, \text{Relaive\_tech}_{ji,t-1}>0, \text{ Relaive\_tech}_{ji,t}>0, \text{ and Relaive\_tech}_{ji,t+1}>0\\ 1 & \text{if Relaive\_tech}_{ji,t-2}>0, \text{Relaive\_tech}_{ji,t-1}>0, \text{ Relaive\_tech}_{ji,t}<0, \text{ and Relaive\_tech}_{ji,t+1}<0\end{cases}$$

That is, if the tech gap between a particular dyad is positive for four consecutive years, this case is deemed as continual; if the tech gap is positive for two years and turns negative in the third year and lasts for at least two years, this case is treated as a reversal.

Table 3.6 displays the distribution of the *reversal* variable. As it suggests, the cases of technological surpassing are quite rare compared to continuous cases. This rate is 3.24% for $\text{Relaive\_tech}_{ji,t}^{(\mathbf{1})}$, 2.65% for $\text{Relaive\_tech}_{ji,t}^{(\mathbf{2})}$, and only 1.68% for $\text{Relaive\_tech}_{ji,t}^{(\mathbf{3})}$. Albeit exceptionally few, there still exist structural reversals, and the key question is whether trade dependence has a correlation with their occurrence. The conditional distributions of trade dependence by reversal are exhibited in Figure 3.8. No remarkable differences between the distributions of trade dependence for reversal cases and for continuous cases exist in any of the plots. This suggests that there is no observable correlation between trade dependence and high likelihood of technological surpassing, which is consistent with the third proposition.

Table 3.6. Distributions of the Reversal Data

	Technological Gap 1		Technological Gap 2		Technological Gap 3	
	No.	% Total	No.	% Total	No.	% Total
$reversal = 0$	89,305	96.76	73,529	97.35	60,688	98.32
$reversal = 1$	2,987	3.24	2,002	2.65	1,035	1.68

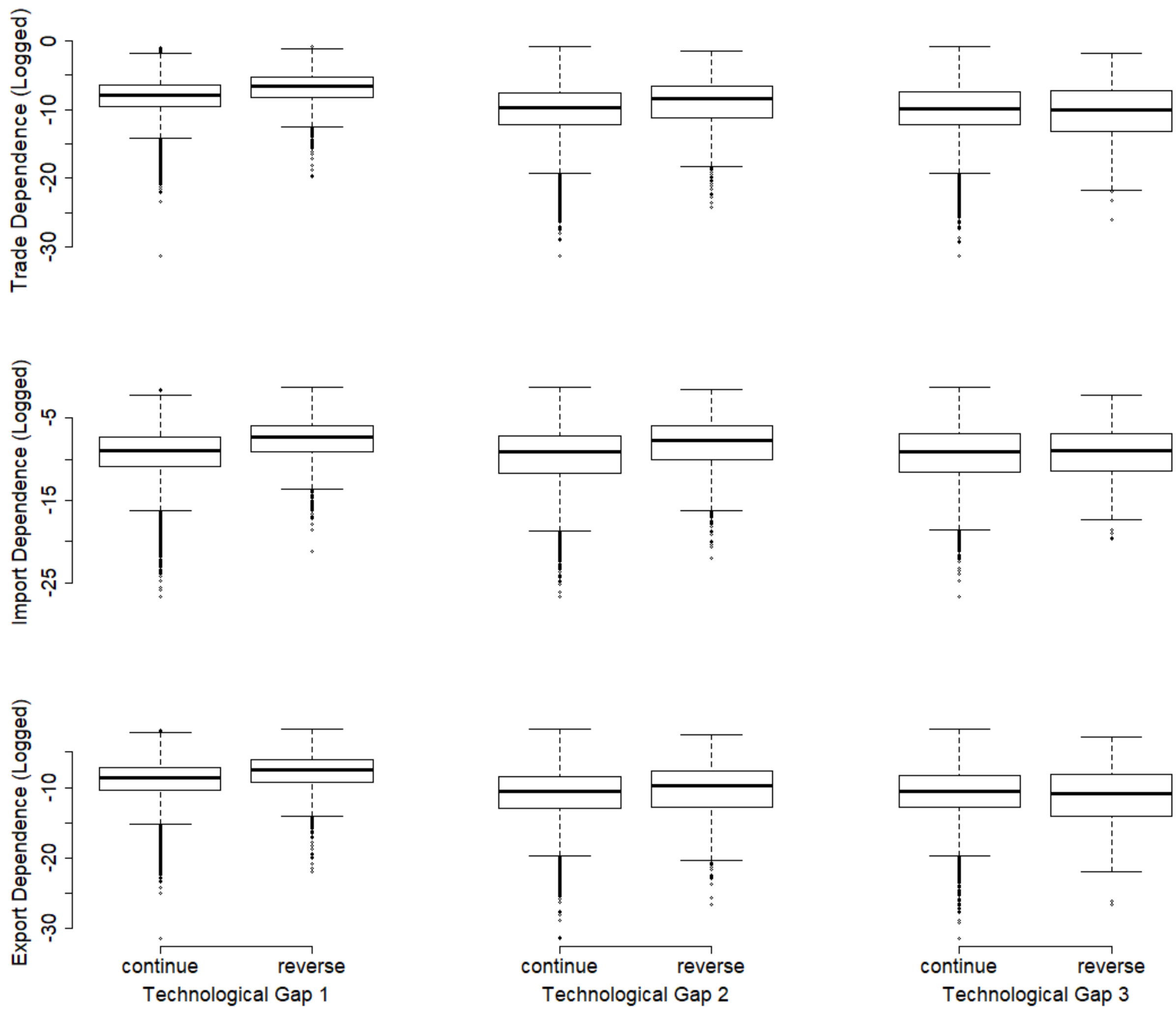

Figure 3.8. Conditional Distributions of Trade Dependence by Continuing or Reversal Categories

III.viii. Conclusion

Existing research shows that external knowledge can contribute to domestic technical development, and some international economists assert that trade can facilitate the process of cross-border technology transfer; these propositions and empirical works are consistent with liberal, optimistic ideals about trade. In political realms, the dependency theorists care more about trade's effects on the global wealth and power distribution, and more specifically, whether dyadic trade relations can contribute to wealth or industrial convergence among partners; they have negative attitudes toward it. I point out two loose ends in former studies. First, the economic research on association between trade and technology transfer mainly focuses on an individual state's technological growth *via* trade, and some have examined trade's impacts on global or regional technical convergence; however, in IR analysis, we are more concerned about how bilateral trade shapes between-state technological power distribution, considering that technology competition is a major part of contemporary power struggles. Second, though the dependency theory is skeptical of trade's positive effect on dyadic technological power convergence, it falls short of explaining why there is significant cross-state and cross-time variation in relationship between trade with advanced states and domestic technological growth; as negative cases against the theory, China and Japan had appeared as technological beneficiaries of their trade with more advanced states, especially the US. As a resolution, I shift the focus from trade volumes or contents to trade dependence and put forth several conjectures. A state's trade dependence on another state will generate unfavorable tech power transition. First, firms' willingness to protect their IP in places which they rely on to receive low-priced intermediates is compromised by pursuit of maximum profits; they are also susceptible to governments' requirement about technology transfer in these places. Second, a backward state has little chance to get rid of adverse influences from and narrow the tech gap with advanced partners that it depends on to get tech supplies. I also point out that in spite of trade dependence's unpleasant effect on dyadic tech power gaps, it will not make tech surpassing. The empirical analyses based on state-level observations from1980 through 2014 basically substantiate my hypotheses.

The research has several limitations, which are expected to get addressed in future's research. First, the empirical inquiry merely covers a period that the technological capacity and trade data are available for, which to some extent limits the external validity of the findings. Therefore, various data sources and alternate measures are in need for future's reassessing. Second, state dependence on different varieties or sectors of imports might exert varying levels of effects, which has not been examined yet. Presumably, an advanced state's reliance on foreign supplies of manufacturing intermediates is more likely to undergo a downward technological power transition toward its backward partner than its dependence on external primary resources, provided that these imports entail and tend to attract more technical inputs from downstream purchasers than raw materials or agricultural goods do. A less advanced state's dependence on external medium- or high-tech goods is more likely to hold it back from catching up toward its developed partners than is its possible dependence on any other kinds of commodities; this is because any technical progress that it could have made would become a competitive advantage that threatens tech-related imports, and its advanced partners would not allow this to happen. Nevertheless, this research's argument can still be robust, considering that when a state's general trade dependence on another is high, it has little economic power to prevent a tech power transition from going unfavorable. Another loose end of this research is that it does not address a potential endogeneity issue. There probably exist interplays between interstate trade relations and their tech power relativeness—Indeed, the following part argues and evidences that between-state tech power parity tends to breed bilateral trade conflict. The major difficulty in tackling this issue is that conventionally used instruments for trade volumes such as geographical proximity are not directed and therefore cannot be utilized to estimate directed trade dependence. Thus, smart techniques that can help mitigate the adverse impact of the potential endogeneity are expected for future's advancement of this theory.

PART IV

STATE TECH POWER POSITION AND INITIATION OF TRADE CONFLICT

IV.i. Introduction

The preceding parts of the dissertation have been dedicated to illustrating the foremost and independent roles that state technological capacity plays in directing state behavior, as well as how and to what extent interstate trade dependence contributes to variation in between-state tech power gaps. It is argued that, unlike material struggles, tech competition is bound to cause non-violent rather than militarized conflict; accordingly, the intriguing and crucial questions than interest IR students shall be whether and how states respond to tech competitions by wielding nonmilitary foreign policies. In this part, I investigate whether and how dyadic technological capacity disparity or parity affect bilateral trade relations. Previous economic research posits and substantiates a positive causal correlation between cross-border trade and tech transfer; additionally, I have shown in Part III that a state's trade dependence on another engender negative tech power transition. Building on these theoretical assertions, I posit that *in the face of between-state tech strength catching-up, a state may tend to initiate trade conflict against the tech power pursuer as a preventive strategy to address its concern that their bilateral trade is disproportionately favoring the challenger and may facilitate further convergence or even surpassing*.

As to interstate trade relations, previous IPE research mainly examines the effects of conventional political factors, such as domestic institutions, alliances, and militarized conflict, on cross-border trade flows (e.g., Morrow et al. 1998), whereas a wealth of studies are concerned about how interstate trade influences militarized conflict (e.g., Polachek 1980). Little research so far has directly and systematically explored explanations of **initiation of trade conflict**, which refers to initiated, not retaliatory, restrictive trade policy that targets certain states, despite a few works explaining the onset of the disputes under the World Trade Organization (WTO) agreement (e.g., Reinhardt 2000; Bown 2005) and fragmented case studies on prominent trade conflicts (e.g., Bown and McCulloch 2009). This is perhaps because there is an implicit assumption that conditions for militarized conflict can be readily employed to explain the rising of economic conflict, which, however, still requires extensive research. This research makes two potential contributions to current literature. First, it advances the power transition theory by adapting it to the modern context—It stresses the important roles that between-state tech power parity plays in shaping trade relations. Second, it systemically examines the emergence of interstate trade conflict.

To evidence this claim, I scrutinize trade sanctions, state withdrawal from PTAs, and the triggering of disputes in the WTO, deeming them as proper proxies for initiation of trade conflict. First of all, I use a game-theoretic analysis to unveil the nature of economic sanctions: They are foreign policies that have alternate utilities in the sense that they render direct (i.e., independent of the target's concession) political outcomes, which may benefit the sender, and meanwhile, they come out with normative requests to coerce the target into certain concessions, serving as a substitute for the direct gain. As political benefits a state can earn from a potential sanction regardless of the target's concession are greater, it is more likely to resort to such a strategy; by using sanctions, which are justified by normative convictions of the target, states can avoid loss of reputation or/and lack of legitimacy due to implementing restrictive trade policy that contravenes liberal norms, or frame focal points to mobilize international concerted action. On this basis, I hypothesize a quadratic connection between dyadic tech strength distribution and trade sanctions—As a technologically weaker state, say State A, is catching up to a more advanced partner, State B, the latter has growing tendency to slap trade sanctions against the former, as a way to impede unfavorable tech power transition; as State A keeps rising to lead ahead, State B becomes less likely to launch sanctions against it in that it does not have enough relative tech power to effectively strike at the other and easily establish import-substitution production to mitigate the adverse effect of trade recession on domestic economy. In a similar vein, when State A is closer to State B in terms of tech power, the latter is more likely to withdraw from an existing trade treaty with the former, which impulse decays if State A crosses parity and leads ahead. Likewise, if both states are members of the WTO, State B tends to trigger trade disputes filed by State A for its restrictive bilateral trade policy. The empirical analyses based on state-level observations from 1980 through 2016, as well as an investigation into two recent trade conflict cases, provide supportive evidence for these hypotheses.

IV.ii. Technological Competition and Trade Dispute: Causal Pathways

As discussed in detail in Part II, state technological strength is at the core of national security, for technologies act as main sources for national power or competitiveness, especially in the modern era. States, from realist viewpoints, urge for power in an anarchic world; they are supposed to have substantial incentives to accumulate tech capacity in an efficient manner; meanwhile, they seek to prevent domestic critical technologies from leakage in order to prevent jobs from offshoring, avoid fostering a competitor, forestall potential foreign threats, or the like, especially when such political cost is significant. Particularly, according to the tenets of the transitional theory, tech competition is supposed to become intensified when two states are positioned closely in terms of tech capacity. Considering that cross-border exchange is likely to facilitate a downward tech flow from the advanced side to the backward (see Part III), may financially or/and materially nourish foreign competing tech corporations, and probably increase tech or economic dependence on a rival partner, erecting trade barriers against tech competitors for the sake of national power and security might be imperative. Specifically, the causation between tech competition and trade conflict can be based on the following mechanisms.

The power transition approach. The transitional theory is applicable to explaining powerful states' anxiety about being caught up to by another in the technological arena. The power transition theory explains that a conflict occurs in two situations: one initiated by the dominant state for the preventive purpose, and the other by the challenger who is dissatisfied with the status quo to change it; in this paper, I focus on the first one–When a rising state reaches parity with a global or regional hegemon in terms of national power, the latter tends to prevent the challenger's further rise and deter its geopolitical expansion; they are quite likely to get into competition or rivalry, engaging in diplomatic, economic, or/and military confrontations (Organski 1968; Organski and Kugler 1980; Lemke 2004). State technological capacity is pivotal in determining national power in modern eras, for it serves as a critical basis for national production, military strength, and global influence (see Part II), all of which are conventionally recognized as indispensable ingredients of national power. A growing number of surveys already directly involve state technology capacity as part of national power (e.g., Krahmann 1927; Saaty and Khouja 1976). Therefore, according to the transitional theory, when an ascending power is about to technologically overtake a global or regional hegemon, they are likely to get into uncontrollable tech contention. It is noteworthy that some transitionists stress that not an interstate conflict like war may be imitated by a dominant state targeting a rising power if the latter is not posing a clear threat to the former. I will point out in the following paragraph that tech power parity is bound to intensify competition for limited global markets, which brings pressures to state leaders whose political life hinges on national economic performance, and domestic industries, who are supposed to pass such stresses onto the government and press for protectionist policy. Namely, between-state tech power catching-up is inherently a threat to national and group economic interests, so trade conflict between a dominant power and its challenger in the tech field is quite likely to occur.

The market competition approach. If two states have similar levels of tech capacity, they are highly likely to have homogeneous indigenous production patterns as well as identical export structures, which situation intensifies their market competition. Global innovation networks are stratified—Technologically leading states put substantial efforts to making cutting-edge innovation; middle-level states focus on learning and performing foreign highest techniques as well as exploring secondary techniques; some backward states even have not set up functional innovation systems, and they focus on investing unskilled labor into global production. The stratification of innovation serves as the basis of production specification. The lower-level states concentrate on producing raw materials or labor-intensive intermediates or commodities, and the more advanced states are specialized in providing capital-intensive goods and services; their exports enter different markets and are confronted with different competitors. Technical advancement is the lynchpin of industrial upgrading; therefore, a state's innovative quality determines its structures of domestic production and exportation. Prior research has shown that between-state economic competition tends to be aggravated when two states have equivalent export structures (e.g., Cao and Prakash 2010). Hence, states are more likely to be competitors vying for limited global markets that accommodate their akin exports when they belong to similar technological levels. To survive the inevitable market races, states in the same rank of tech capacity are bound to seek to possess better technology, which leads to higher levels of production efficiency and quality, and therefore greater competitiveness of products.

Trade-driven downward tech power flows. Trade conflict may emanate from the purpose of preventing a tech competitor from further growth. Existing research has substantiated that technology can be transferred from advanced states to its backward partners via cross-border exchange and direct investment. Trade may provide several channels through which techniques diffuse transnationally—Trade entails cross-border personal contact, which facilitates information exchange; firms can get domestically unavailable knowledge by purchasing and inspecting imports that contain alien technologies; when firms export products, their foreign purchasers may set standards for them and offer information on how to reach such levels of quality (Grossman and Helpman 1991). An indirect technology spillover can also be achieved through learning by doing, given that an inward flow of technology may provide opportunities for further inventive exploration, actualization, or realization of its potentials; major technical breakthroughs can drive a series of minor technical innovations (Rosenberg 1982; Young 1991).

Trade and direct investment interact to facilitate tech transfer. Existing research has provided some evidence for trade-led R&D spillover (Coe and Helpman 1995; Keller 2002b; Madsen 2007). Likewise, several works identify FDI as instrumental for transborder technology spillovers (e.g., Blomström and Kokko 1998; Liu 2008; Clark et al. 2011); the chief reason is that employees who received knowledge from working in MNCs' abroad affiliates may leave and move into domestic similar enterprises, in which way they diffuse their knowledge (e.g., Fosfuri et al. 2001; Glass and Saggi 2002). Trade can spur transboundary tech investment or sharing because tech input alongside outsourcing can help optimize overseas production of intermediates. In return, FDI boosts interstate trade in the sense that parents may sell auxiliaries, intermediates, or other complements to host states as a way to facilitate affiliates' production and sales of final goods (Blonigen 2001). That is, if a state seeks to impede worrying outward tech diffusion *via* cross-border exchange and capital flows, it needs to consider shrinking trade or/and outward FDI.

Meanwhile, a state is likely to receive negative payoffs for their opening of markets to a tech competitor because this allows the latter to have a broader market for its tech products or enjoy an abundant supply of critical intermediates for its high-tech goods or R&D, which can financially or/and materially contribute to the competitor's further innovative growth. It also raises the risk of the state's technological and economic dependence on the rival, which may threaten long-term national security and growth.

Besides, trade restrictions are supposed to be more effective and efficient than militarized action to tackle tech competition. Considering characteristics of the ideational aspect of tech assets, such as the easy hiding, replicating, restoring, and transferring of ideas, formulas, and data, militarized actions cannot weaken state tech capacity or impede its technical progress as effectively as they sabotage state material assets. Moreover, the declining attractiveness of using conventional warfare to address interstate tensions during the postwar period has driven states to utilize nonmilitary measures such as trade policy more frequently to realize national interests.

Accordingly, in a bilateral trade relation, the technically leading side when facing a tech catching-up from the backward side is expected to regress toward protectionist or mercantilist bilateral strategies to maintain its innovative advantages and hinder the worrisome trend of tech strength convergence. In another scenario, a state's trade partner technically leads ahead; then, the state has disincentives to initiate trade conflict against the partner for several reasons. First, preventing a leading-ahead power from further growth is not as urgent as deterring a rising challenger. Second, a technically backward state has relatively few resources to conduct effective economic attacks since its more advanced partners have ample tech resources to make substitutes for the supplies cut by trade recession; by contrast, it is difficult for a technologically weak state to quickly establish tech-import-substituting production to mitigate the adverse impacts of trade conflict. Namely, the correlation between interstate tech power gaps and ruptures in their trade relations is quadratic— Likelihood of trade conflict peaks when a state almost reaches technological parity with another. In sum, I put forth the following proposition.

Proposition 4.1: *All else being equal, a state is more likely to initiate trade conflict against a backward partner, with which its tech gap shrinks; if the partner leads ahead in terms of tech power, the state is less likely to trigger trade conflict against it.*

The principal difficulties in empirically assessing this argument rest in two facts. First, governments possess an array of instruments of trade policy, including tariffs and non-tariff measures such as quotas, subsidies, duties, and quality controls; although increasing tariffs or erecting non-tariff barriers are normally conceived of as key means of constraining exchange at borders, many restrictions measures are not specific-country-targeting but driven by domestic sector-, industry-, or firm-based protectionist demands, which are applied to certain categories of items and indiscriminately influence more than one relevant partners. The second problematic fact is that among trade restrictions targeting specific states, some come out as retaliatory measures like penalty tariffs in response to the target's former unfriendly bilateral trade policy. Only the following types of trade restrictions are state-targeting and seldom used as formal retaliation for trade conflict initiated by other states: *trade sanctions* and *state withdrawal from a free trade agreement*, which have not been claimed by any implementers as retaliatory policy against others' trade restrictions; *triggering of disputes in the WTO*, which can lead to retaliatory policy but is not a retaliation *per se*.

IV.iii. Economic Sanctions

Sanctions are deemed as one of diplomatic tools, or a foreign policy, positioned between diplomacy and war (Askari et al. 2003). Economic sanctions serve as a way of seeking political ends using economic weapons; they are part of coercive foreign policies which are supposed to create pressures on target states to change their behavior in certain ways. There are three major types of economic sanction: limiting exports(embargoes), restricting imports, and impeding financial flows; in most cases, senders would like to take more than one of these options and make a comprehensive sanction (Hufbauer et al. 2007, 20; Eyler 2007, 134-135). The key difference between economic sanctions and regular trade policies, in Eyler's (2007) view, is that the former is "used for changing another country's political choices rather than domestic protectionist purposes" (10). Doxey (1980) distinguishes use of economic measures as sanctions from hostile economic policies amid war by pointing out their divergent purposes; the latter's aim is "to hasten its [enemy's] defeat, to reduce or eliminate its [enemy's] capacity to wage war, and to undermine morale" (9), whereas the objective of imposing sanctions "should be to deter or dissuade states from pursuing policies which do not conform to accepted norms of international conduct"(9). In all, economic sanctions are defined as *coercive foreign policies which take economic measures to carry out moral purposes and initiating of which shall be justified or legitimized by international recognition of target states' wrongdoing*. In this study, I argue that though economic sanctions' purpose is commonly allegedly normative, they can still covertly serve realist objectives, such as crippling a rival state's economy, shrinking trade deficit with an adversary, or closing markets to a rising tech competitor. The dual facets of sanctions allow states to rely on them to carry out realist strategies with minimum loss of moral advantages or reputation through ostensible compliance to international liberal norms, or use them as focal points to mobilize international concerted actions against a target. This proposition will be elaborated in the following section.

Little evidence suggests a general effectiveness of sanctions (e.g., Wallensteen 1968; Drury 1998; Pape 1997; Elliott 1998), and some investigators even suspect that sanctions have counterproductive effects (e.g., Adhikari and Peksen 2022). Empirical research corroborates the intuition that sanctions create economic loss for both senders and targets due to governmental intervention in markets and deviation from specialization. Hufbauer et al. (2007) examine the US-launched sanctions and find that they have adverse effects on the US-target trade and target's trade with its own partners. Likewise, Moorsom (1986) investigates the sanctions imposed by Britain on South Africa against its apartheid institutions, showing that the enforced sanctions had generated economic disruptions in both. Meanwhile, economic, and especially export, sanctions, have been found to be effective in creating humanitarian costs, as such restrictions may prevent from going into target states goods indispensable for economic stability and development; consequently, residents in target states lose access to health, water, education or/and food (Eyler 2007)[43]. Eyler's (2007) analysis of 65 cases suggests that neither export, import, nor financial sanctions demonstrate effectiveness in changing targets' behavior in ways satisfying senders' request in the short term. In the long run, only import sanctions appear significantly positively associated with targets' concession. Yet the results are subject to question due to its small sample size. Hufbauer et al. (2007) expect financial sanctions to be the most effective among alternatives, considering that restrictions on commodity flows can more easily be offset by targets' resorting

[43] Moorsom (1986) shows that sanctions against the apartheid regime had negative side effects on blacks as they lost jobs due to it, which worsened their unfavorable situation (63-68).

to substitutes, black markets, or smuggles than financial sanctions, which postulation has received some empirical support (e.g., Bolks and Al-Sowayel 2000).

Despite the mixed results of comprehensive analyses, modern history has witnessed several prominent successful sanctions. For instance, the anti-apartheid comprehensive sanctions against South Africa since the 1960s, which involved several IOs, European countries, the US, and Japan, and the OPEC's oil embargoes of 1973 as a response to the US endorsement of Israeli military engagement engendered some expected political effects. Generally speaking, there are several preconditions for a sanction succeeding. First, if the target state of a sanction is highly involved in global production networks or greatly dependent on trade with the sanction sender, it is more likely to encounter substantial loss from receiving the sanction, and it is therefore more likely to yield. Likewise, targets' reactions hinge on their elasticities of domestic (Black and Cooper 1987) and global (Kaempfer and Lowenbergr 1988) supplies and demands. Second, there ought to be strong political wills leading senders to afford the monitoring cost of enforcing the sanction.[44] Third, a sender can mobilize the major partners of its target toward a coordinated action (i.e., forming sanction cartels), preventing them from filling the gap caused by the sanction through expanding their own trade with the target. In addition, some researchers find political institutions of targets can condition the success of sanctions (Bolks and Al-Sowayel 2000; Allen 2005)[45].

[44] Private sectors have no political incentives to abide by embargoes, who would manage to eschew such restrictions by fraudulent documentations or routing through a third state to make banned exports still possible. Therefore, physical or/and digital monitoring of cross-border transportation and transactions is the lynchpin of the working of sanctions.

[45] Bolks and Al-Sowayel (2000) argue that how likely targets are to develop countermeasures against sanctions depends on the extent to which their domestic decision-making processes are constrained. Allen (2005) finds that democratic targets are more likely to concede than the others.

IV.iv. Why Sanctions Rather Than Compromise?

As aforementioned, existing cases display low effectiveness of economic sanctions; though they appear able to impair both sides' economies and pose pressures on target, few cases end with concessions by targets that meet senders' declared goals. Some studies point out the censoring issue in prior research on outcomes of sanctions, given that some factors determining the efficacy of threatening sanctions may affect the performance of sanctions in force (Drezner 1998, 2003; Nooruddin 2002). Sanctions can be part of crisis bargaining in which senders present an offer of lifting sanctions if their requests are satisfied (Marinov 2005). They are found to be more successful when considering all, including threatened, rather than implemented sanctions solely (e.g., Drezner 2003; Walentek et al. 2021). The intriguing question shall be why states still impose sanctions even though their threats have proven not efficacious in the first place.

To answer this question, I must point out a shortcoming of former studies on the effects of sanctions—They overlook the fact that if the target of a sanction refuses to make the requested concession, the sanction may still generate political benefits to the sender; this is because sanctions are bound to have straightforward, though sometimes incrementally rising, economic or/and political impacts on targets, senders, or third parties, no matter whether they can be translated into pressures on targets and eventually lead to requested behavioral change. These kinds of direct effects contribute to political gains and costs for senders, which shall be considered before using sanctions. Direct political gains cover a wide range of beneficial outcomes for sanctioners, including creating economic disruptions in a competitor, impeding a rival state's technical or industrial upgrading, expressing senders' ideological identities in front of either international or domestic audiences, stimulating mass uprisings in target states against objectionable regimes, or provoking senders' domestic nationalist agitation and generating rally effects (Whang 2011). I call this phenomenon *alternate utilities* of economic sanctions.

For instance, though an economic sanction normally jeopardizes economies of both sides, when two rival states care about relative gains from their economic contact, they may seek trade disconnection with the other through imposing sanctions if they have confidence in losing less than its rival partner. Sanctioners may want to overthrow a regime as a whole through long-term sanctions, which are supposed to ruin the target's economy and thereby deprive the regime of legitimacy, instead of pressing for immediate, limited policy change. For example, Marinov (2005) points out two mechanisms through which sanctions may lead to targets' concessions—Senders may achieve their ends through coercion, by informing the target state that making requested compromises can help avoid sanctions, or they can use sanctions to destabilize target leaderships and bring about a pliant successor. Relatedly, Grauvogel et al. (2017) do find that economic sanctions tend to stimulate public protests in target states, as they signal powerful states' approval for domestic oppositions and anti-regime activity.

Why do economic sanctions still emerge even though the threat of using them has failed in eliciting concessions from targets? Given the alternate-utility nature of sanctions, in some circumstances, when threatening sanctions, the potential sender may intentionally relate requests to issues of great salience to target states, considerably lowering the likelihood of their being met; in such a case, negotiation is bound to fail, and sanctions must be implemented.[46] Specifically, when a sanction's direct political rewards for senders are too sizable and tempting, their overt

[46] Relatedly, Bapat and Morgan (2009) find that sanctions are more likely to be imposed multilaterally in response to highly salient issues, and therefore they are less likely to succeed than are unilaterally imposed sanctions.

normative demands, as an equivalent collateral for the direct gains, must go so far that a bargaining range is not likely to exist.

Suppose two players, States A and B, have complete information about their interactions demonstrated by the game described in Figure 4.1. State A is supposed to inflict a sanction against State B as long as political rewards like technological security that State A garners straight through from such a sanction outweighs economic costs it engenders (i.e., if $p > \alpha$). In this case, sanctions, for State A, are worth pursuing, and it can receive either $x - \alpha + p$ or $x + m$, both of which are better than the *status quo.*

Then, when the costs imposed by a potential sanction launched by A targeting B to B are less than its loss by following A's behest and changes its behavior (i.e., if $n > \beta$), the two states will jointly move to and stay at O2; this becomes an equilibrium in which State A invokes a sanction against B, and B refuses to make concessions. In another scenario, the cost B receives from the potential sanction initiated by A is greater than the benefits it surrenders if it chooses to placate A by concessions (i.e., if $n < \beta$), and A receives more rewards from its sanction when the latter agrees to concede than when B does not respond (i.e., if $m > p - \alpha > 0$), O3 becomes the equilibrium. Based on the game framework, I propose that *as political gains a state directly receives from a sanction against another is greater, it is more likely to resort to the sanction, even though the raised issue is so salient to the target state that the demand can never be met; the sender uses sanctions rather than regular economic policies that can render similar political outcomes because it wants to avoid loss of reputation or/and lack of legitimacy, or use sanctions as focal points to mobilize international collective action*.

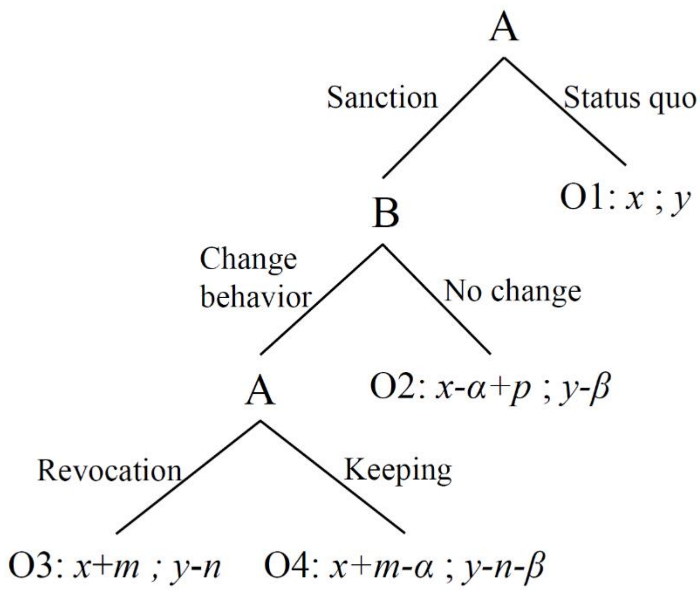

Figure 4.1. The Extensive Form of Interactions Revolving Around Economic Sanctions

Note: *x* and *y* denote the present distribution of benefit for A and B respectively; *α* (*β*) designates economic costs that are imposed by a potential sanction implemented by A against B on itself (B); *p* represents political benefits that State A can gain directly from enforcing a potential sanction; *m* denotes what A can get, and *n* is what B loses, if B changes its behavior in the way that satisfies A's demand. All of variables are nonnegative.

To prove this proposition, suppose the volume of benefits that A requests alongside its sanction against B is linearly positively correlated with how much B needs to pay for such a concession, which relationship is expressed as follows.

$$n = km + l, k > 0, l > 0$$

When $n > \beta$, State B, in the face of sanctions, will change its behavior to meet A's requirement, and State A therefore will get *m*. In this context, if $p - \alpha$ is greater than $(\beta - l')/k'$, State A's best strategy is to make a demand that, if met, supplies A with benefits greater than $(\beta - l')/k'$; otherwise, A will fall in O2, which returns it benefits at $p - \alpha$. When $p - \alpha$ is less than $(\beta - l)/k$, A's optimal demand choice will be $(\beta - l)/k$ (see Figure 4.2).

Suppose the curve for senders' demand and targets' loss is given, as political rewards generated by sanctions themselves surpass $(\beta - l)/k$, the optimal strategy for A is to make a demand greater than $(\beta - l)/k$, making B's loss for yielding outnumber β; in this case, O2 is the equilibrium for the two states—State A slaps a sanction on B and proposes conditions for lifting it that state B can never satisfy (see Figure 4.3). The game-theoretic analysis shows that sanctions themselves can directly cause political rewards, which may have to be covered because they are not as legitimate as what senders overtly demand, and such rewards can be so great that no bargaining ranges between the sender and the target exist whatsoever. That is, trade sanctions may serve as alternatives not only to militarized action but also to trade policy with realist purposes like impeding outward transfer of technology during between-state tech competition. It is noteworthy that sanctions can be and have been used to block supplies of strategic technologies to dangerous, like terrorist, states (Helms 1999), objectionable regimes, or their

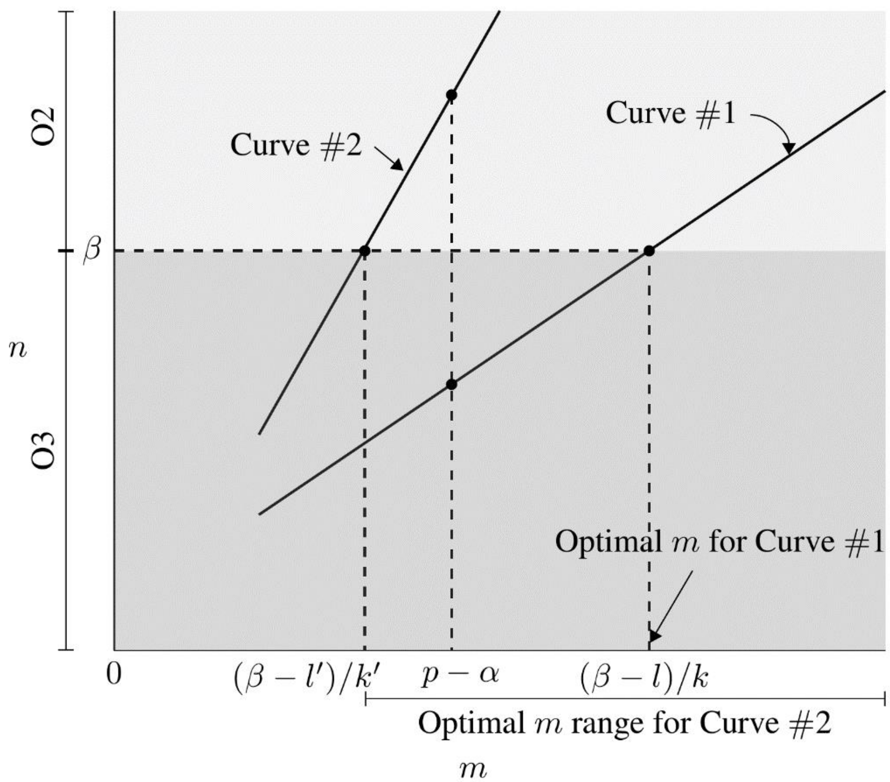

Figure 4.2. The Different Curves for Senders' Demand and Targets' Loss

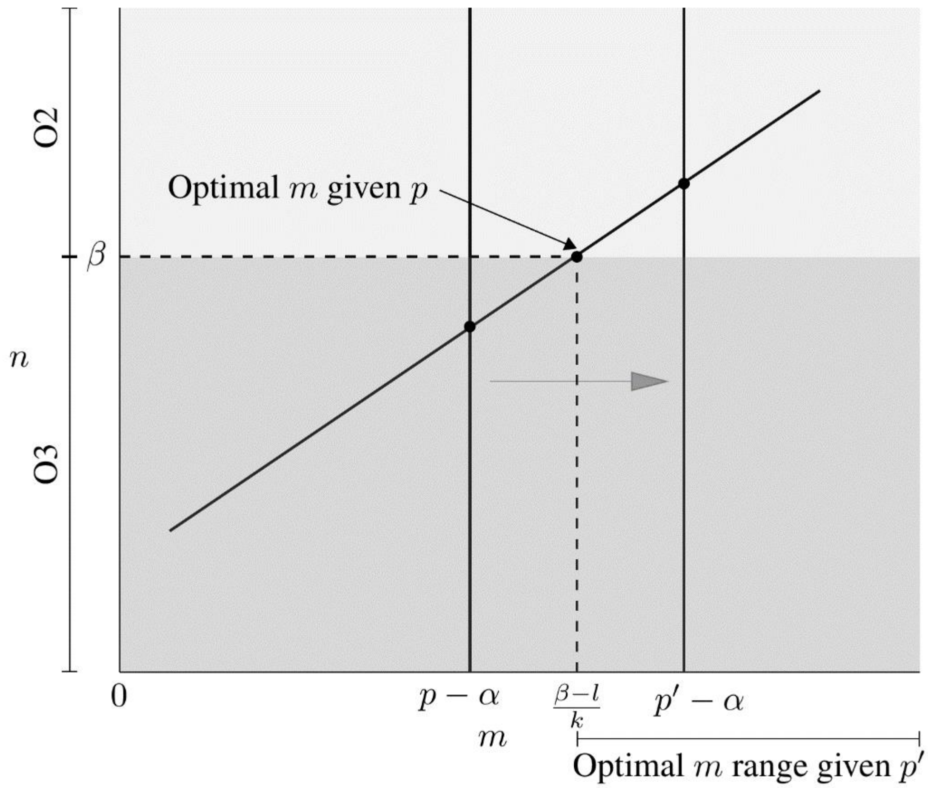

Figure 4.3. The Different Direct Political Gains

subsidiary entities or affiliates. For instance, pursuant to the *Comprehensive Anti-Apartheid Act of 1986*, technologies are banned from being exported to most branches of the South African government. Direct technology sanctions sometimes also aim to slow the target's economic growth and reduce its exportation by restricting supplies of key tech capitals. Nevertheless, this research is concerned about how states use trade sanctions, which are not limited to tech-goods sanction, to deal with tech power catching-up from a competitor.

Most trade sanctions are launched and led by a small number of powerful states through the UN, alliances, or the like, or without resorting to international organizations. Other states can decide whether to follow suit according to an *ex ante* estimation of potential direct and indirect consequences of this action. As previously discussed, states are supposed to have incentives to attenuate trade with their technological competitors; nevertheless, overtly taking restrictive measures for the purpose of maintaining technical advantages defies global liberal principles and therefore tends to create unwanted loss of reputation, especially when liberalism is prevailing as a norm. Likewise, this kind of action can easily incur disputes and retaliation and is hard to defend in international arbitration. Similarly, it is difficult to sell such policies to domestic would-injured groups. Tech competition appears not as urgent as a military threat, which can immediately provoke nationalist rallies; if domestic losers of tech-competition-driven mercantilist policies cannot be effectively diverted from self-interest, they may stick with fierce opposition. By contrast, through resorting to moral rhetoric or normative grounds, or getting closely entangled with national security, tech-related mercantilism can more easily be defended. For example, even if adversely impacted, firms are less likely to resist the implementation of a humanity-related sanction and risk losing reputational capitals. Accordingly, to evade reputational expenses and social resistance, states may find trade sanctions a more convenient way to secure tech advantages than regular trade policy. Thus, I put forth the following hypothesis.

Hypothesis 4.1. *All else being equal, as a technically weaker State A is catching up State B, State B is more likely to make trade sanctions against the former; as A keeps rising to lead ahead, State B becomes less likely to send trade sanctions against the former.*

IV.v. Between-State Tech Gaps and Withdrawal from Free Trade Agreements

Preferential trade agreements are bilateral or multilateral institutions that aim to remove tariff or non-tariff barriers to and reduce transaction costs of cross-border exchange. PTAs are part of trade liberalization and can embody different levels of economic integration, such as free trade areas, customs unions, common markets, and economic unions.[47] PTAs have significantly proliferated in the past twenty years and taken over the major role that the WTO formerly played in governing cross-border trade (Baccini 2019); they make detailed and context-specific mandates relative to the WTO's general norms (Horn et al. 2010; Dür et al. 2014). Though there have been many studies investigating determinants of the emergence of PTAs (Magee 2003; Egger and Larch 2008; Baldwin and Jaimovich 2012; Orefice and Rocha 2014), research on states' withdrawal from PTAs is scant yet.

[47] Free trade areas (FTAs) involve the substantial reduction or elimination of trade barriers on many (if not all) products; customs unions (CU) entail the elimination of trade barriers within the arrangement and the establishment of a common external tariff on the products of third parties; common markets are customs unions in which members also implement similar product regulations and permit the free flow of factors of production between members; economic unions are common markets in which members also use a common currency.

Consistent with their original purposes, PTAs' positive effects on trade flows have been well evidenced by abundant empirical inquiries (e.g., Baier and Bergstrand 2007; Medvedev 2010; Foster et al. 2011); among others, deep agreements are found to have a strong positive impact on trade (Roy 2010; Baier et al. 2014; Dür et al. 2014). Baier et al (2014) also find that free trade agreements can increase either intensive or extensive margin of trade. Baccini and Urpelainen's (2014) investigations suggest that developing states tend to sign PTAs with powerful states to usher in an extensive liberalization reform, which may further reinforce their involvement in global value chains.

PTAs boost FDI flows and stocks as well (e.g., Yeyati et al. 2003; MacDermott 2007; Büthe and Milner 2008; Medvedev 2012). Trade agreements may reduce horizontal FDI, which refers to establishing similar production facilities in multiple countries to minimize transportation, duties, or other costs along with trade. PTAs reduce the cost of cross-border trade by easing or removing barriers; the attractiveness of substitutive FDI therefore declines. Nevertheless, PTAs can stimulate vertical FDI in the sense that they provide an environment in which each participant specializes in indigenous production that intensively uses location-specific endowments rather than pursues an entirety of supply chains; therefore, investment tends to flow offshore to earn high returns from participation in operation of complementary production. Büthe and Milner (2014) point out several mechanisms through which PTAs guarantee a safe environment for FDI. Broadly speaking, PTAs enhance host states' commitments to liberal institutions and help ensure a free market, which can reduce unpredictability around investment. Some PTAs have specific investment clauses, aiming to alleviate investors' concerns about political risks like expropriation, contract, repatriation, and policy risk.[48] Besides, PTAs normally provide dispute-settlement provisions, which may entrust the adjudication of disputes to a third, disinterested party which is willing and able to afford monitoring costs, to enhance the agreement's enforceability. These institutional arrangements elevate the credibility of signatories' commitments, reduce transaction costs, and thereby encourage FDI.

As formerly discussed, cross-border trade and investment serve as key channels through which technology diffuses transnationally, and opening of domestic market supplying critical intermediates to a technically competing state are suspected of financially or/and materially supporting the latter's tech procurement and R&D. Therefore, considering the positive effects of PTAs on bilateral trade and FDI flows, the more advanced side of bilateral trade is assumed to consider withdrawal from existing PTAs with the less advanced but increasingly technically competitive partner. By getting rid of constraints posed by PTAs, states retake autonomy to implement mercantilist policy. Therefore, I propose the following hypothesis.

Hypothesis 4.2. *All else being equal, as State A is technically catching up to State B, State B is more likely to withdraw from an existing trade treaty with the former; if A leads ahead, B becomes less likely to withdraw a trade treaty with the former.*

[48] Contract risk refers to that host states may unilaterally modify, interpret, and carry out investment contracts in ways that investors do not expect (Kesternich and Schnitzer 2010). This can happen because contracts are probably not precise or complete, or the host state lacks effective political institutions. Repatriation risk occurs when there exist impediments like exchange controls and excessive bureaucracy to transfer of profits out of host states (Kesternich and Schnitzer 2010). Policy risk is part of the problem of the *obsolescing bargain*—host governments exploit MNCs through new policies like forced technology transfer, imposing additional duties, or elevating regulations for either economic or political purposes, which are more likely to occur if the MNEs have more fixed assets in the host state (Büthe and Milner 2014).

It is noteworthy that there exist caveats for using state withdrawal from PTAs as a proxy of trade conflict. First, some PTAs are not bilateral, and when a state withdraws from a multilateral agreement, it may be ambiguous which member it is targeting. Second, withdrawing from an international trade agreement usually has complicated backgrounds and derives from reasons with a wide range. Sometimes, a state chooses to opt out of a PTA because it thinks of the treaty as not pro-trade enough and expects or even has begun to formulate a better one. Third, there must be a life cycle of each PTA given that any agreements become out-of-date someday. That being said, these concerns might be lessened to some extent in this research for the following reasons. This research attempts to explore general rules that dictate state policy on PTAs, and thus it treats issue-specific conditions and other factors at different levels as stochastic matters. Besides, it focuses on initiation of withdrawal rather than termination of a PTA; even though states may aim to develop a better treaty by dissolving the current one, the initiator of the renegotiation process is always the one who has discontent with the *status quo*, and thus, this behavior still suggests conflict to some extent.

IV.vi. Interstate Tech Gaps and Disputes under the WTO Agreement

The WTO was founded in 1995, serving as the successor of the General Agreement on Tariffs and Trade (GATT), espousing a multilateral trade regime that promotes cross-border exchange. The WTO advanced the dispute settlement system of GATT by setting a permanent institution pursuant to the *Understanding on Rules and Procedures Governing the Settlement of Disputes*. The arbitration system consists of (*ad hoc*) panels, the Dispute Settlement Body (DSB) and the Appellate Body, which serve to determine and terminate “inconsistent” policies that infringe on the agreements. Member states can file complaints against another that has been witnessed violate agreed market access rights. The ruling issued by the dispute settlement system shall be implemented; otherwise, retaliatory actions will be authorized.

As its membership increases, the WTO's adjudication system has stretched its jurisdiction to cover most bilateral trade disputes. Some research has examined determinants of the onset of trade disputes under the WTO agreement. Trade interest, aid reliance, retaliatory capacity, or legal capacity influences the probability of a state filing disputes (Bown 2005). Besides, members' domestic politics may condition the initiation of WTO disputes. Democracies are found to be more likely to file disputes than nondemocracies (Reinhardt 2000). Rosendorff and Smith (2018) find that leadership changes in autocracies positively influence the onset of disputes.

There are two stages for the occurrence of disputes: First, there emerges a potential breach of commitment to the WTO agreement, and second, an injured state of this inconsistent measure decides to formally file a complaint over it. This study asserts that when a state is being technologically caught up to by another, it has incentives to take restrictive measures in trade with the chaser, an action quite likely to break the WTO agreement and hence trigger disputes. Namely, the shrinking of tech gaps between members of the WTO causes a breach of market access rights on the part of the one under the tech power competition pressure from its ascending follower; the former therefore tends to be the violator and respondent in a dispute filed by the latter. Accordingly, I develop the third hypothesis as follows.

Hypothesis 4.3. *All else being equal, if States A and B are members of the WTO, as the backward State A is technically catching up to State B, State B is more likely to initiate a dispute filed by State A; if A technically leads ahead, State B is less likely to be complained by State A under the WTO agreements.*

IV.vii. Empirical Analysis

The empirical investigations consist of a state-level large-*N* analysis and two case studies. The former is based on state-level time-series-cross-section (TSCS) data for all countries covering the period from 1980 through 2016. This analysis uses trade sanction, export sanction, import sanction, PTA withdrawal, and disputes under the WTO agreement as dependent variables. In addition to the key explanatory variables (three indicators of technological gaps), I include polity, alliance, interstate militarized conflict, and trade dependence as potential confounding factors to control for. Additionally, I scrutinize two trade conflict cases, Japan-South Korea trade conflict since 2019 and historical trade conflict against P.R.China, to explore more evidence.

IV.vii(i). Data

Dependent Variables

According to the hypotheses for empirical testing, three key dependent variables must be involved in analysis, which represent the likelihoods of a state's sending a trade sanction targeting a certain state, state quitting of a PTA with another state, and being a respondent in a dispute under the WTO agreement respectively. I devise the dependent variable, $\text{Trade\_sanction}_{ji,t}$, to designate whether there is at least one trade sanction imposed by state *j* against state *i* in year *t*. This is a dummy variable, which is assigned one if an effective sanction exists and zero otherwise. The data concerning trade sanctions come from the Global Sanctions Data Base (GSDB) (Felbermayr et al. 2020).[49] To assess respective, probably distinctive, effects of technological power gaps on export and import sanctions, two secondary dependent variables,

[49] The GSDB dataset covers a period from 1950 to 2016. Considering the availability of technological data, this research only analyzes the sanctions from 1980 through 2016.

$\text{Export\_sanction}_{ji,t}$ and $\text{Import\_sanction}_{ji,t}$ are constructed to denote whether there is at least one export or import sanction initiated by state *j* against state *i* in year *t* respectively.

The second key dependent variable, $\text{PTA\_withdrawal}_{ji,t}$, denotes that state *j* has the status of being quitting from a PTA with state *i*. It is binary as well. The PTA withdrawal event data come from the work of Dür et al. (2014). Here are the rules for the coding process: $\text{PTA\_withdrawal}_{ji,t}$ is assigned one if state *j* is in the gap between the year its withdrawal from a PTA with state *i* and the year in which it signs another PTA with state *i*; *otherwise*, it takes zero if there is a PTA between the two states in force, or state *i* has the status of withdrawal, given that state *i*'s unilateral withdrawal cannot reflect state *j*'s will to quit. The coding process is illustrated in Figure 4.4. As it shows, in each year between when state *j* chooses to withdraw from a trade treaty with state *i* and the year in which they sign a new one, state *j* is identified having the status of PTA withdrawal with state *i*, and $\text{PTA\_withdrawal}_{ji,t}$ takes one; during the periods covered by alive PTAs, the variable is zero. If there is a breakup of PTA is initiated by state *i unilaterally*, state *j* still has the status of PTA joining, and the variable is still zero.

The third dependent variable, $\text{Being\_complained}_{ji,t}$, is a count variable, which indicates the annual count of filed disputes under the WTO agreements in which state *j* is complained by state *i* for its potential inconsistent measures. In the analysis, only dyads in which both sides are member states of the WTO in a given year are examined, and the data of disputes come from the WTO. Particularly, the European Union (EU) members (in each year) are excluded as they were represented by the EU rather than have an independent status in a dispute once they became an EU member.

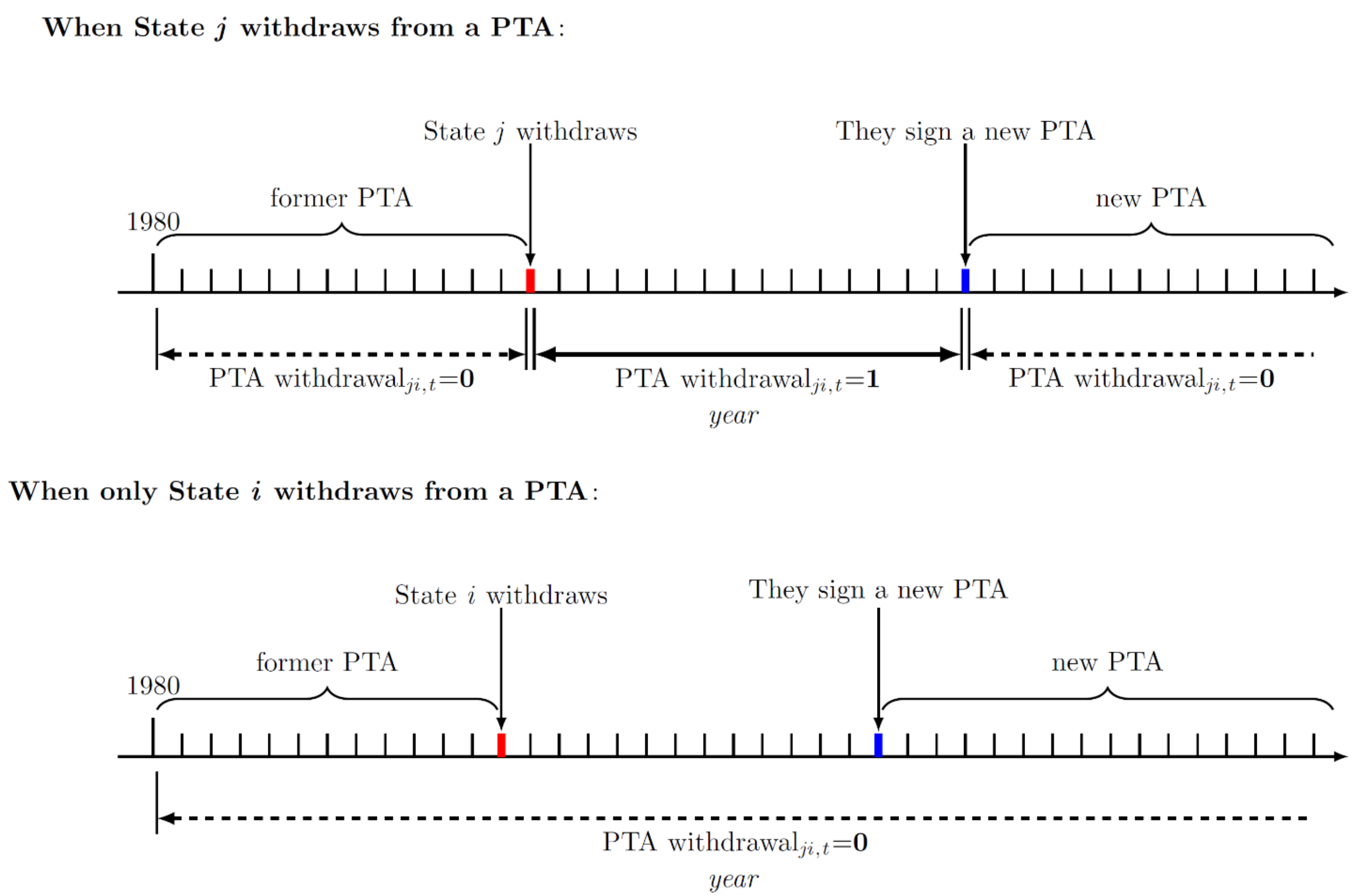

Figure 4.4. The Method for Identifying State *j*'s Withdrawal Status from PTAs with State *i*

Explanatory Variables

The explanatory variable shall denote state *i*'s technological gap with respect to state *j*, which is represented by $\text{Relative\_tech}_{ij,t}^{(1)}$, $\text{Relative\_tech}_{ij,t}^{(2)}$, and $\text{Relative\_tech}_{ij,t}^{(3)}$. The algorithms for computing them are as follows.

$$\text{Relative\_tech}_{ij,t}^{(1)} = \ln\left(\frac{patent\_appls_{i,t}}{patent\_appls_{j,t}}\right)$$

$$\text{Relative\_tech}_{ij,t}^{(2)} = \ln\left(\frac{IP\_receive_{i,t}}{IP\_receive_{j,t}}\right)$$

$$\text{Relative\_tech}_{ij,t}^{(3)} = \ln\left(\frac{hitech\_export_{i,t}}{hitech\_export_{j,t}}\right)$$

In the formulas, *i* and *j* designate states *i* and *j* respectively, and *ij* stands for state *i*'s relative technological capacity with respect to state *j*. Considering the great skewness of the data, I use the difference of their natural logarithms.

Control Variables

Trade dependence can result in technological power shift, which has been investigated in-depth in the preceding chapter. Meanwhile, if a state's economy is dependent on trade with a certain partner, it is less likely to initiate a trade conflict with the latter. The variable, $\text{Trade\_dep}_{ji,t}$, is controlled for in the analysis, which equals to $\left(import_{ji,t} + export_{ji,t}\right)/GDP_{j,t}$. In the regression of the WTO disputes, considering that the likelihood of disputes is highly correlated with two states' trade volumes (trade interest), and their import quantities can represent their respective retaliatory capacities, which also influence the onset of disputes (Bown 2005), I use export volumes instead of trade dependence as control variables. Considering its skewed distribution, its logarithmic version is used.

Allied states are less likely to get into economic conflict than unallied pairs, since mostly military and economic issues are linked in cementing alliances (e.g., Axelrod and Keohane 1985; Koremenos et al. 2001). Powerful states are more likely to assist their allies with techniques for economic or military purposes, which may impact their technological convergence. Therefore, alliances are considered as a confounder to control for in the analysis. The control variable, $\text{Alliance}_{ij,t}$, is binary, and it takes one if states *i* and *j* are formally allied and zero otherwise. The data are drawn from the COW Project's Formal Alliances (v4.1) dataset. Two states amid militarized conflict tend to oppose bilateral tech cooperation, and economic sanctions are more likely to be sent against one another. Therefore, I adopt the militarized interstate dispute (MID) data from the COW Project (Maoz et al. 2019) and include the dummy variable, $MID_{ij,t}$, into models to control for, which has the value of one if there is ongoing MID between the two states and zero otherwise.

According to the democratic peace theory, democracies are less likely to get into militarized conflict with one another than other types of dyads, given that they have constrained governments and externalize domestic liberal rules, which promote information transparency and peaceful resolution to conflict (e.g., Maoz and Russett 1993; Rosato 2003). Likewise, it is expected that democratic dyads are less likely to have trade conflict and more likely to cooperate in multiple realms that are associated with innovation or knowledge transfer than other types of dyads. Besides, there exist domestic losers and winners of technology who have incentives to orient the decision-making process regarding tech policy to their benefit, and political structures therefore may impact R&D spending and distribution (e.g., Drezner 2001). To control for institutions' potential confounding effects, a dummy variable, $\text{Demo dyad}_{ji,t}$, is involved. This variable is assigned one if states *i* and *j* are democratic, and zero otherwise. The Polity2 codes of the Polity V project (Marshall et al. 2019) are used to identify democracies. Specifically, if a state has a Polity2 Score greater than 5, it is designated as a democracy and nondemocracy otherwise.

The Instrument Variable

There exists a potential simultaneity issue in the relationship between between-state tech gaps and their trade conflict, given that trade policies may influence state tech growth. I have two strategies to deal with the issue. First, all explanatory and control variables are with a one-year lag in models to prove the existence of a time interval between their presence and the dependent variable's performance. Second, I use between-state gaps in annual quantity of R&D as an instrument variable for their relative tech capacity and conduct a two-stage regression to control for the potential effect of cross-border exchange on tech capacity relativeness. This is because domestic R&D may indirectly impact bilateral trade relationship by influencing tech growth, but it has no direct association with trade friction, given that only R&D's outputs rather than R&D itself are associated with state tech power. Besides, though trade conflict may impact domestic R&D, the possible resulting R&D change of a trade conflict can happen only in the wake of the trade conflict rather than prior to it. The variable, $\text{Relative\_RD}_{ij,t}$, is equal to $\ln\left(\text{R\&D}_{i,t}\right)-\ln\left(\text{R\&D}_{j,t}\right)$, and the state R&D data come from the World Bank. See Table 4.1 for the information on the data.

Table 4.1. The Summary Statistics of the Sample

Variable	Label	Period	*N*	Mean	Sd.	Min.	Max.
$\text{Relative\_tech}^{(1)}_{ij,t}$	$\ln(patent\_appls_{j,t}) - \ln(patent\_appls_{i,t})$ [a]	1980-2018	298,108	0	3.91	-14.14	14.14
$\text{Relative\_tech}^{(2)}_{ij,t}$	$\ln(IP\_receive_{j,t}) - \ln(IP\_receive_{i,t})$ [a]	1980-2018	222,006	0	5.35	-21.23	21.23
$\text{Relative\_tech}^{(3)}_{ij,t}$	$\ln(hitech\_export_{j,t}) - \ln(hitech\_export_{i,t})$ [a]	2007-2018	184,214	0	5.83	-24.9	24.9
$\text{Trade sanction}_{ji,t}$	A binary variable that takes one if there is a trade sanction imposed by state *j* against state *i* in year *t*, and zero otherwise. [b]	1980-2016	1,828,008	.016	.128	0	1
$\text{Export sanction}_{ji,t}$	A binary variable that takes one if there is an export sanction imposed by state *j* against state *i* in year *t*, and zero otherwise. [b]	1980-2016	1,734,264	.015	.124	0	1
$\text{Import sanction}_{ji,t}$	A binary variable that takes one if there is an import sanction imposed by state *j* against state *i* in year *t*, and zero otherwise. [b]	1980-2016	1,734,264	.01	.102	0	1
$\text{PTA withdrawal}_{ji,t}$	A binary variable that takes one if state *j* has the status of withdrawal from a former PTA with state *i* in year *t*, and zero if there is an effective PTA with state *i* or if state *i* has the status of withdrawal from a former PTA with state *j*. Data source: Dür et al. (2014).	1980-2018	293,876	.011	.107	0	1
$\text{Being\_complained}_{ji,t}$	Annual count of cases filed by state *i* against state *j* in the WTO in year *t*. It only applies to dyads in which both sides are the WTO members. Source: the WTO.	1995-2018	1,117,440	.0002	.016	0	1
$\text{Demo dyad}_{ji,t}$	A binary variable that takes one if both states *i* and *j* are democracies, and zero otherwise. Source: Polity V. [c]	1980-2016	1,760,364	.526	.499	0	1
$\text{Trade\_dep}_{ji,t}$	$(import_{ji,t} + export_{ji,t})/GDP_{j,t}$; GDP in billions of current USD. [d]	1980-2014	754,902	.004	.027	0	3.8
$\text{Export}_{ji,t}$	Export from state *j* to state *i* in billions of current USD.[d]	1980-2014	880,587	.282	3.56	0	472.5
$\text{MID}_{ij,t}$	Source: the COW Project; Maoz et al. (2019).	1980-2014	1,640,520	.002	.045	0	1
$\text{Alliance}_{ij,t}$	Source: the COW Project, Formal Alliances (v4.1); Singer et al. (1966)	1980-2012	1,546,776	.047	.212	0	1
$\text{Relative\_RD}_{ij,t}$	$\ln(\text{R\&D}_{i,t}) - \ln(\text{R\&D}_{j,t})$ [a]; R&D in millions of current USD.	1980-2018	321,089	1.48	3.12	-10.11	13.6

Note: a. Data source: the World Bank.

b. Data source: Global Sanctions Data Base (GSDB) (Felbermayr et al. 2020)

c. If a state has a Polity2 Score greater than 5, it is deemed as democratic, and authoritarian otherwise.

d. Trade source: the COW Project, Trade (v4.0); Barbieri et al. (2009). GDP source: the World Bank.

IV.vii(ii). Models

Logistic and Poisson regressions as well as maximum likelihood estimations are utilized to examine the relationship between interstate relative tech power and trade conflict. Linear models are set up to regress trade sanctions, PTA withdrawal, and being complained in the WTO respectively on the three proxies of dyadic tech power gaps. Particularly, squared terms of state relative technical levels are involved for assessing whether the association of interest is quadratic.

It is noteworthy that the analysis does not employ hazards models since explanatory and control variables are time-variant; nor are time durations' effects considered for the following reasons. First, emergence of a trade sanction is not supposed to be associated with duration of "no sanction", and nor does a WTO dispute relate to the period of "no dispute". Second, as for PTA withdrawal, considering that the dataset only covers thirty-nine years, many observations are censored; therefore, if discrete hazard methods, duration splines, or duration dummies that measure PTA duration are employed, the sample size will decline dramatically. Besides, sanctions are normally continuous, and similarly, state *j*'s withdrawal from PTAs is a status that can last for years; that is, they are not isolated, sporadic occurrences, and controlling for time dependences is therefore not suitable for them.

The logistic model for trade sanction is expressed as follows. Export and import sanctions are assessed using the similar models.

$$\Pr\left(\text{Trade\_sanction}_{ji,t} = 1 \mid e^{\mathbf{x}_{ji,t}\boldsymbol{\beta}^T}\right) = \frac{e^{\mathbf{x}_{ji,t}\boldsymbol{\beta}^T}}{1+e^{\mathbf{x}_{ji,t}\boldsymbol{\beta}^T}}$$

$$\begin{aligned}\mathbf{x}_{ji,t}\boldsymbol{\beta}^T &= \beta_0^T + \beta_1^T \cdot \text{Trade\_sanction}_{ji,t-1} + \beta_2^T \cdot \text{Relative\_tech}_{ij,t-1}^{(\mathbf{1,2,3})} + \beta_3^T \cdot \left(\text{Relative\_tech}_{ij,t-1}^{(\mathbf{1,2,3})}\right)^2 \\ &+ \beta_4^T \cdot \text{Democratic\_dyad}_{ji,t} + \beta_5^T \cdot \log\left(\text{Trade\_depdence}_{ji,t-1}\right) + \beta_6^T \cdot \text{MID}_{ij,t-1} + \beta_7^T \cdot \text{Alliance}_{ij,t-1}\end{aligned}$$

The model specification for regressions of state *j*'s withdrawal from a PTA with state *i* on their relative tech position is identical to the one for regressing trade sanction.

$$\Pr\left(\text{PTA\_withdrawal}_{ji,t}=1\,|\,e^{\mathbf{x}_{ji,t}\boldsymbol{\beta}^W}\right)=\frac{e^{\mathbf{x}_{ji,t}\boldsymbol{\beta}^W}}{1+e^{\mathbf{x}_{ji,t}\boldsymbol{\beta}^W}}$$

$$\begin{aligned}\mathbf{x}_{ji,t}\boldsymbol{\beta}^W &= \beta_0^W+\beta_1^W\cdot\text{PTA\_withdrawal}_{ji,t-1}+\beta_2^W\cdot\text{Relative\_tech}_{ij,t-1}^{(\mathbf{1,2,3})}+\beta_3^W\cdot\left(\text{Relative\_tech}_{ij,t-1}^{(\mathbf{1,2,3})}\right)^2\\ &+\beta_4^W\cdot\text{Democratic\_dyad}_{ji,t}+\beta_5^W\cdot\log\left(\text{Trade\_dependence}_{ji,t-1}\right)+\beta_6^W\cdot\text{MID}_{ij,t-1}+\beta_7^W\cdot\text{Alliance}_{ij,t-1}\end{aligned}$$

Apart from the above models, the Poisson model for regressions of state *j* being the respondent of a case filed by state *i* on their relative tech gap removes the lagged dependent variable from the specification and invloves bilateral trade volumes in each direction instead of state *j*'s trade dependence as control variables. In addtion, Probit regression models are employed in the two-stage regressions.

$$\Pr\left(\text{Being\_complained}_{ji,t}\,|\,e^{\mathbf{x}_{ji,t}\boldsymbol{\beta}^R}\right)=\frac{e^{-e^{\mathbf{x}_{ji,t}\boldsymbol{\beta}^R}}e^{\left(\mathbf{x}_{ji,t}\boldsymbol{\beta}^R\right)\cdot\text{Being\_complained}_{ji,t}}}{\text{Being\_complained}_{ji,t}!}$$

$$\begin{aligned}\mathbf{x}_{ji,t}\boldsymbol{\beta}^R &= \beta_0^R+\beta_1^R\cdot\text{Relative\_tech}_{ij,t-1}^{(\mathbf{1,2,3})}+\beta_2^W\cdot\left(\text{Relative\_tech}_{ij,t-1}^{(\mathbf{1,2,3})}\right)^2+\beta_3^W\cdot\text{Democratic\_dyad}_{ji,t}\\ &+\beta_4^W\cdot\log\left(\text{Export}_{ij,t-1}\right)+\beta_5^W\cdot\log\left(\text{Export}_{ji,t-1}\right)+\beta_6^W\cdot\text{MID}_{ij,t-1}+\beta_7^W\cdot\text{Alliance}_{ij,t-1}\end{aligned}$$

In these models, state *j*'s (state *i*'s) interactions with the states other than state *i* (state *j*), deviations coming from states *j* and *i*'s unilateral factors, and the part of outcomes that can be explained by other bilateral factors, are supposed to lead to stochastic error terms.

The presence of a directed edge that represents a trade conflict may be influenced by the structure formed by other edges, which may confound the estimation of the effect of state tech gaps on trade relations. States may have propensity to use trade conflict as foreign policy (*sociality*); some are major targets of trade sanctions (*popularity*); besides, states may tend to impose trade punishment to each other (*reciprocity*), even though they do not overtly acknowledge their trade policies as retaliation. I use TERGM *via* bootstrap maximum pseudolikelihood estimation to conduct a robustness analysis, aiming to strengthen the validity of the estimated association between between-state tech gaps and initiation of trade conflict through controlling for potential structural factors.

IV.vii(iii). Regression Results

Hypothesis 4.1 obtains for two measures of relative tech capacity. The coefficients of the linear and quadratic terms of relative technological capacity are negative and statistically significant at least at the 99% confidence level in all the models that regress trade sanctions on relative tech capacity calculated based on annual IP receipts and volumes of high-tech export, though the explanatory variables' statistics for relative tech capacity in terms of annul patent files are not satisfactory (see Table 4.2). This indicates a quadratic curve with a downward concave for the probability of a trade sanction with respect to relative technological capacity. Predicted probabilities of trade sanctions based on Models 4.1(5) and 4.1(8) are presented in Figure 4.5. Pikes emerge at negative values (approximately -5) of $\text{Relative\_tech}_{ij,t}^{(2)}$ and $\text{Relative\_tech}_{ij,t}^{(3)}$, which suggest that if state *i*'s technological power gets closer to, though still lagging behind, state *j*'s, the latter becomes more likely to impose trade sanctions against the former. After crossing a threshold of tech gap, if state *i* continues to approach or even outnumbers state *j*'s technical strength, the latter becomes less likely to levy trade sanctions against state *i*. The findings based on $\text{Relative\_tech}_{ij,t}^{(2)}$ and $\text{Relative\_tech}_{ij,t}^{(3)}$ are consistent with theoretical expectations.

Table 4.2. Regressions of Trade Sanctions on Relative Technological Capacity

	4.1(1)	**4.1(2)**	**4.1(3)**	**4.1(4)**	**4.1(5)**	**4.1(6)**	**4.1(7)**	**4.1(8)**	**4.1(9)**
	Trade sanction $_{ji,t}$								
	$\text{Relative\_tech}^{(1)}_{ji}$			$\text{Relative\_tech}^{(2)}_{ji}$			$\text{Relative\_tech}^{(3)}_{ji}$		
$\text{Relative\_tech}_{ij,t-1}$	**0.0355*****	**0.0612*****	**0.0544*****	**-0.0518*****	**-0.105*****	**-0.0996*****	**-0.0238***	**-0.232*****	**-0.315*****
	(5.41)	(6.70)	(5.58)	(-5.00)	(-7.86)	(-6.69)	(-1.72)	(-7.62)	(-5.95)
$\text{Relative\_tech}^2_{ij,t-1}$	**0.00299****	**0.00105**	**0.00152**	**-0.0122*****	**-0.0135*****	**-0.0128*****	**-0.0168*****	**-0.0303*****	**-0.0340*****
	(2.47)	(0.67)	(0.88)	(-8.78)	(-8.04)	(-6.93)	(-8.14)	(-6.47)	(-4.84)
Trade sanction $_{ji,t-1}$	7.732***	7.867***	7.911***	8.263***	7.730***	7.992***	10.14***	12.26***	13.43***
	(153.04)	(115.78)	(108.37)	(101.60)	(80.93)	(70.17)	(60.18)	(23.53)	(15.96)
Democdyad $_{ji,t-1}$		-1.459***	-1.601***		-1.589***	-1.995***		-1.160***	-4.003***
		(-21.98)	(-22.63)		(-16.69)	(-17.57)		(-7.14)	(-8.52)
$\log\left(\text{Trade\_dep}_{ji,t-1}\right)$		0.000294	-0.0161		-0.0120	-0.0520***		0.273***	0.147***
		(0.02)	(-1.21)		(-0.76)	(-2.95)		(8.27)	(3.56)
$\text{MID}_{ij,t-1}$		1.043***	0.482		2.209***	1.275**		1.875***	-1.817
		(3.37)	(1.48)		(5.72)	(2.18)		(4.27)	(-0.70)
$\text{Alliance}_{ij,t-1}$			-0.0911			-0.0652			0.867***
			(-0.63)			(-0.25)			(2.59)
Constant	-5.799***	-5.392***	-5.527***	-6.244***	-5.267***	-5.688***	-6.328***	-3.155***	-3.868***
	(-141.93)	(-46.88)	(-44.18)	(-98.14)	(-33.70)	(-31.31)	(-73.14)	(-12.61)	(-10.76)
	Logit	Logit	Logit	Logit	Logit	Logit	Logit	Logit	Logit
Data range	1980-2016	1980-2014	1980-2012	1980-2016	1980-2014	1980-2012	2007-2016	2007-2014	2007-2012
χ^2	50235.7	34864.8	32069.5	23321.6	15029.4	13642.9	16566.5	8744.5	4950.7
N	259,902	191,987	173,661	184,696	129,059	111,639	128,780	75,211	48,253

Note: 1. *t* statistics in parentheses * $p < .1$, ** $p < .05$, *** $p < .0$

2. The results still hold in random-effect models (see Appendix V.A). Fixed-effect models are not assessed given that within-state cross-year variations are insignificant, and too many observations are omitted if state means are fixed.

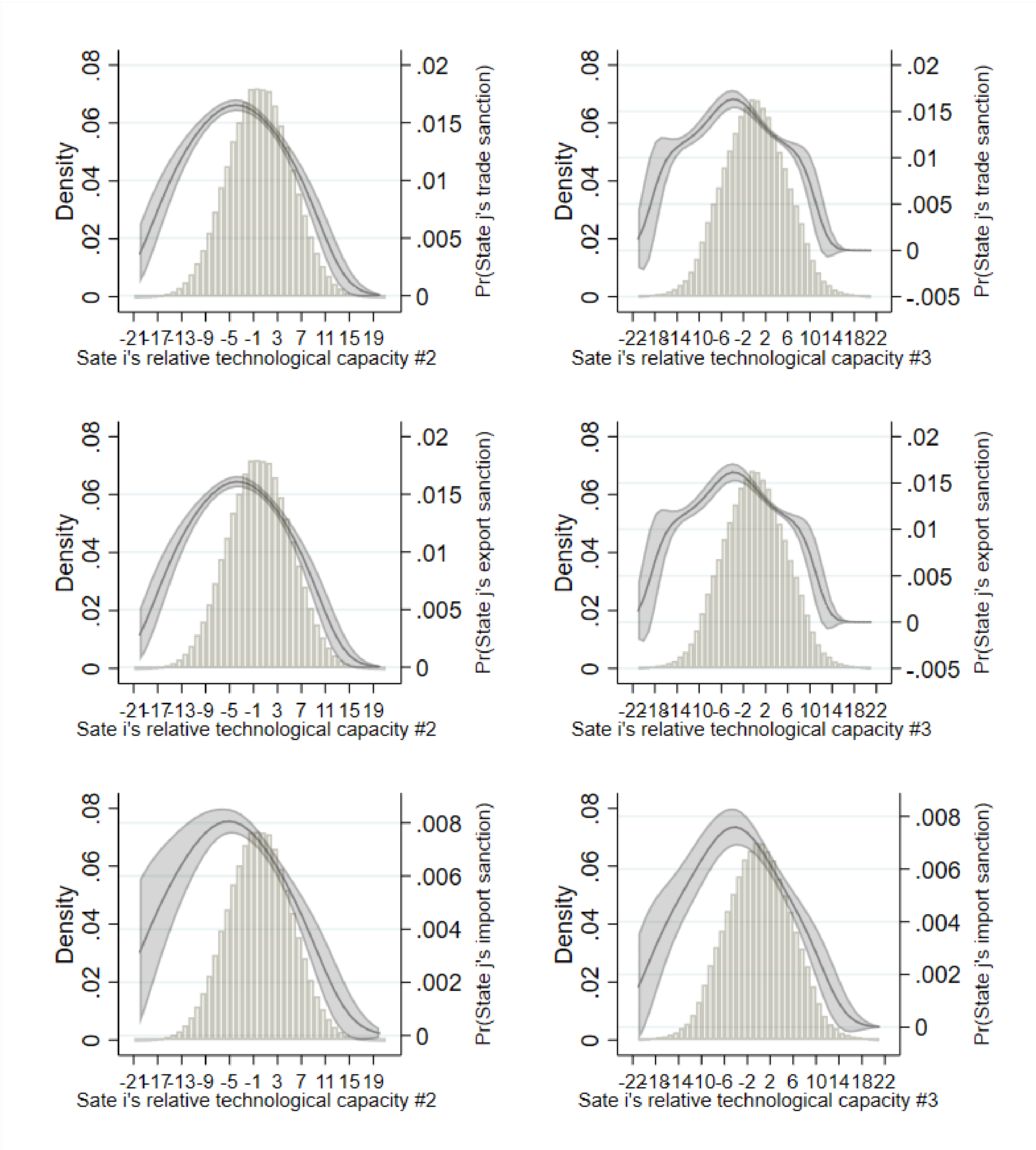

Figure 4.5. The Predicted Probability of Trade, Export, and Import Sanctions

***Note*:** 1. The graphs are based on Models 4.1(5), 4.1(8), 4.B(5), 4.B(8), 4.D(5), and 4.D(8).
2. 95% confidence intervals of predictions are demonstrated in the graphs.
3. All the control variables have their mean values in the prediction.

It is noteworthy that the minimum predicted probability of trade sanctions for $\text{Relative\_tech}_{ij,t}^{(2)}$ is about 0.5% when state *i*'s relative technical capacity is fairly low; and the highest predicted probability is 1.7%; the lowest predicted probability of trade sanctions for $\text{Relative\_tech}_{ij,t}^{(3)}$ is about 0.2% when the state *i*'s technical capacity is far lower than state *j*, and the highest predicted probability is 1.6% (see Figure 4.5). The regression results for export and import sanctions are similar to what is found in regression of trade sanctions. Table 4.3 displays the statistics of regressing export and import sanctions on relative tech capacity. They show that the hypothesis holds in both, suggesting that states tend to use either export or import sanctions to deter tech power challengers. Particularly, the empirical findings show that relative tech capacity's effects on export sanctions appear greater and more significant than on import sanctions. Specifically, the maximum probability of export sanction caused by a narrow tech gap is above 1.6%, whereas the greatest likelihood of import sanction is merely about 0.8% (see Figure 4.5). Besides, most estimated coefficients of $\text{Relative\_tech}_{ij,t}^{(2)}$ and $\text{Relative\_tech}_{ij,t}^{(3)}$ for export sanctions are statistically significant at the 95% confidence level, whereas their coefficients for import sanctions are not persistently significant, especially for $\text{Relative\_tech}_{ij,t}^{(3)}$. This implies that states are more likely to slap export sanctions in face of technological catching-up or competition, which makes sense since embargoes of tech-related products or critical inputs for competitive R&D or tech-related products that a competitor is engaging in or manufacturing are supposed to be more efficient than import controls to retard the target state's technological progress.

Table 4.3. Regressions of Export and Import Sanctions on Relative Technological Capacity

	Export sanction $_{ji,t}$				Import sanction $_{ji,t}$			
	Coef.	Std. Err.	*P*-value	*N*	Coef.	Std. Err.	*P*-value	*N*
IV:								
$Tech\_gap^{(1)}_{ji,t}$								
No controls	.039	.006	<.001	259,902	.072	.009	<.001	259,902
Quadratic term	.003	.001	.01	259,902	.0004	.001	.768	259,902
Without alliance	.065	.009	<.001	191,987	.112	.012	<.001	191,987
Quadratic term	.001	.001	.451	191,987	-.00004	.002	.983	191,987
All controls	.058	.009	<.001	173,661	.104	.013	<.001	173,661
Quadratic term	.001	.001	.322	173,661	.001	.002	.511	173,661
$Tech\_gap^{(2)}_{ji,t}$								
No controls	-.049	.01	<.001	184,696	-.056	.012	<.001	184,696
Quadratic term	-.013	.001	<.001	184,696	-.006	.001	<.001	184,696
Without alliance	-.106	014	<.001	129,059	-.105	.015	<.001	129,059
Quadratic term	-.014	.001	<.001	129,059	-.01	.002	<.001	129,059
All controls	-.103	015	<.001	111,639	-.103	.018	<.001	111,639
Quadratic term	-.013	.001	<.001	111,639	-.007	.002	.004	111,639
$Tech\_gap^{(3)}_{ji,t}$								
No controls	-.021	.013	.122	128,780	-.012	.016	.432	128,780
Quadratic term	-.016	.002	<.001	128,780	-.013	.002	<.001	128,780
Without alliance	-.227	.03	<.001	75,211	-.127	.022	<.001	75,211
Quadratic term	-.03	.004	<.001	75,211	-.015	.003	<.001	75,211
All controls	-.308	.051	<.001	48,253	-.335	.078	<.001	47,960
Quadratic term	-.033	.006	<.001	48,253	-.027	.009	.002	47,960

Note: 1. See Appendices V.B and V.D for statistics of full specifications.

2. The results still hold in random-effect models (see Appendices V.C and V.E). Fixed-effect models are not assessed given that within-state cross-year variations are insignificant, and too many observations are omitted if state means are

The statistics of regressing state *j*'s withdrawal from a PTA with state *i* on state *i*'s relative tech capacities are presented in Table 4.4. As they reveal, coefficients of the linear and quadratic terms of relative technological capacity are negative and statistically significant at the 99% confidence level for $\text{Relative\_tech}_{ij,t}^{(1)}$ and $\text{Relative\_tech}_{ij,t}^{(2)}$, which confirm expectations, while the estimated coefficients of $\text{Relative\_tech}_{ij,t}^{(3)}$ are not significant. The negative squared terms of relative tech capacity indicate a quadratic curve with a downward concave for probability of state *j*'s PTA withdrawal with respect to state *i*'s relative tech capacity. Figure 4.6 displays predicted probabilities of state *j*'s PTA withdrawal. The predicted probability for $\text{Relative\_tech}_{ij,t}^{(1)}$ is about 0.5% when state *i* has the minimum relative technical capacity of the sample; and the highest predicted probability is 2.3%, which emerges at state *i*'s relative tech capacity slightly lower than zero; the lowest predicted probability of PTA for $\text{Relative\_tech}_{ij,t}^{(2)}$ is about 1.3% when the state *i*'s technical capacity is far lower than state *j*; the highest predicted probability are 1.8%, and the lowest occurs at state *i*'s maximum relative tech capacity, which is approximately 0.2%. Table 4.5 exhibits the results for the regression of the annul count of disputes initiated by state *i* against state *j* in the WTO agreement, and the outputs bear out Hypothesis 4.3. The coefficients of the linear and quadratic terms of relative technological capacity are negative across alternative models and mostly significant at least at the 95% confidence level for $\text{Relative\_tech}_{ij,t}^{(1)}$ and $\text{Relative\_tech}_{ij,t}^{(3)}$, supporting a quadratic relationship between the dispute count and state relative tech capacity. Figure 4.7 shows that predicted counts of disputes initiated by state *i* against state *j* increase as state *i*'s relative position rises until their gap is close to zero, and then, the likelihood of state *j* being a respondent in a dispute with state *i* falls as state *i*'s relative tech strength continually ascends.

Table 4.4. Regressions of PTA Withdrawal on Relative Technological Capacity

	4.2(1)	**4.2(2)**	**4.2(3)**	**4.2(4)**	**4.2(5)**	**4.2(6)**	**4.2(7)**	**4.2(8)**	**4.2(9)**
	PTA withdrawal $_{ji,t}$								
	$\text{Relative\_tech}_{ji}^{(1)}$			$\text{Relative\_tech}_{ji}^{(2)}$			$\text{Relative\_tech}_{ji}^{(3)}$		
$\text{Relative\_tech}_{ij,t-1}$	**-0.0780*****	**-0.0967*****	**-0.0942*****	**-0.0749*****	**-0.0561*****	**-0.0579*****	**0.0436**	**-0.0381**	**0.114**
	(-2.67)	(-2.82)	(-2.68)	(-4.25)	(-2.71)	(-2.67)	(1.03)	(-0.38)	(0.42)
$\text{Relative\_tech}_{ij,t-1}^{2}$	**-0.0333*****	**-0.0353*****	**-0.0347*****	**-0.00812*****	**-0.00861*****	**-0.00811*****	**0.00502**	**-0.0163**	**0.0120**
	(-4.20)	(-3.96)	(-3.80)	(-3.23)	(-3.02)	(-2.75)	(0.92)	(-1.02)	(0.25)
PTA withdrawal $_{ji,t-1}$	9.200***	8.769***	8.556***	8.956***	8.853***	8.621***	12.87***	12.69***	0
	(63.13)	(57.40)	(54.62)	(59.17)	(49.71)	(45.65)	(19.35)	(17.84)	(.)
Democ dyad $_{ji,t-1}$		0.333*	0.374**		-0.248	-0.159		-1.205*	0
		(1.92)	(2.13)		(-1.22)	(-0.76)		(-1.65)	(.)
$\log\left(\text{Trade\_dep}_{ji,t-1}\right)$		0.00106	0.00283		-0.0138	-0.0235		0.0962	0.121
		(0.03)	(0.07)		(-0.44)	(-0.70)		(0.89)	(0.79)
$\text{MID}_{ij,t-1}$		0.481	0.493		1.433	1.261		1.394	0
		(0.68)	(0.66)		(1.60)	(1.34)		(0.47)	(.)
$\text{Alliance}_{ij,t-1}$			-0.221			0.326			0
			(-1.06)			(1.26)			(.)
Constant	-6.247***	-6.190***	-6.048***	-6.545***	-6.108***	-6.192***	-10.13***	-7.340***	4.038***
	(-58.04)	(-20.28)	(-17.75)	(-53.71)	(-19.15)	(-17.81)	(-15.44)	(-6.91)	(3.52)
	Logit	Logit	Logit	Logit	Logit	Logit	Logit	Logit	Logit
Data range	1980-2018	1980-2014	1980-2012	1980-2018	1980-2014	1980-2012	2007-2018	2007-2014	2007-2012
χ^2	12889.7	9983.9	8764.5	9726.9	7050.2	5759.8	7513.0	4505.2	1.406
N	78,596	56,183	48,738	73,088	47,896	40,032	60,216	28,832	217

Note: 1. *t* statistics in parentheses * $p < .1$, ** $p < .05$, *** $p < .0$

2. The results still hold in random-effect models (see Appendix V.F). Fixed-effect models are not assessed given that within-state cross-year variations are insignificant, and too many observations are omitted if state means are fixed.

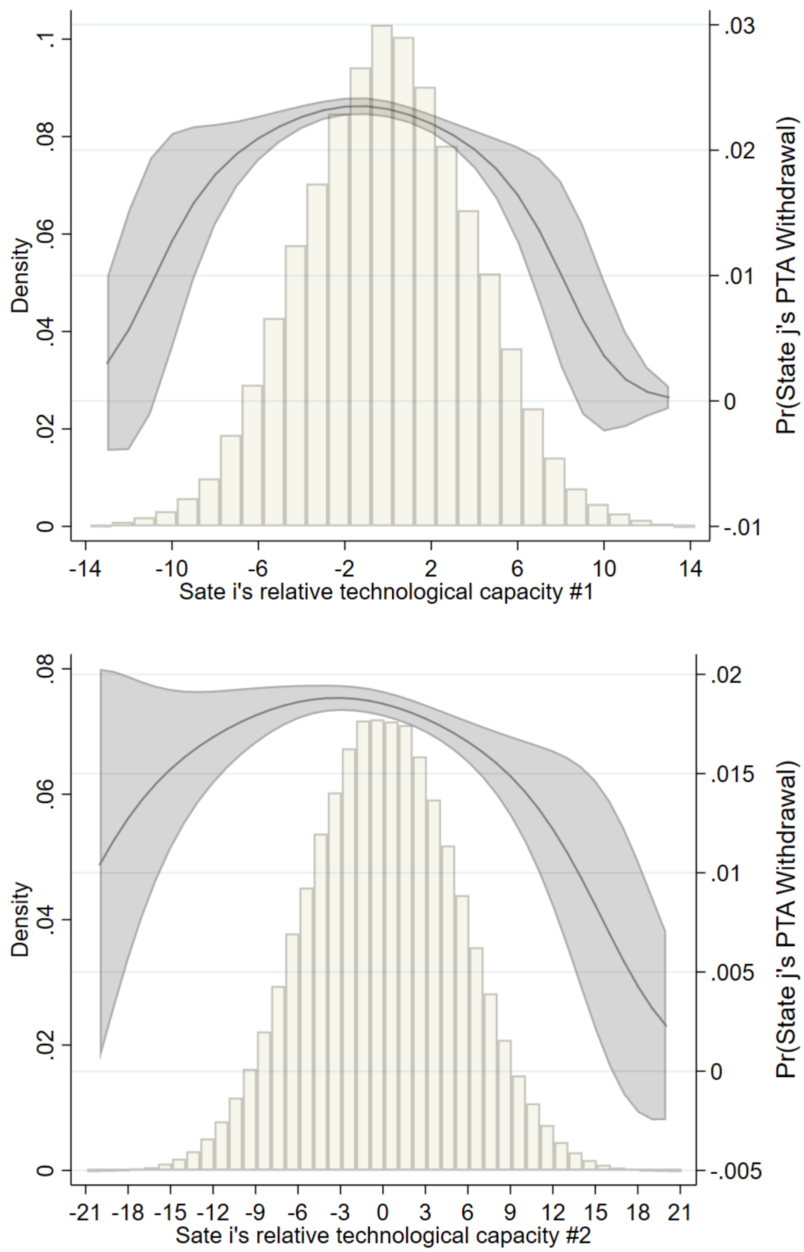

Figure 4.6. The Predicted Probability of PTA Withdrawal

***Note*:** 1. The graphs are based on Models 4.2(2) and 4.2(5).
2. 95% confidence intervals of predictions are demonstrated in the graphs.
3. All the control variables have their mean values in the prediction.

Table 4.5. Regressions of WTO Disputes on Relative Technological Capacity

	4.3(1)	4.3(2)	4.3(3)	4.3(4)	4.3(5)	4.3(6)	4.3(7)	4.3(8)	4.3(9)
	Being complained $_{ji,t}$								
	$\text{Relative\_tech}_{ji}^{(1)}$			$\text{Relative\_tech}_{ji}^{(2)}$			$\text{Relative\_tech}_{ji}^{(3)}$		
$\text{Relative\_tech}_{ij,t-1}$	**-0.0412***	**-0.0337**	**-0.0373**	**-0.0148**	**-0.0111**	**-0.0189**	**-0.0916**	**-0.0677**	**-0.170**
	(-2.64)	(-2.00)	(-2.17)	(-1.25)	(-0.84)	(-1.38)	(-2.49)	(-1.28)	(-2.33)
$\text{Relative\_tech}_{ij,t-1}^2$	**-0.00875***	**-0.0137***	**-0.0134***	**-0.00117**	**-0.0000853**	**-0.000490**	**-0.0649***	**-0.0480***	**-0.0546***
	(-3.02)	(-3.83)	(-3.74)	(-0.72)	(-0.05)	(-0.27)	(-6.65)	(-3.46)	(-3.15)
$\text{Democ dyad}_{ji,t-1}$		0.779***	0.215		0.755***	0.0571		-0.218	-0.717*
		(4.69)	(1.11)		(4.13)	(0.26)		(-0.78)	(-1.91)
$\log(\text{Export}_{ij,t-1})$		0.426***	0.409***		0.410***	0.380***		0.240**	0.259*
		(6.39)	(5.93)		(5.07)	(4.50)		(1.98)	(1.87)
$\log(\text{Export}_{ji,t-1})$		0.243***	0.196***		0.314***	0.269***		0.331***	0.304**
		(3.71)	(2.90)		(3.93)	(3.22)		(2.65)	(2.09)
$\text{MID}_{ij,t-1}$		0.411	0.589*		0.462	0.672**		1.151***	1.367***
		(1.37)	(1.92)		(1.48)	(2.06)		(2.88)	(3.08)
$\text{Alliance}_{ij,t-1}$			1.106***			1.131***			0.393
			(7.03)			(6.08)			(0.97)
Constant	-5.480***	-5.138***	-4.963***	-5.761***	-5.461***	-5.173***	-5.659***	-4.837***	-4.506***
	(-82.96)	(-30.40)	(-29.26)	(-80.69)	(-29.75)	(-28.47)	(-53.71)	(-16.67)	(-14.20)
	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson
Data range	1995-2018	1995-2014	1995-2012	1995-2018	1995-2014	1995-2012	2007-2018	2007-2014	2007-2012
χ^2	16.40	871.2	922.2	2.008	901.1	913.9	120.0	275.2	232.2
N	90,678	53,356	45,912	94,672	48,198	41,528	86,506	29,508	18,280

Note: 1. *t* statistics in parentheses * $p < .1$, ** $p < .05$, *** $p < .0$

2. The results still hold in random-effect models (see Appendix V.G). Fixed-effect models are not assessed given that within-state cross-year variations are insignificant, and too many observations are omitted if state means are fixed.

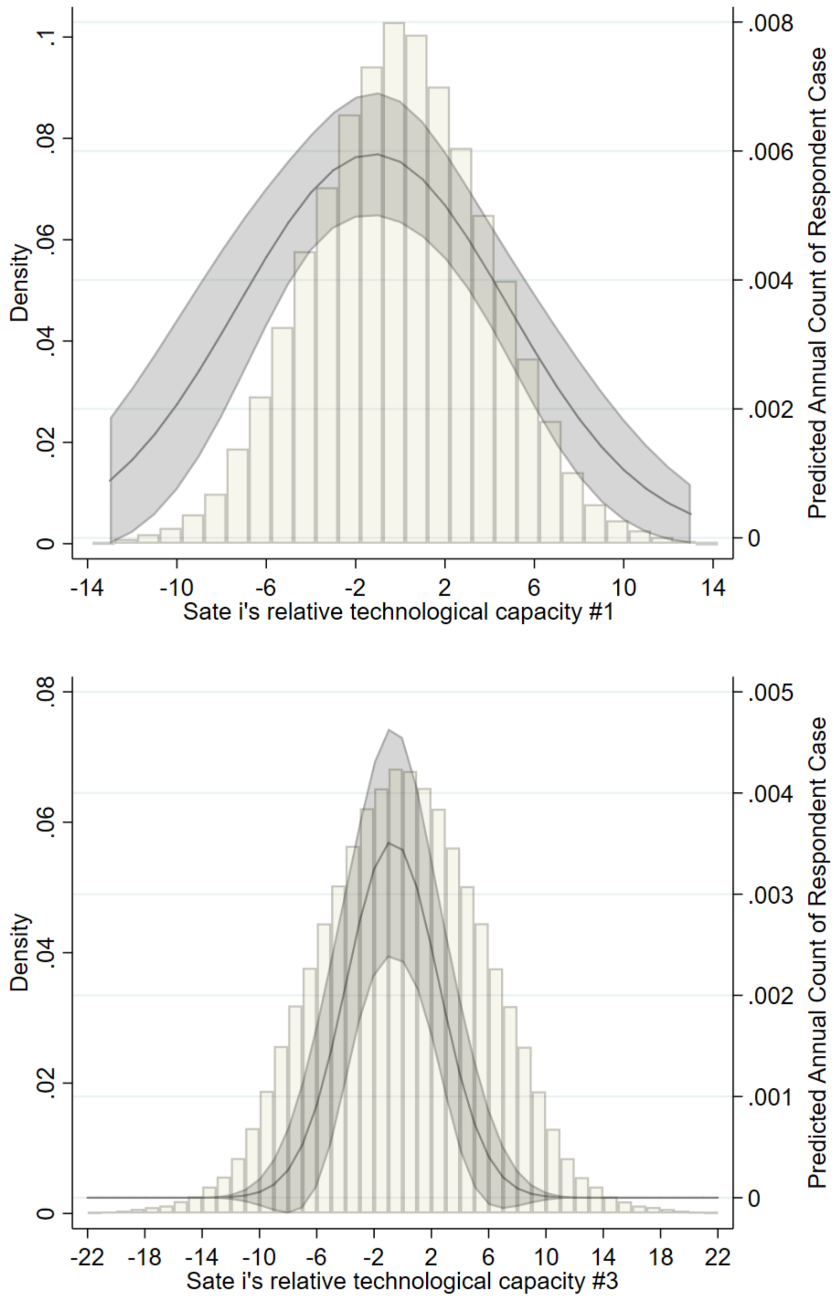

Figure 4.7. The Predicted Count of WTO Disputes

Note**:** 1. The graphs are based on Models 4.3(2) and 4.3(8).
2. 95% confidence intervals of predictions are demonstrated in the graphs.
3. All the control variables have their mean values in the prediction.

IV.vii(iii). Robustness Checks

To address a potential simultaneity between interstate tech gaps and trade conflict variables, I conduct IVprobit and IVpoisson regressions as robustness tests. At the first stage, relative tech capacity and its quadratic term are regressed on the instrumental variable, $\text{Relative\_RD}_{ij,t}$, which is calculated based on state annual total of R&D spending, and its quadratic term respectively. In the second stage, the variables representing trade conflict are regressed on the proxy of the state tech capacity gap obtained from the first stage as well as other external instruments, democratic dyad and MID. The under-identification test statistics show that the instruments are not weak. Table 4.6 presents the results of the second stage regressions, and the estimated coefficients mostly are negative and significant, supporting a quadratic, in a shape of downward concave, relationship between state relative tech capacity position and the onset of trade conflict. The network analysis which includes the structural effects to control for also corroborates the association between interstate tech gaps and the likelihood of trade conflict. Considering that states tend to have the propensity to use sanctions frequently or be a target to receive sanctions from many states for one issue, I include two and three in-going and out-going edges as factors for a new edge. For the other two dependent variables, I only include two in-going and out-going edges. It is not reasonable to expect reciprocity in withdrawing from a free trade containing two states, so *Mutual* is not included in the specification of PTA withdrawal. Dyads with missing values of edges are removed from the analysis, and missing values of tech gaps in the dataset are replaced by zeros. As Table 4.7 suggests, the estimated coefficients of squared state relative tech capacity are negative and significant at the 95% level, and according to the coefficients, peaks of the likelihood of a directed trade conflict mostly occur near the zero value of the tech gap. These statistic outputs show the strength of the hypotheses.

Table 4.6. Two-Stage Regression Models of Technological Gaps on Initiation of Trade Conflict

	4.4(1)	**4.4(2)**	**4.4(3)**	**4.4(4)**	**4.4(5)**	**4.4(6)**	**4.4(7)**	**4.4(8)**	**4.4(9)**
	Trade sanction $_{ji,t}$			PTA withdrawal $_{ji,t}$			Being complained $_{ji,t}$		
$\text{Relative\_tech}^{(1)}_{ji,t-1}$	**-0.0152***** (-3.37)			**-0.0854***** (-10.43)			**-0.0855**** (-2.48)		
$\text{Relative\_tech}^{(1)2}_{ji,t-1}$	**0.000262** (0.28)			**-0.0281***** (-11.41)			**-0.0145**** (-2.35)		
$\text{Relative\_tech}^{(2)}_{ji,t-1}$		**-0.0543***** (-9.47)			**-0.0458***** (-7.40)			**-0.194***** (-3.46)	
$\text{Relative\_tech}^{(2)2}_{ji,t-1}$		**-0.00601***** (-3.94)			**-0.0239***** (-23.13)			**-0.0315***** (-2.97)	
$\text{Relative\_tech}^{(3)}_{ji,t-1}$			**-0.0268***** (-4.62)			**-0.0496***** (-4.79)			**-0.228**** (-2.05)
$\text{Relative\_tech}^{(3)2}_{ji,t-1}$			**-0.00339***** (-3.17)			**-0.0174***** (-7.40)			**-0.0556*** (-1.80)
$\text{Democ dyad}_{ji,t-1}$	-0.950*** (-32.99)	-0.650*** (-16.66)	-0.801*** (-19.33)	0.201*** (4.96)	-0.0651* (-1.71)	-0.152** (-2.37)	0.319 (1.49)	0.293 (1.33)	-0.689** (-2.17)
$\text{MID}_{ij,t-1}$	0.975*** (11.48)	0.903*** (6.65)	1.298*** (9.94)	0.521*** (3.69)	0.381** (2.51)	0.745*** (3.59)	2.588*** (5.81)	2.721*** (6.03)	3.486*** (6.78)
Constant	-1.878*** (-92.78)	-2.078*** (-28.31)	-1.952*** (-57.41)	-2.012*** (-46.02)	-1.005*** (-8.76)	-1.841*** (-23.31)	-5.465*** (-26.61)	-5.153*** (-22.72)	-5.012*** (-14.14)
	Probit	Probit	Probit	Probit	Probit	Probit	Poisson	Poisson	Poisson
Data range	1980-2014	1980-2014	2007-2014	1980-2014	1980-2014	2007-2014	1995-2014	1995-2014	2007-2014
N	107,225	84,314	56,144	35,212	31,217	21,230	46,612	35,183	26,052

Note: 1. *t* statistics in parentheses * $p < .1$, ** $p < .05$, *** $p < .0$

2. External instruments include *Democratic dyad* and *MID*, both of which are lagged with one year; the internal instrument for *Relative tech* is *Relative R&D*, and they are lagged with one year.

Table 4.7. Regressions of Trade Conflict Variables on State Relative Tech Capacity with Controlling for Potential Network Factors

	5.4(1)	**5.4(2)**	**5.4(3)**	**5.4(4)**	**5.4(5)**	**5.4(6)**	**5.4(7)**	**5.4(8)**	**5.4(9)**
	Trade sanction $_{ji,t}$			PTA withdrawal $_{ji,t}$			Being complained $_{ji,t}$		
$\text{Relative\_tech}^{(1)}_{ji,t-1}$	**-0.112** [-0.19, -0.04]			**-0.368** [-0.46, -0.28]			**-0.002** [-0.08, 0.05]		
$\text{Relative\_tech}^{(1)2}_{ji,t-1}$	**-0.058** [-0.07, -0.04]			**-0.31** [-0.47, -0.2]			**-0.067** [-0.09, -0.05]		
$\text{Relative\_tech}^{(2)}_{ji,t-1}$		**-2.312** [-0.28, -0.16]			**-0.181** [-0.27, -0.15]			**0.019** [-0.03, 0.06]	
$\text{Relative\_tech}^{(2)2}_{ji,t-1}$		**-0.037** [-0.07, -0.01]			**-0.081** [-0.16, -0.05]			**-0.023** [-0.03, -0.01]	
$\text{Relative\_tech}^{(3)}_{ji,t-1}$			**-0.009** [-0.13, 0.15]			**-0.215** [-0.39, -0.12]			**-0.027** [-0.12, 0.12]
$\text{Relative\_tech}^{(3)2}_{ji,t-1}$			**-0.01** [-0.03, -0.003]			**-0.121** [-0.22, -0.064]			**-0.124** [-0.25, -0.07]
Mutual	-4.742 [-0.12, -3.50]	-4.799 [-9.16, -3.54]	-3.642 [-6.14, -3.03]				-0.202 [-0.85, -0.37]	-0.248 [-0.9, 0.39]	0.113 [-1.21, 1.16]
Ostar2	-2.011 [-3.08, -1.65]	-2.03 [-3.11, -1.66]	-2.823 [-3.74, -2.52]	-0.043 [-0.14, -0.01]	-0.043 [-0.16, -0.01]	-0.037 [-0.29, 0.01]	-0.277 [-0.88, 0.08]	-0.444 [-1.11, -0.01]	-0.057 [-0.93, 0.17]
Ostar3	0.114 [0.09, 0.32]	0.114 [0.09, 0.32]	0.376 [0.34, 0.49]						
Istar2	0.044 [-0.01, 0.09]	0.041 [-0.01,0.09]	0.059 [-0.04, 0.16]	-3.338 [-4.45, -2.67]	-3.32 [-4.39, -2.67]	-3.62 [-6.34, -3.08]	-1.159 [-2.4, -0.39]	-1.351 [-2.63, -0.56]	-2.028 [-2.64, -1.5]
Istar3	0.001 [0, 0.002]	0.001 [0,0.001]	0.002 [-0.001, 0.01]						
L.DV	13.842 [8.55, 22.33]	13.902 [8.57, 22.54]	10.543 [8.97, 15.57]	-0.31 [7.43, 21.81]	12.663 [7.08, 22.18]	14.07 [5.92, 37.21]			

Note: Confidence intervals at the 95% level in parentheses.

IV.viii. Case I: Japan-South Korea Trade Conflict since 2019

The Japan-South Korea trade disputes begun 2019 with the Japanese Ministry of Economy, Trade and Industry (METI)'s removal of South Korea from its so-called "white list" of trusted partners, making Japanese manufacturers' shipments of controlled items to South Korea subject to more licensing requirements and more stringent screening procedures than before. Though the tightening of export control is widely deemed as retaliation for South Korean courts' decisions that ordered convicted Japanese corporations to compensate Korean families that were forced to supply labor during the war, the Japanese government justified this sanction through accusing South Korea of breaking the rules of export multilateral control regimes by diverting strategic goods and sensitive information to some dangerous places like North Korea and Iran[50], and thereby claiming that this action came out of security concerns. South Korea subsequently filed complaints over Japanese measures in the WTO. The two neighboring states had been closely inter-reliant in high-tech production networks. Japanese industries were major suppliers of high-quality fluorinated polyimide, photoresist, and hydrogen fluoride, all of which are key components of advanced electronics like smartphone displays and chips that South Korean industries had been engaging in producing. Hence, this trade conflict has been widely believed to create substantial damages to both sides' economies.

This case reflects the *alternate-use* feature of economic sanctions. First, it was unlikely that the South Korean government could lessen its request for compensation from convicted Japanese corporations, given that it would have taken huge audience cost imposed by nationalist citizens if it had compromised. Second, even if the South Korean government could yield by

[50] There are some reports on this accusation, including *Reuters*'s report—"South Korea rejects Japan media reports on transfer of material to North Korea" in July 2019 and the *New York Times*'s report—"Japan Cites 'National Security' in Free Trade Crackdown" in July 2019.

revoking the series of compensation demands, Japan's national or corporate loss would not be offset by this concession, given that its GDP loss due to the trade conflict was much higher than the total value of compensations called by the South Korean courts. Why did the Japanese government launch this costly trade dispute even though it could not expect concessions from South Korea? A highly potential explanation is that Japan could get relative gains or long-term profits through export sanctions targeting South Korean technical competitors, which may hinder their growth; this purpose must be hidden, given that compared to accusing South Korea of misconduct in trade, acknowledging the will to commercially strike at a technically competitive democracy is not that legitimate in liberal regimes. By the outbreak of the conflict, scholars had pointed out that South Korean technological industries grew more and more competitive to the Japanese (e.g., Rhyu and Lee 2006). Figure 4.8 displays the tech power gaps between the two states (South Korea's technical figures minus Japan's). All curves take on an upward trend, indicating that South Korea had been steadily approaching, and even led ahead of, Japan in terms of technical capacity by 2018. At the beginning of the dispute, METI stipulated that "exporters shall apply for an individual export license for export of Fluorinated polyimide, Resist, and Hydrogen Fluoride, and their relevant technologies, which may include technology transferred with exports of manufacturing equipment to the Republic of Korea."[51] As aforementioned, the three chemicals put under control were pivotal intermediates for high-tech production and R&D that South Korean tech giants had been undertaking, and thus, cutting their supplies would precisely severely jeopardize South Korean high-tech industries.[52]

[51] Here is the official file: https://www.meti.go.jp/english/press/2019/0701_001.html

[52] Some analysts asserted that both Japan-South Korea and the US-China economic conflicts were innately tech competitions. See *Strife*'s blog article written by Yeseul Woo: "The First Tech War? Why the Korea-Japan Tensions are about the US-China Competition on AI".

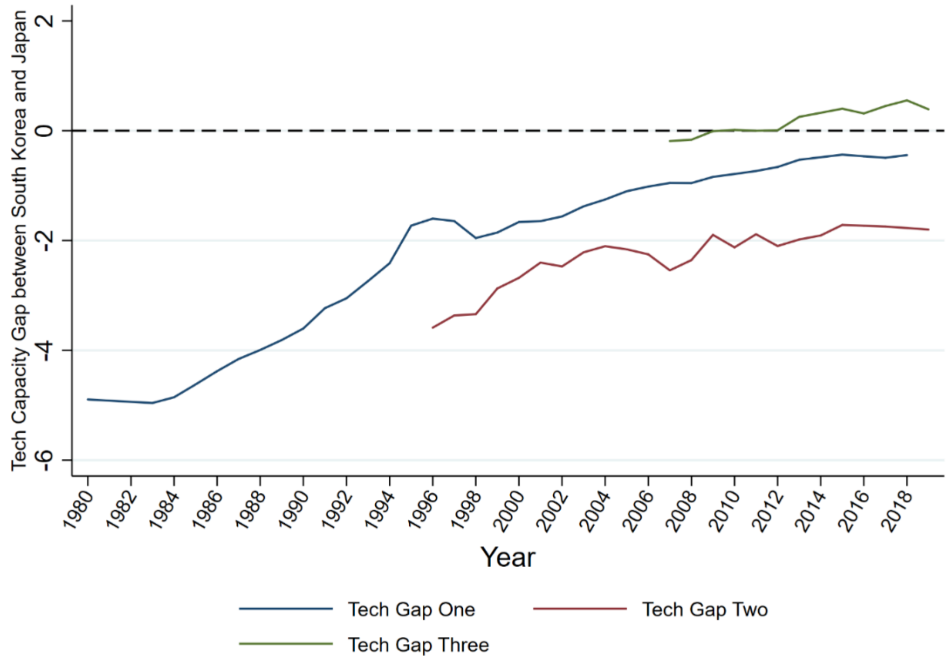

Figure 4.8. Technological Gaps between South Korea and Japan

***Note*:** The three gaps are measured based on their annual numbers of patent files, the annual received IP payments, and the annual volumes of high-tech exports respectively.

IV.ix. Case II: Historical Trade Conflict Facing P.R. China

Fifty-one states have slapped trade sanctions against People's Republic of China, and most of them ended by 1985 (see Table 4.8). The series of embargoes was initiated, led, and sponsored by the US in pursuit of retarding Communist China's aggressions by "creating unemployment and unrest, hindering industrial production and development, and creating serious financial and administrative problems". (Zhang 2001: 32). Only the US extended trade sanctions to the 1990s. For three decades after WWII, China's economy was mostly rural and under-industrialized, and the communist government's devastating planning policies like the *Great Leap* and political movements like the *Cultural Revolution* even worsened the situation. China successfully developed several strategic tech projects like nuclear power and satellites with the Soviets' assistance, but its tech strength was still insignificant relative to advanced countries for nearly four decades after its founding. Among the states that followed the US trade sanctions against China, many were developing states that had parity with China in terms of industrial or tech levels at the time.

However, since China's economy skyrocketed and its global innovative presence dramatically rose after liberalization reforms led by Deng Xiaoping which begun in the late 1970s, the states except for the US that formerly imposed trade sanctions against China did not engage in any new rounds of trade sanctions, even after the Chinese government violently cracked down on Tiananmen liberal protests in 1989; nor have they followed the US trade sanctions against China since 2017. Figure 4.9 demonstrates global trade sanctions in 1980 and 1989, which suggests that China even received far fewer trade sanctions after its government committed human rights abuses during the protest than in 1980.

Table 4.8. China-Targeting Trade Sanctions Senders and Periods from 1950 through 2016

Argentina	1950 - 1985	Luxembourg	1950 - 1985	Barbados	1967 - 1985
Australia	1950 - 1985	Mexico	1950 - 1985	Trinidad and Tobago	1967 - 1985
Belgium	1950 - 1985	Netherlands	1950 - 1985	Jamaica	1969 - 1985
Bolivia	1950 - 1985	New Zealand	1950 - 1956	Grenada	1975 - 1985
Brazil	1950 - 1985	Nicaragua	1950 - 1985	Suriname	1977 - 1985
Canada	1950 - 1985	Norway	1950 - 1985	Dominica	1979 - 1985
Chile	1950 - 1985	Panama	1950 - 1985	Saint Lucia	1979 - 1985
Colombia	1950 - 1985	Paraguay	1950 - 1985	Antigua and Barbuda	1981 - 1985
Costa Rica	1950 - 1985	Peru	1950 - 1985	Saint Vincent	1981 - 1985
Cuba	1950 - 1985	South Africa	1950 - 1985	Bahamas	1982 - 1985
Denmark	1950 - 1985	United Kingdom	1950 - 1985	Saint Kitts and Nevis	1984 - 1985
Dominican Republic	1950 - 1985	United States	1950 - 1994		
Ecuador	1950 - 1985	Uruguay	1950 - 1985		
El Salvador	1950 - 1985	Venezuela	1950 - 1985		
France	1950 - 1985	Japan	1952 - 1985		
Germany	1950 - 1985	Portugal	1952 - 1985		
Guatemala	1950 - 1985	Spain	1952 - 1985		
Haiti	1950 - 1985	Greece	1953 - 1985		
Honduras	1950 - 1985	Turkey	1953 - 1985		
Italy	1950 - 1985	Soviet Union	1960 - 1970		

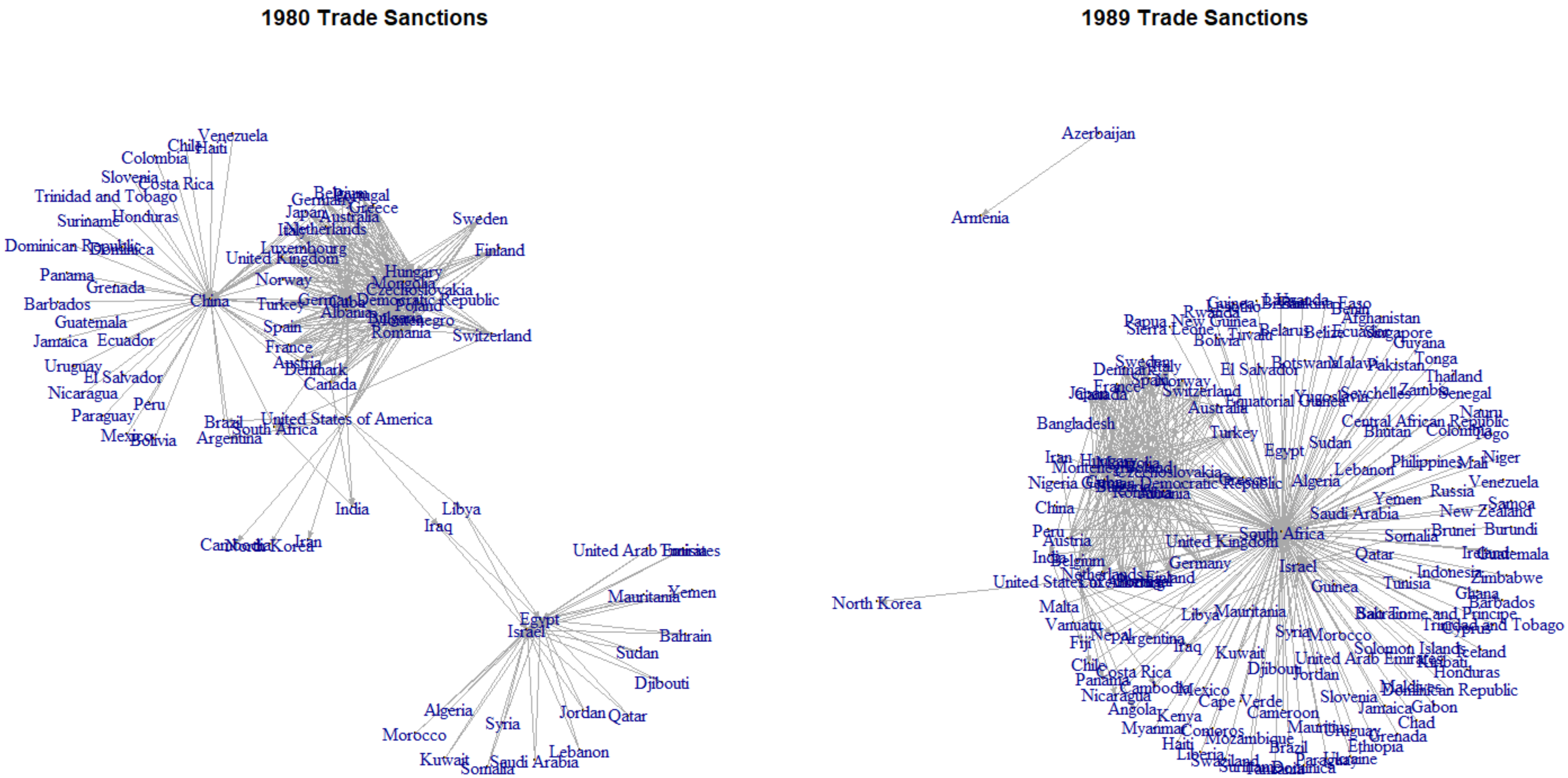

Figure 4.9. Trade Sanctions in 1980 and 1989

China's fast economic growth and its authoritarian nature necessarily partly account for the US feeling threatened. Nevertheless, the very trigger of the US deterrence policies against China was its uncoverable ambitions in technical catching-up toward the US. Since the 2000s, China's technological capacity has increased stunningly, as it had outnumbered the US in terms of the number of annual patent files and high-tech exportation and been close to the US in terms of annual IP receipts (see Figure 4.10). There are two potential explanations for the patterns. First, though China has a great quantity of annual IP applications, IP quality has not been good enough to generate compatibly high returns. Second, China has been a center for assembling final outputs, which can explain its recent leading position in high-tech exports. After all, this country has demonstrated its success and ambition in technical progress in either military or civil realms through the above indexes and high-profile state-sponsored projects like "Made in China 2025" in which the government engages in subsidizing major emerging high-tech industries, such as AI, Big Data, electric cars, drones, robotics, and aviation & aerospace industries, aiming to take over the leadership in global innovation.

In response to China's tech aspirations, in 2017, the US Trade Representative (USTR) investigated under "Section 301" into the US-China economic relations, providing evidence for China's forced technology transfer, strategic acquisition of the US assets, and theft in cyberspace, which established the normative grounds for the Trump Administration's subsequent trade sanctions against China. The trade warfare included four rounds of trade sanctions against China by increasing tariffs. The US has imposed tariffs on $34 billion of Chinese goods since 6th July 2018; on 24th September 2018, the Trump Administration announced another 10% tariff on $200 billion Chinese exports. In early 2019, The US urged for regular reviews of China's progress on domestic trade reforms as a condition for lifting the series of trade sanctions, which would

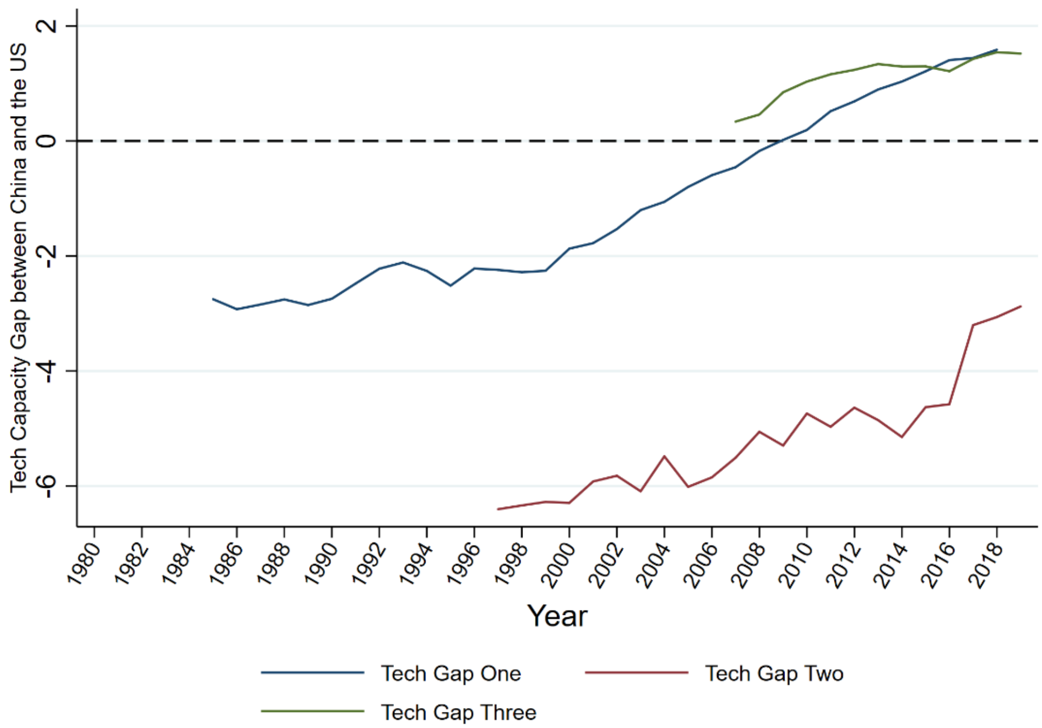

Figure 4.10. Technological Gaps between China and the US

Note**:** The three gaps are measured based on their annual numbers of patent files, annual received IP payments, and annual volumes of high-tech exports respectively.

challenge China's sovereignty and therefore *de facto* humiliated its government.[53] Even though the demand went so far that the Chinese government was not likely to accept, it was by no means unreasonable as the demand was believed by the US government to bear political fruit no less than what it could directly receive from the enforced and planned trade restrictions (see optimal *m* in Figure 4.2). Then, trade sanctions continued to get levied. The tariff on $200 billion Chinese exports was raised to 20% from 10th May 2019; a 10% tariff was placed on the left $300 billion worth of imports from China from the first day of August in 2019. After several rounds of negotiations, the two states have agreed on some steps toward avoiding escalation of the economic conflict; nevertheless, the US government has not yet revoked any of its trade sanctions.

IV.x. Conclusion

This part of dissertation investigates the relationship between interstate tech capacity distribution and state initiation of trade conflict at the dyad level. Considering that cross-border trade facilitates tech transfer, and opening domestic market may financially or/and materially support the partner's tech growth, states are bound to manipulate commercial policy to deter a worrisome pursuer in the tech realm. This is consistent with the transition theory; technologies are critical assets that are highly related to domestic productivity, military strength, and overseas influences, and hence a tech leading state is incentivized to deter an ascending state that is reshaping their relative tech positions. Besides, sharing similar levels of technical capacity is normally

[53] Here is the news source from *Reuters*: https://www.reuters.com/article/us-usa-china-trade-exclusive/exclusive-u-s-demands-regular-review-of-china-trade-reform-idUSKCN1PC2AG

equivalent to having identical export structures, and thus, defending a tech leading position is part of global market competition.

I posit that when a state is being closely chased by its lagging partner in terms of tech capacity, it is quite likely to initiate trade conflict against the latter as preventive measures, attempting to impede adverse tech transfer *via* trade with the latter and prevent its domestic market from buttressing the latter's tech and economic growth. However, if its trade partner technologically leads ahead, the state is less likely to make a trade confrontation with it, given that in this situation it has little relative tech power to carry out effective economic attacks on its more advanced partner. This is because the latter can quickly make substitutes for the lost supplies due to the trade conflict, and meanwhile, it has to afford high costs for the initiation of trade conflict by undergoing great difficulties in making tech-import-substituting production. In practice, this research selects certain events like trade sanctions, PTA withdrawal, and the WTO disputes, which involve specific states, as proxies for trade conflict. Particularly, I point out the alternate utilities of economic sanctions—Sanctions can cause political rewards regardless of targets' concessions, which may have to be sought under the cover of convictions of the target because they are not as legitimate as what senders overtly request; when political gains a state expects to directly receives from a sanction is greater, it is more likely to resort to it; the sender uses sanctions rather than corresponding economic policies that can render the same political outcomes because it wishes to avoid loss of reputation or lack of legitimacy, or use sanctions as focal points to mobilize collective actions. That is, trade sanctions can serve as a convenient instrument for states use to deter a tech competitor under liberal regimes. The state-level large-*N* analysis evidences the hypothetical quadratic relationships between a state's tech capacity relative to another and the likelihood of its initiation of trade conflict.

PART V

CONCLUSIONS

In this dissertation, I propose, based on existing literature, observations, and logics, the following main arguments. First, technology has been rising to be the crucial part of or representative of national power in the modern era, and particularly, state technological capacity can influence state behavior independently of a state's other material power; specifically, tech competition is likely to breed nonmilitary strategy, while material power struggles are mostly violent. Second, state trade dependence on another tends to cause unfavorable tech power transition, because it incentivizes companies to transfer their technology to overseas suppliers of intermediates, aiming to optimize the outsourcing process, and meanwhile, reduces state bargaining leverage during cross-border negotiation regarding tech transfer. That being said, trade dependence is not thought to be able to realize between-state technological power surpassing, given that the knowledge from a more advanced partner that is available for learning is always limited. Third, according to the former propositions, the power transition theory, as well as global market competition, states are believed to care about their tech power parity, and they tend to initiate trade conflict against its trade partner that is technologically catching up, as a preventive strategy to impede further tech convergence or even surpassing.

The claims made in this dissertation help understand the patterns of the growing power competition between the U.S. and China in the twenty-first century. Among many possible explanations, geo-economic competition over high technology is a prominent approach that accounts for the nature of ongoing great power competition. It is argued that the two great powers are competing each other to enhance their powers by protecting and enhancing their technological dominance and economic security. Areas of current technological competition include AI, 5G technology, drone technology, Big Data and aviation & aerospace industries. Apart from contentions revolving around materials, competitions in technological and innovative areas tend to trigger economic conflicts, which explain the US-China escalated trade conflict since 2017.

At the end of the dissertation, I put forth several recommendations, which may have been mentioned somewhere in the dissertation, for future's research in the political economy field. First, existing growth theories mostly treat unitary countries as main objects of investigation, and some focuses on a general global or regional economic convergence. Although many significant explorations have been achieved and employed in guiding economic activity, a loose end exists given that these research endeavors cannot directly engender international relations implications. I therefore recommend more growth research agendas in the future that can weave IR concepts, methods, and concerns into pre-existing either tech or economic growth models and adapt development theories to the present world filled with geopolitical complexity and dynamics, as well as intense competition. Second, as the use of conventional war to address international disputes has been declining, nonmilitary conflict, such as economic or civil frictions, rises to be a field that demands more research attention from realists. Lastly, comparative research on domestic politics of innovation, especially between competitors, shall be increasingly interesting given that they can help explain and predict outcomes of international tech races by referring to endogenous institutions and leadership styles.

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APPENDICES

Appendix III.A1. Regressions of Technological Gap One with Respect to Import Dependence

$\text{Tech\_gap}^{(1)}_{ji,t}$	**A.1(1)**	**A.1(2)**	**A.1(3)**	**A.1(4)**	**A.1(5)**	**A.1(6)**	**A.1(7)**	**A.1(8)**	**A.1(9)**
$\log\left(\text{Import\_dep}_{ji,t-1}\right)$	**-0.537*****	**-0.500*****	**-0.0438*****	**-0.0637*****	**-0.525*****	**-1.356*****	**-1.405*****	**-0.215*****	**-0.458*****
	(-117.62)	(-101.44)	(-23.90)	(-34.98)	(-98.57)	(-44.56)	(-44.41)	(-8.17)	(-18.47)
$\text{Tech\_gap}^{(1)}_{ji,t-1}$				0.0000193**					0.0000390
				(2.54)					(0.69)
$\text{Polity type}_{ji,t-1}$: A		0.732***	0.192***	0.203***	0.823***	-2.841***	-3.411***	-0.00569	-0.0453
		(13.97)	(13.70)	(14.39)	(15.42)	(-6.77)	(-8.01)	(-0.06)	(-0.44)
$\text{Polity type}_{ji,t-1}$: B		1.387***	0.241***	0.284***	1.593***	-2.481***	-2.705***	0.345***	0.313***
		(24.36)	(16.60)	(19.50)	(27.16)	(-5.21)	(-5.61)	(3.55)	(3.09)
$\text{Polity type}_{ji,t-1}$: C		-0.868***	0.0280**	-0.00547	-0.698***	-2.211***	-2.656***	-0.325***	-0.330***
		(-15.61)	(1.97)	(-0.38)	(-12.20)	(-4.85)	(-5.73)	(-3.36)	(-3.27)
$\text{Alliance}_{ij,t-1}$					1.090***		0.703***	0.0783	0.203
					(22.97)		(5.46)	(0.45)	(1.54)
$\text{MID}_{ij,t-1}$					0.979***		0.756**	-0.000549	-0.00226
					(5.69)		(2.31)	(-0.01)	(-0.03)
$\log\left(\text{FDI}_{ij,t-1}\right)$						0.0137	0.00681	-0.00147	0.000327
						(0.74)	(0.36)	(-0.42)	(0.09)
$\log\left(\text{FDI}_{ji,t-1}\right)$						0.191***	0.171***	0.00824**	0.0138***
						(9.84)	(8.63)	(2.37)	(3.77)
Constant	-4.660***	-4.764***	-0.569***	-0.763***	-5.227***	-3.763***	-3.809***	-1.085***	-2.488***
	(-110.19)	(-72.48)	(-28.37)	(-19.86)	(-73.67)	(-8.75)	(-8.69)	(-5.88)	(-12.55)
	Newey	Newey	FE	RE	Newey	Newey	Newey	FE	RE
N	190,969	174,572	174,572	174,572	157,075	4,777	4,272	4,272	4,272
R^2			0.00591					0.0377	

t statistics in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$

Appendix III.A2. Regressions of Technological Gap Two with Respect to Import Dependence

	A.2(1)	**A.2(2)**	**A.2(3)**	**A.2(4)**	**A.2(5)**	**A.2(6)**	**A.2(7)**	**A.2(8)**	**A.2(9)**
$\text{Tech\_gap}^{(2)}_{ji,t}$									
$\log\left(\text{Import\_dep}_{ji,t-1}\right)$	**-0.675***	**-0.598***	**-0.0493***	**-0.146***	**-0.629***	**-1.271***	**-1.320***	**-0.0175**	**-0.902***
	(-109.89)	(-88.67)	(-10.37)	(-32.61)	(-83.61)	(-26.47)	(-25.78)	(-0.16)	(-15.51)
$\text{Tech\_gap}^{(2)}_{ji,t-1}$				0.0000379**					0.000125
				(2.20)					(0.77)
Polity type $_{ji,t-1}$: A		0.753***	-0.0535	0.00126	0.757***	-3.285***	-3.539***	-0.0114	-0.559
		(7.73)	(-1.17)	(0.03)	(7.37)	(-4.89)	(-4.83)	(-0.03)	(-1.43)
Polity type $_{ji,t-1}$: B		2.676***	-0.456***	-0.128***	2.722***	-0.738	-0.837	-0.113	-0.0937
		(25.37)	(-9.84)	(-2.79)	(24.43)	(-1.07)	(-1.11)	(-0.28)	(-0.24)
Polity type $_{ji,t-1}$: C		-2.234***	0.371***	0.109**	-2.064***	-4.613***	-4.698***	0.112	-0.622
		(-21.34)	(8.03)	(2.39)	(-18.75)	(-6.74)	(-6.26)	(0.28)	(-1.61)
$\text{Alliance}_{ij,t-1}$					1.473***		0.628***	0.0243	0.555**
					(18.13)		(3.29)	(0.02)	(2.22)
$\text{MID}_{ij,t-1}$					1.543***		0.666	-0.00459	-0.00623
					(5.21)		(1.38)	(-0.02)	(-0.02)
$\log\left(\text{FDI}_{ij,t-1}\right)$						-0.0469*	-0.0496*	-0.000272	-0.00146
						(-1.73)	(-1.69)	(-0.02)	(-0.11)
$\log\left(\text{FDI}_{ji,t-1}\right)$						0.246***	0.228***	-0.00329	0.0277**
						(9.39)	(7.95)	(-0.24)	(2.03)
Constant	-6.074***	-5.755***	-0.416***	-1.424***	-6.195***	-2.911***	-3.218***	-0.0691	-4.536***
	(-99.52)	(-51.37)	(-6.99)	(-19.38)	(-50.83)	(-4.20)	(-4.27)	(-0.08)	(-9.13)
	Newey	Newey	FE	RE	Newey	Newey	Newey	FE	RE
N	132,937	116,611	116,611	116,611	101,128	4,150	3,672	3,672	3,672
R^2			0.00565					0.000185	

t statistics in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$

Appendix III.A3. Regressions of Technological Gap Three with Respect to Import Dependence

	A.3(1)	**A.3(2)**	**A.3(3)**	**A.3(4)**	**A.3(5)**	**A.3(6)**	**A.3(7)**	**A.3(8)**	**A.3(9)**
$\text{Tech\_gap}^{(3)}_{ji,t}$									
$\log\left(\text{Import\_dep}_{ji,t-1}\right)$	**-0.740*****	**-0.639*****	**0.0104****	**-0.0880*****	**-0.669*****	**-0.923*****	**-0.979*****	**-0.0383**	**-0.419*****
	(-97.64)	(-81.07)	(2.51)	(-21.95)	(-71.19)	(-20.18)	(-19.20)	(-0.81)	(-10.39)
$\text{Tech\_gap}^{(3)}_{ji,t-1}$				0.0000107					-0.0000148
				(0.95)					(-0.73)
$\text{Polity type}_{ji,t-1}: A$		0.619***	0.000844	0.00276	0.676***	-0.841	-1.073	-0.180	-0.193
		(5.31)	(0.02)	(0.06)	(4.95)	(-1.31)	(-1.43)	(-0.81)	(-0.93)
$\text{Polity type}_{ji,t-1}: B$		2.426***	0.0466	0.408***	2.739***	-0.168	0.00547	-0.0144	0.132
		(19.40)	(0.94)	(8.39)	(18.60)	(-0.24)	(0.01)	(-0.08)	(0.76)
$\text{Polity type}_{ji,t-1}: C$		-2.408***	-0.0415	-0.414***	-2.384***	-0.874	-1.193	0.000446	-0.217
		(-19.05)	(-0.83)	(-8.47)	(-15.93)	(-1.22)	(-1.41)	(0.00)	(-1.24)
$\text{Alliance}_{ij,t-1}$					1.720***		0.604***	0	0.245
					(17.77)		(3.49)	(.)	(1.02)
$\text{MID}_{ij,t-1}$					1.790***		0.137	-0.00134	-0.00641
					(4.31)		(0.27)	(-0.02)	(-0.09)
$\log\left(\text{FDI}_{ij,t-1}\right)$						-0.0425	-0.0586**	0.00439	0.00610
						(-1.63)	(-1.98)	(1.03)	(1.35)
$\log\left(\text{FDI}_{ji,t-1}\right)$						0.185***	0.172***	-0.00583	-0.000814
						(6.78)	(5.53)	(-1.36)	(-0.18)
Constant	-7.002***	-6.254***	0.0465	-0.879***	-6.782***	-3.778***	-4.166***	-0.0272	-2.204***
	(-90.76)	(-45.52)	(0.81)	(-12.62)	(-40.78)	(-5.76)	(-5.28)	(-0.09)	(-7.03)
	Newey	Newey	FE	RE	Newey	Newey	Newey	FE	RE
N	85,837	75,449	75,449	75,449	51,905	2,212	1,708	1,708	1,708
R^2			0.000159					0.00454	

t statistics in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$

Appendix III.B1. Regressions of Technological Gap One with Respect to Export Dependence

	B.1(1)	B.1(2)	B.1(3)	B.1(4)	B.1(5)	B.1(6)	B.1(7)	B.1(8)	B.1(9)
$Tech\_gap^{(1)}_{ji,t}$									
$\log\left(Export\_dep_{ji,t-1}\right)$	**-0.398*****	**-0.378*****	**0.0140*****	**0.00274**	**-0.401*****	**-1.289*****	**-1.339*****	**-0.345*****	**-0.493*****
	(-76.39)	(-69.25)	(7.74)	(1.52)	(-68.09)	(-39.84)	(-42.73)	(-14.35)	(-21.51)
$Tech\_gap^{(1)}_{ji,t-1}$				-0.00000214					0.0000426
				(-0.28)					(0.78)
Polity type $_{ji,t-1}$: A		0.485***	0.146***	0.150***	0.532***	-2.625***	-3.260***	-0.00775	-0.0435
		(8.79)	(10.36)	(10.59)	(9.44)	(-6.22)	(-8.68)	(-0.08)	(-0.43)
Polity type $_{ji,t-1}$: B		1.582***	0.212***	0.249***	1.726***	-2.629***	-2.989***	0.391***	0.379***
		(26.88)	(14.75)	(17.23)	(28.38)	(-5.37)	(-6.59)	(4.09)	(3.87)
Polity type $_{ji,t-1}$: C		-1.309***	0.00112	-0.0339**	-1.219***	-1.697***	-2.133***	-0.372***	-0.392***
		(-22.27)	(0.08)	(-2.34)	(-20.11)	(-3.66)	(-4.98)	(-3.92)	(-4.02)
$Alliance_{ij,t-1}$					0.804***		0.667***	0.130	0.217
					(15.72)		(5.24)	(0.77)	(1.64)
$MID_{ij,t-1}$					0.778***		0.718**	-0.000905	-0.00201
					(4.20)		(2.36)	(-0.01)	(-0.03)
$\log\left(FDI_{ij,t-1}\right)$						0.0147	0.00690	0.00288	0.00484
						(0.80)	(0.37)	(0.84)	(1.37)
$\log\left(FDI_{ji,t-1}\right)$						0.179***	0.163***	0.00818**	0.0109***
						(9.28)	(8.28)	(2.41)	(3.11)
Constant	-3.412***	-3.510***	0.0187	-0.0600	-3.869***	-3.649***	-3.624***	-1.753***	-2.688***
	(-71.63)	(-49.46)	(0.94)	(-1.50)	(-50.30)	(-8.82)	(-9.43)	(-10.07)	(-14.02)
	Newey	Newey	FE	RE	Newey	Newey	Newey	FE	RE
N	190,800	174,413	174,413	174,413	156916	4777	4272	4272	4272
R^2			0.00265					0.0746	

t statistics in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$

Appendix III.B2. Regressions of Technological Gap Two with Respect to Export Dependence

	B.2(1)	**B.2(2)**	**B.2(3)**	**B.2(4)**	**B.2(5)**	**B.2(6)**	**B.2(7)**	**B.2(8)**	**B.2(9)**
$\text{Tech\_gap}^{(2)}_{ji,t}$									
$\log\left(\text{Export\_dep}_{ji,t-1}\right)$	**-0.488***	**-0.434***	**0.00451**	**-0.0383***	**-0.472***	**-1.292***	**-1.343***	**0.0334**	**-0.808***
	(-63.26)	(-54.13)	(0.96)	(-8.48)	(-53.78)	(-27.43)	(-26.91)	(0.34)	(-13.76)
$\text{Tech\_gap}^{(2)}_{ji,t-1}$				0.0000190					0.000115
				(1.11)					(0.70)
$\text{Polity type}_{ji,t-1}: A$		0.613***	0.0411	0.0468	0.626***	-3.367***	-3.625***	-0.000931	-0.501
		(5.87)	(0.90)	(1.04)	(5.68)	(-6.12)	(-6.10)	(-0.00)	(-1.28)
$\text{Polity type}_{ji,t-1}: B$		3.023***	-0.369***	-0.103**	3.047***	-1.234**	-1.386**	-0.107	-0.0736
		(27.23)	(-8.00)	(-2.25)	(26.02)	(-2.17)	(-2.25)	(-0.27)	(-0.19)
$\text{Polity type}_{ji,t-1}: C$		-2.648***	0.460***	0.195***	-2.521***	-4.262***	-4.271***	0.126	-0.558
		(-23.60)	(9.93)	(4.24)	(-21.30)	(-7.68)	(-7.12)	(0.31)	(-1.44)
$\text{Alliance}_{ij,t-1}$					1.029***		0.633***	-0.0137	0.487*
					(12.44)		(3.45)	(-0.01)	(1.91)
$\text{MID}_{ij,t-1}$					1.123***		0.665	-0.00349	-0.00751
					(3.43)		(1.53)	(-0.01)	(-0.03)
$\log\left(\text{FDI}_{ij,t-1}\right)$						-0.0398	-0.0475*	-0.00113	0.00338
						(-1.50)	(-1.67)	(-0.08)	(0.24)
$\log\left(\text{FDI}_{ji,t-1}\right)$						0.243***	0.229***	-0.00382	0.0204
						(9.50)	(8.23)	(-0.28)	(1.49)
Constant	-4.296***	-4.180***	0.0689	-0.348***	-4.632***	-2.924***	-3.247***	0.192	-4.054***
	(-59.26)	(-33.36)	(1.16)	(-4.62)	(-34.10)	(-5.23)	(-5.42)	(0.24)	(-8.10)
	Newey	Newey	FE	RE	Newey	Newey	Newey	FE	RE
N	132,912	116,605	116,605	116,605	101,122	4,150	3,672	3,672	3,672
R^2			0.00464					0.000215	

t statistics in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$

Appendix III.B3. Regressions of Technological Gap Three with Respect to Export Dependence

	B.3(1)	**B.3(2)**	**B.3(3)**	**B.3(4)**	**B.3(5)**	**B.3(6)**	**B.3(7)**	**B.3(8)**	**B.3(9)**
$\text{Tech\_gap}^{(3)}_{ji,t}$									
$\log\left(\text{Export\_dep}_{ji,t-1}\right)$	**-0.415*****	**-0.355*****	**-0.0298*****	**-0.0581*****	**-0.379*****	**-0.823*****	**-0.884*****	**-0.329*****	**-0.529*****
	(-44.14)	(-38.53)	(-7.22)	(-14.56)	(-33.93)	(-15.83)	(-16.13)	(-7.92)	(-14.47)
$\text{Tech\_gap}^{(3)}_{ji,t-1}$				0.00000917					-0.0000212
				(0.83)					(-1.11)
$\text{Polity type}_{ji,t-1}$: A		0.430***	-0.00215	0.0137	0.486***	-0.586	-0.938	-0.194	-0.211
		(3.41)	(-0.04)	(0.28)	(3.23)	(-0.84)	(-1.29)	(-0.89)	(-1.07)
$\text{Polity type}_{ji,t-1}$: B		2.989***	0.0420	0.368***	3.291***	-0.223	-0.276	-0.0384	0.0813
		(22.36)	(0.84)	(7.62)	(20.49)	(-0.29)	(-0.35)	(-0.23)	(0.49)
$\text{Polity type}_{ji,t-1}$: C		-2.767***	-0.0495	-0.355***	-2.829***	-0.380	-0.716	-0.0414	-0.196
		(-20.47)	(-1.00)	(-7.37)	(-17.35)	(-0.50)	(-0.87)	(-0.25)	(-1.18)
$\text{Alliance}_{ij,t-1}$					0.924***		0.544***	0	0.304
					(8.56)		(3.14)	(.)	(1.26)
$\text{MID}_{ij,t-1}$					0.980**		0.112	-0.00498	-0.00792
					(2.01)		(0.22)	(-0.08)	(-0.12)
$\log\left(\text{FDI}_{ij,t-1}\right)$						-0.0431	-0.0607**	0.00772*	0.00921**
						(-1.62)	(-2.02)	(1.85)	(2.15)
$\log\left(\text{FDI}_{ji,t-1}\right)$						0.175***	0.166***	-0.00387	-0.00186
						(6.33)	(5.31)	(-0.93)	(-0.44)
Constant	-3.786***	-3.497***	-0.213***	-0.550***	-3.894***	-3.524***	-3.788***	-1.518***	-2.807***
	(-42.24)	(-22.77)	(-3.73)	(-7.69)	(-20.52)	(-5.17)	(-4.96)	(-5.33)	(-9.47)
	Newey	Newey	FE	RE	Newey	Newey	Newey	FE	RE
N	85,821	75,436	75,436	75,436	51,892	2,212	1,708	1,708	1,708
R^2			0.000901					0.0624	

t statistics in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$

Appendix V.A. Random-Effect Regressions of Trade Sanctions on Relative Technological Capacity

	A.4(2)	**A.4(3)**	**A.4(5)**	**A.4(6)**	**A.4(8)**	**A4.(9)**
	$\text{Relative\_tech}_{ji}^{(1)}$		$\text{Relative\_tech}_{ji}^{(2)}$		$\text{Relative\_tech}_{ji}^{(3)}$	
$\text{Trade sanction}_{ji,t}$						
$\text{Relative\_tech}_{ij,t-1}$	**0.0621*****	**0.0559*****	**-0.118*****	**-0.123*****	**-0.232*****	**-0.315*****
	(6.40)	(5.34)	(-7.71)	(-6.80)	(-7.62)	(-5.95)
$\text{Relative\_tech}_{ij,t-1}^{2}$	**0.00145**	**0.00227**	**-0.0142*****	**-0.0130*****	**-0.0303*****	**-0.0340*****
	(0.87)	(1.23)	(-7.52)	(-6.04)	(-6.47)	(-4.84)
$\text{Trade sanction}_{ji,t-1}$	7.878***	7.953***	7.840***	8.258***	12.26***	13.43***
	(108.90)	(99.75)	(69.71)	(56.32)	(23.53)	(15.96)
$\text{Democ dyad}_{ji,t-1}$	-1.519***	-1.698***	-1.710***	-2.333***	-1.160***	-4.003***
	(-21.20)	(-21.66)	(-16.05)	(-16.46)	(-7.14)	(-8.52)
$\log\left(\text{Trade\_dep}_{ji,t-1}\right)$	-0.0112	-0.0345**	-0.0129	-0.0683***	0.273***	0.147***
	(-0.83)	(-2.39)	(-0.77)	(-3.52)	(8.27)	(3.56)
$\text{MID}_{ij,t-1}$	1.031***	0.358	2.319***	1.186*	1.875***	-1.817
	(3.15)	(1.00)	(5.69)	(1.76)	(4.27)	(-0.70)
$\text{Alliance}_{ij,t-1}$		-0.0393		0.0619		0.867***
		(-0.26)		(0.22)		(2.59)
Constant	-5.610***	-5.846***	-5.491***	-6.211***	-3.155***	-3.868***
	(-41.55)	(-38.92)	(-31.19)	(-27.93)	(-12.61)	(-10.76)
	RE	RE	RE	RE	RE	RE
/lnsig2u	-1.144***	-0.899***	-0.622**	-0.133	-9.446	-11.12
	(-3.78)	(-3.62)	(-2.09)	(-0.59)	(-0.78)	(-0.75)
N	191,987	173,661	129,059	111,639	75,211	48,253

t statistics in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$

Appendix V.B. Regressions of Export Sanctions on Relative Technological Capacity

	B.4(1)	B.4(2)	B.4(3)	B.4(4)	B.4(5)	B.4(6)	B.4(7)	B.4(8)	B.4(9)
	$Relative\_tech^{(1)}_{ji}$			$Relative\_tech^{(2)}_{ji}$			$Relative\_tech^{(3)}_{ji}$		
Export sanction $_{ji,t}$									
$Relative\_tech_{ij,t-1}$	**0.0399*****	**0.0658*****	**0.0583*****	**-0.0491*****	**-0.107*****	**-0.104*****	**-0.0216**	**-0.227*****	**-0.308*****
	(5.94)	(7.03)	(5.84)	(-4.59)	(-7.60)	(-6.60)	(-1.55)	(-7.47)	(-5.98)
$Relative\_tech^2_{ij,t-1}$	**0.00319*****	**0.00121**	**0.00174**	**-0.0131*****	**-0.0145*****	**-0.0140*****	**-0.0167*****	**-0.0301*****	**-0.0335*****
	(2.58)	(0.75)	(0.99)	(-9.02)	(-8.14)	(-7.11)	(-8.09)	(-6.42)	(-4.83)
Export sanction $_{ji,t-1}$	7.824***	7.985***	8.033***	8.376***	7.851***	8.147***	10.16***	12.28***	13.44***
	(151.22)	(113.51)	(106.12)	(99.62)	(79.14)	(67.85)	(60.00)	(23.54)	(15.96)
Democ dyad $_{ji,t-1}$		-1.500***	-1.648***		-1.637***	-2.074***		-1.205***	-4.066***
		(-21.94)	(-22.57)		(-16.54)	(-17.33)		(-7.34)	(-8.54)
$\log\left(Trade\_dep_{ji,t-1}\right)$		0.000312	-0.0165		-0.0141	-0.0553***		0.275***	0.148***
		(0.02)	(-1.21)		(-0.87)	(-3.03)		(8.27)	(3.60)
$MID_{ij,t-1}$		1.138***	0.523		2.066***	0.757		1.680***	-4.550***
		(3.46)	(1.47)		(4.84)	(1.16)		(3.53)	(-3.40)
$Alliance_{ij,t-1}$			-0.0892			-0.103			0.835**
			(-0.59)			(-0.38)			(2.49)
Constant	-5.864***	-5.452***	-5.592***	-6.305***	-5.327***	-5.769***	-6.348***	-3.127***	-3.839***
	(-139.31)	(-46.10)	(-43.47)	(-95.51)	(-33.01)	(-30.61)	(-72.72)	(-12.44)	(-10.76)
	Logit	Logit	Logit	Logit	Logit	Logit	Logit	Logit	Logit
χ^2	50411.9	34887.3	32087.0	23213.3	14923.1	13551.0	16505.0	8724.6	4937.3
N	259,902	191,987	173,661	184,696	129,059	111,639	128,780	75,211	48,253

t statistics in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$

Appendix V.C. Random-Effect Regressions of Export Sanctions on Relative Technological Capacity

	C.4(1)	**C.4(2)**	**C.4(3)**	**C.4(4)**	**C.4(5)**	**C.4(6)**
	$\text{Relative\_tech}_{ji}^{(1)}$		$\text{Relative\_tech}_{ji}^{(2)}$		$\text{Relative\_tech}_{ji}^{(3)}$	
$\text{Export sanction}_{ji,t}$						
$\text{Relative\_tech}_{ij,t-1}$	**0.0671*****	**0.0605*****	**-0.119*****	**-0.130*****	**-0.227*****	**-0.308*****
	(6.70)	(5.59)	(-7.42)	(-6.67)	(-7.47)	(-5.98)
$\text{Relative\_tech}_{ij,t-1}^{2}$	**0.00167**	**0.00262**	**-0.0151*****	**-0.0141*****	**-0.0301*****	**-0.0335*****
	(0.97)	(1.38)	(-7.53)	(-6.06)	(-6.42)	(-4.83)
$\text{Export sanction}_{ji,t-1}$	8.014***	8.102***	8.005***	8.528***	12.28***	13.44***
	(105.26)	(95.55)	(65.38)	(50.83)	(23.54)	(15.97)
$\text{Democ dyad}_{ji,t-1}$	-1.568***	-1.761***	-1.771***	-2.480***	-1.205***	-4.066***
	(-21.07)	(-21.47)	(-15.82)	(-15.98)	(-7.34)	(-8.54)
$\log\left(\text{Trade\_dep}_{ji,t-1}\right)$	-0.0131	-0.0383**	-0.0152	-0.0750***	0.275***	0.148***
	(-0.95)	(-2.55)	(-0.87)	(-3.68)	(8.27)	(3.60)
$\text{MID}_{ij,t-1}$	1.127***	0.384	2.196***	0.710	1.680***	-4.550***
	(3.24)	(0.97)	(4.91)	(0.92)	(3.53)	(-3.40)
$\text{Alliance}_{ij,t-1}$		-0.0312		0.0372		0.835**
		(-0.19)		(0.12)		(2.49)
Constant	-5.709***	-5.970***	-5.589***	-6.410***	-3.127***	-3.839***
	(-40.38)	(-37.77)	(-30.17)	(-26.59)	(-12.44)	(-10.76)
	RE	RE	RE	RE	RE	RE
/lnsig2u	-0.989***	-0.735***	-0.479	0.0613	-10.66	-11.77
	(-3.50)	(-3.15)	(-1.64)	(0.28)	(-0.50)	(-0.25)
N	191,987	173,661	129,059	111,639	75,211	48,253

t statistics in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$

Appendix V.D. Regressions of Import Sanctions on Relative Technological Capacity

	D.4(1)	D.4(2)	D.4(3)	D.4(4)	D.4(5)	D.4(6)	D.4(7)	D.4(8)	D.4(9)
	$\text{Relative\_tech}_{ji}^{(1)}$			$\text{Relative\_tech}_{ji}^{(2)}$			$\text{Relative\_tech}_{ji}^{(3)}$		
Import sanction $_{ji,t}$									
$\text{Relative\_tech}_{ij,t-1}$	**0.0722*****	**0.112*****	**0.105*****	**-0.0562*****	**-0.105*****	**-0.104*****	**-0.0128**	**-0.128*****	**-0.335*****
	(7.97)	(8.77)	(7.49)	(-4.45)	(-6.59)	(-5.57)	(-0.79)	(-5.58)	(-4.24)
$\text{Relative\_tech}_{ij,t-1}^{2}$	**0.000481**	**-0.0000464**	**0.00160**	**-0.00661*****	**-0.0102*****	**-0.00759*****	**-0.0131*****	**-0.0150*****	**-0.0279*****
	(0.29)	(-0.02)	(0.66)	(-3.57)	(-4.42)	(-2.85)	(-5.60)	(-4.90)	(-3.07)
Import sanction $_{ji,t-1}$	8.431***	8.396***	8.514***	8.638***	7.895***	8.259***	10.34***	9.448***	0
	(121.89)	(90.81)	(83.40)	(80.44)	(65.85)	(58.98)	(49.81)	(31.97)	(.)
Democ dyad $_{ji,t-1}$		-1.233***	-1.539***		-1.024***	-1.462***		-0.583***	-3.881***
		(-13.33)	(-14.79)		(-8.78)	(-10.50)		(-3.03)	(-6.41)
$\log\left(\text{Trade\_dep}_{ji,t-1}\right)$		-0.0554***	-0.0879***		0.0576***	-0.0243		0.306***	0.132**
		(-3.40)	(-4.95)		(2.67)	(-1.00)		(8.51)	(2.34)
$\text{MID}_{ij,t-1}$		1.609***	0.898**		2.286***	1.303*		2.177***	0
		(4.61)	(2.22)		(5.77)	(1.90)		(5.03)	(.)
$\text{Alliance}_{ij,t-1}$			-0.146			-0.0774			1.319***
			(-0.72)			(-0.23)			(3.24)
Constant	-6.213***	-6.318***	-6.610***	-6.626***	-5.318***	-6.154***	-6.682***	-3.658***	-4.866***
	(-122.35)	(-39.99)	(-37.23)	(-84.63)	(-25.97)	(-24.59)	(-65.71)	(-13.05)	(-9.69)
	Logit	Logit	Logit	Logit	Logit	Logit	Logit	Logit	Logit
χ^2	33752.6	20739.2	18406.3	12070.1	7329.6	7271.6	9579.6	3848.9	145.2
N	259,902	191,987	173,661	184,696	129,059	111,639	128,780	75,211	47,960

t statistics in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$

Appendix V.E. Random-Effect Regressions of Import Sanctions on Relative Technological Capacity

	E.4(1)	E.4(2)	E.4(3)	E.4(4)	E.4(5)	E.4(6)
	$\text{Relative\_tech}^{(1)}_{ji}$		$\text{Relative\_tech}^{(2)}_{ji}$		$\text{Relative\_tech}^{(3)}_{ji}$	
Import sanction $_{ji,t}$						
$\text{Relative\_tech}_{ij,t-1}$	**0.124***	**0.116***	**-0.111***	**-0.110***	**-0.128***	**-0.335***
	(8.56)	(7.45)	(-6.42)	(-5.32)	(-5.58)	(-4.24)
$\text{Relative\_tech}^2_{ij,t-1}$	**-0.00121**	**0.00141**	**-0.0111***	**-0.00840***	**-0.0150***	**-0.0279***
	(-0.50)	(0.53)	(-4.46)	(-2.94)	(-4.90)	(-3.07)
Import sanction $_{ji,t-1}$	8.509***	8.642***	7.917***	8.309***	9.448***	0
	(76.18)	(70.76)	(60.81)	(53.52)	(31.97)	(.)
$\text{Democdyad}_{ji,t-1}$	-1.295***	-1.710***	-1.071***	-1.629***	-0.583***	-3.881***
	(-12.80)	(-14.26)	(-8.71)	(-10.26)	(-3.03)	(-6.41)
$\log(\text{Trade\_dep}_{ji,t-1})$	-0.0615***	-0.102***	0.0588***	-0.0307	0.306***	0.132**
	(-3.58)	(-5.47)	(2.65)	(-1.21)	(8.51)	(2.34)
$\text{MID}_{ij,t-1}$	1.606***	0.691	2.307***	1.261*	2.177***	0
	(4.33)	(1.50)	(5.72)	(1.74)	(5.03)	(.)
$\text{Alliance}_{ij,t-1}$		-0.0648		-0.0133		1.319***
		(-0.30)		(-0.04)		(3.24)
Constant	-6.664***	-7.033***	-5.399***	-6.349***	-3.658***	-4.867***
	(-36.61)	(-34.16)	(-25.33)	(-23.75)	(-13.05)	(-9.69)
	0.124***	0.116***	-0.111***	-0.110***	-0.128***	-0.335***
	(8.56)	(7.45)	(-6.42)	(-5.32)	(-5.58)	(-4.24)
	RE	RE	RE	RE	RE	RE
/lnsig2u	-0.370	-0.336	-1.374**	-0.885**	-12.18	-6.933
	(-1.55)	(-1.41)	(-2.31)	(-2.12)	(-0.56)	(-0.52)
N	191987	173661	129059	111639	75211	47960

t statistics in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$

Appendix V.F. Random-Effect Regressions of PTA withdrawal on Relative Technological Capacity

	F.4(1)	**F.4(2)**	**F.4(3)**	**F.4(4)**	**F.4(5)**	**F.4(6)**
	$\text{Relative\_tech}_{ji}^{(1)}$		$\text{Relative\_tech}_{ji}^{(2)}$		$\text{Relative\_tech}_{ji}^{(3)}$	
PTA withdrawal $_{ji,t}$						
$\text{Relative\_tech}_{ij,t-1}$	**-0.0967*****	**-0.0942*****	**-0.0561*****	**-0.0579*****	**-0.0381**	**0.114**
	(-2.82)	(-2.68)	(-2.71)	(-2.67)	(-0.38)	(0.42)
$\text{Relative\_tech}_{ij,t-1}^{2}$	**-0.0353*****	**-0.0347*****	**-0.00861*****	**-0.00811*****	**-0.0163**	**0.0120**
	(-3.96)	(-3.80)	(-3.02)	(-2.75)	(-1.02)	(0.25)
PTA withdrawal $_{ji,t-1}$	8.769***	8.556***	8.853***	8.621***	12.69***	0
	(57.40)	(54.62)	(49.71)	(45.65)	(17.84)	(.)
$\log\left(\text{Trade\_dep}_{ji,t-1}\right)$	0.333*	0.374**	-0.248	-0.159	-1.205*	0
	(1.92)	(2.13)	(-1.22)	(-0.76)	(-1.65)	(.)
Democ dyad $_{ji,t-1}$	0.00106	0.00283	-0.0138	-0.0235	0.0962	0.121
	(0.03)	(0.07)	(-0.44)	(-0.70)	(0.89)	(0.79)
$\text{MID}_{ij,t-1}$	0.481	0.493	1.433	1.261	1.394	0
	(0.68)	(0.66)	(1.60)	(1.34)	(0.47)	(.)
$\text{Alliance}_{ij,t-1}$		-0.221		0.326		0
		(-1.06)		(1.26)		(.)
Constant	-6.190***	-6.048***	-6.108***	-6.192***	-7.340***	4.038***
	(-20.28)	(-17.75)	(-19.15)	(-17.81)	(-6.91)	(3.52)
	RE	RE	RE	RE	RE	RE
/lnsig2u	-11.87	-12.65	-11.66	-11.96	-12.47	-12.23
	(-0.70)	(-0.85)	(-0.76)	(-0.64)	(-0.18)	(-0.03)
N	56,183	48,738	47,896	40,032	28,832	217

t statistics in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$

Appendix V.G. Random-Effect Regressions of Respondent Case on Relative Technological Capacity

	G.4(1)	G.4(2)	G.4(3)	G.4(4)	G.4(5)	G.4(6)
	$\text{Relative\_tech}^{(1)}_{ji}$		$\text{Relative\_tech}^{(2)}_{ji}$		$\text{Relative\_tech}^{(3)}_{ji}$	
Being complained $_{ji,t}$						
$\text{Relative\_tech}_{ij,t-1}$	**-0.00472**	**-0.0142**	**0.000539**	**-0.0114**	**-0.0508**	**-0.130**
	(-0.20)	(-0.59)	(0.03)	(-0.55)	(-0.80)	(-1.64)
$\text{Relative\_tech}^2_{ij,t-1}$	**-0.0137*****	**-0.0159*****	**-0.00530***	**-0.00531***	**-0.0446*****	**-0.0456****
	(-3.03)	(-3.35)	(-1.83)	(-1.76)	(-2.89)	(-2.56)
$\text{Democdyad}_{ji,t-1}$	1.325***	1.017***	1.165***	0.674**	0.731*	0.0445
	(5.71)	(4.30)	(4.20)	(2.39)	(1.68)	(0.10)
$\log\left(\text{Export}_{ij,t-1}\right)$	0.376***	0.385***	0.349***	0.342***	0.312**	0.362**
	(5.24)	(5.09)	(4.00)	(3.67)	(2.27)	(2.30)
$\log\left(\text{Export}_{ji,t-1}\right)$	0.212***	0.202***	0.296***	0.293***	0.230*	0.168
	(3.09)	(2.79)	(3.44)	(3.18)	(1.70)	(1.10)
$\text{MID}_{ij,t-1}$	-0.144	-0.129	-0.263	-0.205	-0.249	-0.135
	(-0.36)	(-0.31)	(-0.61)	(-0.45)	(-0.41)	(-0.19)
$\text{Alliance}_{ij,t-1}$		1.201***		1.210***		0.779
		(6.12)		(5.12)		(1.62)
Constant	-5.614***	-5.632***	-5.604***	-5.543***	-5.552***	-5.235***
	(-25.56)	(-25.84)	(-21.56)	(-22.15)	(-13.80)	(-12.45)
	RE	RE	RE	RE	RE	RE
/lnsig2u	0.785***	0.471	0.781***	0.461	1.895***	1.589**
	(2.94)	(1.63)	(2.76)	(1.48)	(3.99)	(2.54)
N	59,149	50,743	45,827	38,662	32,240	20,146

t statistics in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$

VITA

Tianjing Liao was born and grew up in Sichuan (Szechwan). She attended Zhejiang University and received a Bachelor of Science degree in Physics. She attended Peking University and received a Master of Law degree. After that, she was a lawyer. She found herself interested in politics and decided to study politics. She attended University of Tennessee to pursue a Doctor of Philosophy degree in Political Science and a Master of Science degree in Statistics.