A MULTI-METHOD SOCIO-POLITICAL ANALYSIS OF THE NUCLEAR DEVELOPMENT IN EAST ASIA

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A dissertation submitted in partial fulfillment of
the requirements for the degree of

DOCTOR OF PHILOSOPHY

WASHINGTON STATE UNIVERSITY
Department of Sociology

MAY 2017

To the Faculty of Washington State University:

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Abstract

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May 2017

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This dissertation research sheds light on the social factors contributing to the development of the nuclear industry. The guiding theoretical framework comprises two approaches: the world systems analysis and the theory of the developmental state. First, the world systems analysis provided a concise image of a hierarchically ranked inter-state system which strongly represented the relative strength and weakness of the countries and highlighted the unequal exchange between the core and peripheral states. Second, the literature of the developmental state indicated that state autonomy which was embedded in specific structural conditions strongly influenced the consequences of economic development.

Three methods were applied to analyze the global nuclear industry: event history analysis, social network analysis, and comparative historical analysis. First, by measuring the time interval from the start of construction to the commercial operation of a nuclear power plant, the event history analysis evaluated the postponement and efficiency of developing the nuclear industry and tested the effects of social factors. Second, by illustrating the global network of nuclear reactor transactions, the network analysis assessed the core/periphery positions of nations

pursuing nuclear development. Finally, by presenting the time sequences of the nuclear development in the East Asian countries, the comparative historical analysis further elaborated the institutional conditions of developing nuclear power.

Overall, this research found that the global nuclear development showed an uneven distribution along with the hierarchical order of the modern world system. The results indicated that developing countries positioned on the peripheral level of the world system could not gain the premium of importing nuclear technology. Instead of achieving self-sufficiency and industrialization, these countries stagnated in the dependency on the core countries. Although East Asian countries had significant growth in developing nuclear power, their developmentalist mode was not universally applicable to all nations and thus should be considered a product of historical contingency interacting with specific structural conditions such as the Cold War rivalry.

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CHAPTER ONE

INTRODUCTION

The Fukushima disaster has renewed interest in the nuclear industry and policies. There is no consensus to abandon nuclear power; thus, the debate surrounding nuclear technology continues. This dissertation strives to explain the social factors contributing to the development of and continued support for the nuclear industry.

As the debate continues, nuclear power has been considered in a bifurcated way. On the one side, it has been viewed as an infrastructure that is positive to national development. On the other hand, people are concerned regarding the negative effects generated from the potential radioactive pollution and large scale nuclear disasters. However, by being preoccupied with the opposition between development and risk, a key question has been left unanswered: Is it really development for all the devoted countries to develop nuclear power and the related infrastructure? Instead of immediately discussing the either-or myth of the opposition between development and risk, this research starts with discussing the skepticism on the habitually presumed developmentalist mindset.

To achieve a better understanding of this issue, this research strives to move beyond past theories and empirical research in three respects. First, the sociological literature has placed primary emphasis on the anti-nuclear movement. Second, past research has focused on the western advanced industrial economies. Third, there has been an over-simplification of the relationship between nuclear weapons and the civilian nuclear industry.

First, although nuclear power has long been a topic in political and social sciences, the sociological literature has been primarily concerned with the anti-nuclear movement, and the

nuclear industry itself is separated as just the opposite of anti-nuclear movement. While the study regarding contentious politics and the anti-nuclear movement helps explain when and where nuclear programs are phased out, it says nothing regarding why and how the nuclear programs succeed and thrive in many other countries. To address this deficit, this research highlights the analysis of the nuclear industry, and considers the development of the nuclear industry as a corresponding result of the industrial policy. In short, this research shifts the focus from the anti-nuclear movement to the industrial policy related to the nuclear programs.

Second, to a large extent, prior research on nuclear politics has focused on the United States and Western Europe. However, the development of the nuclear industry after 1990 is disproportionately concentrated in East Asia. Despite witnessing or even experiencing the Fukushima catastrophe, most East Asian countries have no immediate plans to phase-out nuclear technology. In fact, these East Asian countries are eagerly exporting nuclear technology to other developing countries, or even more strikingly, selling it back to the developed countries. For example, in addition to exporting to the United Arab Emirates (UAE), Japan and South Korea are competing in Southeast Asia. More astonishingly, in 2015, the United Kingdom, as an old western advanced industrial economy, unprecedentedly signed a contract for importing a nuclear reactor from China, a latecomer in the nuclear industry. To explain these emerging trends, it is necessary to study the nuclear policy in non-Western political economies, especially the East Asian countries with strong insistence on nuclear power. In short, this research refocuses the research scope by extending to the global level and including the whole world system.

Third, there has been a tendency to emphasize direct connections between nuclear weapons and nuclear power. This link was pronounced for the United States, the Soviet Union, and other early nuclear powers. In addition, research into nuclear power has continued to

emphasize this linkage with a concern over the proliferation of nuclear weapons. This concern played a major role in recent negotiations between the United States and Iran, which reached a provisional agreement on Iran's construction of the nuclear power plants. Nevertheless, the assumption that nuclear weapons and nuclear power are intertwined distorts dynamics in East Asia. The two nations that have experienced the most rapid and sustained growth in the nuclear industry, Japan and South Korea, have never possessed or manufactured nuclear weapons. Although successfully developing and manufacturing nuclear weapons early in 1960s, China did not pursue civilian nuclear programs until late in 1980s, which is more similar to an ambitious enterprise conforming to its market-oriented reform than a cover-up for developing or manufacturing nuclear weapons. Because the historical experience of East Asian cases oppose the assumption that the nuclear power industry is pursued to develop nuclear weapons, this dissertation challenges this widespread assumption and provides insight into contemporary efforts to develop nuclear power capabilities.

The theoretical framework that guides this research borrows from two seemingly competing approaches and attempts to weave a productive synthesis. On the one hand, considering the nuclear programs as an enterprise significantly affected by the state's developmental strategy and industrial policy, this research draws on the developmental state literature. This framework is widely used to analyze the East Asian socio-political configuration, their rapid industrialization after World War II, and their astonishing economic growth. In contrast to both liberal market-dominated polities and socialist regimes, developmental states are marked by high state autonomy, bureaucratic rationality, and strong state planning to guide a market-oriented economy. In pursuing research into nuclear power in the East Asian countries, this dissertation examines if the nuclear industry is institutionally favored by the developmental

state. On the other hand, the nuclear programs of East Asian nations can also be seen in the context of international trade flows and being structurally influenced by the hierarchy of the world system. For this reason, this research is also influenced by the world systems theory. Instead of attributing the success or failure of the industrial policy to the political will of the specific state, the structural analysis of the world system considers relationships among nations, foreign dependencies, the international division of labor, and international inequality. This research examines if and how the international trade of the nuclear power reactors is influenced by the hierarchical positions in the world system and distributed in terms of the unequal exchange between the core and peripheral countries. In other words, to achieve a comprehensive understanding of the development of the nuclear industry, this dissertation considers (1) the endogenous perspective, the developmental state and the industrial policy it pursues, and (2) the exogenous perspective, the world system and the international context in which these states are situated. These two emphases supplement one another. This research determines how the external, international context conditions the developmental strategy within each state; it also examines if states act at some historical conjunctures; thus this research differentiates their paths of developing nuclear programs as developmental strategies for freedom from foreign dependency. Methodologically, this research combines several methods. Comparative historical analysis is used to highlight the convergence and divergence among East Asian states. In addition, this research uses two additional tool-kits: the event history analysis and the social network analysis.

In general, this research finds that the global nuclear development shows an uneven distribution along with the hierarchical order of the modern world system, and that the developmentalist mode illustrated in the development of nuclear power is not universally

applicable to all nations. The results indicate that the developing countries positioned on the peripheral level of the world system cannot gain the premium of importing nuclear technology. Instead of achieving self-sufficiency and industrialization, they stagnate in being dependent on the core countries.

The theories and methods used for this research are reviewed in Chapter 2. Inspired by the discussion of the rapid economic growth in East Asia, this research considers the possibility that the thriving nuclear industry in East Asia is the product of the developmental state. With the core idea of the embedded autonomy (Evans 1995), the developmental state is distinctive for its strong capability to plan and act, a capability made possible by its bureaucratic rationality and integrative organization. The distinctiveness of the developmental state goes beyond autonomy. Instead, this dissertation research extends the discussion to the social embeddedness supporting or constraining such autonomy. Recent research has theorized embeddedness in terms of social networks (Granovetter 1985; Krippner, Granovetter, Block, Biggart, Beamish, Hsing, Hart, Arrighi, Mendell, Hall, Burawoy, Vogel, and O'Riain 2004; Krippner 2002; Krippner and Alvarez 2007). This approach has been extended to the developmental state; for example, scholars are beginning to theorize and emphasize networked governance (Block 2008; Block and Keller 2011; Negoita 2014; Negoita and Block 2012; O'Riain 2004; O'Riain 2011). To date, networked governance has most often been used as an illustrative metaphor. In contrast, this dissertation presents an approach to develop and use a tangible, falsifiable measure of networked governance. To achieve this result, this research borrows ideas and methods from researchers who have pursued a network analysis of the world system (Clark 2008; Clark 2010; Kentor 2000; Kim and Shin 2002; Lloyd, Mahutga, and De Leeuw 2009; Mahutga 2006; Mahutga and Smith 2011; Nemeth and Smith 1985; Smith and White 1992; Snyder and Kick 1979). The literature

analyzing the world system makes a compelling case (theoretical and empirical) that it is difficult for nation-states to move from the periphery (or semi-periphery) to the core. Scholars emphasizing the network structure of the world system consistently point to the developmental states of East Asia as exceptions. Specifically, these states are not only distinctive in how they are governed; they are also distinctive for moving from the periphery to the core. In addition to synthesizing theories of the developmental state with network analyses of the world system, this dissertation research draws on comparative historical research to provide a detailed interpretation and examination of the nuclear ambitions and accomplishments of East Asian states.

Chapter 3 presents an event history analysis of the nuclear industry. This analysis is not restricted to East Asian developmental states. Instead, by including all nations that pursued nuclear power, this analysis provides a comparison and highlights the distinctiveness of East Asian states. In this analysis, the dependent measure is the time interval from the start of construction to the commercial operation of the nuclear power plant. Thus, the focus is on the postponement and efficiency of developing the nuclear industry and allowing an empirical test of factors highlighted in prior research. Independent variables include foreign dependency, possession of nuclear weapons, and the degree of democracy. In addition, each nation is sorted into one of four regimes: the old capitalist democracies, the former socialist states, the developmental states, and the other developing countries. Finally, to test claims that nuclear development is influenced by the geopolitical context timing, a dummy variable for the Cold War period is included,

Chapter 4 presents the findings of a social network analysis that examines the clustering and dispersion of nuclear countries. Inspired by the network analysis of the world system, this research assesses the core/periphery position of nations pursuing nuclear development.

In Chapter 5, a comparative analysis of the nuclear policy in four East Asian countries, Japan, South Korea, Taiwan, and China, is conducted to elaborate the differences and similarities in the institutional conditions. With the more detailed narratives concerning the nuclear policy, this research complements the results gained from the quantitative analysis performed in the previous chapters.

CHAPTER TWO

COMPETING THEORIES: DEVELOPMENT OR DEPENDENCY

1. Introduction: Nuclear Politics–Development or Under-Development?

Nuclear energy has been typically analyzed from the perspectives of political economy of industrial policy and social movements. Both perspectives inspire many studies on nuclear policy and thus enhance the understanding of the social implications of nuclear energy. However, these perspectives have been found to over-emphasize Western democracies and pay less attention to the development of global nuclear industry. To fix these problems, this research borrows from and finally synthesizes two alternative theories: the world systems theory and the developmental state theory.

Political Economy of Industrial Policy: Structural Contradictions and Historical Conditions

First, to analyze the general trends of developing nuclear power, the political economy of industrial policy focuses on the structural conditions of nuclear industry and the inevitable contradictions generated by these conditions. Campbell (1988) conducts a case study on the nuclear industry in the United States, and determines that its collapse can be attributed to many institutional constraints. These institutional constraints come from both state and economic structures and are also produced by the intersection of these two structures. On the one hand, Campbell stresses that the state autonomy is constrained or empowered by the given political institutions such as partisanship, laws, regulations, and jurisdiction. The U.S. state apparatus is federated, fragmented, and decentralized; thus, its ability to intervene in the pro-nuclear policy is

limited. As many administrative agencies check and balance each other and the process of decision making is permeated by numerous interest groups, the efforts of the state for promoting nuclear industry are obstructed by the plural democracy. In addition, the role conflict between promoting nuclear energy and monitoring nuclear industry prohibits a proactive engagement of the state in the nuclear enterprises. On the other hand, Campbell also stresses that the structure of economy highly influences the development of nuclear industry. As faced with a highly competitive market, the private corporates in the nuclear sector cannot make long-term plans but only can pursue short-term profits. Given the uncertainty produced by the intense competition, the nuclear reactor vendors are keen on looking for increasingly larger designs instead of standardization. Although this short-term strategy helps specific corporates obtain comparative advantages, it raises the cost across the whole sector and finally forms a huge financial burden. Finally, concerning the interaction between state and economic structures, the laissez-faire tradition and anti-trust regulation extinguish the opportunities for the administrative sector to intervene in the competition and integrate the nuclear sector.

In addition to determining that there is an inherent trend of nuclear policy toward structural contradictions, scholars also indicate that the historical origin of nuclear industry was inseparable from military considerations regarding nuclear weapons. To explain why the light water reactor (LWR), which has no clear technological superiority than the heavy light reactor (HWR), finally won over in the world market, Cowan (1990) attributes LWR's triumph to the path dependence on military considerations. He indicates that the LWR was first applied to power generation for the military vehicles. Due to the arm race with the USSR and the anxiety of catching-up, the United States hastily choose the easy way to transfer the LWR design to the civilian power generation rather than invest more on the R&D of the HWR, which is assumed as

more time-consuming. McLauchlan and Hooks (1995) also indicated that the nuclear weapons project and the nuclear arm race between the two superpowers during the Cold War era fostered and supported the huge military-industrial-science complex. However, as the Cold War gradually ended in the 1980s, the nuclear industry, which has always been a major part of the huge complex, was inevitably challenged by public discontent.

In sum, the political economy of nuclear industry indicates that there are structural contradictions inherent in the development of nuclear power. The growth of nuclear industry is also inseparable from the military need of developing nuclear weapons, and its collapse can be expected as the post-Cold War civil society casts more and more skepticism on the military-industrial-science complex.

Social Movements Research: The Lineage from Anti-War to Anti-nuclear Movements

The other typical entry to the research on nuclear policy is social movement. As sharing the assumption of the close connection between civilian nuclear industry and nuclear weapons, scholars usually assume that there is a connection between the anti-war movement and the anti-nuclear movement. With empirical evidence from the United States, Rosa and Clark Jr. (1999) indicated that the anti-nuclear movement was directly linked to the anti-war protests and established a sound basis. Their case study of the United States shows that there is an unresolved structural contradiction between nuclear programs and democracy: the military-industrial-science complex embodied in the nuclear programs inevitably conflicts with the civil society and thus confronts an inherent decline of the public trust which gradually erodes its governing legitimacy (Rosa and Clark Jr. 1999). In other words, the grievance generated from the anti-war and civil

right movements toward the governments is transformed into available resources for the anti-nuclear movements.

Thus, with the concern of the transformed social forces inherited from the anti-war and civil right movements, sociologists have focused on social movements to stop nuclear power. Under the perspective of social movements, nuclear energy has been assumed as an object fueling public discontent and being closely linked to huge risks. With real-political concerns, nuclear policy is usually taken as the consequences of anti-nuclear movements. To analyze how states reject or decline nuclear power, research on anti-nuclear movement (Joppke 1991; Joppke 1992; Joppke 1993; Kitschelt 1986; Koopmans and Duyvendak 1995) attributes the abandonment of nuclear power to the political climate within separated nation-states. With the comparison of the anti-nuclear movement in different countries, several scholars stress that the rise and fall of the movement are highly influenced by the domestic political opportunity structures (POS). State structures such as state capacity and political alliance first affect the chances of anti-nuclear mobilization. The political arena and political partisanship are established as rules of games and the boundaries of political participation are defined. In addition to state structures, political opportunity structures include political culture and resources of competing movement organizations.

In general, the social movements research on nuclear policy undoubtedly shares the structural perspective of the political economy approach, but it centers more on the political mobilization against the nuclear industry.

Shared Assumptions and Problems in the Given Literature

Both approaches provide following research paradigmatic frameworks to study the development of nuclear industry, but they also share some assumptions that limit developing a more comprehensive understanding.

First, there has been an over-emphasis on Western democracies. Previous studies focus on only the North America and Western Europe and neglect the rest of the world. However, rather being an endemic problem only in the western advanced industrial economies, the development of nuclear industry after 1990 increasingly spread out to the developing areas such as East Asian countries. These political regimes with thriving nuclear development have substantially different state-society relationship from the old democracies. For example, with a detailed historical comparison between the United States and South Korea, Jasanoff and Kim (2009) find that their nuclear programs are driven by significantly different political purposes and thus differentiate the extent of tension between the state and civil society. In the United States, due to the self-positioning as the world police, much more attention is paid on how to control the negative effects of nuclear power. This policy presumption inevitably reinforces the image of losing-control and subtly sets the U.S. nuclear program as the antithesis of public fear. In contrast to the containing policy prioritizing safety and prevention, the South Korean state advocated nuclear power as a proactive development project for state-building and national independence. With eagerness to strive for autonomy and protection from external threats, the state and the dissents reach a covert and conditional consensus on the necessity of developing nuclear power. This comparison indicates that regarding nuclear development, there is not only a distinction between fast and slow tracks, but also a variety of different strategies and conditions. It also re-casts questions on the West-centered framework and makes us turn to examine the

affinity between the development of nuclear power and the East Asian political regimes. In addition, the over-emphasis on Western democracies makes researchers ignore that nuclear development is not only a domestic policy option, but also an international exchange involving more than one state. Consequently, the global dimension of nuclear development has been totally ignored.

Second, they assume that connections between military weapons and civilian nuclear power are necessary and that a large-scaled anti-nuclear movement must come after a large wave of anti-war protests. However, as shown in the non-Western cases, both connections are weak or even non-existential. In the East Asian cases, the growth of the nuclear industry continues unabated after the transition to democracy and end of the Cold War.

Third, sociologists have focused on social movements to stop nuclear power. However, social movement opposition is weak in some countries or has nothing to do with anti-war movements. In the perspective of anti-nuclear movements, nuclear industry itself is usually simplified as the opposite of anti-nuclear movements. The analysis of nuclear industry is left in blank, or treated as a constant in each country. In contrast to such assumption, nuclear energy has been consensually accepted in many developing countries with differentiated levels of development.

To resolve these research problems and enhance our understanding of nuclear development, we need to address the missed analysis on the global level, the variety of connections between nuclear weapons and civilian nuclear industry, and how anti-nuclear movement institutionalized in different contexts of contentious politics. For this purpose, this study borrows from two competing theoretical traditions: the world systems theory and the theory of the developmental state. On the one hand, in contrast with the domestic-centered

perspective, we treat the development of nuclear power as not only domestic business, but as international trades. As international trades are involved in the following analysis, the research borrows from the dependency theory or the world systems theory focusing on the unequal exchange between the core and the periphery. On the other hand, in contrast with the West-centered perspective, we include the recent expansion of nuclear industry in East Asia into the following analysis for grasping the states of the late but quickly catching-up nuclear users. Based on their trajectories of state formation and rapid economic growth, social scientists develop the concept of the developmental state to refer to these countries. While the world systems theory focuses on structural constraints external to states, the developmental state theory places emphasis on autonomy, capability, or agency emerged from within states. Rather than accepting this seeming contradiction between the two perspectives, we work to find a breaking point through which we can reach a theoretical synthesis.

In the following paragraphs, we first introduce the network analysis of the world system and then the theory of the developmental state. Finally, considering that the former highlights the factors exogenous to the state but that the latter stresses endogenous, we discuss if it is possible to reconcile the two perspectives for generating a more encompassing analytical framework.

2. World Systems Analysis and Social network Analysis

Opposing the theory of modernization and concerning the unequal exchanges on the global level, the world systems theory provides a concise image of a hierarchically ranked inter-state system that strongly represents the relative strength and weakness of the countries (Wallerstein 1974). More than figuring out the under-development caused by the foreign dependency (Amin 1976; Cardoso 1977; Evans 1979; Frank 1967), the world systems theory

further shows the world inequality in terms of general social spaces, consisting of the trichotomy of core-semiperiphery-periphery.

Breakthrough Positions in the World System? Semi-periphery and China

After addressing that the dominant structure of the modern world system consists of the unequal exchange between the cores and peripheries, a following theoretical question has been raised: Does the gap within the world system go toward convergence or divergence? In other words, scholars are interested in determining if the world system becomes more equal or uneven (Clark 2016).

Scholars working on the mobility of the world system focus on the semi-periphery, which intermediates between the core and periphery. The intermediate position can be easily imagined as a ladder for those at bottom to climb up or a slide for those on top to go down. On the other hand, it may also play the role of an invisible ceiling, legitimating the myth of national development. Although the semi-peripheral states attempt to resist the exploitation from the core states, at the same time, they may extract the resources from the peripheral states and exacerbate their marginalization (Arrighi 1990). Considering the paradoxical roles of the semi-periphery, the quest now determines if the intermediate position is a mechanism of equalizing wealth or reproducing inequality.

With the initial quantitative analysis, unfortunately, the hierarchical structure has been durable and stable. Only seldom cases can achieve upward mobility, and most were East Asian countries, such as Japan, South Korea, and Taiwan (Arrighi 1990; Arrighi and Drangel 1986). In other words, although the semi-peripheral states illustrated sufficient growths of their national

wealth, they were exceptional cases rather than an applicable mode of national development for the peripheral states (Arrighi 1990).

Instead of totally denying the existence of upward mobility, other scholars keep enriching the concept of semi-periphery and further examining where the upward mobility may conditionally concentrate (Clark 2008; Clark 2010; Clark 2016; Clark and Beckfield 2009; Mahutga 2006; Mahutga and Smith 2011; Nemeth and Smith 1985; Smith and White 1992; Snyder and Kick 1979). These efforts began with the pursuits of delimiting the boundaries of the trichotomy. Snyder and Kick (1979) first use the network analysis to concretely cluster the states into blocs along with the trichotomy of core-semiperiphery-periphery. They show that being positioned as semi-peripheral and peripheral is harmful to a state's economic prospects. Nemeth and Smith (1985) revise the model of Snyder and Kick (1979), dividing the semi-periphery into upper and lower tiers. This re-clustering narrows the core as a more homogenous and coherent top cluster and highlights the semi-periphery revealing greater competitions and tensions. Considering the effects of the globalization and the regional integration, Kim and Shin (2002) provide a benign perspective on the changing international trade network, indicating that the density of the international trades' network is significantly increased by the globalization; it is also decentralized by the increasing share of the member states in the middle strata, i.e., the semi-peripheries. They show that the average geodesic distance between the nodes (i.e., the states in the world system) significantly decreases along with the expansion of the globalization, implying that the isolation between any two countries declines. In contrast, Mahutga (2006) illustrates another story by arguing that even the introduction of new international division of labor can be the reproduction of the unequal structure of the world system. Thus, there is more persistence than upward mobility in the world system. The successful cases of upward mobility

are rare, and the hierarchical structure of the world system is invariant. With the results showing high stabilities in the components of the core and the periphery, Mahutga (2006) refutes the optimistic view considering that the globalization can level the field of the world system. With further examination, Clark (2010) synthesizes both standpoints. He indicates that both the upward mobility of the semi-periphery in Kim and Shin (2002) and the halting status of the periphery in (Mahutga 2006) certainly co-exist, but they are combined to form an increasing divergence in the world system, making the structural inequality persist. Thus, Clark (2008; 2010) refutes the presumption that the connections networking the states must be the dependent relationships disfavoring the developing countries and shall be discarded unconditionally. Instead, for the developing countries, the dyad relationship is not only determined by the volume of trade flows but also by the strategical position on the international trade network (Clark 2008; Clark 2010).

However, the semi-peripheral states are not the only part of the world system irritating the debate about the mobility. Scholars find that the total amount of global wealth inequality has declined in recent decades, but the decline is not contributed by the development of the least-developed countries (LDCs). Instead, the rise of China's economic power has led to the effect of equalizing the world wealth hierarchy (Arrighi 2007; Hung 2009; Hung 2015; Hung and Kucinskas 2011). In contrast to the East Asian semi-peripheral states moving upwardly in the world system hierarchy early in the 1970s and through the 1980s, China kept a far distance from the capitalist world economy until the late 1970s. Although it is still too early to announce the end of the U.S. hegemony, China has already been one of the centers of gravity in the world system and has made a huge comeback in climbing up the global wealth hierarchy.

In general, for most of the time, the top and bottom levels of the world system are kept intact. The East Asian countries are the rare cases that can move upwardly in the system.

Keep the Relational Thinking: The Synthesis of the World Systems Theory and the Network Analysis

Based on the systematic thinking on the configuration of the capitalist world economy, Wallerstein (2000) calls into question the concept of societal development, which places emphasis on the developing strategies for looking for a single nation state's development without considering the dynamics and interconnections on the global level. This emphasis on the systematic framework of analysis also reveals the need to keep the relational thinking in the world systems analysis, and network analysis can perfectly meet this need

In fact, network analysis has been a method often used in the world systems analysis (Lee 2009). First, the network analysis of the world system challenges the endogenous theories considering only the domestic factors within each political-economy entity and brings in more structural and relational thinking into the models (Lloyd, Mahutga, and De Leeuw 2009; Nemeth and Smith 1985; Snyder and Kick 1979). In this dissertation, the economic performances are considered as determined by not only the adaptation of the states, but also the international environments and interactions external to the individual states. Moreover, as countering the literature stressing on the state strategies for the comparative advantage in the competitive international market, the network analysis of the world system can also provide an alternative to the neo-classical doctrine that attributes the economic performance only to the openness to the liberal market and the degrees of accepting the market-oriented ideology. With the concepts such as structural equivalence and centrality power (Borgatti 2005; Borgatti and Everett 1992;

Wasserman and Faust 1994), network analysis can effectively elaborate the structural positions of the states locating in the world system, efficiently evaluate the relationships between the states, and soundly test if unequal exchange exists and persists.

In addition, as the core-periphery relationship may be based on not only economic transactions, but also other forms of domination, network can be the best conceptual tool to elaborate the power relationship behind each form of exchange. In contrast to measuring the global wealth hierarchy by using only indicator of economic performance such as GDP per capita (Arrighi and Drangel 1986), network analysis can be applied to analyze any type of interconnection implying different forms of power relationship. By using network analysis, we can understand how the power relationship is interconnected by a specific medium such as international trade, diplomatic interaction, or even nuclear transaction. In the network analysis of the world system, international exchanges are translated into commodity chains, and a single commodity chain can bear multiple social meanings. To rethink the qualities of the global commodity chains, scholars suggest that the network ties embodying the commodity chains can be attached with the image of the rhizome borrowed from the actor-network theory (ANT), highlighting the connections of heterogeneous qualities (Callon 1990; Grabher 2006; Hess 2004). For example, Quark and Slez (2014) use the international transactions of cotton to illustrate how the power relationship changes along with the Cold War rivalry. With the specific connection to the apparel industry considered as intensively engaged in the "new international division of labor (NIDL)", the international transactions of cotton map two distinct networks perfectly representing the geopolitics before and after the Cold War: the first one illustrates the single core played by the United States, and the second one marks the bi-core structure consisting of both the United States and China. In our case, it has been determined that nuclear power inevitably

oscillates between civilian and military uses. This concern presupposes that the international trades of the nuclear technologies cannot be viewed as usual economic activities immune to political interventions, but they should be viewed as a vessel containing multiple meanings and relationships. As an industrial policy potentially bearing the goal of state-building, the nuclear programs reflect the ambivalent nature of state-building involving multiple forms of social powers. To elaborate the entanglement of the multiple forms of social powers to avoid the reductionism of the economic determinism, scholars have proposed many classifications and categorizations. For instance, illustrated in the terms of a network of interacting powers (Mann 1986), a dialect between capital and coercion (Tilly 1992), and a form of meta-capital or state capital embodying both physical and symbolic violence (Bourdieu 1994). As stressing on the differentiated role of the military power, scholars also specifically claim that war mobilization is highly associated with economic growth and reorganization of political power (Hooks and Rice 2005). With the theoretical concern of the military-industrial complex (Mills 1956), the military sectors' involvement in the economic activities of the civilian industrial sectors can be traced in the industrial policies of the United States. From post-WWII era till recently, even the United States has long been universally recognized as having a prevalent liberalist ideology for minimizing the state intervention in the economic market (Block 2008; Hooks 1991; Hooks and McQueen 2010; Keller 2011). In addition, the nuclear programs are just the most typical case embodying the war-mobilizing governance with the mingling of militarization, science, and the state planning (Hooks and McLauchlan 1992; McLauchlan and Hooks 1995). In summary, to determine the power relationships among the countries using and transacting nuclear power, the trades of the nuclear power plants potentially implying both civilian and military interests are measured as the ties networking the transacting countries.

In general, the network analysis implies that the major determining factors are external to the individual nodes, being structured by the unequal exchange between the core and the periphery. This approach provides an effective tool for concisely illustrating the power distribution in world system. However, as staying on the analytical level of inter-state structure exogenous to the individual states, the network analysis perfectly illustrates the dynamics of state mobility but provides no information about the strategies for each state to reach the positions. To understand how the agency works for breaking the structural constraints of the core-periphery relationship, we discuss the theory of the developmental state in the following paragraphs.

3. The Developmental State: Embedded autonomy and bureaucratic rationality

Although the political economy of industrial policy indicates the importance to investigate the state autonomy for developing nuclear power, the West-centered perspective obstructs the further understanding of the nuclear development in the rest of the world, especially the thriving nuclear users in East Asia. The nuclear program, as described by Campbell (1988), in the United States is obstructed due to the state's weak power relative to the market and the civil society. In contrast, the nuclear industry thrives in East Asia, especially in countries identified as the typical cases of the developmental state such as Japan (Johnson 1982), South Korea (Amsden 1989; Evans 1995; Woo 1991), and Taiwan (Wade 1990). This affinity between the developmental states and the nuclear programs thus leads the research to the direction of determining the characteristics of the developmental state are intrinsic to favor the establishment of nuclear power. Comparing to the federated, fragmented, and decentralized state depicted by Campbell (1988), the developmental state is highlighted by its organizational coherence, cohesiveness, and supremacy relative to the market and the civil society.

State-led Economy and Late-development

The developmental state is conceptualized for explaining the economic success in the East Asian countries, which are late industrialized but grow rapidly (Amsden 1989; Evans 1995; Wade 1990; Woo 1991). For the proponents of this ideal type of state formation, these late comers' catchup marks the successful state intervention into the global liberal market economy. As inspired by the state-centered approach and the calling for "bringing state back in"(Evans, Rueschemeyer, and Skocpol 1985), the theoretical focus is placed on the relative autonomy of the state apparatus, especially the bureaucracy. With such theoretical concern, Chalmers Johnson (1982) attributes the Japanese economic miracle to the proactive role of the governmental agency, the Ministry of International Trade and Industry (MITI). Based on the uniqueness of the Japanese case, he provides a trichotomy of states: the liberal market economy (the United States), the socialist planned economy (Soviet Union), and the developmental state considering both state planning and market imperatives (Japan). In his prototype of the developmental state (Johnson 1982; 1999), the most prominent element is the elite state officials and their planned intervention. The state autonomy is concretely demonstrated in the administrative discretion for intervening or even integrating private economic activities occurring in the market.

Weberianness as Bureaucratic Rationality

To identify the secret recipe of the excellent state capacity, Evans (1995) uses a seemingly paradoxical term embedded autonomy to refer the specific state-society relationship in the developmental regimes. On the one hand, with sufficient state capacity, which is typically signified as the modern Weberian bureaucracy, the state can reach its policy goals and fulfill the planning. On the other hand, the conflicts and contradictions between the state apparatus and the

social groups can be reconciled or repressed by setting specific political arrangements such as land reform. The state involvement with this embedded autonomy makes the development projects work on the right track and achieve the policy goals and economic growth, without the development falling into the wrong hands of the predatory state and finally losing comparative advantages on the international market. With their significant and rapid economic growth in a relatively short time, Evans marks South Korea and Taiwan as the prototype of the developmental state.

To elaborate the idea of bureaucratic rationality, Evans and Rauch (1999) conducted a cross-national comparison study to test the relationship between the Weberianness of rational bureaucracy and the level of economic growth. By surveying the civil service managers in less- and late-developed countries, they measured the Weberianness as the level of meritocratic recruitment and stable career ladder, which are further operationalized as if there is a formal exam for governmental employment and if the governmental employee's promotion and rewards are determined by his concrete performances. The results once again confirm that the states with the features of Weberian bureaucracy such as the East Asian Tigers significantly perform better on their economic performances and grow at a more rapid pace.

Weberianness as Nodal Agency

Following the thesis of bureaucratic rationality as a driving force of the developmental state, Chibber (2002; 2003; 2014) also stresses the importance of the internal coherence within the Weberian bureaucracy, but he moves the analytical level from the micro- to the meso- or even macro-foundation. Instead of focusing on the individualistic characteristics of the bureaucrats, he pays more attention to the inter-organizational coordination regarding the nodal

agency, which functions as the core element of a state's development project. With the comparison between South Korea and India, he attributes the former's superior economic performances to its nodal agency, the Korean Economic Planning Board (EPB), having a greater hierarchical status and political power over the other coordinating state agencies, and thus avoiding the inefficiency on information and investments. Although the Indian state has the similar ambition of state involvement and qualified bureaucrats for the tasks of state-building, its coordinating agency, the Planning Council, does not have power to overcome the inter-agency incoherence due to the potential competition among different ministries. In summary, the elaboration of the bureaucratic rationality stresses that in addition to the state capacity illustrated in the meritocratic traits of the rational bureaucrats, the inter-agency coherence within the state is a necessary condition of the embedded autonomy contributing to the success of the development projects.

By addressing that bureaucratic rationality and a nodal agency-led mode of decision-making, this literature determines where the state capacity may exist. Considering the affinity between the use of nuclear power and the East Asian developmental states, this research assumes that the specific state involvement, which is marked by the Weberian bureaucracy, may be a determinant mechanism for these states to settle down the infrastructure of the nuclear power. The emergence of specific technocracy may due more to the political imperatives of the state than to the efficiency or marketability of the specific science and technology. First, it involves the fostering of the Weberian bureaucrats or technocrats. With a thorough historical investigation, for example, Johnston (2009) indicates that the evolution of nuclear-engineering into an academic discipline, comparing to other profession and sciences has been a highly state-managed process. Due to the concerns with national security and military secrecy

prevailing in the Cold War, the U.S. state subsidizes the research institutes of nuclear science and strictly regulates the spreading of nuclear knowledge. In addition, in contrast to the British scientists considering that nuclear engineering is not an independent discipline from other basic sciences such as physics and mechanical engineering, the U.S. scientists leading the studies of nuclear power claim that nuclear engineering is a newly emerged science and should be established as a synthetic discipline. In contrast to other disciplines, nuclear engineering receives more state subsidies at its initial stage of establishment. Second, to examine if the developmental state associates with the nuclear programs with the concern of the inter-agency integration, we need to investigate the position and status of the nuclear sector on the inter-agency network. As shown in the U.S. case (Campbell 1988), the absence of a nodal agency prioritizing the nuclear program finally contributes to the stagnation of the nuclear industry. The schizophrenic roles of the nuclear authorities that must promote and control the nuclear industry at the same time inevitably offset the drive to invest more in the nuclear program. In contrast, Jasanoff and Kim (2009) indicate that the South Korean state established the nuclear program with a national consent. Regarding Chibber's (2002, 2003) depiction of the inter-agency integration within the developmental state, e.g., South Korea, it is reasonable to deduce that the nuclear program must be incorporated into the developmental strategy of the nodal agency that is able to unite the conflicting interests or externalize the negative effects without being politically challenged. In short, as an enterprise prone to state intervention owing to its special connections to the wars, developmentalism and market failure, the nuclear program tends to burgeon more rapidly in the developmental state whose state autonomy emerging either from the Weberian bureaucrats or the inter-agency coherence.

Bureaucratic Rationality or Balance-of-Power? – Or More Generally Speaking, "Embeddedness"

The explanations of the Weberian bureaucracy and the nodal agency seem to look for the determining factors endogenous to the state and attribute the results to single characteristics or subjects. However, more relational thinking has been bear in the literature of the developmental state. Not only the state autonomy but also the institutional contexts in which the autonomous state embeds are included into the following analysis. Instead of only sticking on the existence of a nodal agency, Chibber (2003; 2014) indicates that the analysis shall include the more general political configuration, the balance of power marked by the specific state-society relationships. With the comparison between India and South Korea, he stresses that in addition to the inter-agency integration within the state, another distinguishing factor is how the state gains the sanction power to persuade or even force the capitalist class to turn away from the rent-seeking in the import-substitution industrialized domestic market to the risky international trade. In contrast to the Korean business class failing to resist the state control under the martial law, the Indian capitalist class effectively mobilizes to organize business associations to boycott the trade policies against their monopoly of the post-import-substitution domestic market; thus, they avoid to be pushed into the fierce international business competition. With the comparison of the Asian Tigers (South Korea, Taiwan, Singapore, and Hong Kong) and the Latin American countries (Mexico and Brazil), Haggard (1990) indicates that the interplay between the international regime and the domestic institutions determines the direction of a country toward either export-led growth or import-substitution industrialization. As joining the U.S. containment policy under the Cold War, the Asian Tigers obtained access to international trade and have covert but powerful supports for their repression to both labor class and land class. Furthermore,

the docile labor force also fosters the growth of labor-intensive manufactures. Although casting skepticism on the bureaucratic rationality of the developmental state and illustrating the corruption of the crony-capitalist state, Kang (2002) highlights that the South Korean state and the capitalist class reach an alternative power balance, mutual hostage, moderating the rent-seeking of either the state or the capitalist class and redirecting the flow of capital to the developmental strategies rather than the predatory results. In summary, although all the elaboration of the developmental state works in concert with the theme of state autonomy, the embeddedness from which the autonomy emerges needs more attention in the discussion.

Changing Embeddedness

However, due to the Asian financial crisis outbreaks in 1997, the efficacy of the developmental state has been increasingly questioned in recent decades. Block and Evans (2005) argue that the prosperity of the East Asian developmental state in the last quarter of the 20th century is a product of institutional innovation embedding in a triangular relationship among state, economy, and civil society, which enabled the state to flourish before but stagnate now. In other words, embeddedness is not static but dynamic.

To examine the changing embeddedness of the developmental state, several conditions are considered. First, as the Cold War ends, the following triumph of the capitalist world against the socialist regimes and the prevailing of the neoliberal market ideology form a new landscape of international politics (Stubbs 2009; Williams 2014). As benefited from the U.S. containment policy in the Far East, the developmental state soothes its anxiety of national security while obtaining significant aid for its economic boom. How the newly emerging geopolitical competition affects the rivalries and alliances is still an open question.

Second, as the de-industrialization deepens and a more knowledge-based economy develops, the secret formula of the developmental state for manufacturing is in doubt (Evans 2014a; Evans 2014b; Williams 2014). Comparing to the industrial start in East Asia, it is now more believed that the comparative competitive advantage comes from innovation rather than imitation. It becomes urgent for the state to construct a system of innovation for keeping pace with the transformation. However, the state-led model of central planning does not necessarily fit these new social needs, and thus inevitably partially loses its legitimacy for monopolizing the power of decision-making.

Last, as interwoven with the mentioned conditions, the calls for democracy spread and are intensified (Evans 2002; Evans 2014a; Evans 2014b; Haggard 2004; Williams 2014). Although working effectively with strong state capacity, the developmental state has long been criticized for sacrificing political freedom to keep friendly and stable business climates. However, as new social needs emerge and systematic functions become highly complex, it is more and more difficult to use economic performance as the only panacea for all problems. For coping with such concerns, Sen (1999) claims that development shall be measured as freedom to incorporate human capability for pursuing basic social goods. Instead of defining development with a simplistic utilitarian perspective that substitutes everything to economic values, he proposes that five instrumental freedoms are essential to human development, functioning as both means and ends and interconnecting with each other: (1) political freedoms, (2) economic facilities, (3) social opportunities, (4) transparency guarantees, and (5) protective security. As repeatedly arguing the necessity of political liberty, which is illustrated in the form of political participation, he provides robust evidences showing that economic growth and expansion of political participation are positively associated rather than negatively associated, as what late

former Singapore Prime Minister Kwan-Yao Lee asserts in his "Asian Value." Borrowing Sen's understanding of development as freedom, Evans (2002; 2014a; 2014b) complements his analysis of embedded autonomy with a renewed capability-enhancing approach. Considering that building a robust system of innovation has been the most urgent task for the state eager to strive for development and growth, he asserts that the major source of innovation must be the human capability illustrated in the forms of knowledge or ideation. To enhance the capability which is beyond the scale of given state planning and not able to be generated form the close system of current bureaucracy, a more cross-section power sharing is required. In other words, comparing to the developmental state in the 20th century benefiting from its institutional innovation embedding in the Cold War stalemate and the manufacture-based economy, the developmental state confronting the neoliberal globalization and an economy requiring more flexible production must reinforce its state capacity by adjusting its composition to have more openness and networking more closely to the civil society.

In conclusion, scholars attribute the agency of the developmental state for getting rid of the status of under-development to the embeddedness consisting of not only the state-civil society relationship but also the international geopolitical contexts shaping the specific political regime. On the one hand, the Weberian bureaucracy and the nodal agency play the role of the selected agent grabbing the opportunities to enhance the state autonomy for effectively fulfilling their goals of development. On the other hand, the selection of the developmental states indicates that a friendly environment has existed along with the geopolitical opposition between the superpowers. In other words, the embeddedness refers not only the intra-state conditions, but also the international contexts. With the evolving idea of embeddedness, it also shows a trend that the embeddedness of the developmental state has been gradually represented as the network.

4. From Embeddedness to Network: To Position the Developmental State in the World System

Regarding the concept of embeddedness, it mostly refers to the context in which the subject embeds. For the developmental state, we have a double-layered structure, or double contexts on both the intra-state and international levels. On the intra-level, the structure refers to the socio-political structure where the Weberian bureaucrats moves up and down (Evans and Rauch 1999) or the inter-organizational domain of governmental agency (Chibber 2002; Chibber 2003; Evans 1995). On the international level, the structure refers to the Cold War confrontation which stimulated the drive toward the export-led growth or reinforced the need to monopolize the domestic market (Haggard 1990; Haggard 2004).

For studying embeddedness, it is a practical research strategy to embody it in the form of network (Emirbayer 1997; Granovetter 1985). Using nodes to signify actors and ties to relationship, we can avoid being trapped by either the methodological atomism assuming under-socialized actors or the methodological holism assuming an over-socialized monolithic integration. Two networks, intra- and inter-state, of the developmental state are investigated. On the one hand, drawing the network of governmental agency around the nuclear policy hopes to address that the network in which the organization embeds matters rather than the individual organization doing something right. On the other hand, mapping the international trade network of the nuclear power plant hopes to examine if the developmental state occupies a specific position or status on the hierarchy of the world system.

In the following paragraphs, this study first elaborates the intra-state embeddedness with a variant of the classic developmental state called the developmental network state. Afterwards, the focus shifts to the exterior of the state and moving to a network on the global level to

determine if the position of the developmental state on the global network matters to other geopolitical competitions.

The Developmental Network State (DNS) vs. the Developmental Bureaucratic State (DBS)

As a key condition for the transformation of the earlier embeddedness, the rise of the knowledge-based economy challenges the role of state intervention in pursuing economic growth. However, this does not mean that the state capacity never works again, but it must be adjusted to correspond to the more complex, flexible mode of production. For instance, while South Korea fell into the financial crisis at the end of the 20th century, Ireland's economy roared to life. Although the wake-up of the "Celtic Tiger" is attributed to the state-led mode of development, O'Riain (2000, 2004, 2011, 2014) distinguishes them as two different types of the developmental state. First, the Irish experiences relied more deeply on R&D. In contrast to gaining comparative competitive advantage from the manufacturing, Ireland's success came from the rapid growth of its information technology industry. In addition, comparing to the East Asian Tigers which consist of cohesive, coherent, and rigid bureaucracies, the Irish developmental state has a flexible and loosely-coupled state apparatus that is multiply embedded and relatively fragmented.

By using the metaphor of network as the major distinction between Ireland and the earlier cases in East Asia, O'Riain (2000, 2004) names the former as the developmental network state (DNS) and the latter as the developmental bureaucratic state (DBS). In contrast to the DBS nodal agency only consisting of bureaucrats, the core element of the DNS is a network of development agencies, consisting of not only technocrats but also of many indigenous industry and local professionals (O'Riain 2011, 2014). In short, although the state has been still taking an important

role in developing the economy, the DNS is more decentralized than the DBS and extends the coordinating network to include more public-private collaboration.

With the DNS framework, Block (2008) and Block and Keller (2011) provide an alternative perspective for challenging the commonsensical understanding of the United States as a typical liberal state. They indicate that the United States is a hidden developmental state which actually has the core elements of the developmental state, though intertwined with the laissez-faire ideology on the surface. Since the DBS of the United States is highly decentralized, it is also relatively invisible. As subtly led by several minor agencies within the Federal government, a technological community is gradually organized as a system of innovation focusing on R&D. In other words, the state agencies work as brokers to connect the scientists to the business.

In addition to Ireland and the United States, Negoita and Block (2012) also stress that Chile's rapid economic growth in recent years is contributed by the emergence of the DNS. On the one hand, the state agencies assist the local firms to obtain access to foreign technologies or even directly transfer the technology to the local firms. On the other hand, with the state agencies' supports and subsidies, a group of small and medium enterprises create associations of specific industries from the bottom up. Wang (2014) examines the development of the biotechnology industry in Taiwan, which is a typical case of the 1st generation developmental state, to determine if the logic of the developmental state changes. He found that in the early stage of developing the biopharmaceutical industry, as following the old developmental strategy for developing the IT industry, the Taiwanese state itself led the enterprises but finally failed to obtain access for the Taiwanese firms to the global production chain. After being joined by the prominent Taiwanese scientists returning from the United States and thus being hooked to the

global biopharmaceutical industry, the Taiwanese biopharmaceutical industry has obtained significant growth in profits and technological renovation. In the latter stage, although the state has been still providing significant supports and resources, it does not play a leading role anymore but yield its decision power to the network of the Taiwanese scientists.

In summary, the embeddedness of the DNS shows a more inclusive and open composition than the DBS. Here network is treated as a synonym for embeddedness.

Network as Governance

In contrast to the DBS whose strength is attributed to the coherent state apparatus, the DNS is marked by the coordinating network that combines public and private sectors. Instead of a retreat to market for resolving state failure, the network is established as an alternative for development, which is a third method between over-rigidity and total disorganization (Powell 1990).

However, whether the DNS works depends on not only the existence of network, but also its qualities. In other words, a network may fail to contribute to the development even if it survives and lasts long on a solid basis (Negoita 2014; Schrank and Whitford 2011; Whitford and Schrank 2011). A working network must resolve two kinds of problems: opportunism and lack of competency. To solve the problem of opportunism, a network must generate sufficient trust among the network members or construct a monitoring mechanism to reduce rent-seeking. To solve the problem of ignorance, a network needs to provide sufficient sources of knowledge or expertise. For example, as shown in the successful cases of Chile (Negoita and Block 2012), on the one hand, the associations of small and medium enterprises construct code standards for their products, prevent any single firms exporting unqualified products that may lower the whole

evaluation of Chile's products. On the other hand, as the state agencies transfer technologies to the local industry, the network overcomes the problem of lacking competency.

This discussion of network failure provides an insightful understanding of what may be the contents of those flowing or exchanged within the networks. However, as most discussion focuses on the contents of the network, the forms (or structures) of the network are paid with less attention or even excluded from the literature. On the network-related research, Smith-Doerr and Powell (2005:380) indicate that there has long been a bifurcation between the research more focusing on methods and the other one more concerning with governance. Most of the literature on the DNS falls into the latter category. In other words, although the nodes (for example, state agencies and firms) and ties (for example, the interpersonal relationships such as trust or the communicated media such as expertise or skill) are elaborated, articulated, and analyzed, the shapes of the web are rarely touched.

As network is taken as synonym of embeddedness in the DNS literature, the bifurcated uses of network may correlate to the multiple interpretation of embeddedness. As developed along with different academic lineages, the concept of embeddedness is increasingly covered by vagueness (Dale 2011; Krippner 2002; Krippner and Alvarez 2007; Krippner, Granovetter, Block, Biggart, Beamish, Hsing, Hart, Arrighi, Mendell, Hall, Burawoy, Vogel, and O'Riain 2004). Krippner and Alvarez (2007) reviewed the embeddedness literature and generalized this concept in two approaches: the Grannovetterian and the Polanyian. Both approaches fight against the atomist assumption in social science and claim the importance of taking relational thinking on the concept of embeddedness (Block 2012; Granovetter 1985). Regarding their distinction, as partially influenced by their applied methods, they are directed separately to the exterior and interior sides of embeddedness. The Granovetterian, heavily relying on the technique of social

network analysis, is prone to focusing on the structural relations of network, illustrating the embeddedness as the contexts outside the economy (Uzzi 1996; Uzzi 1997). On the other hand, the Polanyian, greatly influenced by Polanyi's discussion on the self-regulating market and the double movements between the self-regulating market and the self-protection of society, tends to focus on how the state and economy interpenetrate each other, illustrating the embeddedness as the links inside the socio-economy (Block and Evans 2005). As shown in the DNS literature, the concept of the DNS is mostly depicted as the interior relationships between the public and private sectors and the concept of network, though taken as a keyword and presenting everywhere in the literature, is rarely measured in the quantitative index of network analysis or shown in the graphic forms of network shapes. In other words, the DNS research skews heavily toward the Polanyian approach, presuming the network as a kind of governance but excluding the topological analysis of network.

Criticism on the Network Governance Approach

Although there is a danger for social network analysis to over-emphasize the structural dimension of the network and thus strip the contents of the ties (Emirbayer and Goodwin 1994), to sacrifice the analysis of network forms for more detailed depiction of contents makes no sense as well. Grabher (2006) warns that it is important to balance the positional analysis of network structure and the network governance approach. As the network governance approach prioritizes the qualities of ties such as trust and mutual learning, their meanings and values may be totally overturned if the tertius gaudens (the third party of a triad) is added to the model, which is best exemplified as the concept of structural holes (Burt 1992) or structural equivalence (White 1992). In short, the narratives regarding the DNS or the network governance need to be proved by the

structural analysis of network. The similar ties on the networks with different structures may vary greatly, depending on if the shapes of the webs have any topological differences.

Moreover, Krippner and Alvarez (2007) mention that the Polanyian approach assumes an always-embedded-economy. As taking embeddedness and network as synonyms, does that mean we may also find the network everywhere, even in the DBS? As indicating that the Weberianness of the DBS also refers to organizational features of the state, Moon and Prasad (1998) argue that a network-like understanding has been placed in the analysis of the developmental bureaucracy, though the network is only used as a metaphor in the related research that refers to intermediate mechanisms such as embedded autonomy and internal organization. The border between the DNS and DBS is thus blurred. To clarify the distinction between the two, it must borrow the hard version of the network analysis to determine if there are real differences between the structures of the DNS and the DBS and even all the other kinds of states. In short, the graphic or topological configurations of networks neglected by the network governance approach provide the comparability of different state configurations.

In addition to neglecting the structural dimension of network, the network governance approach also tends to neglect the networks on the international level. Bair (2008) indicates that as assuming the positive functions of network such as trust and mutual learning, the concept of embedded network is prone to stick on the micro-level interpersonal networks. Hess (2004) notices that many case studies of the embedded network focus on how the local firms benefit from the regional culture or local institutions, and thus subtly accept an over-territorialized perspective, sticking on the single dyadic ties or the local proximity but ignoring the global network. As reviewing the nature of dyadic ties, Rivera, Soderstrom, and Uzzi (2010) list at least three mechanisms of dyads: assortative, relational, and proximity. The first refers to individual

actors' attributes, the second refers to relational links on networks, and the third refers to geographical proximity. As focusing only on the local or intra-state level, the assumed network is referred to the geographical proximity, often sticking on the regional entities without touching the relational thinking on the global or inter-state level.

With the positional analysis of the world system, it also shows that the East Asian countries that are most often classified as the developmental states are the only deviant cases to the structural reproduction of the world system's hierarchy. Considering the potential of the developmental state for upward-moving in the world system, the research determines that the deviance in the East Asian countries is due to a historical contingency or affected by some structural conditions.

As shown in the following table, there is still significant variation among the East Asian developmental states, though all of them show a significant upward mobility. Considering the initial positions, Japan stands on the top tier, South Korea and Taiwan are in the middle strata, and China is at the bottom (Nemeth and Smith 1985; Snyder and Kick 1979). On the other hand, considering the amount of mobility on the ordinal scale, Japan shows less mobility because of its long presence at the top tier of the core. South Korea and Taiwan are second, showing significant upward mobility from the periphery to the upper semi-periphery (Kim and Shin 2002; Mahutga 2006; Smith and White 1992). China presents the most dramatic change from the periphery to the core (Clark 2008; Clark 2010; Clark and Beckfield 2009; Mahutga and Smith 2011; Quark and Slez 2014). In summary, as the earliest case of the developmental state, Japan's position is closer to the core group, highlighting the closeness to the typical western capitalist economies. On the tier of semi-periphery, South Korea and Taiwan are structurally homologous, illustrated as two competing cases struggling for moving upwardly. China, as clustered in the socialist

world previously, now shows a distinct path with the greatest escalation in the hierarchy of the world system.

Table 2.1: Positions of developmental states in the literature on the world system network

Research\Country	Japan	South Korea	Taiwan	China
Snyder and Kick (1979)	Core	Semi-peripheral	Semi-peripheral	Peripheral
Nemeth and Smith (1985)	Core	Strong Semi-peripheral	N/A	N/A
Arrighi and Drangel (1986)	Semi-peripheral → Core	Peripheral → Semi-peripheral	N/A	N/A
Smith and White (1992)	Semi-peripheral → Core	Lower Semi-peripheral → Upper Semi-peripheral	N/A	N/A
Kentor (1998)	Low dependency on Foreign investment and high economic growth (Japan has the lowest dependency)			N/A
Kim and Shin (2002)	East Asia: moving up South Korea and Taiwan's trade ties are the most increased (1st & 2nd)			N/A
Mahutga (2006)	Core (#7 in 1965 → #3 in 2000)	Lower Semi-peripheral → Upper Semi-peripheral (#37 in 1965 → #10 in 2000)	N/A	N/A
Clark (2008)	"High income countries" excluded		N/A	Upward mobility / Network integration
Clark and Beckfield (2009)	Orthodox position: Core	Orthodox position: Semi-peripheral	Orthodox position: Semi-peripheral	Orthodox position: Peripheral
	Trade Position: Core	Trade Position: Core	N/A	Trade Position: Core
Clark (2010)	Upward mobility	Upward mobility	N/A	Upward mobility
Mahutga and Smith (2011)	Core	Lower Semi-peripheral → Upper Semi-peripheral	N/A	Lower Semi-peripheral → Upper Semi-peripheral
Quark and Slez (2014)	Key importers of the U.S. cotton during the Cold War			One of the bi-core of cotton exports after the Cold War

In summary, the DNS perspective needs to be complemented with a more structure-oriented network analysis, elaborating the relative position of the developmental state on both domestic and international levels. To clarify the ambiguity caused by the metaphoric use of network, it coincidentally gives us a call for return to the network analysis of the world system, which provides a useful tool for clearly depicting the social spaces of international exchanges.

5. Conclusion and Methodological Concerns

In the above discussion of the theoretical development, based on the theory of the developmental state, we identify that the uniqueness of the East Asian NICs is typically attributed to the Weberian bureaucracy or the organizational integration of a nodal agency controlling the political power of planning and implementing for efficiently and effectively completing the transition from the import substitution to the export-oriented industrialization (Chibber 2002; Chibber 2003; Evans 1995; Evans and Rauch 1999). However, these institutional qualities endogenous to the developmental state are enhanced or limited by other external conditions. On the one hand, the praised state autonomy and capability are forged by the societal embeddedness constituting a subtle balance between the state, the civil society and the market economy (Block and Evans 2005; Chibber 2014; Evans 2014b; Williams 2014). On the other hand, the subtle balance is a product of the international context such as the Cold War confrontation that stimulates the drive toward the export-led growth or reinforces the adherence to the monopoly of domestic market (Haggard 1990; Haggard 2004). In other words, the embedded autonomy can be a recursive function of the developmental state acting or reacting its position in the international context or the world system. Therefore, to examine the effects of the developmental state on the development of the nuclear industry and understand the role of the

developmental state in the world system, it is also helpful to use the network analysis. This method is inherently attached with a positional analysis, which is helpful for determining the location of the developmental state in the hierarchy of the world system.

Based on the complementary theories, this research uses multiple methods to assess the global nuclear development in the following chapters. First, we conduct an event history analysis (Abbott and Tsay 2000; Allison 2014; Burt 2000) for understanding the emergence and decay of the dyads within the global nuclear industry, which are measured as the transactions of the nuclear power plants. The theme of the developmental state also is examined by the event history analysis. In the next chapter, to investigate the dynamic of the changing embeddedness and its corresponding networks, this research uses the network analysis to cluster the transacting countries to check if the clustering is consistent with other groupings based on other socio-political attributions. Finally, by using case-based method, this research conducts a comparative historical analysis to further examine the strategies for the developmental states to develop nuclear energy.

CHAPTER THREE

OVERCOMING TARDINESS: EVENT HISTORY ANALYSIS OF GLOBAL NUCLEAR DEVELOPMENT

1. Introduction

Developing nuclear power has been taken by some countries as a practical strategy for pursuing industrial development and energy sovereignty. There has been research indicating that the choice of entering the nuclear industry is highly correlated with the demands of economic growth, energy sovereignty, and the perception of nuclear accidents (Fuhrmann 2012). Yet our question does not end here. As the debate on nuclear power usually falls into the either-or myth of the opposition between development and risk, the question of how this investment works in different countries and under different social arrangements has been neglected. Even for those bold risk-takers who deny all the risk and expect only the returns, it is still needed to ask that if the development is really developmental. Thus, this research focuses on examining if the development of nuclear power is equally developmental in each country that participates in this specific investment.

The following question is to define the concept of developmental. In contrast to the typical definition of the developmental considering only the amounts of invested resources, here we add a dimension of temporality to measure the quality of the efforts to develop a given enterprise. Development, referred to the catch-up of latecomers and the reduction of gaps, contains not only material resources but also time-spans. “Time is money;” a time-consuming construction costs not only financial resources, but also the political support and the public trust (Campbell 1988). By calculating the time consumed for constructing a nuclear reactor, the

efficiency of the nuclear industry in a specific country can be quantified and thus can be compared. With the further examination of the associations between the relative efficiency of the construction of the nuclear power plants and other explaining variables, the question whether the settlement of nuclear program is developmental can be clarified. In other words, this research strives to determine what social factors help enhance the efficiency or overcome the tardiness of developing nuclear power.

A major problem of calculating tardiness or efficiency is measuring the time-span of a nuclear reactor that is under construction. Although the time can be measured in the comparable unit, the status of the construction implies that the experienced time may not be homogeneous. If calculating the average construction time by treating the under-construction cases as missing values and thus deleting them, it removes the potentiality of current development and thus makes the trends misjudged. The later construction that occurs in a changed political or social environment may consume more time than the earlier ones and expand the range of the construction time. It is misinformed if it considers only the cases in which the construction is completed. On the other hand, while keeping the under-construction cases in the data but treating them as equal to the completed subjects, the development is certainly exaggerated and over-estimated. How to capture the status of construction accurately but not sacrifice the explaining power of the cases that are under construction thus becomes the major challenge to this research. To overcome this dilemma, this research uses the event history analysis to manage the construction time with different completion statuses. Neither excluding the subjects that the expected incidents do not occur nor omitting the different values of incidences, the event history analysis takes all the subjects into account but keeps the difference in the status (Allison 2014; Cleves, Gould, Gutierrez, and Marchenko 2010).

By considering the subjects with non-observed events as censored cases, event history analysis combines the time-to-event interval and the status of event occurrence as single variables such as survival time and incidence ratio (hazardous ratio). Furthermore, with the comparison of the K-M survival curves of different groups of countries, the association between the tardiness of nuclear development and the socio-political status of the nuclear users can be analyzed in a more specific way.

Scholars have already applied the event-history analysis to study the construction duration of nuclear power reactors (Csereklyei, Thurner, Bauer, and Küchenhoff 2016; Thurner, Mittermeier, and Küchenhoff 2014). Their research indicates that the efficiency of constructing nuclear power reactor is in positive relationships with economic demands and technological conditions such as reactor standardization. On the effect of democracy, they all find a positive relationship between democracy and construction efficiency, although only the latter study shows a statistically significant result (Csereklyei, Thurner, Bauer, and Küchenhoff 2016). In addition, regarding the geographical distribution, these studies find that higher efficiency appears in the areas of Asia and Africa. The given research undoubtedly makes an important contribution in illustrating the dynamics of developing nuclear energy and the existence of socio-political impacts. However, the theses based on our theoretical concerns are left untouched or categorized in a different manner in these studies. First, the connection between military and civilian uses of nuclear power is missed. Second, the sampled countries are categorized by the geographical locations rather than the distinction based on the positions in the world capitalist economy or the state-led developmental strategies.

To resolve our research questions, the following section elaborates the research hypotheses based on the theoretical concerns discussed in chapter two.

First, to test the shared assumptions in the given literature on the development of nuclear industry, we reexamine the effects of democracy, the possession of nuclear weapons, and the Cold War milieu. On the one hand, democracy and war mobilization are both considered as negatively related to the development of nuclear energy. As the given literature over-emphasized on the experiences of Western democracies, it is habitually presumed that the democratic politics inevitably lead to the public's anti-war grievance and then directly benefit an encompassing anti-nuclear movement. On the other hand, war mobilization, which is typified as the possession of nuclear weapons and the Cold War milieu, is sometimes considered as having a positive relationship with the development of nuclear industry. Due to its duality of *sword and plow*, the development of civilian nuclear programs is unsurprisingly entangled with the proliferation of nuclear weapons. Thus, it is assumed that the possession of nuclear weapons may have a positive effect on the efficiency of constructing nuclear power plants. In addition, as corresponding to the sphere of the Cold War, the construction of nuclear power plants may encounter a friendlier climate than in the post-Cold War era when the alliance is dismantled or reorganized in another way. As shown in these intertwined and paradoxical presuppositions, the hypotheses of the effects of democracy, the possession of nuclear weapons, and the Cold War milieu need to be reexamined. Second, we examine the hypotheses based on the two alternative theoretical perspectives, the world systems theory and the theory of the developmental state. Based on the world systems theory, it is assumed that the construction of nuclear power reactor is delayed due to a less-developed country's dependency on a core state's export of technology, which is also an unequal exchange implying the power relationship between core and periphery. On the other hand, in contrast to highlighting the external domination, the perspective on the developmental state centers on the role of state autonomy and state capacity overcoming the tardiness of

development. Thus, both the effects of world systematic hierarchy and the developmental state mode are emphatically examined.

2. Research Hypotheses

Democracy

The longevity of the construction implies not only the level of science and technology, but also the institutional conditions of this industrial development. Based on the experiences of constructing nuclear power plants in the United States and Western Europe, for example, the delay of construction is a result of decentralized governmental power, over-competition of the big-business, public acceptance, and the divergence of political agenda (Campbell 1988; Jasper 1990). These institutional constraints are also highlighted in the literature on the contentious politics of anti-nuclear protests (Joppke 1991; Joppke 1992; Joppke 1993; Kitschelt 1986; Koopmans and Duyvendak 1995).

Political institutions determine whether the industrial policy succeeds or fails. In his case study on the nuclear industry in the United States, Campbell (1988) stresses that one of the major institutional constraints contributing to the collapse of this industry is the constrained state autonomy. The U.S. state apparatus is relatively federated, fragmented, and decentralized; thus, its ability to intervene in the pro-nuclear policy is limited. As many administrative agencies check and balance each other and the process of decision making is permeated by numerous interest groups, the efforts of the state for promoting nuclear policy are obstructed. In addition, role conflict between regulating and promoting the nuclear programs also prohibits the sufficient engagement of the authority into the nuclear enterprises. Furthermore, as a mature capitalist economy, the over-competition in the U.S. nuclear market makes the standardization and

long-term planning impossible and the costs of construction skyrocket (Campbell 1988). In addition to the political economy of industrial policy, Jasper (1990) shifts the focus to the level of the political arena, seeing how the partisan cleavages work on the nuclear politics and considering account different groups of actors such as the economists, the scientists, and the environmentalist activists other than only the bureaucrats and politicians. In his analysis, the political cleavages and following political struggles based on the cost-benefit, the technological determinist, or even environmental moralist distinctions determine the fates of the nuclear industry in specific countries.

The research scope of these case studies disproportionately concentrates in the western advanced industrial economies, which are all the old, matured democracies. In addition, as addressed in the literature on anti-nuclear movements (Joppke 1991; Joppke 1992; Joppke 1993; Kitschelt 1986; Koopmans and Duyvendak 1995), the collapse of the nuclear industry is usually determined by the efficacies of the related social movements, which are the ordinary political landscapes in the old democracies but absent in other types of political regimes. While many countries belonging to the First World are removing their nuclear programs, more and more post-socialist regimes and the newly industrialized countries are being involved in the nuclear industry.

Based on the opposition between the typical old democracies and the other types of political regimes, the political structure of Western democracies is less compatible with the development of nuclear industry than the other types of political economies. To test this presupposition, this research first examines if the level of democracy affects the efficiency of the construction.

Hypothesis 1: A country's level of democracy is in a negative relationship with the efficiency of construction.

Nuclear Weapons

The boundary between military and civilian uses of nuclear technology is not wide enough to classify them as irrelevant to each other. Since starting with the Manhattan Project, the nuclear industry has generated a complex mixing of "big weapon, big science, and big state" (McLauchlan and Hooks 1995), embodying the subtle intervention of military sectors into civilian productions. However, whether the effect of possessing nuclear weapons on the development of civilian nuclear energy is positive or negative is still in question due to a twofold consideration.

On the one hand, as the connection between nuclear weapons and civilian nuclear programs has been broadly perceived by the public, the public discontent over nuclear weapons can also exacerbate the public distrust of nuclear energy. In the United States, for example, scholars indicate that the anti-nuclear movement has been strengthened by the rising public resentment against the nuclear arm race (Rosa and Clark Jr. 1999). As both nuclear weapons and civilian nuclear programs are viewed as part of the power complex overstepping democratic governances, scholars thus expect that the technocracy and experts behind both the military and civilian enterprises lose their legitimacy and support and are finally obstructed by large-scale public protests.

On the other hand, although the connection between the military and civilian uses of nuclear power has been taken for granted, both kinds of enterprises may not always be perceived as bearing only negative externalities, especially in non-Western political regimes. For example,

instead of seeing nuclear bombs as totally disastrous for humans, South Korea, as liberated from the colonization of Japan, which is the only victim of the A-bombs, thus intensified the belief of technological power and took nuclear power as a short-cut to national development (Jasanoff and Kim 2009; Jasanoff and Kim 2013; Kim 2009). In addition, as shown in the path dependence of developing nuclear energy (Cowan 1990), the initial design of nuclear reactor was determined by the military consideration of keeping ahead of the opposing super power. The experiences of the developing nuclear weapons thus contingently bring the advantages of entering earlier in the world market to the development of civilian nuclear programs.

This ambivalence implies a theoretical thesis underlying the relationship between nuclear weapons and civilian nuclear programs: The context-based conversion or convertibility between different forms of resources. Tilly (1992) provides a general theory of state formation focusing on the dialectic between economic and military resources. He stresses that the most important two resources for state-building are economic capital and military coercion. The capital is accumulated by the monopoly of economic resources and means of production, and the coercion is accumulated through the monarch's monopoly of the weapons or other coercive tools. There is conversion between the accumulations of capital and coercion; thus, he identifies three paths of state formation: capital intensive, coercion intensive, and the capital-coercion trade-off path. In other words, capital and coercion complement each other in the process of state-building, embodying the structure of the military-industrial complex and the symbiosis between military sectors and civilian production.

The dialect between capital and coercion fits in with the ambivalence of using nuclear power for either civilian power generation or nuclear weapons. With the dual images of sword and plow, nuclear programs imply, on the one hand, the self-sufficient provision of energy, and

on the other hand, the intimidating power of nuclear weaponry. Thus, to determine the relationship between nuclear weapons and civilian nuclear programs, we need to compute how the possession of nuclear weapons, which represents the accumulation of coercive measures, converts to the effects on the efficiency of establishing civilian nuclear programs, which represents the accumulation of economic capital.

Hypothesis 2: The possession of nuclear weapons enhances the efficiency of construction (i.e., decreases the tardiness).

The Cold War

With the similar theoretical concern disclosed in the above paragraphs, war mobilization has its own economic consequences. War-preparation makes the reorganization of political power between the military and civilian sectors, and thus changes the consequences and modes of economic production and distribution (Hooks and Bloomquist 1992; Hooks and Rice 2005; McLauchlan and Hooks 1995; Tilly 1992). When analyzing the power structure of American society, for example, Mills (1956) indicated that the rising military power has gradually shared a privilege with the political and economic elites. Benefited by the wartime mobilization, the state strengthens and extends its autonomy relative to the civil society and gains the power and opportunities to involve the production in civilian sectors (Hooks 1991; Hooks and McLauchlan 1992). In other words, the status of war-preparation significantly affects the paces and results of industrialization. Based on this reasoning, this research hypothesizes that the nuclear program can be influenced by the world-wide political environment such as the Cold War.

With this consideration, it is assumed that the Cold War is a friendlier environment for developing nuclear power than the post-Cold War era. During the Cold War, the general inter-state system was divided into two blocs separately led by the United States and the Soviet Union. Although the two blocs were divergent and antagonistic, both sides had a tacit understanding that industrialization was their highest priority and the central object of competition (McMichael 2011). On the one hand, both sides of the rivalry provided considerable military and economic aids to their alliances and subordinates. For containing the spread of communism, the U.S. aids went to the East Asian countries, which were the fronts of the Korean War and the Vietnam War. In addition to exporting material resources and technological knowledge, the Soviet Union directly constructed the nuclear power plants in its subordinate countries such as Ukraine and Bulgaria. On the other hand, as a controversial technology arousing public debates and skepticism, the nuclear program was constructed with less political disturbances under the quasi- or true wartime situations such as the declaration of state of emergency or even martial law. In sum, it is reasonable to assume that the Cold War provided this controversial enterprise a friendly environment where most of the political obstacles have been excluded.

Hypothesis 3: The time period of the Cold War is positively related to the efficiency of construction (i.e., shows less tardiness).

Foreign Dependency

After reviewing the research hypotheses generated from the given literature with the over-emphasis on Western democracies, we address two alternative theories. To oppose the

western-centered perspective, first, we discuss the world systems theory to determine a more holistic and systematic explanation of the global nuclear development; second, we address the developmental state theory to deconstruct the configurations of state-society relationship fixed in the given literature.

The world systems theory inspires us to examine the development of nuclear industry from a perspective highlighting the inter-state relationship. It first illustrates the world inequality in terms of general social spaces, consisting of the trichotomy of core-semiperiphery-periphery (Wallerstein 1974). From the local perspective of the peripheral or semi-peripheral states, the introduction of advanced technologies certainly bears on their expectation of achieving industrialization. However, the initiates of nuclear programs are not self-reliant but dependent on the import of nuclear technology from the more advanced economies, i.e., the core states. The core states, with their own hegemonic plans or geopolitical interests, thus constrain the exports or solicit it in tough stances to keep their oligarchical status and maintain the dependency of the periphery.

The dependency theorists argue that the industrialization based on the foreign investment from the core only causes the unequal exchange favoring the countries occupying the dominant positions and even keeps the peripheral countries in the plight of development of underdevelopment (Amin 1976; Cardoso 1977; Frank 1967). Even in the era of globalization in which the international interactions become more intense and frequent, and the reality of the uneven development seems to be closer to the extension of dependency rather than the optimistic modernization (Guillén 2001). The disparity of development on the global level not only persists, but also extends to dimension other than economy, such as ecology (Wallerstein 2005). Even the industrialization of a developing country under the asymmetrical power relationship may

improve relative to its initial condition, and it may also be entangled with the predicament of dependent development, which the invested foreign capital, transnational corporations, local capital, and local state form an alliance and eventually obstruct the state's developmental strategies (Evans 1979). With significant evidences, Kentor (1998) and Kentor and Boswell (2003) also found that the dependency on foreign investment negatively correlates to a nation's economic growth.

The world systems theory expands the concept of dependency to a more encompassing trichotomy of core-semiperiphery-periphery and keeps investigating the dynamics of global wealth hierarchy (Arrighi 1990; Arrighi and Drangel 1986). With the concern regarding the reproduction of unequal exchange, the research focusing on the international trade networks indicates that, with the only exception of East Asia, upward mobility in the hierarchy of the world system is rare and limited, and most peripheral countries are trapped in the given relationships with the core countries (Clark 2008; Clark 2010; Kim and Shin 2002; Mahutga 2006; Mahutga and Smith 2011).

Seen through the perspectives of the world systems theory and the dependency theory highlighting the role of unequal exchange, the development of nuclear power is distributed by the logic of core-periphery relationship, which the tardiness of developing nuclear power is distributed along with the hierarchy of patron-client relationship.

Hypothesis 4: The dependency on the foreign vendors is in a negative relationship with the efficiency of construction (i.e., in a positive relationship with the tardiness).

The Developmental State

The other alternative to the western-centered theories is the developmental state theory. In contrast to the weak state illustrated in prior studies on the development of nuclear industry in Western democracies, the ideal type of the developmental state illustrates a political regime having higher state autonomy, larger state capacity, and a level of state intervention into economy (Amsden 1989; Evans 1995; Johnson 1982; Wade 1990; Woo 1991).

The U.S. nuclear programs illustrated by Campbell (1988) are finally obstructed due to the state's weak power relative to the market and the civil society. In contrast, the nuclear industry thrives in East Asia, especially in Japan. Based on the uniqueness of the Japanese economic miracle, Johnson (1982) thus provides a trichotomy of states: the liberal market economy (the United States), the socialist planned economy (Soviet Union), and the developmental state considering both state planning and market imperatives (Japan). In his prototype of the developmental state (Johnson 1982; 1999), the most prominent element is the elite state officials and their planned intervention. The state autonomy is concretely demonstrated in the administrative discretion for intervening or even integrating private economic activities occurring in the market.

Based on the trichotomy of states, first, this research plans to classify the old capitalist democracies led by the United States into the variable capitalist democracies, which are all western advanced liberal market economies. Second, the countries which once have been socialist regimes placed in a bundle, including Russia, the former Soviet Union subordinates, China, and the former Yugoslavia subordinates. Finally, the developmental state is classified as sui generis. In the literature of the developmental state, three countries are identified as the most typical cases of the developmental states: Japan, South Korea, and Taiwan (Amsden 1989;

Chang 1994; Chang 2002; Chibber 2002; Chibber 2003; Cumings 1984; Cumings 1999; Evans 1995; Evans and Rauch 1999; Haggard 1990; Johnson 1982; Kang 2002; Kohli 2004; O'Riain 2004; Wade 1990; Waldner 1999; Weiss 1998; Woo 1991) (see Appendix A). The rest of the countries that are not counted in these three categories include several Latin American countries and the countries once belonging to the Non-Aligned Movement such as India and South Africa. Thus, the final group of countries is categorized as the other countries. The fourth category consists of the Non-Alignment Movement countries such as India and the Latin American countries. To compare how effective the different political regimes overcome the tardiness, the capitalist democracies are set as the baseline for the comparison.

Hypothesis 5.1: Compared to Western capitalist democracies, the post-socialist regimes are negatively associated with the efficiency of construction (i.e., positively related to the tardiness).

Hypothesis 5.2: Compared to Western capitalist democracies, the developmental states are positively associated with the efficiency of construction (i.e., negatively related to the tardiness).

Hypothesis 5.3: Compared to Western capitalist democracies, the states other than Western capitalist democracies, socialist states, and the developmental states are negatively associated with the efficiency of construction (i.e., positively related to the tardiness).

Table 3.1: Cases considered as the developmental states

	The developmental state(s)	Compared case(s)
Johnson (1982)	Japan	N/A
Cumings (1984)	Bureaucratic-authoritarian industrializing regimes (BAIRs): Japan, South Korea & Taiwan	N/A
Amsden (1989)	South Korea	N/A
Wade (1990)	Taiwan	N/A
Haggard (1990)	South Korea & Taiwan	Singapore, Hong Kong, Mexico & Brazil
Woo (1991)	South Korea	N/A
Evans (1995)	South Korea (& Taiwan)	Brazil, India
Weiss (1998)	"East Asian Developmental States"	"Swedish Model" Germany Globalization
Evans and Rauch (1999)	East Asian Tigers: South Korea, Taiwan, Hong Kong, Singapore	Latin America and Africa
Waldner (1999)	South Korea & Taiwan	Syria, Turkey
Sen (1999)	South Korea, Taiwan, Singapore	Western/Advanced industrial countries The Third World
Kang (2002)	South Korea	Philippines
Chang (2002)	NICs in East Asia: Japan, South Korea, Taiwan	Western/Advanced industrial countries
Chibber (2002, 2003)	South Korea	India
O'Riain (2004)	Developmental bureaucratic state (DBS): South Korea, Japan Developmental network state (DNS): Ireland, Taiwan, Israel	
Kohli (2004)	Japan & South Korea	Brazil, India, Nigeria
Block and Evans (2005)	Japan, South Korea, Taiwan	N/A
Block (2008); Block and Keller (2011) Negoita and Block (2012)	Hidden developmental state: The United States DNS: Chile	N/A

Table 3.2: Types of political regimes

Political Regimes	Included Countries	Number of countries	%
Capitalist democracies	Belgium, Canada, France, Germany, Italy, Netherlands, Spain, Sweden, Switzerland, United Kingdom, United States, Finland	355	53.22
Socialist states	Armenia, Belarus, Bulgaria, Czech Republic, East Germany, Hungary, Kazakhstan, Lithuania, Romania, Russia, Slovak Republic, Ukraine, China, Slovenia	165	24.74
Developmental states	Japan, South Korea, Taiwan	97	14.54
Non-Aligned States	Argentina, Brazil, India, Iran, Mexico, Pakistan, South Africa, UAE	50	7.50
Total		667	100

3. Data and Research Method

Data Source

For the nuclear industry, the data are extracted from the dataset of the World Nuclear Association (WNA). In addition to gathering the data about the amount of nuclear electricity generation and the share of nuclear power, this research also collects the data about the construction of nuclear reactors, especially the transactions of nuclear reactors. The data on nuclear reactors are drawn from the WNA Reactor Database (World Nuclear Association 2016). The database shows the following attributes of each reactor: geographical location, status, vendor, owner, and dates of start construction and commercial operation. Through 2016, this data contains 670 reactors from all over the world, including the long-term shutdown, permanent shutdown, operational, and under construction reactors. However, three reactors are excluded because they are research prototypes and have never been commercially operated. Thus, there are only 667 subjects (n = 667).

Table 3.3: World reactors by current status

Current Status	n	%
Long-term Shutdown	1	0.15
Operational	449	67.32
Permanent Shutdown	155	23.24
Under Construction	62	9.30
Total	667	100

To compute the level of democracy for each country, this research uses the dataset of the "*Polity IV Project*" (Marshall, Gurr, and Jaggers 2014) for categorizing the political regimes according to their degrees of democratization.

Dependent Variable and Event History Analysis

The dependent variable is the efficiency (or the tardiness) of the construction of the nuclear power plant, measured as the time interval between the start construction date and the commercial operation date. Instead of conceptualizing the tardiness and catch-up of the state-building only in terms of volume, this research attempts to add the dimension of temporality to illustrate the degrees and eagerness of the latecomers for pursing industrial development. As mentioned previously, the delayed construction and the late commercial operation directly costs the nuclear industry large amounts of money and resources. Thus, the lengths of the time intervals are used as the tardiness of industrialization in nuclear programs.

However, there a problem remains regarding computing the time interval between start construction and commercial operation. Nearly 10 percent of the nuclear reactors over the world are still under construction. Either deleting these cases as missing values or computing them directly as the construction-completed cases causes mistaken estimations. In other words, in addition to the measurement of the time interval, whether the expected event or incident (the formal commercial operation) occurs needs to be computed with the time interval. To take the

measurement considering the time interval and the status of the ending event, this research opts to use the event history analysis.

Although typically used in the research of public health and in clinics, the event history analysis can be properly applied to examine the continuations and endurances of the relational ties (Burt 2000; Burt 2001). In event history analysis, the time interval is computed as the survival time that the end of the time interval can be either the expected event, such as commercial operation, or the stop time of the data collection. A dummy variable notifying whether the expected incident happens is attached to the computation of survival time. The observation in which the expected event does not occur at the stop time of the data collection is marked as censored. Then, the computation can generate the incidence rate, implying the probability of the occurrence of the expected event in a given unit of time (counted by year in this research). Thus,

Survival time = commercial operation date (current date if the observation is censored) – start construction date

Failure event / death / incidence: coded as "1" if it has been commercial operation; "0" if still under construction.

In the studies of Thurner, Mittermeier, and Küchenhoff (2014) and Csereklyei, Thurner, Bauer, and Küchenhoff (2016), the time interval of construction duration ends at the date of grid connection. Technically, the IAEA notes that the construction time refers to the interval from the start construction date to the grid connection date. However, in this study, we measure not only the technological level of constructing countries, but also the social factors involved with the

whole project of infrastructure building, such as public protests and political boycotts over the nuclear industry. In addition, a case that successfully completed grid connection but failed to achieve commercial operation exists. Therefore, in this research, we count the date of commercial operation as the real end of the time interval.

The incidence (hazard) rate shows the probability of the event (commercial operation) occurring. To compare incident rates of the different groups, the distribution of the survival time can be graphed as the Kaplan-Meier survival curve that visualizes the change of the survival time. In this research, the survival time implies the delay of the commercial operation. By using the log-rank test of K-M survival curves, the differences on the tardiness of the construction between different groups of countries can be statistically tested. Finally, a semi-parametric Cox regression model of survival time is conducted to examine the associations between the tardiness and the independent variables. The statistical software Stata (StataCorp 2009) is used to conduct the event history analysis.

Independent Variables

Three variables are coded as dummy variables to operationalize the above hypothesis:

Democracy – The level of democracy is measured as the polity scores in the Polity IV dataset, ranging from 10 ("strongly democratic") to -10 ("strongly autocratic) (Marshall, Gurr, and Jaggers 2014).

Possession of nuclear weapons – If the country owning the reactor ever possesses any nuclear weapons, it is coded as 1; otherwise 0.

The Cold-War rivalry – If the construction of a reactor is started before 1990 (i.e., the end year of the Cold War), it is coded as 1; otherwise 0.

Dependency – If a reactor is purchased from a foreign vendor, its dependency is coded as 1; otherwise 0.

Political regimes – three dummy variables are coded to mark four kinds of political regimes: 1) Capitalist democracies: If the country owning the reactor belongs to capitalist democracies before the end of the Cold War, it is coded as 1, and non-capitalist democracies as 0; 2) Socialist regimes: If the country once has been a socialist or communist regime, it is coded as 1, and non-socialist regime as 0; 3) The developmental states: Japan, South Korea and Taiwan are coded as 1, and the other non-developmental state are coded as 0; and 4) The other states: If the country does not belong to the above three categories, it is coded as 1, and 0 if not.

The date of start construction is added to the model as a control variable to determine if the associations are only derivations of the "dividends for latecomers" or "the latecomers' competitive advantages" caused by the evolution of the technology itself.

4. Results

In the 667 nuclear reactors built for civilian power generation, 90 percent already have entered or passed through the stage of commercial operation, and 10 percent are still under construction.

Table 3.4: Reactors by censored/incidence

	Freq.	%
Still Under Construction ("Censored")	62	9.30
Ever been Commercial Operation ("Incidence")	605	90.70
Total	667	100

In general, the incidence rate of completing the construction and entering the commercial operation on the world-wide level is 0.1203.

Table 3.5: Average status of reactors construction

	Time at risk	Incidence rate	no. of subjects	Survival time 25%	50%	75%
Total	5029.746752	0.1203	667	5.1581	6.4257	8.8323

Nuclear Weapons

The survival functions for the group having nuclear weapons (nuke weapon = 1) and the group having no nuclear weapons (nuke weapon = 0) show that at any time point, the possession of nuclear weapons is associated with survival rate but in an opposite direction to the research hypothesis. In contrast to the hypothesis of the possession of nuclear weapons, the non-nuclear weapon states complete the construction more efficiently: The incidence rate of the group having no nuclear weapons is 0.1288, and the group having nuclear weapons is 0.1155. In addition, the difference of the two groups is statistically significant ($\chi^2 = 8.14$, and $p = 0.0043$). In other words, the construction in the countries owning nuclear weapons is slower than in those having no nuclear weapons. In other words, the possession of nuclear weapons implies a longer duration of completing the construction.

Table 3.6: Reactors by countries possessing nuclear weapons

Having nuclear weapons?	time at risk	Incidence rate	no. of subjects	Survival time 25%	50%	75%
No	1816.8515	0.1288	253	4.6954	5.9986	8.2053
Yes	3212.8953	0.1155	414	5.5086	6.7488	9.4374
Total	5029.7468	0.1203	667	5.1581	6.4257	8.8323

Table 3.7: Log-rank test for equality of survivor functions: Possession of nuclear weapons

Having nuclear weapons?	Events observed	Events expected		
No	234	201.06		
Yes	371	403.94		
Total	605	605.00	$\chi^2 = 8.14$	$Pr > \chi^2 = 0.0043$

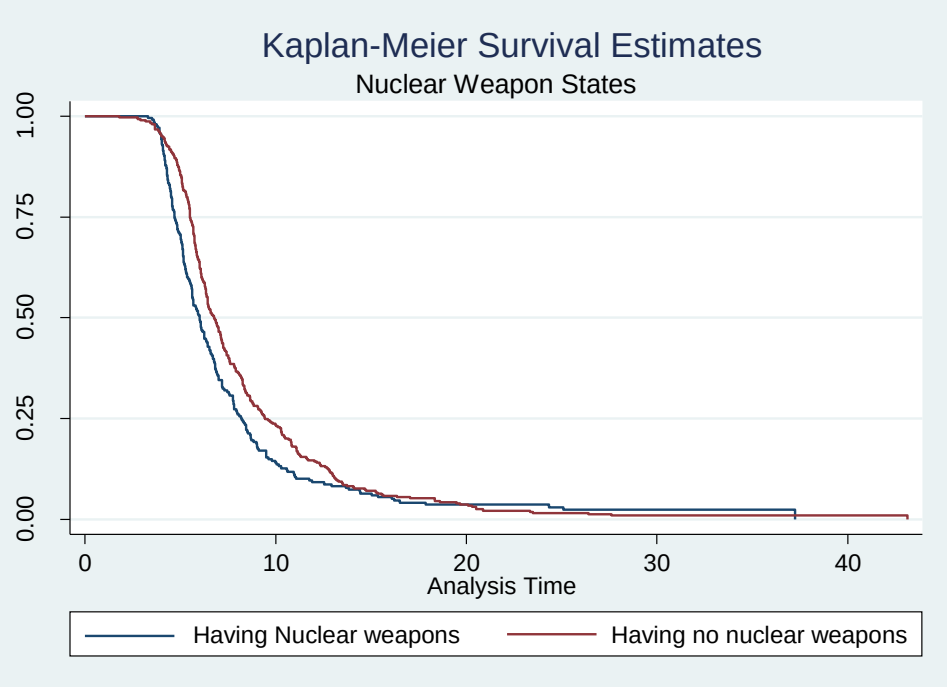


Figure 3.1: K-M curve by possession of nuclear weapons

The Cold War

The survival functions for the group of reactors constructed during the Cold War (Cold war = 1) and the group constructed after the Cold War (Cold war = 0) show that the constructions during the Cold War are more efficient: The incidence rate of the group during the Cold War is 0.1243, and the group after the Cold War is 0.0975. However, the difference between the two groups is not statistically significant ($\chi^2 = 0.06$, and $p = 0.8138$). In other words, although it seems that the construction under the Cold War has a shorter duration and may be

completed more efficiently, the effect of the Cold War cannot be considered as statistically significant.

Table 3.8: Reactors by Cold War period

The Cold War?	time at risk	Incidence rate	no. of subjects	Survival time 25%	25%	25%
After	759.2361	0.0975	131	5.0924	5.9658	10.2286
During	4270.5106	0.1243	536	5.2841	6.4887	8.8323
Total	5029.7468	0.1203	667	5.1581	6.4257	8.8323

Table 3.9: Log-rank test for equality of survivor functions: During/after the Cold War

The Cold War	Events observed	Events expected		
After	74	72.14		
During	531	532.86		
Total	605	605	$\chi^2 = 0.06$	$Pr > \chi^2 = 0.8138$

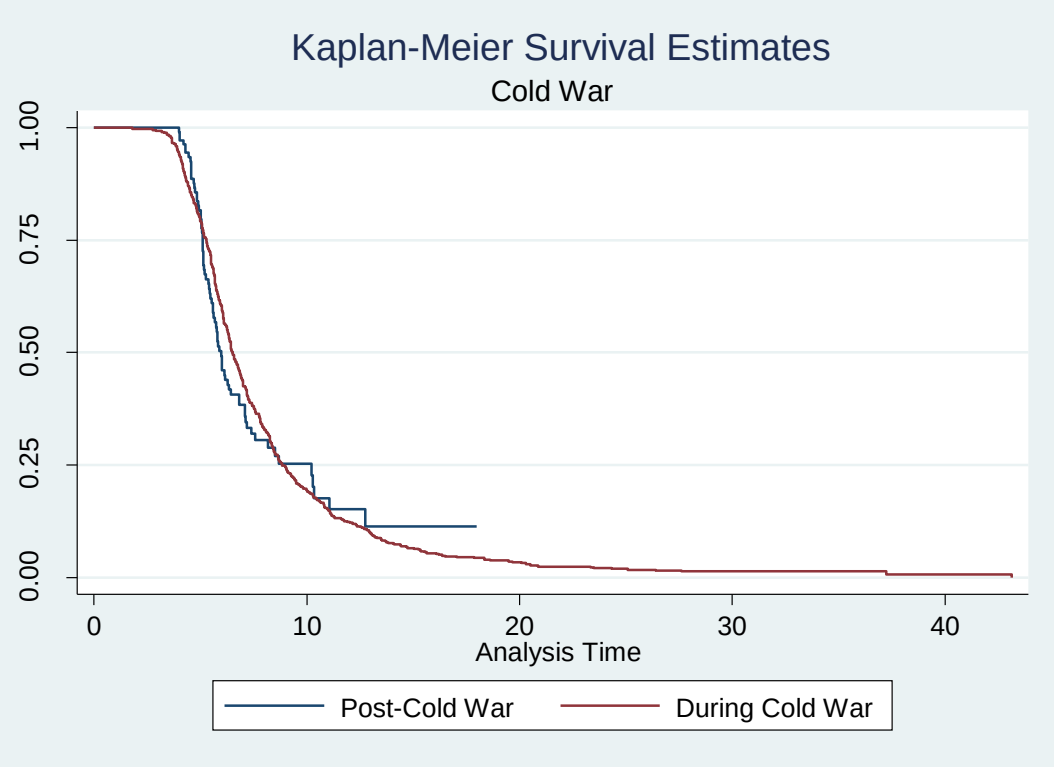


Figure 3.2: K-M curve by during/after Cold War

Foreign Dependency

First, the figure and table below show the survival functions for the group having dependent relationships or foreign vendors (dependency = 1) and the group of indigenizing the constructions of their own nuclear power plants (dependency = 0). The survival functions presented here show that at any time point, the dependency on the foreign vendor is associated with higher survival rate. The incidence rate of the indigenized construction is 0.1276, and the dependent is 0.1014. In addition, the difference between the indigenized and the dependent is statistically significant ($\chi^2 = 8.42$, and p =0.0037). In other words, the indigenized construction is faster than the dependent; thus, the dependency implies a longer duration of completing the construction.

Table 3.10: Reactors by foreign dependency

Dependency	time at risk	Incidence rate	no. of subjects	Survival time 25%	50%	75%
Indigenized	3620.0000	0.1276	499	5.1444	6.3765	8.6516
Dependent	1409.7467	0.1014	168	5.2238	6.8200	9.6318
Total	5029.7468	0.1203	667	5.1581	6.4257	8.8323

Table 3.11: Log-rank test for equality of survivor functions: Foreign dependency

dependency	Events observed	Events expected		
indigenized	462	430.01		
dependent	143	174.99		
Total	605	605	$\chi^2 = 8.42$	$Pr > \chi^2 = 0.0037$

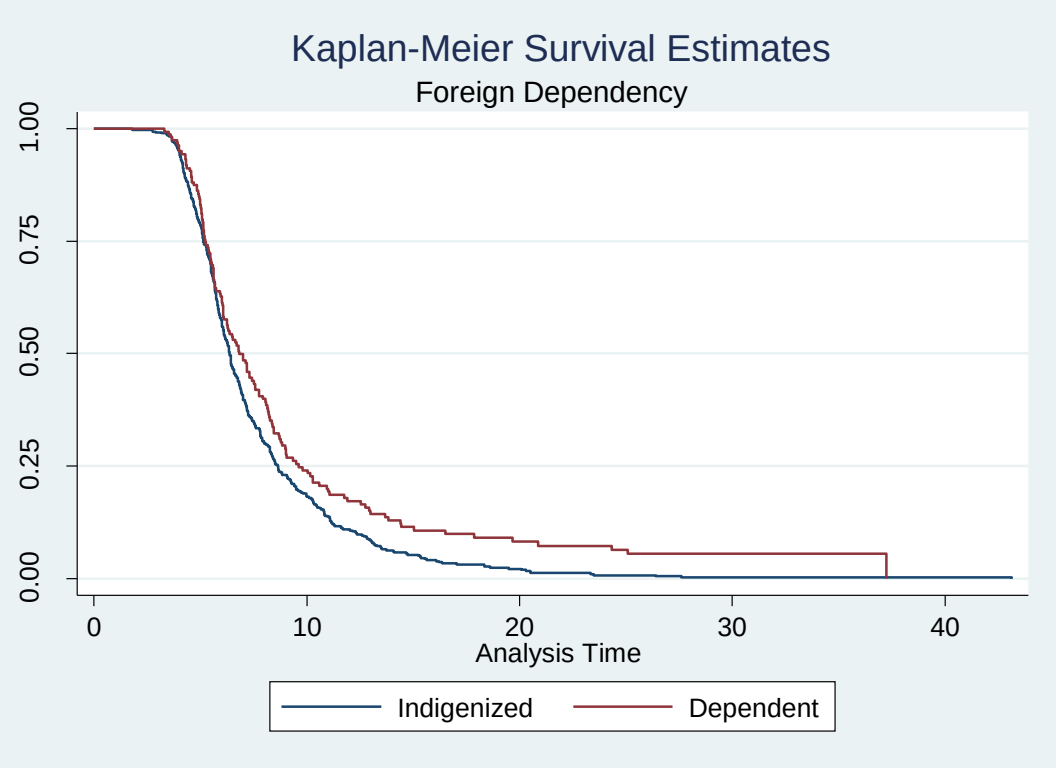


Figure 3.3: K-M curve by foreign dependency

Types of Political Regimes

The survival functions of different types of political regimes show that the constructions in the developmental state are the most efficient (incidence rate = 0.1753), capitalist democracies are the second (incidence rate = 0.1286), the socialist regime is the third (incidence rate = 0.0894), and the other state is the last (0.0699).

Table 3.12: Reactors by types of political regimes

Political Regime	time at risk	Incidence rate	no. of subjects	Survival time		
				25%	25%	25%
Capitalist dem.	2730.4942	0.1278	355	5.4757	6.7488	9.1608
Socialist regimes	1300.7529	0.1015	165	5.6099	6.7817	9.0240
Dev. States	519.2580	0.1733	97	4.2847	5.0240	5.9055
Other	479.2416	0.0709	50	7.1239	10.2286	13.6728
Total	5029.7468	0.1203	667	5.1581	6.4257	8.8323

The incidence rates of both capitalist democracy and the developmental state are higher than the average (incidence rate = 0.1203), and the socialist state and the other state are lower than the average. However, the difference of capitalist democracies to the average condition is not statistically significant (χ^2 = 0.11, p=0.7438). In other words, the constructions in the capitalist democracies have no significant differences against the average conditions. Thus, following this result, this research set capitalist democracies as the baseline category for comparing the efficiency and tardiness of each kind of political regime.

Table 3.13: Log-rank test for equality of survivor functions: Capitalist democracies

Capitalist democracies	Events observed	Events expected		
No	256	259.93		
Yes	349	345.07		
Total	605	605	$\chi^2 = 0.11$	$Pr > \chi^2 = 0.7438$

On the other hand, the differences of the other three categories of political regimes are all statistically significant. The developmental states have the shortest duration from start construction to commercial operation, implying that they complete the constructions faster than any other political regimes. In contrast to the developmental states, the survival functions and K-M curves of both socialist regimes and the other states are above the total survival function and its K-M curve. In other words, the durations of the constructions are longer in these two kinds of political regimes.

Table 3.14: Log-rank test for equality of survivor functions: Socialist regimes

Socialist	Events observed	Events expected		
No	473	446.20		
Yes	132	158.80		
Total	605	605	$\chi^2 = 6.27$	$Pr > \chi^2 = 0.0123$

Table 3.15: Log-rank test for equality of survivor functions: The developmental states

Socialist	Events observed	Events expected		
No	473	446.20		
Yes	132	158.80		
Total	605	605	$\chi^2 = 6.27$	$Pr > \chi^2 = 0.0123$

Table 3.16: Log-rank test for equality of survivor functions: Other

Other	Events observed	Events expected		
No	571	539.12		
Yes	34	65.88		
Total	605	605	$\chi^2 = 17.67$	$Pr > \chi^2 = 0.0000$

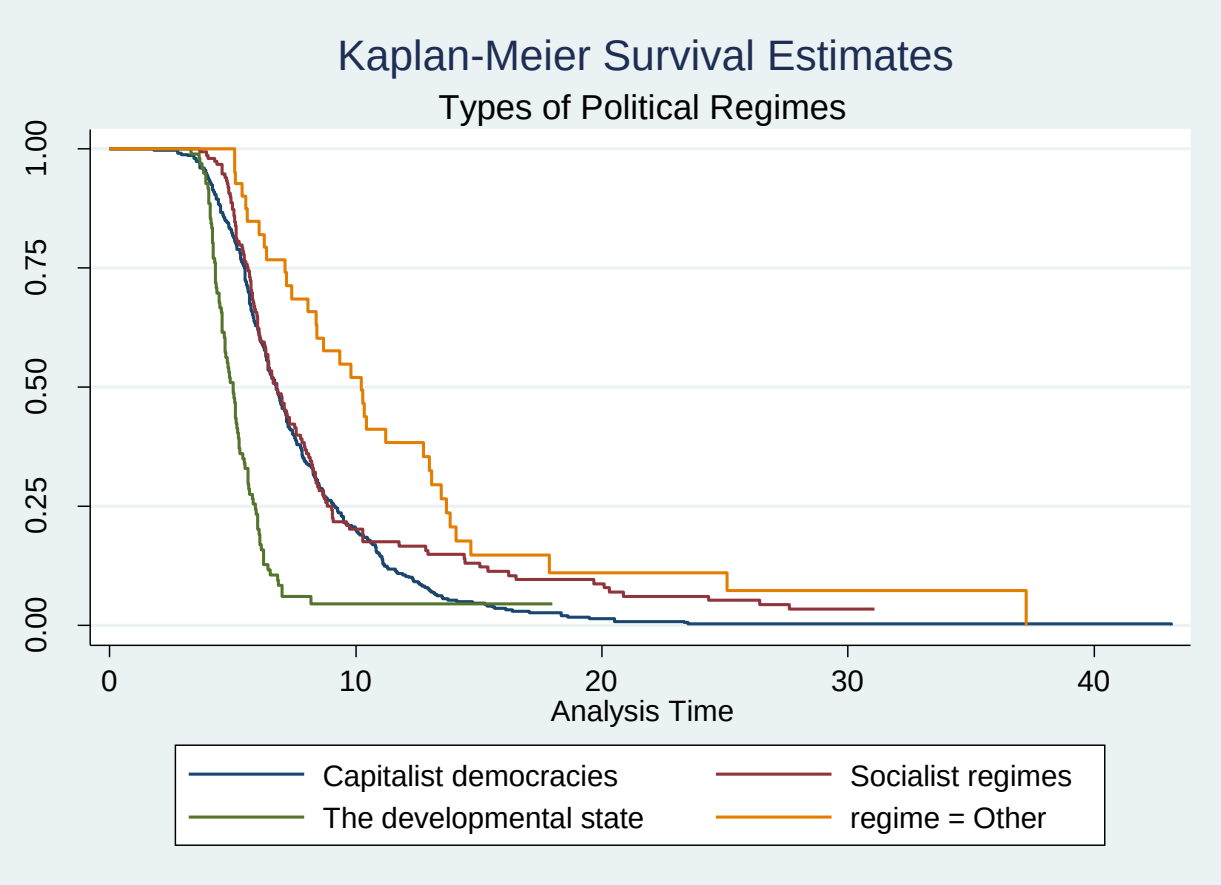


Figure 3.4: K-M curve by types of political regimes

Semi-Parametric Cox Regression Model

Hazard ratio is typically used in clinical or public health research for computing if the risk of a given event such as death increases or reduces. A hazard ratio below 1 indicates a decrease in the probability of the expected event, and above 1 means an increase.

Models 1, 2, 3, 4, and 5 examine the hypothesis related to the level of democracy, owning nuclear weapons, the milieu of the Cold War, and the foreign dependency. Model 1 indicates that the level of democracy is positively associated with the efficiency of construction, which is in contrast to the general impression that democracies with routinized channels of contentious politics may disfavor the construction of the nuclear power reactor. Although the democratic degree reaches the statistical significance, the probability of its influence is relatively lower (close to 1). Model 2 shows that owning nuclear weapons has a statistically significant association with the efficiency of construction, but in a negative way in contrast to the research hypothesis. Instead of increasing the probability of entering the commercial operation and reducing the duration of construction, owning nuclear weapons tends to be more similar to a liability than an asset, delaying the constructions. Model 3 indicates that the Cold War is not significantly associated with the efficiency of construction. Model 4, with statistical significance, indicates that the coefficient of the foreign dependency shows that the reduced probability of the expected event is in the same direction with the research hypothesis that the dependency prolong the construction time. Models 6, 7, and 8 further examine the effects of political regimes. With the statistical significances, these models show that compared to capitalist democracies, the developmental state is associated with an obvious increase in the incidence rates. In other words, the developmental state is more likely to complete the construction of a nuclear power plant or to complete it in a shorter time. On the other hand, the constructions in the former socialist regimes

and the other countries including the members of the Non-Alignment Movement and the Latin American countries are far behind capitalist democracies.

Table 3.17: Semi-parametric Cox Regression models: Models 1-8

VAR.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Democracy	1.0151***				1.0077			0.9997
	(0.0058)				(0.0068)			(0.0130)
Nuclear Weapons		0.7882***			0.6303***			0.8960
		(0.0660)			(0.0594)			(0.0985)
Cold War			0.9707		0.9117		1.1893	1.2283
			(0.1214)		(0.1143)		(0.1671)	(0.1846)
Dependency				0.7561***	0.6364***			0.6969***
				(0.0731)	(0.0799)			(0.0920)
Political Regimes								
Socialist						0.8143**	0.8385*	0.9601
						(0.0844)	(0.0889)	(0.2117)
Dev. States						2.6708***	2.8881***	3.0625***
						(0.3262)	(0.3948)	(0.5141)
Other						0.4949***	0.5169***	0.6025**
						(0.0895)	(0.0951)	(0.1220)
N	654	667	667	667	654	667	667	654

Coefficients are **hazard ratios**; Standard errors in parentheses
*** p<0.01, **
p<0.05, * p<0.1

When adding the variables of political regimes to the models, the effects of foreign dependency, democracy, and owning nuclear weapons are offset. As illustrated by the degrees with which the different political regimes overcome the tardiness of pursuing the development of nuclear power, the types of political regimes may partially include the explaining elements of

these two variables. It is especially shown in the developmental states that excel over all the other states in the constructions. For the effect of foreign dependency, the developmental state has a higher percentage of indigenization (72.45%) than both the former socialist regimes (57.23%) and the other states (44.00%). For the effect of owning nuclear weapons, the developmental states are all excluded from the proliferation of nuclear weapons.

Table 3.18: Indigenization of nuclear reactors construction

Political Regimes	Foreign Dependency				
	Indigenized		Dependent		
	#	%	#	%	Total
Capitalist democracies	313	87.92	43	12.08	356
Socialist regimes	95	57.23	71	42.77	166
Developmental states	71	72.45	27	27.55	98
Other	22	44.00	28	56.00	50
Total	501	74.78	169	25.22	670

In Models 9 and 10, the interactions of foreign dependency and owning nuclear weapons with different political regimes are added. For foreign dependency, all the interactions are significant, except the one with the typical capitalist democracies countries. In addition, the associations show that foreign dependency lowers down the efficiency of construction severely. For owning of nuclear weapons, the associations show that nuclear weapons are more similar to liabilities than assets to the construction of civilian nuclear power plants.

Table 3.19: Semi-parametric Cox Regression models: Models 9 & 10

VARIABLES	(9)	(10)
Dependency × Capitalist democracies	1.1170	
	(0.1806)	
Dependency × Socialist	0.6176***	
	(0.0871)	
Dependency × The Dev. State	1.4578*	
	(0.3012)	
Dependency × Other	0.4224***	
	(0.1025)	
Nuclear Weapons × Capitalist democracies		0.8093**
		(0.0741)
Nuclear Weapons × Socialist		0.8300
		(0.1009)
Nuclear Weapons × The Dev. State		-
Nuclear Weapons × Other		0.5525***
		(0.1127)

N = 667
Coefficients are hazard ratios; Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In Models 11 and 12, the interaction between the Cold War and political regimes is added. The interaction between the Cold War and political regimes is not only statistically significant, but they also drastically intensify the association with the developmental states. In other words, the effects of the Cold War on the efficiency of construction in the different political regimes cannot be ignored.

However, we still need to examine if the catch-up of the developmental state comes from the latecomers' competitive advantage by avoiding the costs of trial-and-error in the earlier stages of the R&D. By illustrating the time points of the first construction in each country, compared to the other political regimes, the developmental states are relatively late in joining the group of nuclear users.

Table 3.20: Semi-parametric Cox Regression models: Models 11 & 12

VARIABLES	(11)	(12)
Dependency × Cold War		0.8091
		(0.1047)
Nuclear Weapons × Cold War		0.8547
		(0.0970)
Capitalist democracies × Cold War	0.9642	1.1061
	(0.1241)	(0.1735)
Socialist × Cold War	0.6880**	0.8458
	(0.1085)	(0.1631)
The Dev. State × Cold War	3.6271***	4.0047***
	(0.6335)	(0.7358)
Other × Cold War	0.4090***	0.5033**
	(0.1008)	(0.1365)

N = 667
Coefficients are hazard ratios; Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

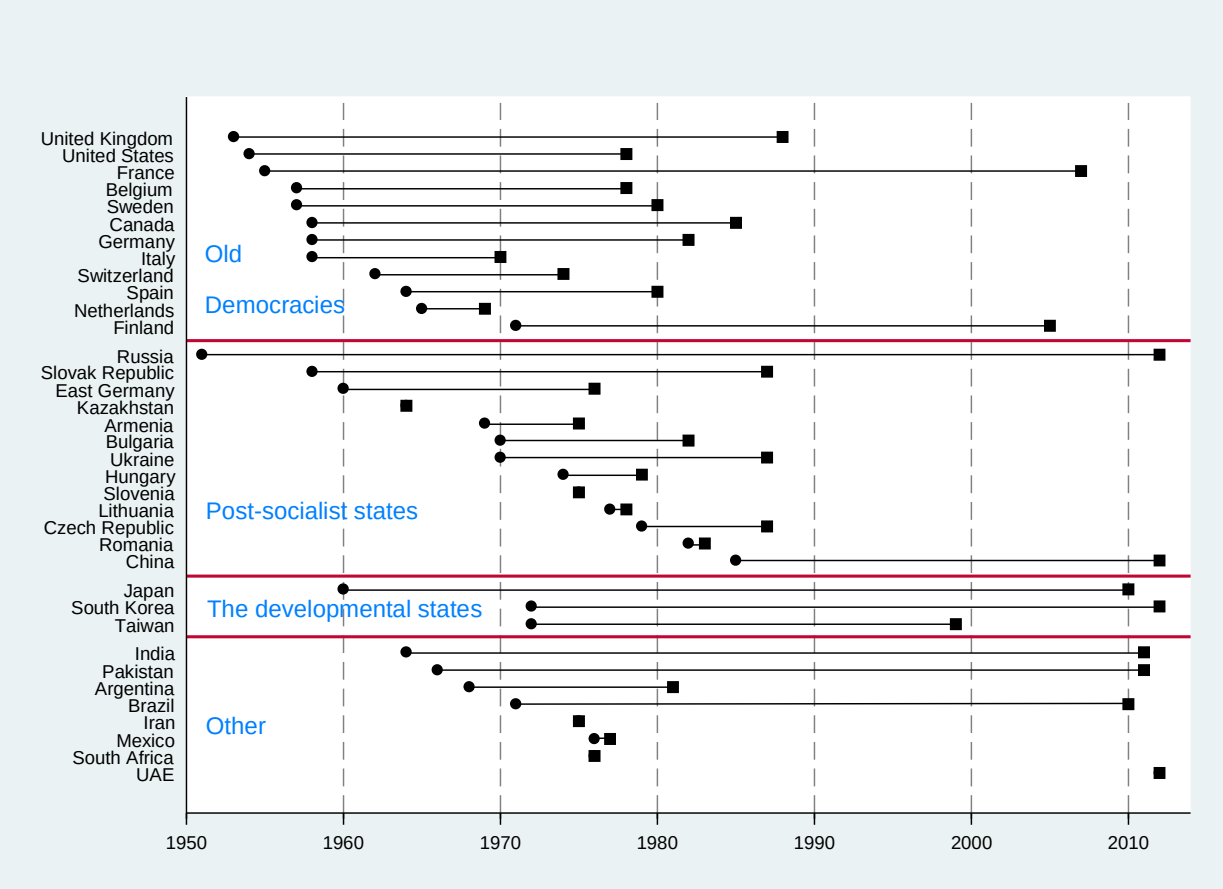


Figure 3.5: Time-span from first to latest reactor construction

To determine if the efficiency of the developmental state comes from the dividends for the latecomers, the start construction date is added to the models. Although the effect of the start construction date reaches the statistical significance, it does not illustrate the expected dividends for the latecomers. Instead, the efficiency of construction gradually declines slightly. In addition, as shown in Models 17 and 18, even after adding the start construction date to the models, the developmental state still has significant effects on the efficiency of the constructions. In other words, the effect of latecomers' dividends is slight, and the developmental state is still a key point for overcoming the tardiness and reducing the duration of construction.

Table 3.21: Semi-parametric Cox Regression models: Models 13-18

VARIABLES	(13)	(14)	(15)	(16)	(17)	(18)
Democracy				1.0000		1.0087
				(0.0070)		(0.0128)
Nuclear Weapons	0.7719***		0.6222***	0.6222***		0.8863
	(0.0648)		(0.0593)	(0.0593)		(0.0975)
Start Construction Date	0.9999***	1.0000***	1.0000***	1.0000***	0.9999***	0.9999***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Dependency		0.7910**	0.6133***	0.6135***		0.6675***
		(0.0768)	(0.0675)	(0.0792)		(0.0883)
Political Regimes						
Socialist					1.0779	1.4760*
					(0.1187)	(0.3252)
The Dev. State					4.0382***	4.5369***
					(0.5515)	(0.7324)
Other					0.6240**	0.8002
					(0.1148)	(0.1606)

N = 640
Coefficients are hazard ratios; Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5. Discussion

Several trends can be discovered with the analysis presented in this chapter.

First, in contrast to the hypothesis, democracy does not slow the development of the nuclear industry. Instead, the results show a counter-intuitive trend that democracy is in a slightly positive relationship with the efficiency of construction, illustrating a slight increase on the probability of completing the construction in a shorter time. In addition, after adding the types of the political regimes to the model, the effect of democracy is not statistically significant. In other words, that democracy is not intrinsically against the development of civilian nuclear power.

Second, as being against the hypothesis but statistically significant, possessing nuclear weapons is negatively associated with the development of nuclear power. There is no evidence supporting the argument that there can be a positive spill-over from the development of nuclear weapons to the civilian nuclear power. Instead, the possession of nuclear weapons plays a role more similar to a liability than an asset for developing the civilian nuclear power. As shown in the interactions of owning nuclear weapons with the types of political regimes, the possession of the nuclear weapons significantly reduces the efficiency of completing the constructions on time in the former socialist regimes and the developing countries other than the East Asian NICs. In contrast, although the referred developmental states have greater potentiality for developing nuclear energy, they do not possess any nuclear weapons.

Third, when interacting with specific types of political regimes, the Cold War milieu favored the development of nuclear policy. Considering the interaction between the Cold War and the political regimes, the effects of war-mobilization are more significant and intense. Under the milieu of the Cold War, the developmental states experience high growth in the civilian nuclear programs.

Fourth, the effect of foreign dependency is negative. In addition, the distribution of the disadvantage brought by the foreign dependency is uneven. This dependency is highly concentrated in the countries belonging to the group of former socialist countries that are dependent on Russia (42.77%) and the group of the non-East Asian developing countries (56.00%). For the developing countries in the Global South, they are more likely to be entrapped by foreign dependency. In addition to the capitalist democracies, the developmental states also achieve a higher proportion of self-reliance in a relatively short time. Although foreign dependency may also appear in the initial stages of the development of nuclear industry in the capitalist democracies and the developmental states, its effect is insignificant and even shows a slightly positive association with the efficiency of construction. In short, instead of a short-cut to a full-fledged nuclear industry and the attached economic efficiency, foreign dependency is more similar to a trap of under-development or dependent development, especially for the developing countries other than the developmental states.

Finally, the political regime of the developmental state is the most prominent factor determining the efficiency of developing nuclear power. As immune to the negative effect of foreign dependency, absent of nuclear weapons, and favored by the Cold War milieu, the developmental state is prominent in overcoming the tardiness of developing nuclear power. Moreover, by adding the control variable, the start construction date, to examine if this advantage is caused by the evolution of the technology itself, namely the latecomers' competitive advantage, the significance of the effects brought by the developmental state do not disappear but are intensified. In short, the strong association between the developmental state and the efficiency of the construction of the nuclear power plants shows that the developmental state is the most effective factor to predict the efficiency of developing nuclear power. When

considering all the variables in a single model (Model 8), the effect of foreign dependency shows statistical significance, but the effect of the developmental state is still the variable that explains the development of nuclear power the most and even increases its influence.

6. Conclusion

The results of the event history analysis generally address the research question of how the development of nuclear power is affected by different social arrangements. The findings first show that the given western-centered perspective oversimplified the relationships of democracy and war mobilization with the development of nuclear power. Then they indicate that the two alternative perspectives, the world systems theory and the developmental state theory, are more powerful explanations: The development of nuclear power embodies the unequal exchange between the core and periphery, which is empowering the patrons and weakening the clients. On the other hand, the developmental states are the rare cases that can get out of the trap, being in the semi-peripheral positions of the world system.

First, the role of democracy in developing nuclear power is not negative, as illustrated in the given literature. The assumed structural contradiction between the political contentions in democracies and the nuclear industry is not inevitable or inherent on the global level.

In addition, the lineage from the anti-war grievance to the anti-nuclear movement is not the only route followed by the nuclear development. War-making or war-preparation is associated with the development of the nuclear industry but in a complex way. The relationship between "the sword and the plow" is not a direct conversion, but more similar to a trade-off or a curve-linear relationship. On the one hand, the negative association between the possession of nuclear weapons and the efficiency of constructing nuclear power plants supports the argument

that the weapon R&D of modern military-production complex leads to the bottleneck of baroqueness, obstructing the positive spill-overs of technological innovations from the military sectors to the civilian sectors and finally damaging the legitimacy of the military R&Ds (McLauchlan and Hooks 1995). This also implies that the conversion rate between coercive measures and economic capital is changed according to the geopolitical contexts (Tilly 1992). For example, although the East Asian developmental states do not formally possess any nuclear weapons, they harnessed the threat of proliferation to trade in the United States promising to provide more diplomatic, military, economic, and technological supports (Choi and Park 2008; Green and Furukawa 2008; Hersman and Peters 2006; Hong 2011; Jasanoff and Kim 2009; Jasanoff and Kim 2013; Kang and Feiveson 2001; Kogan 2013).

On the other hand, the positive association of the Cold War milieu also implies the context-based conversion between coercion and capital. The Cold War, as a continual process of war mobilization, set an emergency situation or state of exception that can effectively silence the public debates and democratic accounting regarding this sensitive technology. The developmental state that has been the most efficient in developing the nuclear industry is the most typical case of this situation. In his analysis of the developmental state, Cumings (1984, 1999) also defines this polity as the bureaucratic authoritarian industrial regime, which is just formed by and under the hegemonic plan of the United States in the Cold War and is a major part of the containing policy of the communist regime. In addition, as criticizing the Japanese nuclear industry as a sacrificial system externalizing the costs of nuclear disaster to the people and communities living in the peripheral areas in Japan, Takahashi (2014) clearly determined that this asymmetric power relationship was legitimized by the rhetoric of wartime mobilization and emergency situation. In brief, with the results stressing that the Cold War formed a friendly

environment for the development of the nuclear industry, the affinity between the wartime mobilization and the industry policy once again gets supported.

The two alternative theoretical perspectives and their related hypotheses are supported by the findings. First, the negative effect of foreign dependency regarding the efficiency of construction supports the world systems theory, indicating that the development of global nuclear industry generally follows the rule of unequal exchange between the core and periphery. Second, we find that the developmental state is the most prominent factor predicting the efficiency of developing nuclear power.

Although these two theoretical arguments appear to be conflicting, this research considers that they are actually compatible with each other: They indicate that the East Asian developmental states have been embedded in the semi-peripheral layer of the world system, playing the intermediate role of maintaining the whole structure. With the examination of the interaction between the effects of foreign dependency and the political regime of the developmental state, it indicates that the early dependency of the developmental states is slighter than the Soviet camp and the non-East Asian developing countries. As elaborated in the review of these two theoretical perspectives in the last chapter, the following questions are how the world system constitutes the embeddedness of the semi-peripheral position and how the developmental states work to overcome the external constraints imposed by the embeddedness.

In addition to the problem of the compatibility between the two theoretical perspectives, we also must manage two deviant cases against the theories. First, on the developmental state theory, although typically categorized as the developmental state and sharing the reputation of the economic miracle, Taiwan did not produce the fast pace of developing nuclear power. Compared to Japan and South Korea, which have high efficiency and successfully achieved the

import-substitution of nuclear industry, Taiwan is still solely dependent on the United States in developing its nuclear programs and has a far lower efficiency. The questions of why and how Taiwan failed to overcome the tardiness and achieve the self-reliance indicates the need to examine if there are further differences between the developmental states having major differences regarding nuclear development.

On the world systems theory, in addition to the exceptional upward mobility of the semi-periphery, China has been noted by scholars for its astonishing ascent in the hierarchy of global wealth. However, the event history analysis does not reflect this trend. China started its civilian nuclear programs late in the mid-1980s. Although China's civilian nuclear industry is young, its scale is large and soon to be self-reliant. While the number of the reactors is increasing rapidly, more than half of the reactors are still under construction and must be measured as the censored observations. This situation reduces the incidence rate of entering commercial operation and thus obstructs the accurate estimation of its potentiality. In addition to the problem of measurement, the ambiguity in classification also involves China. On the one hand, although clustered in the former socialist bloc, its first civilian nuclear program was developed in the period of the market-oriented reform. Whereas the other socialist countries developed their nuclear industry under the socialist ideology and state-planning, the late-born nuclear industry of China seems to be following its neighbors' developmental strategy. Scholars argue that China has been a developmental state since the late 1970s market-oriented reform (Baek 2005; Whyte 2009). In addition, seen through the case study of the infrastructure projects such as dam construction in China and Southeast Asia, it is easy to find the influences of Japanese developmentalism (McCormack 1999). On the other hand, although having the geographical adjacency, whether China steps on the similar path of the neighboring developmental states has

long been in debate. While all East Asian countries have learned the developmental model from the Greater East Asia Co-Prosperity Sphere manufactured in WWII, the war experiences also place skepticism on the Japanese developmental mode and thus form an unresolved contradiction inherent in the regional identity (Kern, Mayer, and Nam 2014). Furthermore, although state-owned enterprises take a large share of China's economy, the political wills of the central and local governments may not be integrated with each other to the extent of the embedded autonomy in the developmental state (Lee 2014). Instead, the nuclear politics in China indicates that the sector in charge of developing the civilian nuclear power, rather than a nodal agency monopolizing the power of decision-making (Chibber 2002, 2003), is a far less-integrated organization checked and balanced by many other vested interests or local governments (Xu 2010). In short, although categorized as a post-socialist regime because of its socialist legacy before late 1970s, China also contains several key elements of the developmental state such as the state-led enterprises and the market-oriented economy, thus making the categorization and comparison difficult to be conducted.

The following task for resolving the problems brought by the deviant cases is to determine how the developmental state can achieve this status and clarify if this concept needs to be modified to reach a more comprehensive explanation reconciling these deviant cases. Most literature on the developmental state focusing on the embedded autonomy has been investigating the role of the state capability. With this reminder, this research next conducts a comparative analysis of the nuclear development in the four East Asian countries to determine if there are any nuances of the compositions of the developmental state making the distinction in the destiny of the nuclear industry. On the other hand, to avoid overemphasizing the social embeddedness within the state and thus misrecognizing the compared states as isolated entities, the network

analysis is used to examine how the external conditions influence nuclear development, such as the structural positions in the hierarchy of the world system.

Table 3.22: Incident rates by country (countries having less than 15 reactors in lower half)

location	time at risk	incidence rate	no. of subjects	Survival time		
				25%	50%	75%
Japan	292.8898	0.2014	61	4.1287	4.4600	5.1526
South Korea	153.3854	0.1630	28	5.0240	5.4757	6.0041
Germany	253.7878	0.1419	36	4.9993	6.5873	7.7974
France	493.7413	0.1418	71	5.6674	6.3354	7.5127
Canada	180.9281	0.1382	25	5.6646	6.9432	8.5202
China	281.3005	0.1244	55	5.2676	5.8125	6.8200
United Kingdom	367.2498	0.1225	45	5.3251	6.4175	8.6653
United States	1161.7385	0.1145	137	5.4976	7.2936	11.0965
Russia	392.0137	0.1046	48	5.6728	6.5763	9.0842
Ukraine	210.7789	0.0901	21	5.1225	6.6311	8.8268
India	247.6961	0.0848	27	7.1923	10.2888	13.0705
Netherland	8.2218	0.2433	2	3.9014	3.9014	4.3203
Belgium	48.4764	0.1650	8	4.9391	5.6263	6.8337
Switzerland	30.4723	0.1641	5	4.0000	5.6865	5.9165
Italy	25.1691	0.1589	4	3.5044	4.5832	5.1663
Sweden	82.6968	0.1572	13	5.2895	6.4148	6.9131
Armenia	13.1061	0.1526	2	4.8405	4.8405	8.2656
Bulgaria	46.4120	0.1293	6	5.6099	7.3046	8.7173
Slovenia	7.7591	0.1289	1	.	.	.
Pakistan	32.1752	0.1243	7	5.3854	5.5880	6.3518
Spain	82.4011	0.1214	10	5.1362	8.9719	10.5708
Lithuani	16.6324	0.1202	2	7.0007	7.0007	9.6318
Hungary	34.5654	0.1157	4	7.1677	8.0849	9.0240
South Africa	17.4127	0.1149	2	8.0548	8.0548	9.3580
Kazakhstan	8.7885	0.1138	1	.	.	.
Finland	38.4586	0.1040	5	6.0233	6.6886	8.4298
Czech Republic	61.3032	0.0979	6	7.2170	7.8056	15.3539
Taiwan	72.9829	0.0822	8	5.9329	6.2368	7.0007
Mexico	31.6797	0.0631	2	13.8234	13.8234	17.8563
Romania	38.7570	0.0516	2	14.4230	14.4230	24.3340
Slovak Republic	140.1615	0.0499	9	8.6899	14.4011	16.4956
Brazil	45.5880	0.0439	3	13.6728	13.6728	25.0869
Argentina	54.7159	0.0366	4	6.0616	9.8042	.
Iran	37.2485	0.0268	1	.	.	.
UAE	12.7255	0.0000	4	.	.	.
Belarus	6.3272	0.0000	2	.	.	.
Total	5029.7468	0.1203	667	5.1581	6.4257	8.8323

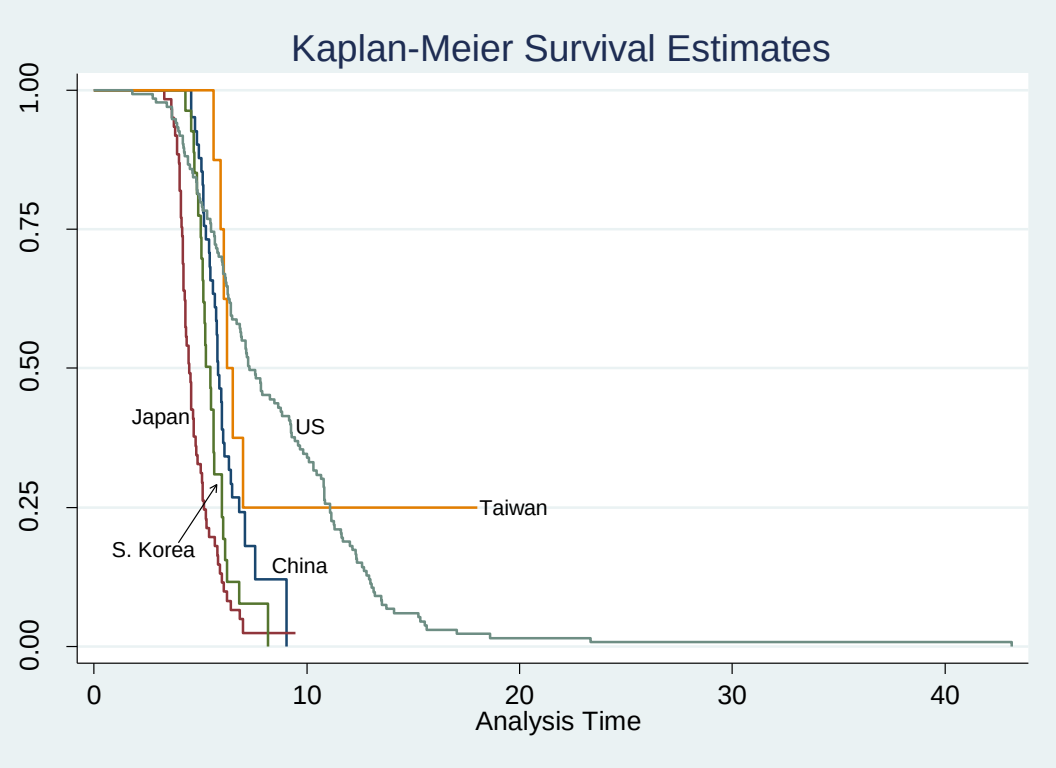


Figure 3.6: K-M curves of US/Japan/South Korea/Taiwan/China

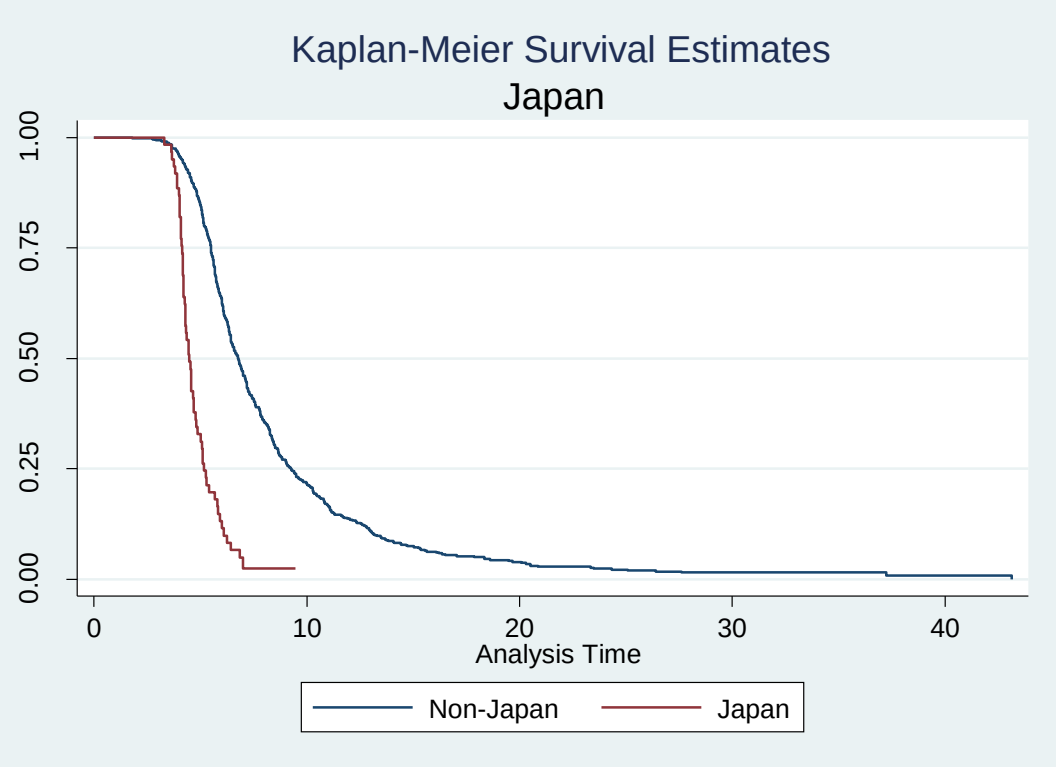


Figure 3.7: K-M curve of Japan

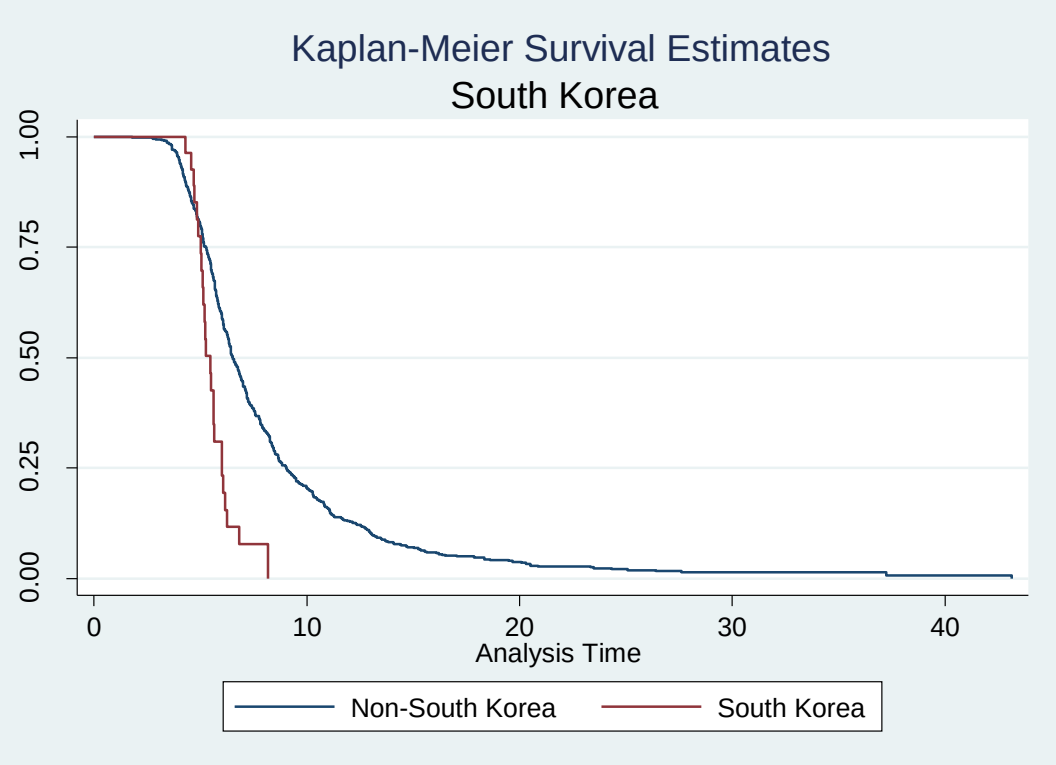


Figure 3.8: K-M curve of South Korea

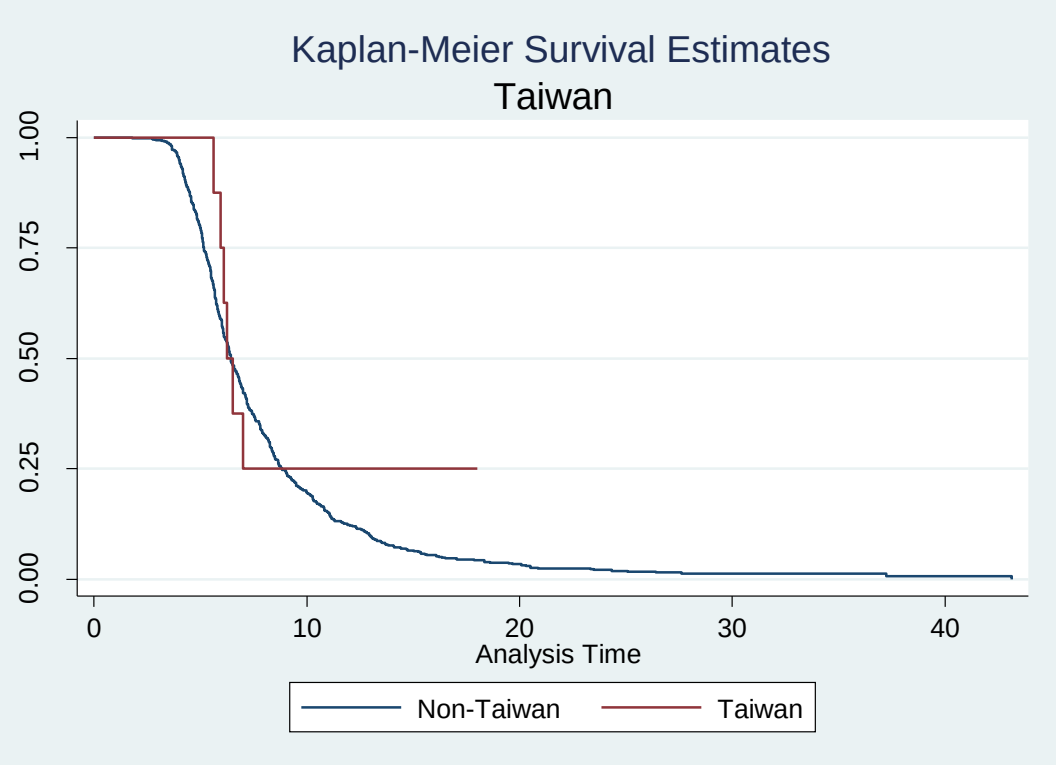


Figure 3.9: K-M curve of Taiwan

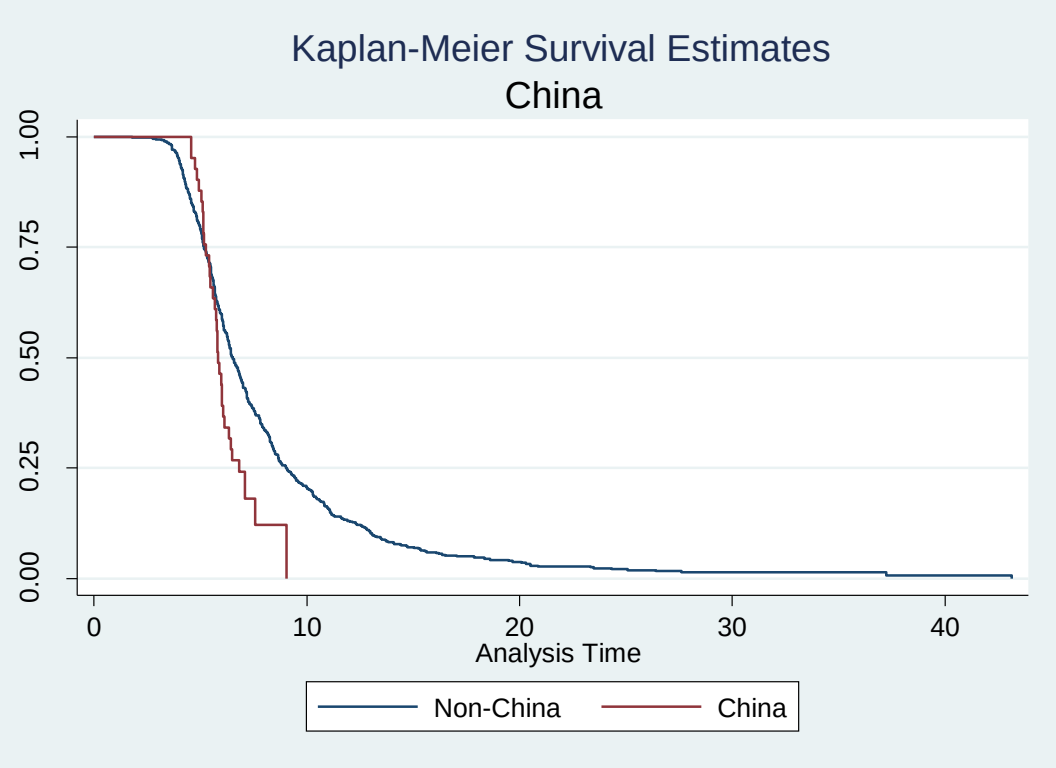


Figure 3.10: K-M curve of China

CHAPTER FOUR

NETWORKING DEVELOPMENT: SOCIAL NETWORK ANALYSIS OF GLOBAL NUCLEAR DEVELOPMENT

1. Introduction

Following the results of chapter 3, the development of the nuclear industry is highly associated with the developmental state and the milieu of the Cold War. Whereas foreign dependency delays the constructions in the former socialist countries and the non-East Asian developing countries, it does not harm the efficiency of construction in the old capitalist democracies and the developmental states. This stark contrast leaves an open question regarding how the developmental state can achieve the self-reliance and eliminate the side-effects of foreign dependency. The reverse function of foreign dependency in the typical capitalist democracies and the developmental states provides a clue, indicating that the connections between the patrons and clients do matter in the development of the nuclear industry.

However, instead of being depicted as a general context or a whole map, this patron-client relationship is more often elaborated in terms of the client-led project, thus de-emphasizing the structural positions in the world system occupied by both the patrons and clients. When considering the strategies of the developmental state for developing its industrial policy, scholars typically look inward to the state apparatus or the state-civil society relationships to understand the configurations of the embedded autonomy (Chibber 2002; Chibber 2003; Evans 1995). But this perspective de-emphasizes the effects of international relationships, which are usually sketched as constant and invariant. When conducting the comparative analysis, the compared cases are easy to be assumed as isolated subjects making rational choices and being

independent from their structural positions. In other words, the connections and relationships tend to be lost in the comparison. To understand relations between nations, network analysis has been suggested as a practical technique capable of properly capturing the structural characteristics (Emirbayer 1997; Gould 2003).

In addition, although not synonymous, network has an extremely close affinity with embeddedness (Granovetter 1985; Krippner, Granovetter, Block, Biggart, Beamish, Hsing, Hart, Arrighi, Mendell, Hall, Burawoy, Vogel, and O'Riain 2004; Krippner 2002; Krippner and Alvarez 2007). Embeddedness is a key concept inevitably involved in the discussion of the developmental state referred to as the basic conditions of the embedded autonomy (Block and Evans 2005; Evans 1995). The network is used to depict the social complex of governance, consisting of intertwining political and economic institutions (Block and Keller 2011; Negoita 2014; Negoita and Block 2012; O'Riain 2004). However, the network in the network governance approach is typically used as a metaphor rather than a concrete analytical tool-kit (Smith-Doerr and Powell 2005). Scholars warn that this metaphor may cause serious risks that neglect several key elements for analysis. On the one hand, with the over-emphasis on local embeddedness, the metaphorically-used networks can be over-territorialized, paradoxically cut from the more comprehensive network on the global or international level (Bair 2008; Hess 2004). On the other hand, if the network is only used as a metaphor, then the network is biased to interpretative analysis and may blind the researchers from its structural dimensions, especially the effects generated from network configurations, such as the tertius gaudens (the third party of a triad) or structural holes (Grabher 2006; Smith-Doerr and Powell 2005).

Thus, we consider the necessity of retaining relational thinking, including both the patrons and clients in international interdependence and specifying the configurations of the

relational networks with tangible structures. This research conducts a network analysis of the global supplies of the nuclear power reactors. Instead of taking for granted that the development of the nuclear industry is a direct product of the developmental state's strategy, the construction of the nuclear power plant is treated as a trade chain between the vendor and buyer states in which the nuclear technology flows from countries in the high-positions to those in low-positions. Based on this consideration, two approaches are combined in this study: world systems analysis and social network analysis. To embody the relational structure, we investigate not only the dyads, but also the triads and even the subgraphs that constituting the whole structure.

2. Methods

To conduct a network analysis, first, we must define the nodes and ties. As a highly sensitive technology and material resource, the supplies and exports of the nuclear programs are always engaged with the state. Thus, this research illustrates the commodity chain in the following diagram:

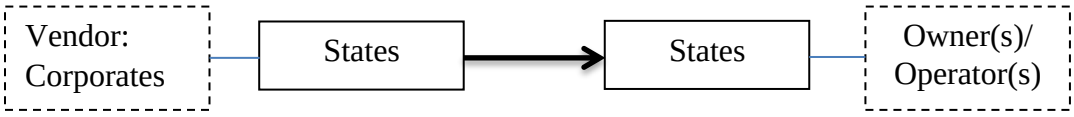


Figure 4.1: Commodity Chain

Every inter-state transaction is measured as a tie in the nuclear transaction network and weighted by the total number of the transacted reactors. The nodes refer to the political-economy entities using, importing, and exporting nuclear power. A further issue in defining the nodes needs to be addressed: the separation and independence of the former Soviet states from the USSR,

Yugoslavia, and Czechoslovakia. This research does not include USSR, Yugoslavia, and Czechoslovakia to avoid the confusion that would be caused by defining the same nodes more than once in the network. Instead, only the current, independent political entities from these countries are taken as the nodes for analysis, including Armenia, Kazakhstan, Lithuania, Romania, Russia, Ukraine, Slovenia, Czech Republic, and Slovakia. The vendor states belonging to the USSR or Czechoslovakia are coded as Russia or Czech Republic, which are the most directly inherited from these states. On the other hand, with the same concern of confounding relationships based on different historical situations such as the political division and the post-transitional re-union, East Germany is kept as a distinct node in this research.

This research uses node centrality to represent the relative power of each nuclear user in the network. Node centrality is a major indicator used to estimate power (Bonacich 1987; Bonacich 2007; Bonacich and Lloyd 2001; Borgatti 2005; Borgatti and Everett 2006; Freeman 1979; Freeman, Borgatti, and White 1991; Hanneman and Riddle 2005; Opsahl, Agneessens, and Skvoretz 2010; Wasserman and Faust 1994). To operationalize the measure of centrality, three aspects of centrality are most often calculated: degree, closeness, and betweenness (Freeman 1979). Degree is the simplest form of centrality measure, representing the centrality as the summation of a node's connections to other nodes. Here, the in-degrees measure imports and the out-degrees measure exports. However, the simple degree measure considers only the general volume of the connections, missing other core aspects of centrality. Bonacich (1987) developed a centrality measure that considers the adjacency and the transitivity of the asymmetric power relationships to the degree centrality measure. This centrality measure, beta (β) considers aspects of the entire network, giving each tie different weights. With the centrality measure of Bonacich

power, network analysis can better manage the problem of dependency and adjacency (Bonacich 1987; Hanneman and Riddle 2005).

In addition to degree, the other two most-often used measures are closeness and betweenness. Both closeness and betweenness consider the geodesic distances, the shortest paths between two specific nodes, as a key element of their measurements. The measure of closeness is a reverse function of the geodesic distances, measuring the distance or far-ness of a given node to all the other nodes. However, the network of the global supply of the nuclear power reactors is an unconnected graph because not every node can reach any other point on the network through ties. When a network is unconnected or disconnected, the inverse closeness of the unconnected nodes, i.e., their geodesic distances, is infinite; thus, the measurement of closeness cannot be computed. Due to this limitation, this research does not compute the closeness for measuring the node centrality.

The measure of betweenness considers the intermediate role of nodes, highlighting their positions between nodes along the geodesic path. Considering that intermediate positions may be attached with greater bargaining power to both sides of the transactions, betweenness has been taken as a major indicator of node centrality. However, the concerned network of this research has only a few intermediate nodes, making it difficult to present the centrality of power with the measurement of betweenness. Despite that it is unable to use the measurement of betweenness as a direct indicator of the power on the network, this research still computes the betweenness for illustrating the diffusion of the nuclear technology with the network-flow thinking (Borgatti 2005).

Furthermore, on the node centrality, the matrix consists of the column and row of the transacting countries. To measure the degree of the self-reliance, this research keeps the values

of the diagonal axis and measures it as valid rather than invalid. In other words, when a state produces a nuclear reactor in its own territory, this research does not count this nuclear reactor as zero but sums it up to the value of this state's degree. Moreover, instead of measuring the ties as binary or dichotomized, compressing the different weights of the ties, this research measures the ties and the network as a valued graph with directed ties to illustrate the asymmetrical power relationships (Freeman, Borgatti, and White 1991; Opsahl, Agneessens, and Skvoretz 2010).

Finally, a triad census is conducted to depict the structure of the whole network (Borgatti, Everett, and Johnson 2013; Holland and Leinhardt 1976; Moody 1998). With the perspective of the world systems analysis, this research strives to examine whether the exchanges between the states are even or uneven. With the techniques for elaborating the distribution of dyads and triads, network analysis perfectly fits to address these exchanges and their unevenness. By translating unevenness or inequality into transitivity or reciprocity between nodes, the triad census can provide a holistic evaluation of whole network structure. To investigate how power relationships influence a network, we can first represent the relations as directed ties. For this purpose, Holland and Leinhardt (1976) constructed a series of graphs showing all types of directed dyads and triads. First, they defined the directed dyads as the following three relations: Null, asymmetric, and mutual.

When translating into the language of the world systems analysis, an asymmetric connection between the receiving and sending nodes can refer to the dependency of the periphery on the core. A mutual connection, on the other hand, represents reciprocal or equal relationship. A null connection indicates isolation or exclusion.

Holland and Leinhardt (1976) then listed all the 16 possible configurations of triads and coded them according to the amounts of each type of connections within the triads. Following

the mutual-asymmetric-null (MAN) order, for example, a triad containing no transactions (0 mutual connections, 0 asymmetric connections, but 3 null connections) will be coded as "003" (Borgatti, Everett, and Johnson 2013:158; Holland and Leinhardt 1976:6; Moody 1998:292). By calculating the proportions of each component in the concerned network, we can determine the transitivity or reciprocity of the whole network. Based on the measurement of the network transitivity and the distribution of all-types triads, we can finally grasp the underlying power relationship and the dynamic of the changing world system.

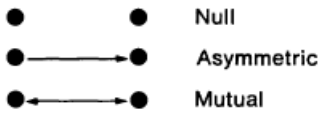


Figure 4.2: Types of directed dyads (Holland and Leinhardt 1976:5)

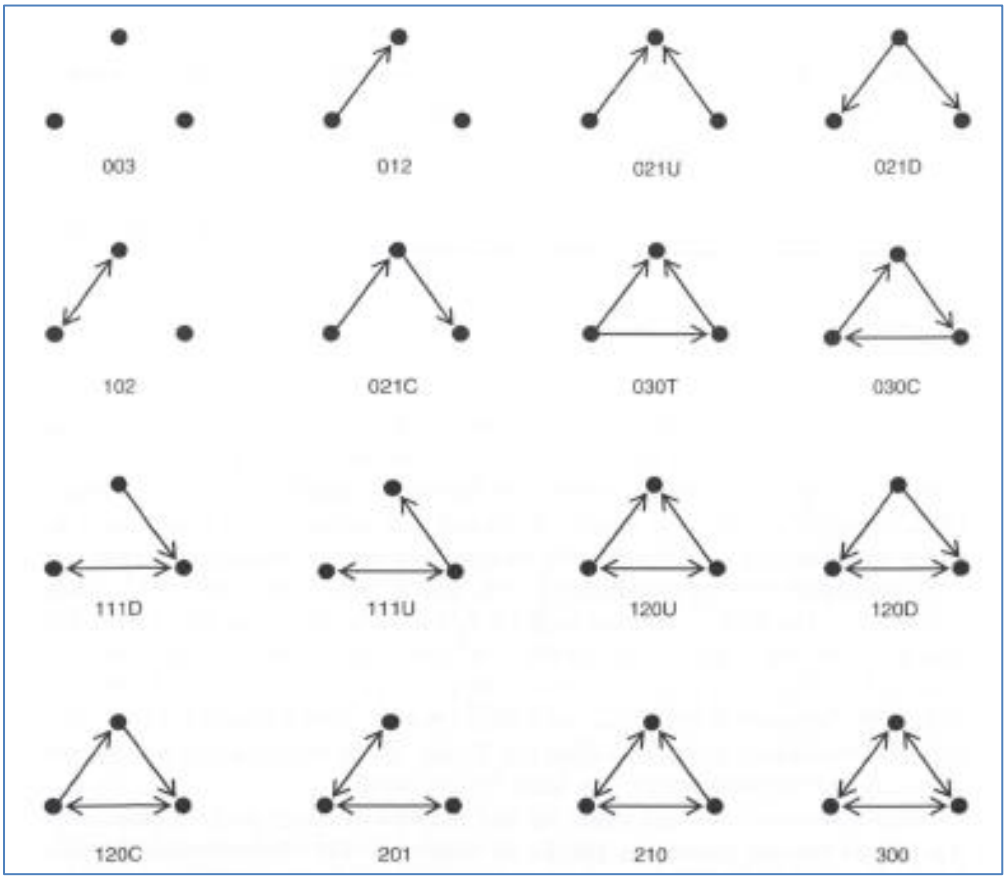


Figure 4.3: Mutual-asymmetric-null (MAN) codes of triad types (Borgatti, Everett, and Johnson 2013:158; Holland and Leinhardt 1976:6; Moody 1998:292)

3. Results

In the following sections, this research illustrates the measures of centrality to present the relative power of the modes, i.e., the countries using and transacting nuclear power reactors, on the global network of the nuclear power reactor transactions. Second, the results of triad census are presented to illustrate how the unevenness of the global nuclear power reactor transactions changes (or maintains)

The Measures of Centrality

There are 36 nodes in the general network with the time-span ranging from 1950 to 2016. Intuitively, we can see two stars or "hubs of the wheels" on the network: The United States and Russia. Considering the simplest form of degree, the measure of out-degree also shows the results matching to this intuitive observation, approving the higher centralities of their positions.

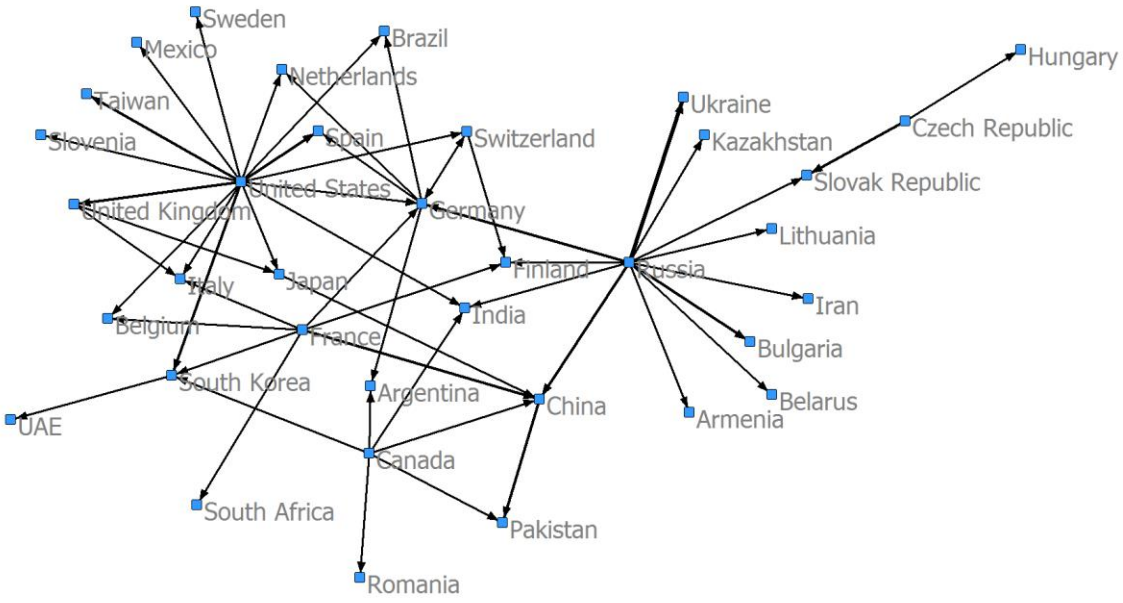


Figure 4.4: Global network of nuclear power reactor transactions, 1950–2016

Table 4.1: Centrality measures of global network of reactor transactions, 1950–2016

Country	Out-Degree	Normalized Out-Degree	Rank	Bonacich Power	Normalized Bonacich Power	Rank	In-Degree	Normalized In-Degree	Rank	Between-ness	Normalized Between-ness
United States	191	5.457	1	39803.477	6.000	1	137	3.914	1	0	0
Russia	101	2.886	2	162.063	0.024	3	48	1.371	5	0	0
France	87	2.486	3	187.044	0.028	2	71	2.029	2	0	0
Japan	59	1.686	4	102.338	0.015	4	62	1.771	3	4	0.336
China	47	1.343	5	66.930	0.010	5	56	1.600	4	5	0.420
United Kingdom	41	1.171	6	58.239	0.009	6	45	1.286	6	0	0
Canada	37	1.057	7	47.556	0.007	7	25	0.714	10	0	0
Germany	33	0.943	8	40.739	0.006	8	36	1.029	7	15	1.261
India	21	0.600	9	24.779	0.004	9	27	0.771	9	0	0
South Korea	18	0.514	10	20.037	0.003	10	28	0.800	8	3	0.252
Czech Republic	16	0.457	11	16.729	0.003	11	6	0.171	18	0	0
Sweden	10	0.286	12	10.783	0.002	12	13	0.371	12	0	0
Switzerland	4	0.114	13	4.327	0.001	13	6	0.171	18	2	0.168
Belgium	4	0.114	13	4.120	0.001	14	8	0.229	15	0	0
Argentina	1	0.029	15	1.007	0.000	15	4	0.114	22	0	0
Ukraine	0	0.000	16	0	0	16	21	0.600	11	0	0
Spain	0	0.000	16	0	0	16	10	0.286	13	0	0
Slovak Republic	0	0.000	16	0	0	16	9	0.257	14	0	0
Taiwan	0	0.000	16	0	0	16	8	0.229	15	0	0
Pakistan	0	0.000	16	0	0	16	7	0.200	17	0	0
Bulgaria	0	0.000	16	0	0	16	6	0.171	18	0	0
Finland	0	0.000	16	0	0	16	5	0.143	21	0	0
Hungary	0	0.000	16	0	0	16	4	0.114	22	0	0
Italy	0	0.000	16	0	0	16	4	0.114	22	0	0
UAE	0	0.000	16	0	0	16	4	0.114	22	0	0
Brazil	0	0.000	16	0	0	16	3	0.086	26	0	0
Armenia	0	0.000	16	0	0	16	2	0.057	27	0	0
Belarus	0	0.000	16	0	0	16	2	0.057	27	0	0
Lithuania	0	0.000	16	0	0	16	2	0.057	27	0	0
Mexico	0	0.000	16	0	0	16	2	0.057	27	0	0
Netherlands	0	0.000	16	0	0	16	2	0.057	27	0	0
Romania	0	0.000	16	0	0	16	2	0.057	27	0	0
South Africa	0	0.000	16	0	0	16	2	0.057	27	0	0
Iran	0	0.000	16	0	0	16	1	0.029	34	0	0
Kazakhstan	0	0.000	16	0	0	16	1	0.029	34	0	0
Slovenia	0	0.000	16	0	0	16	1	0.029	34	0	0
Nodes = 36											
Ties = 670											

However, when comparing the simple form of the out-degree to the centrality measure of the Bonacich power, a slight but interesting difference appears in the ranks of the two centrality measures. In contrast to the rank of the out-degree showing that Russia stands only second to the

United States, the rank of the Bonacich power shows that France's centrality is higher than Russia. This difference shows that although Russia (and the former USSR) has a large number of outward relationships, its adjacency and the linked neighborhood show far less power than its rivals, consisting of not only the United States, but also the other western advanced industrial economies such as France and the United Kingdom.

In contrast to the out-degree relating to the exports, the in-degree counts the volume of the incoming ties. The volume of the infrastructure projection is typically taken as the potential and prospect of the state-building, measured as the summation of the incoming investments. However, as accounting the volume of the constructions on the domestic level, the measurement of in-degree is inconsistent with the other centrality measures, indicating that although the amount of the infrastructure projections may reflect the intentions and ambitions of the local states for overcoming the lateness of development, it needs to be further examined with the accompanied network and relationships to evaluate if the investments are the driving forces to the development or the resisting forces of the long-term dependency.

After examining the degree-related centrality measures, the focus shifts to the measure of betweenness. On the one hand, the measure of betweenness cannot be directly treated as equal to the power centrality, because many major vendor states develop the civil nuclear power generation independently rather than depend on the imports; thus, they generate the 0 betweenness that also appears in the one-sidedly dependent countries. On the other hand, although the measure of betweenness cannot be directly treated as equal to the power centrality, the non-zero betweenness still indicates the dynamics of catching-up underlying the intermediate positions. Instead of a meaningless indicator, it implies a strategical position marking the

completion of both the import-substitution and export-oriented industrialization. The countries that have non-zero betweenness are Germany, Japan, South Korea, China, and Switzerland.

However, the cross-sectional network cannot show the general mobility of the nuclear users. To illustrate the mobility of the nuclear users, the cross-sectional network is divided into two time sections, during and after the Cold War. With a significant similarity to the cross-sectional network, the graph of the network during the Cold War era shows that the world is divided into two components, the U.S.-led NATO and the USSR-led Warsaw-Pact countries, and only thinly connected by Finland, which imported the nuclear technology from both sides of the rivalry. With the only exception being UAE, almost all the nuclear users are included in the network during the Cold War, implying that most of the acceptances of the civilian nuclear power occurred during the Cold War era.

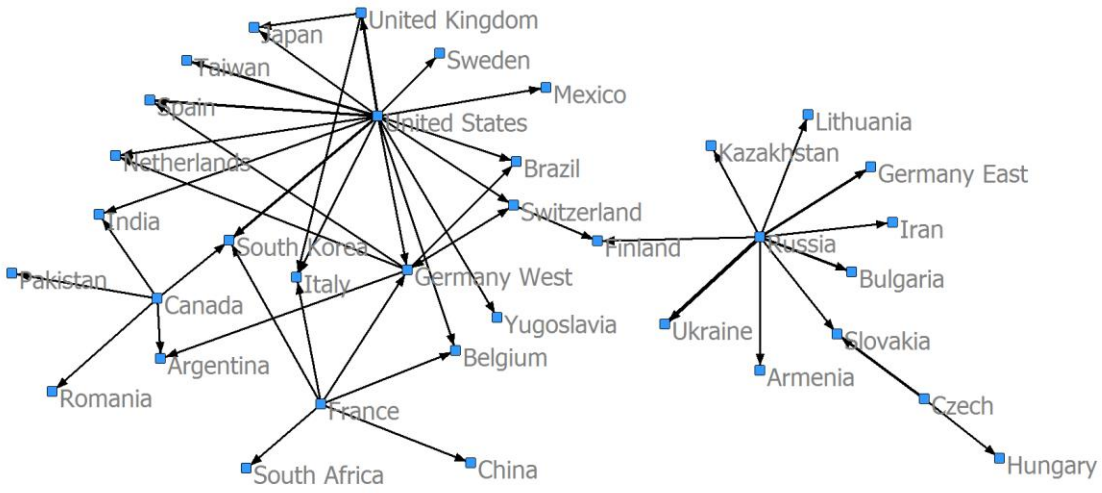


Figure 4.5: Global network of nuclear power reactor transactions, 1950–1989

Table 4.2: Centrality measures of global network of reactor transactions, 1950–1989

Country	Out-Degree	Normalized Out-Degree	Rank	Bonacich Power	Normalized Bonacich Power	Rank	In-Degree	Normalized In-Degree	Rank	Between-ness	Normalized Between-ness
United States	184	5.412	1	37943.555	5.916	1	133	3.912	1	0	0
Russia	82	2.412	2	114.571	0.018	3	38	1.118	5	0	0
France	80	2.353	3	166.196	0.026	2	69	2.029	2	0	0
Japan	44	1.294	4	65.591	0.010	4	49	1.441	3	0	0
United Kingdom	41	1.206	5	58.583	0.009	5	45	1.324	4	0	0
Germany West	32	0.941	6	39.768	0.006	6	30	0.882	6	11	0.980
Canada	32	0.941	6	39.518	0.006	7	25	0.735	7	0	0
Czech	16	0.471	8	16.752	0.003	8	6	0.176	15	0	0
Sweden	10	0.294	9	10.809	0.002	9	13	0.382	9	0	0
India	8	0.235	10	8.509	0.001	10	12	0.353	10	0	0
Switzerland	4	0.118	11	4.330	0.001	11	6	0.176	15	3	0.267
Belgium	4	0.118	11	4.123	0.001	12	8	0.235	14	0	0
China	1	0.029	13	1.008	0.000	13	3	0.088	23	0	0
Ukraine	0	0	14	0	0	14	21	0.618	8	0	0
South Korea	0	0	14	0	0	14	10	0.294	11	0	0
Spain	0	0	14	0	0	14	10	0.294	11	0	0
Slovakia	0	0	14	0	0	14	9	0.265	13	0	0
Bulgaria	0	0	14	0	0	14	6	0.176	15	0	0
Germany East	0	0	14	0	0	14	6	0.176	15	0	0
Taiwan	0	0	14	0	0	14	6	0.176	15	0	0
Finland	0	0	14	0	0	14	4	0.118	20	0	0
Hungary	0	0	14	0	0	14	4	0.118	20	0	0
Italy	0	0	14	0	0	14	4	0.118	20	0	0
Argentina	0	0	14	0	0	14	3	0.088	23	0	0
Armenia	0	0	14	0	0	14	2	0.059	25	0	0
Brazil	0	0	14	0	0	14	2	0.059	25	0	0
Lithuania	0	0	14	0	0	14	2	0.059	25	0	0
Mexico	0	0	14	0	0	14	2	0.059	25	0	0
Netherlands	0	0	14	0	0	14	2	0.059	25	0	0
Romania	0	0	14	0	0	14	2	0.059	25	0	0
South Africa	0	0	14	0	0	14	2	0.059	25	0	0
Iran	0	0	14	0	0	14	1	0.029	32	0	0
Kazakhstan	0	0	14	0	0	14	1	0.029	32	0	0
Pakistan	0	0	14	0	0	14	1	0.029	32	0	0
Yugoslavia	0	0	14	0	0	14	1	0.029	32	0	0
Nodes = 35 Ties = 538											

Compared to the cross-sectional network, there is no significant difference between the ranks of the two networks' measures of centrality, except for two East Asian countries, China and South Korea. As shown in the measure of out-degree during the Cold War, South Korea does

not achieve the status of self-reliance, and China has a very low out-degree, implying the very initial stage of the self-reliance. Moreover, the non-0 betweenness is contributed by Germany and Switzerland, which both are typical western advanced industrial economies.

Compared to the network during the Cold War era, only 16 nodes stay in the post-Cold War era. The decrease of the nodes implies that many countries do not have any new constructions of the nuclear power reactors after the Cold War. In this era, China dramatically rises as the new core of the global network of nuclear power reactor transactions. South Korea also experiences a rapid rise in the out-degree rank. These rises coincide with these two countries' highlighting non-zero betweenness.

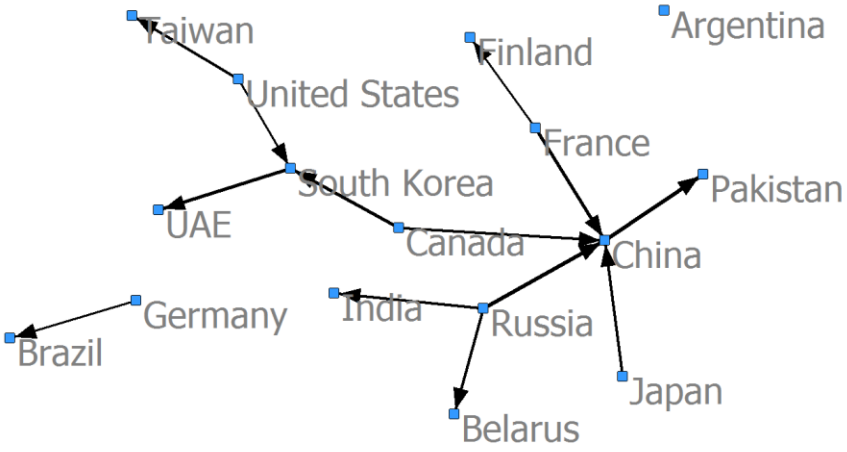


Figure 4.6: Global network of nuclear power reactor transactions, 1989–2016

Table 4.3: Centrality measures of global network of reactor transactions, 1989-2016

Country	Out-Degree	Normalized Out-Degree	Rank	Bonacich Power	Normalized Bonacich Power	Rank	In-Degree	Normalized In-Degree	Rank	Between-ness	Normalized Between-ness
China	46	3.067	1	9200.000	3.908	1	53	3.533	1	4	1.905
Russia	19	1.267	2	1549.692	0.658	2	10	0.667	5	0	0
South Korea	18	1.200	3	27.618	0.012	6	18	1.200	2	2	0.952
Japan	15	1.000	4	698.614	0.297	4	13	0.867	4	0	0
India	13	0.867	5	19.213	0.008	7	15	1.000	3	0	0
France	7	0.467	6	970.692	0.412	3	2	0.133	9	0	0
United States	7	0.467	6	8.536	0.004	8	4	0.267	7	0	0
Canada	5	0.333	8	464.761	0.197	5	0	0	15	0	0
Argentina	1	0.067	9	1.026	0.000	9	1	0.067	12	0	0
Germany	1	0.067	9	1.000	0.000	10	0	0	15	0	0
Pakistan	0	0	11	0	0	11	6	0.400	6	0	0
UAE	0	0	11	0	0	11	4	0.267	7	0	0
Belarus	0	0	11	0	0	11	2	0.133	9	0	0
Taiwan	0	0	11	0	0	11	2	0.133	9	0	0
Brazil	0	0	11	0	0	11	1	0.067	12	0	0
Finland	0	0	11	0	0	11	1	0.067	12	0	0

Nodes = 16
Ties = 132

In contrast to Russia, which still occupies the second position in both the out-degree and the Bonacich power rank, the western advanced industrial economies yield the leading positions. However, in considering both the index of the Bonacich power and the in-degree, there are two changing traits of the western advanced industrial economies that need to be addressed. First, as three western advanced industrial economies, the United States, Canada, and Germany – have very small and even 0 in-degrees but still stand on the middle strata of the out-degree rank, although there might be a recession of the nuclear industry within these advanced economies, the outward links of the exports are maintained. Second, although the out-degree ranks of France and Canada are lower than the East Asian countries, their Bonacich power degrees are higher than South Korea and Japan, showing that their centralities are still favored by their given adjacencies to the relatively central exchange partners – China and South Korea.

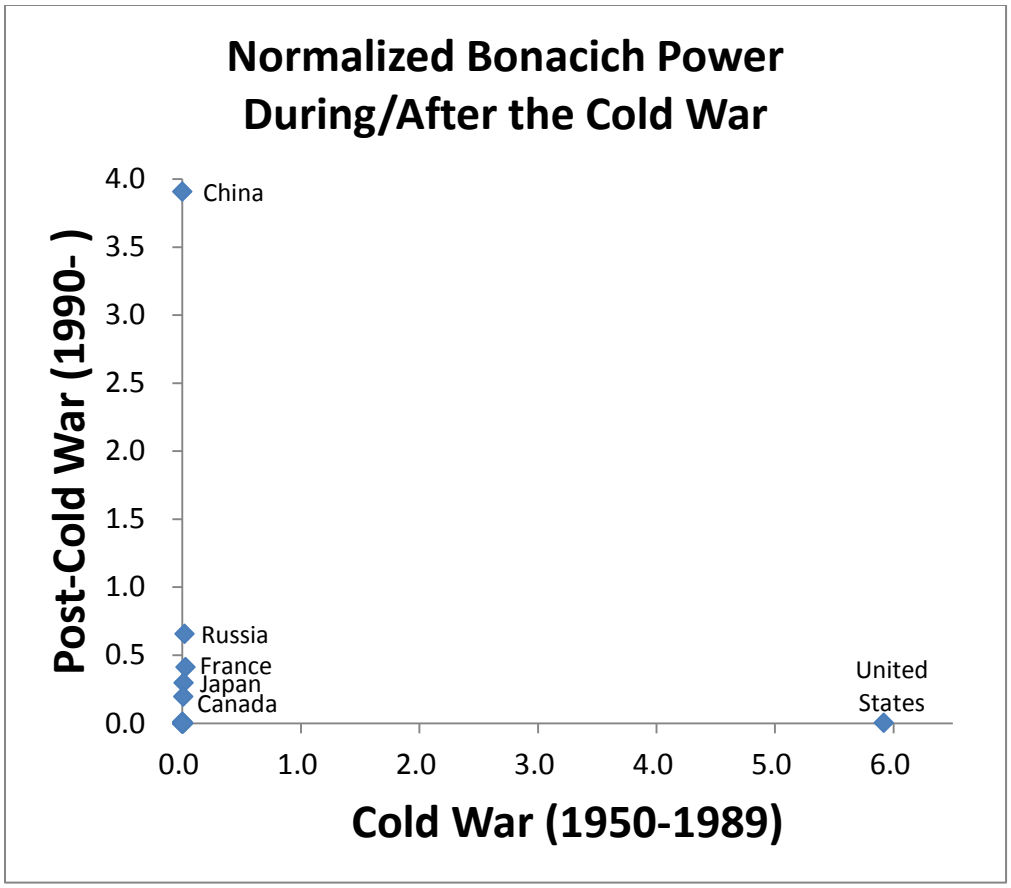


Figure 4.7: Normalized Bonacich power during/after the Cold War

The Triad Census

The triad census indicates that the whole network transitivity is extremely low. First, there is high isolation among the states. With the statistic of the empty graph whose MAN code is "003," we can find that most nodes are isolated from each other. Second, reciprocity, which is represented by reciprocal ties, is rare. Almost no reciprocity exists. The only mutual tie lies between Germany and Switzerland, indicating that one of the vendors to these two countries has been a joint venture. All the networks majorly consist of directed chains ("012" & "021C"), a few out-stars ("021D") and in-stars ("021U). Comparing the networks before and after the Cold

War, we can further find the total extinction of triads containing reciprocal ties ("111D," "111U," "030T," and "120D") and the increase in proportion of directed chains.

Table 4.4: Triad Census of global network of nuclear power reactor transactions

		Network					
Triad	MAN code	Cross-sectional	%	Cold War	%	Post-Cold War	%
A, B, C.	003	5608	78.54%	5263	80.41%	397	70.89%
A→B, C.	012	1243	17.41%	1059	16.18%	144	25.71%
A↔B, C.	102	26	0.36%	26	0.40%	0	0.00%
A←B→C.	021D	208	2.91%	168	2.57%	6	1.07%
A→B←C.	021U	23	0.32%	11	0.17%	7	1.25%
A→B→C.	021C	18	0.25%	6	0.09%	6	1.07%
A↔B←C.	111D	2	0.03%	1	0.02%	0	0.00%
A↔B→C.	111U	5	0.07%	5	0.08%	0	0.00%
A→B←C, A→C.	030T	6	0.08%	5	0.08%	0	0.00%
A←B←C, A→C.	030C	0	0.00%	0	0.00%	0	0.00%
A↔B↔C.	201	0	0.00%	0	0.00%	0	0.00%
A←B→C, A↔C.	120D	1	0.01%	1	0.02%	0	0.00%
A→B←C, A↔C.	120U	0	0.00%	0	0.00%	0	0.00%
A→B→C, A↔C.	120C	0	0.00%	0	0.00%	0	0.00%
A→B↔C, A↔C.	210	0	0.00%	0	0.00%	0	0.00%
A↔B↔C, A↔C.	300	0	0.00%	0	0.00%	0	0.00%
Transitivity		0.219		0.333		0	

4. Discussion

Several trends can be discovered with the shapes of network graphs, the measures of centrality, and the triad census.

First, through the visualization of the global nuclear reactor transactions, the network, no matter at which time point, is always a star graph that indicates most transactions radiate from

the core to the periphery. The network during the Cold War is divided into two components separately led by the United States and Russia (the USSR). Whereas the component centered on Russia (the USSR) operates with a single-core star-shape structure, the component centered on the United States is illustrated with a multi-center star-shape, implying the connections to the exchange partners with greater power. After the Cold War, the star shape largely remains, but the cores move from the western capitalist democracies to the East Asian countries.

Second, the centrality measures help elaborate not only the core-periphery structure, but also the lifecycle of nuclear industry from import-substitution to export-orientation and the power of alliance. Each centrality measure highlights an important attribution:

1) Out-degree and in-degree: they show a node's power relative to the rest of others, indicating the position occupied by each node. As shown in the following figures, the United States has the greatest out-degree and in-degree during the Cold War, thus occupying the highest position in the hierarchy.

   On the other hand, the post-Cold War network stresses that China has reached to the highest position as the new core and South Korea has increased rapidly as the new challenger. The positioning based on the measures of out-degree and in-degree also indicates the up and down of different regions, clearly illustrating that the East Asian countries replace the western capitalist democracies as the major participants in the post-Cold War era.

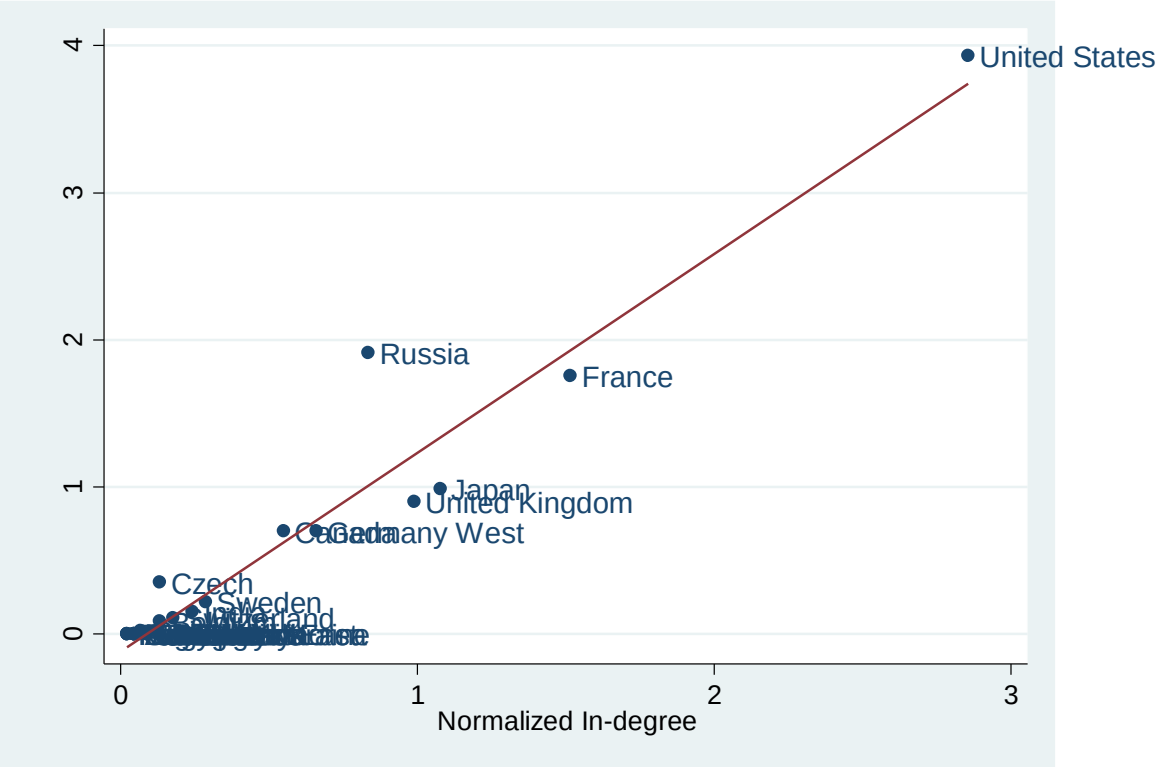


Figure 4.8: Normalized out-degree vs. in-degree during the Cold War

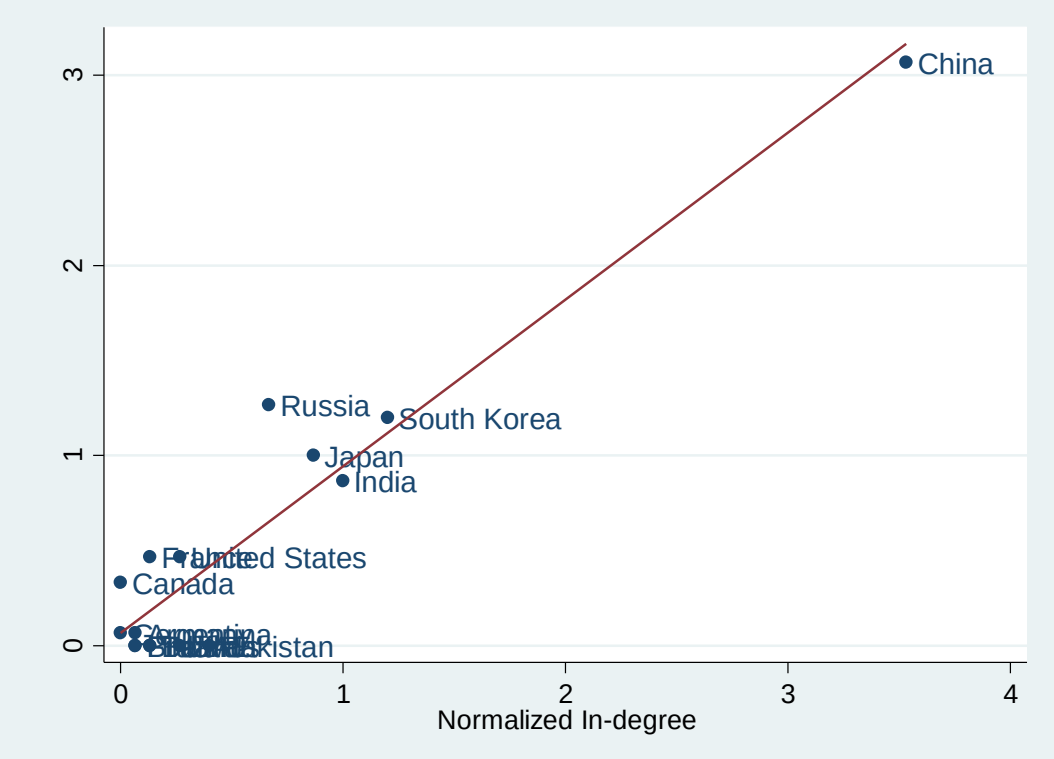


Figure 4.9: Normalized out-degree vs. in-degree after the Cold War

2) Betweenness: Non-zero betweenness that is preceded by non-zero out-degree marks the completion of the lifecycle from total dependency to import-substitution and then to export-oriented industrialization. Only a few countries fulfill this lifecycle, including Germany, Switzerland, Japan, South Korea, and China.
3) Bonacich power: Compared to out-degree and in-degree, Bonacich power focuses more on measuring the power coming from adjacency and alliance. The measure of Bonacich power indicates that in both the cross-sectional and the Cold War era networks, the nodes on the NATO side have greater Bonacich Power than those on the Warsaw-Pact side, signifying an asymmetry of power favoring the NATO side. In other words, the western bloc and its subordinates are more integrated and cohesive than the socialist bloc based on the domination of the USSR. In addition, as shown in the Bonacich power of the remaining western bloc nodes in the post-Cold War network, although most western advanced industrial economies stopped constructing new power plants domestically after the Cold War, they still have greater Bonacich power degrees than the East Asian countries, showing the power of influence from the continual cooperation with their former customers.

Finally, the triad census, by computing network transitivity, indicates that the major network structure remains intact. The absence of reciprocity implies that the patron-client relationships either remain or disappear but never reverse. Although some latecomers climb up the hierarchy levels, the former patrons do not really fall from the top tiers. They simply quit. The network components largely consisting of directed chains illustrate either a star shape or a pyramid scheme corresponding to the results gained from other centrality measures.

In sum, these findings suggest that there is significant upward mobility among the East Asian developmental states, but it is not in a fixed or unformed pattern.

1) They end in different positions. Considering the cross-sectional out-degrees and Bonacich power degrees, Japan is at the top among the four countries, China is the second, South Korea is the third, and Taiwan is the bottom country, which is 0 on both the out-degree and the Bonacich power. The 0 out-degree and Bonacich power indicates that Taiwan is the only exception of the four that does not complete the import-substitution industrialization in nuclear power. In addition to the degree measures, the non-zero betweenness of China and South Korea shows that although their centralities are lower than Japan, they outpace Japan in exporting the nuclear technology, turning their roles from the self-reliant producers to the vendor states. In short, based on the centrality measures, Japan, South Korea, and China are self-reliant and in competing positions; in contrast, Taiwan's nuclear industry falls behind its counterparts in East Asia, although occupying a middle strata position in the in-degree rank.
2) They have different initial conditions and growth rates. The measures of centrality during the Cold War show that Japan occupies a position closer to the western advanced industrial economies. In contrast to Japan, South Korea and Taiwan stand on the same level with equal out-degrees (both are 0) and similar in-degrees, implying similar initial investments in the nuclear industry. In other words, Japan reached the core position far earlier than the East Asian Tigers and China. In experiencing the market-based reform and starting its first construction of the civilian nuclear power reactor late in the early 1980s, China achieved the status of self-reliance in less than a

decade, showing great potential and ambition in developing the nuclear industry. In sum, in the network during the Cold War era, Japan occupied a core-like position, China started late but showed great potential, and South Korea and Taiwan were in similar positions and had very similar initial conditions. As playing the role as the new core in the post-Cold War network, China had the most astonishing growth rate.

3) A final note is that they had different diversity of nuclear technology sources; thus, forming different kinds of commodity chains. Two features are most highlighted. First, there is a clear distinction between their major sources: The United States or another country. Japan, South Korea, and Taiwan all have firm connections to the United States, which was the most core state in the Cold War network. On the other hand, China initiated its civilian nuclear programs by importing from non-U.S. western capitalist democracies such as France and Canada. Second, there is a distinction between relying on single resources or diversifying the importing sources. Among the four East Asian states, Taiwan is the only one that relied on a single source. Compared to Taiwan, the other three countries diversified their sources. South Korea and China's diversification strategy highlights the roles of France and Canada as the bridge or leverage. Combined with the status of industrialization lifecycle from dependency to import-substitution and then to export-oriented production, the four East Asian countries can thus be classified into these four types of commodity chains:

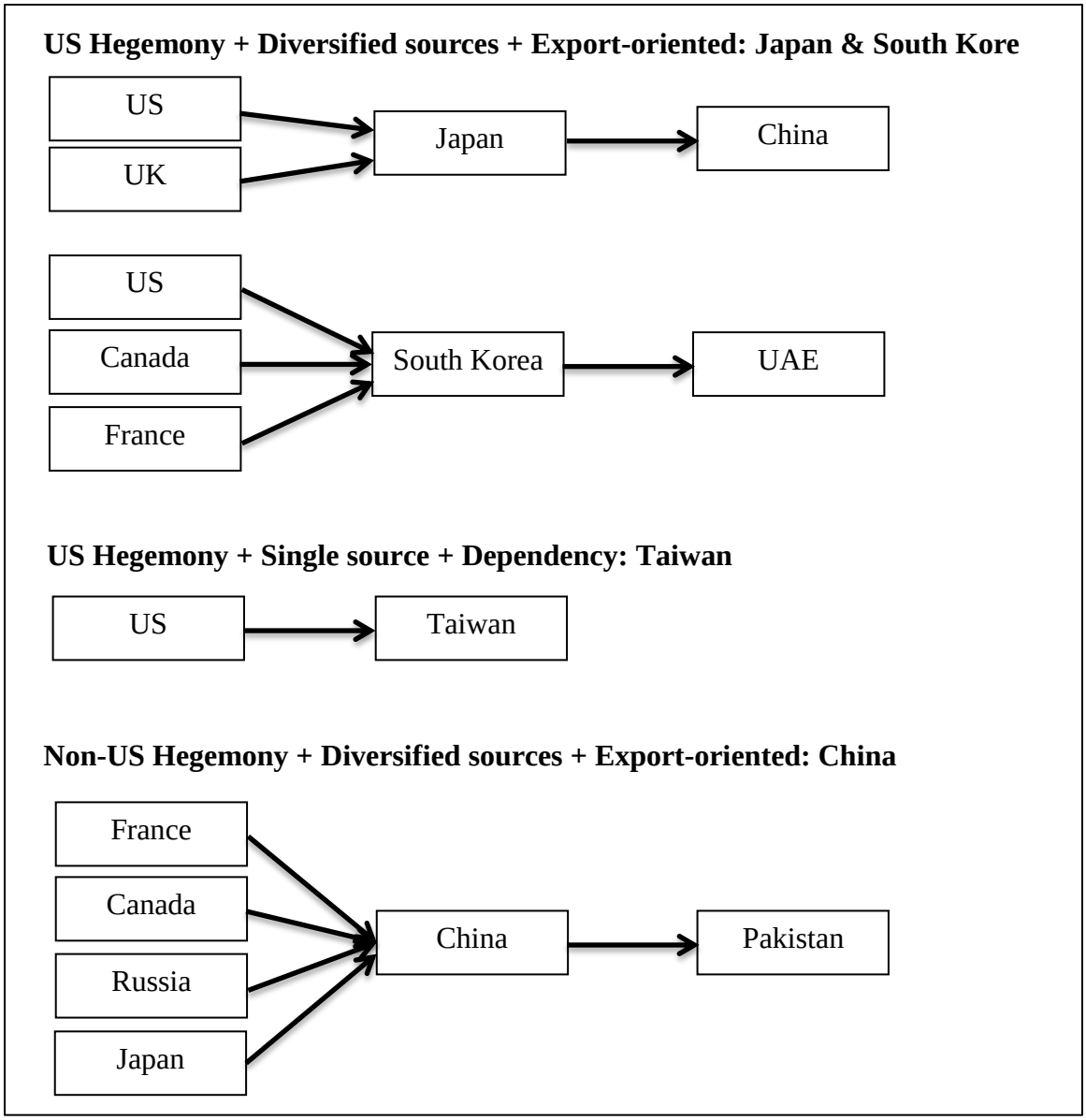


Figure 4.10: Types of nuclear commodity chains in East Asia

In contrast to the usual observations on the developmental state stressing the uniformed success of the industrial policy, the divergence between their mobility in the global network of the nuclear power reactor transactions implies a large variation of industrial policies within the group. The corresponding differences among their initial connections to the nuclear technology

sources and their diversify strategies suggests that it is needed to examine how these connections and diversification work in the processes of developing nuclear industry.

5. Conclusion

The findings support the assumption used in the world systems analysis regarding global nuclear development: Instead of spreading advanced technology benefitting human well-being, the global nuclear industry is more similar to a reproduction mechanism maintaining the existing unequal exchange between the core and the periphery. With the results from the triad census, this research finds that the embedded structure has been consistently intransitive, non-reciprocal, and directed. This result matches the general trend related to foreign dependency, indicating that it is rare for the developing states to jump over the dependency and never reverse the domination of the core states. Although most core states quit nuclear development after the Cold War, the vacancies were soon filled by the East Asian countries such as Japan, South Korea, and China. The centrality power of the Cold War era core states is significantly decreasing but not correspondently transferred to the developing world that has been continually involved in the global nuclear industry. Instead, the strong semi-peripheral countries, or say the East Asian developmental states, quickly took the business. The fact that the upward mobility of the semi-periphery in the global nuclear industry has been accompanied with the invariant hierarchical structure also corresponds to the theoretical perspective of the world systems analysis, arguing that the global inequality has been largely remained intact and that the mobility with the layer of semi-periphery plays the role of sustaining they system more than challenging the system (Arrighi 1990; Clark 2016; Wallerstein 2000).

On the other hand, with the assistances of network drawing, we show the connections constituting the embeddedness in which the East Asian developmental states in the Cold War era and China later in the post-Cold War Era can harness to reverse or reconcile the negative effects of foreign dependency: the initial connections to the United States and the diversity of nuclear technology sources. These two components combine to form a tension generating polarized effects on the nuclear development of these four East Asian countries.

There are further research issues raised due to two derived puzzles. First, there is still a need to identify how diversification in the networking of the nuclear industry occurs. Considering that the similar initial connections to the United States produce different results of developing nuclear industry for Japan, South Korea, and Taiwan, additional research should examine how the effects of the initial connections can be transformed or maintained under specific historical conjunctions. Although the network analysis can depict the international contexts in which these countries are embed, the contents of ties may also be compressed into measurable links sacrificing much meaningful information (Emirbayer 1997; Emirbayer and Goodwin 1994). Second, a more detailed comparison of the four East Asian nuclear commodity chains must be made to clarify the conflicts between the different indicators of nuclear development. In the event history analysis, whereas Japan and South Korea show significantly high efficiency in developing nuclear power, China and Taiwan fall far behind. However, considering the centrality power in the global nuclear transactions network, China obtains the highest coreness in the post-Cold War era. To conduct an encompassing evaluation of the global nuclear development, we must include both indicators. Both research goals demand a further comparative research on the nuclear policy of the developmental states. With this consideration, a comparative historical analysis of the nuclear development in the four East Asian countries are

conducted in the next chapter to determine if there are any subtle but determining differences between the unfolding paths of developing the nuclear programs.

CHAPTER FIVE

TRACKING FISSION: COMPARATIVE HISTORICAL ANALYSIS OF NUCLEAR DEVELOPMENT IN EAST ASIA

1. Introduction

The analyses based on the world systems theory and the developmental state theory in the former chapters show how the global development of nuclear power has progressed. The findings indicate that the global nuclear development has maintained a persistent structure of unequal exchange between core and periphery, and the East Asian developmental states that share the specific configuration of embedded autonomy have been the rare cases moving upwardly in the hierarchy of global nuclear development. Both analyses indicate that the Cold War was a friendlier environment for developing nuclear power than the post-Cold War era.

However, two discrepant cases seemingly challenge the theoretical validity of the above analyses. On the developmental state theory, although sharing the features of the developmental states such as Japan and South Korea, Taiwan does not show the same efficiency in developing the nuclear industry and never removes of the dependency on U.S. technology. On the world systems theory, although occupying the core position in the global network of the nuclear reactor transactions in the post-Cold War period, China shows a far lower efficiency of developing nuclear power.

Table 5.1: Four cases of nuclear development in East Asia

	Japan	South Korea	Taiwan	China
Efficiency (S(x) of NPP construction)	+ (High, 0.2014)	+ (High, 0.1630)	− (Medium, 0.1244)	− (Low, 0.0822)
Network Power				
Upward mobility in the Network of reactor supply	+ (Semi-periphery → Semi-periphery)	+ (Periphery → Semi-periphery)	− (Periphery → Periphery)	+ (Periphery → Core)
Indigenization & Export capability?	+	+	−	+

2. Method

The case-based method is helpful to manage the problem of deviant cases. In contrast to the variable-based method focusing on the generalization but risking the over-simplification of the explanation, the case-based method can reach deep-rooted elaboration and diversify the simplified theoretical implications (Mahoney 2015; Mahoney and Goertz 2006; Mahoney and Rueschemeyer 2003; Ragin 1989; Ragin 2000). By tracing how the sequence of a case develops, the comparative historical analysis can determine the ordering of the events, which is necessary for identifying the causal mechanisms (Mahoney 2000; Mahoney 2004; Pierson 2000). For this purpose, this research uses the comparative historical analysis, leaning to the case-based method.

First, this research checks the sequence of how the cases develop. In general, the sequences illustrated in the comparative historical analysis can be categorized into two types: the self-reproducing process and the reactive-events chain (Mahoney 2000). The idea of the self-reproducing process is inspired by the neo-institutionalist economics that place an emphasis on a critical initial condition, triggering the emergence of a set of institutions with continuing reinforcement. On the other hand, the reactive events chain refers to the sequence that is full of

the events shifting the direction of the development or even offsetting the power for maintaining the interested consequences. With this categorization, to examine the nuclear development in the four cases, this research depicts how the four paths consist of these two types of sequences.

Next, we examine how specific events change the directions of paths to determine if the concerned events are critical breakpoints in the development of the cases, and pinpoint the mechanisms shaping the consequences. As accompanied with the path dependence analysis, the critical events are marked and compared across the cases to examine their impacts. To identify the critical events and their potential impacts, we need to construct the counterfactual situations to determine if the occurrences of specific events appear in only the cases that have the concerned consequences (Capoccia 2015; Capoccia and Kelemen 2007; Mahoney 2000). In our research, the deviant cases generated from the above analyses serve as the counterfactual situations to the positive cases (i.e., Japan and South Korea). For the counterfactual analysis, we highlight the differences between Taiwan and South Korea. They are similar in their initial conditions of developing nuclear power, but their subtle differences have a large effect on the nuclear development. The four sequences are juxtaposed with each other for comparative sequence analysis to determine if the ordering of the events affects the consequences (Bennett and Checkel 2015; Collier 2011; Falleti 2010; Falleti and Mahoney 2015; Mahoney 2010; Mahoney 2012).

In the following sections, we depict the four paths of nuclear development in East Asia to determine if they are self-reproducing or hindered by the reactive events. After the simple depictions of the sequences, a comparative sequential analysis is performed to determine if the timing of the events matters.

3. Four Paths of nuclear development in East Asia

Japan

During WWII, Japan conducted nuclear research and had sufficient human resources to maintain the research. However, when the war ended in 1945, the following U.S. occupation forced the nuclear development to be suspended until the declaration of the "Atoms for Peace" in 1953. Since then, the nuclear programs in Japan had steady growth until the Fukushima accident in 2010.

Before 1945

Scholars indicate that nuclear research was seriously conducted in Japan during WWII (Grunden, Kawamura, Kolchinsky, Maier, and Yamazaki 2005; Grunden, Walker, and Yamazaki 2005; Low 1990). At least two research groups were organized for developing nuclear energy for military uses, and even a latter Nobel Prize laureate physicist joined the research team. Although the equipment for the nuclear research was dismantled as soon as the U.S. occupation began in Japan, there was no significant loss of the human resources due to any political purges. In addition to the scientists, experts, and governmental officials, the public had an optimistic attitude toward the development of atomic energy before the bombing of Hiroshima and Nagasaki. Atomic energy was imagined as a potential measure to end the war, illustrated as atomic weapons in public media, and advocated as a panacea to many human and social problems (Nakao 2009). In short, Japan already had the available infrastructures and sufficient human resources for conducting nuclear research before 1945, and the image of nuclear power was mostly positive in the eyes of the public.

1945–1953: Prohibition

The bombing of Hiroshima and Nagasaki in 1945 not only ended WWII, but it also interrupted the nuclear research. As Japan surrendered to the Allied Powers, the equipment for the nuclear research was soon dismantled. With the same concerns of disarmament and demilitarization, nuclear research was also prohibited.

The turning point was the start of the Korean War in 1950. To contain Communism, the former enemy now was a new ally. Viewing nuclear power generation as an alternative to aid the allied developing countries, the United States changed its policy about the development of nuclear power in Japan. Accompanied with the declaration of Eisenhower's project "Atoms for Peace" in 1953, the United States adjusted its policy from prohibition to cooperation. In short, the emergent needs of war mobilization for containing Communism overturned the status of Japan, and replaced prohibition with aid.

1954–1965: Institutionalization

In 1954, the United States conducted a hydrogen bomb test at Bikini atoll in the Marshall Islands. The Japanese fish boat "Lucky Dragon 5" was working in the nearby area and was unfortunately exposed to the radioactive fallout. The injuries caused by the fallout, combined with the collective memories of the atomic bomb victimhood, provoked the anti-nuclear protests and the following aversion to nuclear power (Saito 2006). However, the aversions and protests against nuclear power were distracted by the media sponsored by the U.S. and Japan governments and finally targeted only nuclear weapons rather than the peaceful uses of nuclear power (Dusinberre and Aldrich 2011; Kim 2013).

On the other hand, the development of civilian nuclear power started to be institutionalized at the same time (Dusinberre and Aldrich 2011; Kim 2013; Low and Yoshioka 1989; Low, Nakayama, and Yoshioka 1999). In the same year of the Lucky Dragon incident, the Diet member Nakasone Yasuhiro (the latter Prime Minister) proposed a special and huge budget for the construction of a nuclear reactor. In the next year, the US-Japan Atomic Energy Agreement was signed. In the following few years, several institutions for developing nuclear power were formed, including the Japan Atomic Energy Research Institute (JAERI), the Science and Technology Agency (STA), the Japan Atomic Industrial Forum (JAIF), the Japan Atomic Fuel Corporation (JAFC), and the Japan Atomic Power Company (JAPCO).

In summary, although the Lucky Dragon incident prompted the general aversion to nuclear power, the state-planning of developing nuclear power and the institutionalization of nuclear development based on the US-Japan alliance was not affected.

1966–1995: Steady growth

In 1966, the Tokai-1 reactor started its commercial operation, which was Japan's first commercial nuclear power plant. The UK-made Magnox-type reactor was a gas-cooled reactor (GCR) using natural uranium as fuel, which was free of the dependency of enriched uranium on the major supplier, the United States. However, as the light water reactor (LWR) was the most popular design in the world market and was assumed to be a more reliable technology, Japan also opted to import the technology of LWR. In addition, as the Japanese large firms, the "Zaibatsu," had long-lasting and close relationships with the U.S. firms GE and Westinghouse, they enthusiastically imported the nuclear technology from the United States (Lester 1982; Low

and Yoshioka 1989; Low, Nakayama, and Yoshioka 1999). In 1970, the Tsuruga-1 LWR started its commercial operation.

In the 1970s, having the capacity to build its own reactors, Japan gradually achieved the goal of indigenization. Several domestic-made reactors began their commercial operations in the 1970s: the Mihama-2 in 1972, the Shimane-1 in 1974, and the Fukushima Daiichi-3 in 1976. With licensing agreements and joint ventures, Japan completed the nuclear technology transfer of construction, design, and manufacturing. On the other hand, Japan was also devoted to the R&D of the fast breeder reactor (FBR) involving the technology of spent fuel reprocessing. For example, the Joyo FBR became critical in 1977, the Monju FBR started construction in 1985, and the construction was completed in 1991.

In short, from the late 1960s to the mid-1990s, Japan's nuclear industry had steady growth and achieved the goal of technological indigenization.

1995–Present: Expansion and setbacks

Through the mid-1990s to 2011, the nuclear development in Japan gradually turned from a smooth path to a bumpy road. From the mid-1990s, several significant nuclear accidents raised the level of public distrust. The FBR "Monju" achieved criticality in April 1994 and started its commission in August 1995. However, after moving into formal operation only for few months, it was quickly shut down due to a serious leak of sodium coolant and subsequent fire. In 1999, a serious criticality accident occurred at the fuel reprocessing facility in Tokaimura, Ibaraki Prefecture, resulting in an emergency evacuation of the nearby area and the deaths of two technicians exposed to excess radiation. This event was rated 4 on the International Nuclear Event Scale (INES) (Albright 1999), only second to the Fukushima accident in 2011. Meanwhile,

the Japanese nuclear industry was still in expansion. In the 2000s, the recipients of imported technology now were in the dominant position. With their astonishing financial power, the large Japanese firms that enduringly invested in developing nuclear power took a more ambitious strategy for expansion to merge with Western suppliers. In 2006, Toshiba won the bid for the sale of Westinghouse Electric Company, buying in the nuclear equipment manufacturing sector. In 2007, Hitachi completed a merger with GE. In other words, while the risk grew regarding nuclear accidents, the nuclear industry continually increased its own scale and influence.

In addition, the industrial policy insisting on the nuclear development stood still even after the 2011 Fukushima accident. Although the local governments and grass-root organizations gained more resources and public sympathies for anti-nuclear movements than before, the political structure and the dominant political parties still leaned to the pro-nuclear stance (Kingston 2013; Vivoda and Graetz 2015). Although most nuclear reactors had been temporarily shut down for a safety review, the current Japanese government kept proposing the plans of reactivation. In short, although the Fukushima accident violently shook the foundation of the nuclear industry and the public trust in nuclear power, it did not totally overturn the dominance of the so called "nuclear village" that consisted of the bureaucracy, the ruling political party, the utility companies, and big business.

In general, although deprived of the right to develop nuclear power after the defeat in WWII, Japan soon benefited from the following Cold War rivalry as a new ally of the United States for containing the expansion of Communism, thus obtaining the opportunity to build its nuclear enterprises. Since the early 1950s, there has been steady growth of the Japanese nuclear industry. While the debate over nuclear power has been an impasse after the Fukushima accident,

the nuclear industry and its allies did not totally lose their power and influence. For example, a few reactors have been reactivated recently and phase-out has not been added as an option in the political arena. In summary, although affected by the shock of the Fukushima disaster, the path of Japan's nuclear development is a self-producing process that has been partially buffered rather than totally overturned.

South Korea

With the astonishing efficiency shown in the construction of nuclear power plants and the rare import-substitution industrialization in the nuclear programs, South Korea implemented a path seemingly straight toward the successful development of the nuclear industry. However, each stage of the process developed at a different pace. Although nuclear power had been already recognized as a key item for the state-building at the initial stage, the locomotive power of the nuclear industry was not at full speed until the 1960s.

In addition, although the nuclear development of South Korea illustrated a similar consequence to Japan with a high efficiency and completing the transition from the import-substitution to the export-oriented industrialization, there were significant divergences between the routes of nuclear development in these two countries. In the field of war mobilization, in contrast to the de-militarization due to being a vanquished state in the WWII, the newly de-colonized state developed both military and civilian uses of nuclear power. Moreover, this military consideration was directly connected to the war status with North Korea, which has had a fierce contest of sovereignty with each other.

Mid-1950s–1961: The division of Two Koreas

The start-up of the nuclear programs in South Korea was inspired and empowered by the war experiences. Kim (2009a) indicated that in contrast to sharing the fear and victim sense of the atomic bombs in Japan, the Korean people paid much more positive attention to the application of nuclear power. Attributed as an emancipatory measure, which finally terminated Japan's occupation, atomic bombs were widely perceived as an easy way to strive for safety and independence.

Under this rationale, it is not surprising that the first South Korean President Rhee Syngman greatly supported the development of nuclear power. However, the initial stage of developing nuclear power fell far below the expectation due to conflicts among the South Korean administration, the foreign experts, and the local scientists (Dimoia 2010; Park 2013). Although developing nuclear power was accepted as a common goal by all the actors, there was great divergence on how to reach this goal at the initial stage. Scholars typically depicted that nuclear development in South Korea resulted from the formation of the developmental state, which was eager to pursue security and self-reliance (Jasanoff and Kim 2009; Kim and Byrne 1990; Kim and Byrne 1996; Valentine and Sovacool 2010), but it showed a different story at the initial stage.

In summary, instead of being blocked by the fear and loathing of the atomic bombs, the development of nuclear power was full-heartedly and universally accepted in South Korea. However, despite the consistent enthusiasm of developing nuclear power, there were great divergences within and around the planning and preparation of the nuclear program at the initial stage.

1961–1968: the consolidation of the developmental state

After Rhee Syngman's resignation as the President due to the police shootings of students in the protests in April 1961, the high-ranking military officer Park Chung-hee grabbed the political power of the South Korean state through a military coup in May 1961. Following the emergence of the military regime, the institutional arrangements related to the development of the nuclear industry experienced several reorganizational phrases. Resulting from the reorganization, the power struggle over the direction of the research funded by the state was settled, and the interpenetration between the governmental sectors and the groups of scientists was significantly increased.

Compared to the former stage, the sectors in charge of science and technology had more congruence but less autonomy. To quell the uprising and justify the legitimacy of the military regime, Park's administration advocated that economic development would be prioritized as the most important goal of the administration for the nation's security and self-reliance. Soon after his seizure of power in 1961, Park established the Economic Planning Board (EPB) for managing the creation and implementation of economic policy. This "nodal agency" played the role of implementing Park's political will to achieve economic growth; thus, it was given a higher authority than the rest of the governmental sectors (Chibber 2002; 2003). The policy of science and technology also fell under the jurisdiction of the EPB's subordinate organizations and was embodied in the following five-year technology plans. In addition, assigning scientists that highlight the importance of applied technologies rather than pure science to oversee the major institutions related to the policy of science and technology successfully reduced the influence of the discontented scientists stressing basic research in the universities (Kim 2011). In

short, through organizational integration, Park's administration consolidated the developmental regime by focusing on economic growth and directing the community of science and technology closer to the needs of the state.

Following the principle of making science and technology subordinate to economic development, the nuclear sector also faced a reorganization of personnel (Park 2013). On the one hand, Park's administration downgraded the juridical level of the sectors responsible for the nuclear regulation and deprived them of the bureaucratic autonomy for decision-making. The high-ranking personnel of the nuclear regulation sectors were replaced with a group of scientists having close ties to Park. On the other hand, it increased the resources of the sectors responsible for the R&D of atomic energy and gave the industrial sectors greater discretion to perform the construction and operation of the nuclear power enterprises than regulating sectors to supervise the safety issues. In other words, a developmental state was formed under the military regime where the discontents were effectively silenced.

In summary, by forming the nodal agency and re-integrating the bureaucratic organizations responsible for the development of nuclear power, Park's administration greatly strengthened the nuclear industry.

However, the nuclear development was determined not only by the domestic politics, but also by the external circumstances such as the Cold War rivalry and the international geopolitics. In the process of developing nuclear power in East Asia, one of the most notable features was the dependency on the United States. Although the United States provided abundant aid to its allies in East Asia to contain Communism, the bilateral relationships consisted of not only simple reciprocities but also complicated tensions, suspicions, and secrecy. As the bilateral relationship changed in the following stage, the nuclear development also altered its character radically.

1969–1979: the attempt of diversification & the bargaining with the United States

However, the dependency of South Korea on the United States was double-edged. On the one hand, as the relationship between the United States and the third party was ameliorated, the risk of being abandoned by the United States skyrocketed and damaged the legitimacy of the ruling power. On the other hand, as the bond between the aiding and aided countries intensified, the economic and military supports reduced the state autonomy and diverted development to the purposes irrelevant to the needs of the state or violated the interests of the ruling group (Kroenig 2009a; Kroenig 2009b; Kroenig 2010; Monteiro and Debs 2014; Reiter 2014; Snyder 1984). As entangled in this dilemma, a series of contingent events occurring at this stage created a critical juncture for the nuclear development in South Korea.

Although the Cold War rivalry continued through this stage, several incidents blurred the border between the two worlds and deepened the sense of insecurity and distrust between the United States and the East Asian allies, in particular South Korea and Taiwan. In 1969, the U.S. President Richard Nixon put forward the Guam Doctrine, announcing that the United States would reduce its participation in the defense of the Asian allies as one of the responses to the request for disengaging from the endless Vietnam War. This announcement implied that the United States may retreat its troops from the East Asian allies even though they were still facing threats of invasion from neighboring hostile forces. What was more astonishing was Nixon's sudden visit to China with the claim of normalizing the US-China relationship in 1972. The suspicion that the United States would accelerate the pace of withdrawing its troops from East Asia peaked in South Korea and made Park's administration more inclined to look for an alternative deterrence to fill the gap of national defense left by the United States. Nuclear

weapons, whose destructive power was witnessed at the end of the WWII, certainly had the potential to satisfy the need for deterrence (Choi and Park 2008; Choi 2014; Hong 2011; Kim 2001; Pollack and Reiss 2004).

On the other hand, while the incentive for the East Asian allies to develop nuclear weapons significantly increased because of the ameliorated relationship between the United States and China, the cost of developing nuclear weapons also increased. The development of nuclear power also became a more sensitive issue, because a stricter non-proliferation policy was triggered by India's first nuclear test in 1974 (Choi and Park 2008; Choi 2014; Hong 2011; Kim 2001; Pollack and Reiss 2004). While it was hard to determine if the R&D of nuclear power was for peaceful or military use (Abraham 2006; Hecht 2006; Krige and Barth 2006; Scheinman 1985), the United States intensified its monitoring of its East Asian allies' nuclear programs. It implied that compared to the earlier years of developing nuclear power, there were more limits on the imports of the nuclear technology. However, an unanticipated consequence was derived from the tension between the incentive and cost: the development of nuclear weapons, no matter if the countries succeeded or failed at obtaining them, became an important stake for the East Asian allies, especially South Korea and Taiwan, to bargain for the continuation, extension, or even expansion of the United States' economic and military support.

One of Park's most important leverages was to import the spent nuclear fuel reprocessing technology from the countries other than the United States (Högselius 2009; Kang and Feiveson 2001). On the surface, the reprocessing technology served to deal with the nuclear wastes generated by the civilian nuclear power generation. However, it could also generate plutonium, which is necessary for nuclear weapons, and it is inevitably viewed as a serious threat to the non-proliferation regime. In addition, the transaction of reprocessing technology with a third

party can diversify the sources of nuclear fuel and reduce the dependency of enriched uranium from the United States. With this concern, Park's administration contacted a Canadian supplier in 1972 and a French supplier in 1973 for purchasing the reprocessing technology and the related equipment. Moreover, while the United States attempted to block these transactions through diplomatic negotiations, Park's distrust in the United States and his anxiety about North Korea's invasion were further deepened by the United States' failure to preserve the South Vietnamese government and a series of North Korea's secret military operations.

As the tension between Park's administration and the United States peaked in 1975, three following critical events made the nuclear development in South Korea dramatically turn to a divergent path and finally decoupled from the military use of nuclear power. First, although finally forced by the United States to abandon the program intended for nuclear weapons, the South Korean government made an advantageous tradeoff for developing the civilian nuclear programs. In December 1975, to urge Park's administration to give up the attempt to acquire the reprocessing technology, the United States threatened to withdraw the loan for building South Korea's first civilian nuclear power plant. While making the compromise to suspend the contracts with France and Canada, Park's administration utilized the opportunity of revising the US-ROK nuclear cooperative agreement to negotiate for more technological support in civilian nuclear programs (Hong 2011; Kim 2009b). While Park focused largely on keeping the United States' deployment of troops and the coverage under its nuclear umbrella, the South Korean nuclear technocrats, who were relatively autonomous in the field of science and technology and played a proactive role in the negotiation, focused exclusively on acquiring more resources for developing nuclear power. Although at the expense of the reprocessing technology, many key technologies such as nuclear fuel fabrication and reactor design were added to the agreement. In

other words, despite the failure of obtaining the reprocessing technology necessary for developing nuclear weapons, the South Korean government used the crisis as a leverage to negotiate for a more beneficial agreement that greatly improved the import-substitution industrialization of nuclear energy.

Second, a small military conflict at the Joint Security Area (JSA) between the two Koreas on August 18, 1976, later called the "Panmunjom axe murder incident," consolidated the alliance between South Korea and the United States and significantly reduced Park's distrust of the United States' commitment to defend against the threats of North Korea (Choi 2014). After a quarrel regarding an operation of trimming a tree at the JSA by a team consisting of several United States army officers and South Korean soldiers, the North Korean soldiers at the scene attacked the team with the trimming tools and killed two U.S. army officers and injured several South Korean soldiers. In addition to raising the alert level of North Korea's threats, the United States Forces deployed in South Korea soon performed a counter operation called "Paul Bunyan" to cut down the disputed tree. Based on the interview with the director of the department responsible for developing nuclear weapons, Choi (2014:88) indicated that Park commanded the halt of nuclear weapon program in response to the United States' operation. In short, through the incident, Park received a clear signal from the United States that reduced the uncertainty associated with the United States' changing foreign policy caused by the failure of the Vietnam War and Nixon's China policy.

Finally, Park's assassination in 1979 secured the demilitarization of South Korea's nuclear development. Chun Doo-hwan, the succeeding President who also took power by a military coup, decided to abolish the nuclear weapon program thoroughly to trade for the United States' political support for maintaining the ruling legitimacy (Choi and Park 2008; Choi 2014;

Hong 2011; Kim 2001). To persuade the United States, he even conducted a large-scale political purge in the Agency for Defense Development (ADD), which was responsible for the R&D of the missiles for carrying the nuclear warheads (Hong 2011; Kim 2004; Kim 2001).

In summary, the nuclear development in South Korea in the 1970s encountered crises and crossroads. The changing stances of the United States on the containment of Communism and the non-proliferation policy challenged the South Korean plans for developing nuclear energy with covert or potential military uses. However, instead of stagnating or falling behind, the South Korean nuclear development turned into a favorable situation that was created by a series of contingent events that contributed to more technological assistance focusing on civilian uses from the United States and the demilitarization of the nuclear industry.

1980–Present: From import-substitution industrialization to export-oriented industrialization

After the critical junctures in the 1970s, the nuclear development in South Korea entered a self-reproducing process that successfully and smoothly went through the stages of import-substitution and export-oriented industrialization.

From the 1980s to the 1990s, South Korea gradually completed the self-reliance project. In the early 1980s, South Korea implemented a series of policies for improving the indigenization of nuclear technology, including the designation of specific large companies as the monopolist contractors to produce NPP components, the state sponsorship of all technology transfers, and the assignments of groups of engineers to study abroad for nuclear technologies (Sung and Hong 1999). Also in the 1980s, the South Korean nuclear industry started its self-reliance project, building the NPPs in which all the constructions were performed by the Korean companies (Ahn and Han 1998; Townsend 1987). In the mid-1990s, the NPP equipped

with the South Korea-made reactors formally started its commercial operation, implying the completion of the self-reliance project (Ahn and Han 1998; Sung and Hong 1999). In 2008, the South Korean nuclear business group won the bid of the United Arab Emirates (UAE) NPP contract (Park and Chevalier 2010), implying that the South Korean nuclear industry finally achieved its export-oriented industrialization.

In addition, the 1980s was also the starting stage of the democratization in South Korea. However, as the state was challenged by political and social movements mobilized by the civil society, there was no corresponding anti-nuclear movement on the national level to challenge the nuclear industry. Compared to Taiwan, which had many similarities to South Korea and has been classified as a typical case of a developmental state, an anti-nuclear movement strong enough to block the expansion of the nuclear industry was absent in South Korea (Kim 2000; Lee 1999; Sung and Hong 1999). In short, although the political regime of South Korea experienced democratization starting from the 1980s, there was no equal challenge in the field of the nuclear development.

In general, the nuclear development in South Korea was a significantly positive case, but not all the stages moved in a consistent direction. In the 1950s, the South Korean nuclear program started ambitiously but moved at a slow pace due to the organizational disintegration of the state bureaucracy. As the developmental state was consolidated in 1960s, the nuclear development soon began to dramatically increase. While the international context changed to the direction unfavorable for the nuclear programs with potential military applications and triggered the crisis of the non-proliferation negotiations in the 1970s, the South Korean nuclear development was unanticipatedly neutralized by a series of contingent events and greatly

profited from the disarmament. With the state-directed industrialization and without any strong anti-nuclear movements, the nuclear industry has grown steadily since the 1980s and finally fulfilled the goal of exporting nuclear technologies in 2000s. In summary, although the self-reproducing force of the nuclear development in South Korea is shown in the consolidation of the development state, several contingent events made the nuclear development drift with a fixed pace and fluctuate around these critical points.

Taiwan

As emphasized in the literature review, Taiwan has been taken as a typical case of the developmental state model and share the name of "East Asian economic miracle" with South Korea and Japan. However, compared to Japan and South Korea, Taiwan did not have high efficiency of developing nuclear power and never achieved the indigenization of nuclear technology. This obvious discrepancy seemingly reduces the validity of the developmental state theory on the nuclear development. To resolve the theoretical problem, the Taiwanese case is taken as the most important negative case to construct the counterfactual situations and to examine if the distinctions within the configuration of the developmental state cause the nuclear development gap.

First, Taiwan had great similarities in the initial conditions to South Korea: both were the United States' allies during the Cold War and received large amounts of U.S. aid, both were in a division system confronting an aggressive hostile force with the political claim of unification (Taiwan vs. China, South Korea vs. North Korea), both were authoritarian regimes facing democratization in the 1980s, and both were typical cases of the developmental state.

Compared to the South Korean case, the path of the Taiwanese nuclear development started with a similar stage but followed a different map in the unfolding process. At the initial stage from the late 1940s to 1950s, the mission of developing nuclear power was also triggered by the astonishing impression of the atomic bombs and the need of war mobilization. From the 1960s to the mid-1980s, the struggle between the secret R&D of nuclear weapons and the tightening monitoring for the non-proliferation policy could also be seen in Taiwan. However, while the interweaving of the civilian and military uses finally ended in the demilitarization which is similar to what happened in South Korea, the interception of the nuclear weapon program did not lead to any trade-offs that were advantageous to the development of the civilian nuclear industry. Moreover, as encountered by a strong anti-nuclear movement fostered by the democratization in the 1980s, the Taiwanese nuclear industry quickly went downhill and never completed the import-substitution of nuclear technology.

The late 1940s–the early 1960s: Around the fission between Beijing and Taipei

Similar to South Korea, the nuclear development in Taiwan was also driven by the war experiences and the urgency of war preparation. First, impressed by the destruction caused by the atomic bombs, the Kuomintang (Chinese Nationalist Party, KMT) government also acknowledged that the possession of nuclear weapons was inherently connected to geopolitical interests and advantages. To seize nuclear capability, the KMT government requested that the United States share the knowledge and information regarding the Manhattan project, which it was refused. Afterwards, the KMT government turned to its former foe: In 1946, several high-ranking bureaucrats of the KMT government proposed to recruit famous Japanese physicists involved in the wartime nuclear research for developing nuclear power in China (Liu

2006). Although the recruiting project was finally aborted due to some Chinese scientists' nationalist antipathy against Japan, it sufficiently demonstrated the KMT's substantive intention for possessing the capability of nuclear deterrence.

Second, the defeat of the KMT by the Chinese Communist Party (CCP) and its following retreat to Taiwan in 1949 gave the KMT far more urgency to develop nuclear weapons (Albright and Gay 1998; Hersman and Peters 2006; Mitchell 2004; Wang 2008). While being criticized as economically irrational and wasteful by the leading scientists, Chiang Kai-shek insisted on developing the nuclear program with potential military uses (Albright and Gay 1998). While the general investment of the KMT government in the science and technology stagnated in the early postwar years, the research department of nuclear science was supported and generously sponsored by the state (Greene 2008). In addition, the military sector has penetrated the nuclear research group from the very initial stage. In 1956, the first graduate program of nuclear science and the first research reactor were established at National Tsing-Hua University, Hsin-Chu, as the beginning of developing atomic energy in Taiwan. According to the alumni history of the Institute of Nuclear Science, 10 of the 13 graduate students graduating in 1962 were military officers (College of Nuclear Science 2011:4).

In summary, although the initiation of the Taiwanese nuclear program was for "Atoms for peace," it was designated to develop sufficient deterrence against the possible aggression of the CCP government. As shown in the priority given by the KMT government to the nuclear research at the very first stage, the nuclear development in the Republic of China (ROC) whose government fled to Taiwan in 1949 was closely associated with war mobilization.

The mid-1960s–the mid-1980s: the consolidation of the developmental state & the (failed) bargaining with the United States

Similar to the nuclear development in South Korea, the organizational integration of the nuclear technocracy and the crisis of the non-proliferation policy also appeared in Taiwan.

The first similarity between the nuclear development in South Korea and Taiwan is the consolidation and empowerment of the nuclear technocracy under the military regime. Stimulated by the first nuclear weapon test of the People's Republic of China (PRC) in 1964, the KMT government was eager to acquire the same deterrence as the correction of the imbalance of terror. Thus, the KMT government activated the "Hsin-Chu Program" for developing nuclear weapons in the late 1960s (Albright and Gay 1998; Kemburi 2009; Mitchell 2004). In addition to a large budget proposed by the Ministry of National Defense for developing nuclear weapons in 1967, the KMT government established the Institute of Nuclear Energy Research (INER) and the Chung-shan Institute of Science and Technology (CSIST) to direct the R&D of nuclear energy and weapons in the next year (Albright and Gay 1998). In the original organizational arrangement, the INER was a direct subordinate unit under the Atomic Energy Council (AEC), which consisted of non-military personnel. However, as soon as it was instituted, the INER was moved to the jurisdiction of the CSIST, which was the subordinate of the Ministry of National Defense, and its primary management positions were filled with military personnel (Albright and Gay 1998; Mitchell 2004). In other words, the penetration of the military regime into the nuclear program could be seen in the organizational arrangement of the agencies responsible for the nuclear R&D, and the initiation of the nuclear program was triggered by the war preparation.

The organizational integration featuring the developmental state could also be seen in the civilian industrial sector. While the R&D of nuclear technology was assigned to the INER, the

construction and operation of the commercial nuclear programs were assigned to the Taiwan Power Company (Taipower) (Chu 1984; Markettos 1980). As a state-owned and monopoly power utility under the authoritarian regime, Taipower was granted political discretions for fulfilling Chiang's political will over the power policy and immune to the political elections and public contentions.

The changing foreign policy of the United States in the 1970s that pushed South Korea toward looking for the alternative measure of deterrence also made Taiwan lean more toward the strategy for importing the reprocessing technology. Taiwan's situation was the worst among the East Asian allies, since Nixon looking to ameliorate the diplomatic relationship for diminishing the influence of the Soviet Union was the KMT government's largest threat. In 1971, one year before Nixon's visit to China, the United Nations passed the resolution for recognizing the PRC and expelling the ROC (i.e., the KMT government in Taiwan) as a non-member. Meanwhile, the United States placed pressure on the Taiwan authority to drop the plan for developing the reprocessing capability and even warned other countries to not sell the related equipment and facilities to Taiwan. In 1973, the United States successfully persuaded West Germans to stop the transaction with Taiwan for a reprocessing plant. In 1975, the United States stopped the France-Taiwan agreement of nuclear cooperation (Kroenig 2009a; 2009b; 2010:105-106). In 1977, threatening with the suspension of all the technological assistances and the nuclear fuel provision, the United States required Taiwan to terminate its hot lab and all the reprocessing facilities (Albright and Gay 1998; Kemburi 2009; Mitchell 2004). In contrast to the similar crisis occurring in South Korea, there were no any further bargains on the civilian nuclear technology transfer but stricter sanctions and monitoring in the Taiwanese case. Although both South Korea and Taiwan conceded to the United States and gave up in the nuclear weapon programs,

Taiwan's general nuclear capability deteriorated more than the nuclear capability of South Korea (Hersman and Peters 2006).

The KMT government's secret plan for developing nuclear weapons was still working in secret table until it was exposed in 1988 by a military officer in charge of the management of the INER, who has also been working with the CIA for years. This contingent event led to not only the United States' sanction to remove the related research equipment, but also the transition of the INER from the military institution to the civilian research institute. Under the requirement for demilitarizing the nuclear research program, the INER finally returned to the jurisdiction of the AEC, as a subordinate unit for conducting the R&D works of nuclear technology.

In summary, although there was significant progress in the organizational integration for developing nuclear power in the early years of this stage, the failure of the KMT government to diversify the import of nuclear technology and the setbacks of negotiating for the reprocessing technology finally deepened the dependency on the United States. Compared to South Korea, which took a great leap in the nuclear development by making an advantageous deal in the nonproliferation negotiations, Taiwan confronted harsher conditions and received nothing but sanctions in the negotiations due to the derogation of its sovereign status. Since then, the divergence in the nuclear development in South Korea and Taiwan has increasingly widened.

The mid-1980s–Now: The failed indigenization and the rising anti-nuclear movement

While the nuclear development in South Korea was pushed closer to the completion of the import substitution industrialization in the early 1980s, it ended in a stalemate in Taiwan. When conducting comparative analysis of the nuclear development in East Asia, scholars highlighted the absence of completed localization in Taiwan (Kido 1998; Kim and Byrne 1996),

but they did not fully address that it was a failed project rather than a non-project. Instead of showing no interest in the indigenization, the high-ranking management officials of Taipower Company clearly disclosed their fierce intentions for localizing the nuclear industry (Chu 1982; Chu 1983; Chu 1985a; Chu 1985b; Chu 1981; Chu 1984; Liu 1994; Markettos 1980; Townsend 1987).

However, compared to South Korea, Taiwan's performance on nuclear technology transfer was unsatisfactory. In the construction of the first nuclear power plant, there was very limited participation of the Taiwanese companies (Surrey 1988:469). Taiwan also formed joint ventures with the leading contractors in the construction of nuclear power plants (Cook and Surrey 1989) and then the joint ventures turned to consultant engineering companies (Chu 1984). However, Tai-Power's evaluation indicated that these joint-venture companies failed in promoting the capabilities of reactor design (Chiang 1990). A staff member of the Atomic Energy Council also admitted that even until the mid-1990s, "major systems and equipment for nuclear power plants rely totally on foreign vendors" (Liu 1994:109). Even recently, the Ministry of Economic Affairs, as the supervising agency and the biggest shareholder of Taipower, admitted in the response to the Taiwanese congress that Taiwan did not have the capability of designing and manufacturing reactors, nuclear safety systems, NSSS, or any other major element of nuclear equipment (Ministry of Economic Affairs 2015).

In addition to the failure of achieving import-substitution, the Taiwanese nuclear industry was challenged by a growing anti-nuclear movement. In May 1985, the residents living around the chosen site for the fourth nuclear power plant protested the site placement. In addition, there was an accidental fire at the third nuclear power plant in July. In 1986, as the Chernobyl disaster occurred, the public trust was lowered to the bottom.

Meanwhile, as a bold step to challenge the KMT government's ban on organizing political party, the major opposing party "Democracy Progress Party" (DPP) was formed. As critical to the KMT party-state system, the DPP brought many concurrent antitheses of the authoritarian regime into its political program, including the request for terminating all nuclear programs (Ho 2003; Hsiao 1999). After lifting martial law in 1987 and Chiang Ching-Kuo's death in 1988, the DPP's candidate won the local election where the site of the fourth NPP was in 1989. In 1994, the local government held a local referendum for the project of the fourth NPP, and the result showed that more than a 96% majority was against the project.

The political struggle over the fourth NPP encountered a tipping point in 2000, the DPP's first winning of the president election. Since then, the issue of terminating the Fourth NPP was formally raised to the national level. However, as the pro-nuclear KMT was still a majority in the congress (the Legislative Yuan), President Chen Shui-bian finally made a concession and claimed that the construction of the fourth NPP would not be halted. In his two four-year presidencies, Chen failed to fulfill the DPP's promise of immediately terminating the nuclear programs in Taiwan. On the other hand, although the KMT retook the power in 2008, the Fukushima nuclear accident occurred in 2010, overturning the public perception of the nuclear safety and precipitating several large-scale anti-nuclear demonstrations. In addition, in 2014, an unprecedented scale of social protest against the KMT's pro-China service trade agreement, which was later called the "Sun Flower Movement," radically undermined the legitimacy of the KMT' s governance. As the KMT had long been a part of the pro-nuclear coalition, the pro-nuclear stance turned from political assets to liability (Chen 2016). In the presidential election in 2016, both candidates of the DPP and the KMT accepted the idea of "non-nuclear

homeland" as part of their political agenda. In other words, the Taiwanese nuclear industry lost all its political support.

In summary, through the mid-1980s till now, the nuclear development in Taiwan has been obstructed by the gradually enhanced anti-nuclear movement. The democratization in the 1980s first provided a friendly environment for the development of the social forces opposing the KMT's authoritarian party-state system, and the incorporation of the anti-nuclear issue into the political agenda of the opposing party created the political opportunities for subverting the pro-nuclear coalition. When the confrontation over the fourth NPP turned into a tense standoff through the 2000s, the Fukushima accident in 2010 emerged as a critical event tilting the balance of power toward the forces opposing the nuclear programs though there was no equivalent impact in South Korea and Japan.

In general, the nuclear development in Taiwan is a negative case, but it interestingly demonstrates a path with the initial conditions and developmental strategies similar to the most typical positive case, South Korea. At the first stage, through the early years of the post-WWII to the early 1960s, the development of nuclear power was well encouraged by the urgency of war preparation under the Cold War framework and further triggered by the arm race with its counterpart in the division system, Communist China, which successfully conducted a nuclear test in 1964. At the second stage, through the mid-1960s to the early 1980s, the organizational integration of the nuclear bureaucracy that embodied the consolidation of the developmental state was also seen in the Taiwanese experiences, and the nuclear development confronted the pressure of demilitarization resulting from the changing foreign policy and the non-proliferation requirement of the United States. At the final stage, from the 1980s till now, Taiwan experienced

the democratization that had also occurred in South Korea, but the impacts of the anti-nuclear movement and the Fukushima disaster only influenced Taiwan rather than South Korea. With the large gap between the nuclear development in these two countries and the significant similarities in their structural conditions for developing nuclear power, the process of the nuclear development in Taiwan can serve as the optimal case for constructing the counterfactual contexts to specify the determinants of nuclear development and determine if there are any sub-conditions that may diversify the functions of the given structural conditions.

China

Although occupying a core position in the current global market of nuclear exports and having an astonishingly fast expansion, China shows low efficiency of constructing nuclear power plants in the above event-history analysis. In addition, compared to its East Asian counterparts, the Chinese nuclear industry shows a very different growth curve and life cycle. Although China conducted its first nuclear weapon test early in 1964, its civilian nuclear energy programs were not practically activated until the market-oriented economy reform in the late 1970s. Despite its postponement of developing civilian nuclear energy, it completed the indigenization of nuclear technology in a short time and competed aggressively in the global market of nuclear exports.

1949–1978: Bombs over pants

China started its nuclear research early in the 1950s, but disproportionally concentrated on the development of nuclear weapons. At the first stage, most resources were poured into the nuclear weapons project, and the development of nuclear energy was shelved when the budget

was tight (Sovacool and Valentine 2012; Xu 2010; Zhou, Rengifo, Chen, and Hinze 2011). With the geopolitical concerns stimulated by the Korean War and the following Cold War rivalry, Communist China looked forward to possessing the nuclear capability for deterring hostile forces such as the United States and the KMT government in Taiwan. In the 1950s, while its East Asian counterparts depended on the United States' aid and nuclear cooperation, the PRC government looked for help from the Soviet Union for developing nuclear weapons. However, in contrast to the United States' nuclear cooperation with Japan, South Korea, and Taiwan, which lasted through the Cold War period or even longer, the Soviet Union's technological assistance to China soon closed at the end of the 1950s.

Despite such difficult circumstances, China conducted its first nuclear test and thus shocked the neighboring countries in 1964 (Clemens 1967). However, the R&D of nuclear reactor was halted in the early 1960s, because the budget was squeezed by the decision of prioritizing the weapons program. While China was mocked internationally for investing too much in the development of atomic bombs than investing in providing daily supplies for the Chinese people, the Chinese authority replied firmly that "they rather choose the atomic bombs than the pants" (Margolis 1964). As the R&D of science and technology was further hampered by the political turmoil of the Cultural Revolution, there was no significant progress in the civilian nuclear program until the reactivation of reactor research in the early 1970s (Zeng, Wang, Duan, Sun, Zhong, and Zhang 2016).

In summary, since the founding of the PRC in the 1970s, although China successfully developed and possessed nuclear weapons, the development of the civilian nuclear program was postponed and even suspended for reallocating limited resources to the weapons program.

1978–2005: Transition from military to civilian

As Deng Xiaoping won the post-Mao political struggle and grabbed the power in the late 1970s, China began its market-oriented economy reform. In contrast to the former stage in which the priority of the nuclear development was placed into military use, it was driven in this period by the needs of energy for pursuing industrialization and economic growth (Sovacool and Valentine 2012; Xu 2010; Zhou, Rengifo, Chen, and Hinze 2011).

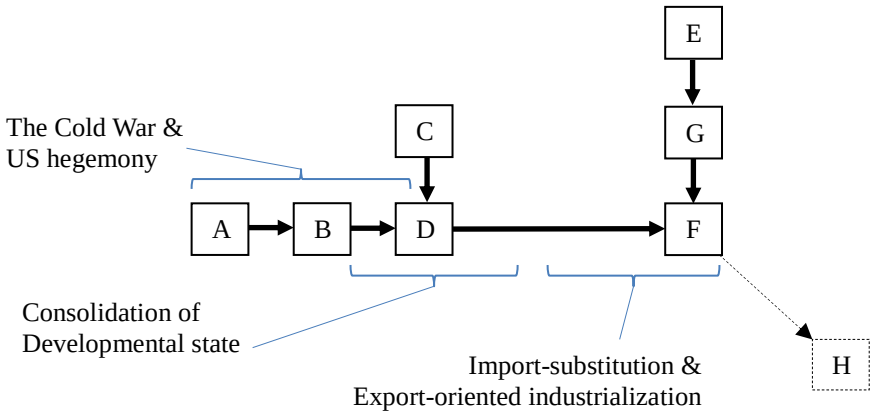
Despite the political power being consolidated and centralized in the current leadership, there was still a divergence in the policy for developing the civilian nuclear program. The initiation of the nuclear energy program was accompanied with a debate of whether the nuclear development would go the route of self-reliant R&D or the way to dependence on foreign technology transfer (Xu 2010). Instead of following only one trend, the Chinese state finally decided to work on both tracks. On the one hand, as encouraged by the ideal of self-reliance and the lobbying of the domestic scientists, the construction of the Qinshan Project started in 1983, which the R&D of the major equipment was assigned to the local research institutes and the Chinese nuclear scientists. On the other hand, the Chinese government negotiated with several foreign nuclear suppliers for the bid of the Daya Bay Nuclear Power Plant that was adjacent to the newly opened special economic zone (SEZ), and finally signed the contract with the French supplier for a turnkey project in 1984. The construction of the Daya Bay NPP started in 1987. In 1994, both the Qinshan and Daya Bay NPPs started their commercial operation. Through the 1980s to the 1990s, keeping self-reliance in nuclear technology as the goal, the Chinese nuclear industry worked more proactively on importing foreign nuclear technologies and conducting technology transfer for fostering the capability to design and manufacture nuclear power plants.

With such strategy for developing nuclear power, China soon reached the goal of self-reliance in nuclear technology. In 2000, China successfully exported its technology for constructing nuclear power plants to Pakistan, implying that the Chinese nuclear industry had sufficient capability for constructing NPPs (Xu 2010; Zeng et al. 2016). In 2005, the construction of the first Chinese self-designed reactor "CPR-1000" at the Ling-Ao NPP began and was completed in 2010, featuring China's completely indigenization of nuclear technology.

In general, the path of nuclear development in China was characterized by its postponement of developing civilian nuclear power. Although having significant achievements in developing nuclear power, China's civilian nuclear program started relatively late. While China began the construction of its first nuclear power plant in the mid-1980s, Japan had already completed its indigenization, and South Korea and Taiwan had been working on the technology transfer for more than a decade.

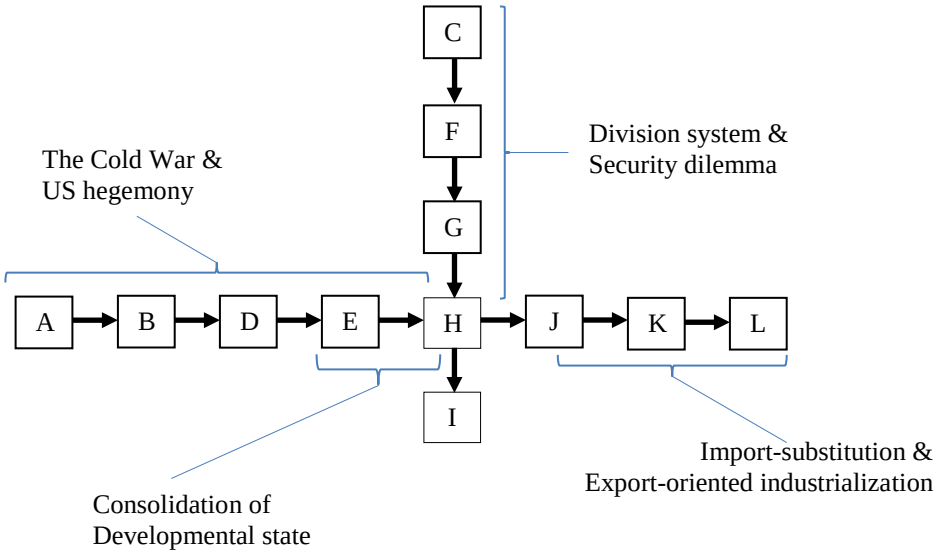
To further summarize the four cases, we visualize the four paths into four graphs of time sequence to illustrate how nuclear development progresses in each country. Additionally, the structural conditions regarding the theoretical concerns were interwoven with each other through the four paths but generated heterogeneous impacts. In general, the two positive cases, Japan and South Korea, consisted of self-reproducing processes in large part; on the other hand, the two negative cases, Taiwan and China, reached several critical turning points during the process, more consisting of reactive events chains. However, the Taiwanese and South Korean cases shared most initial structural conditions. Also, though some of the structural conditions can be

found in the path of China, the time ordering of these conditions is significantly distinct to the other East Asian countries.



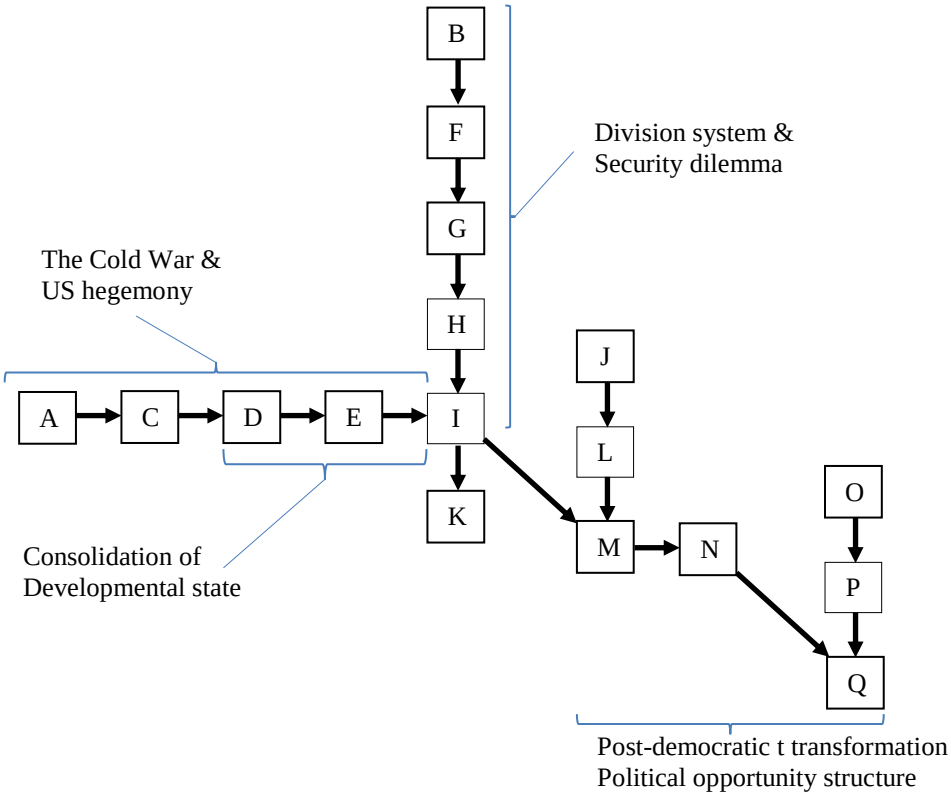
Key:
A: A-bombs in Nagasaki & Hiroshima
B: Korean War
C: Lucky Dragon 5 incident
D: Purchased LWRs from GE & Westinghouse in 1960s
E: Tokaimura incident 1995
F: Toshiba's buying Westinghouse in 2006 &Hitachi's merger with GE
G: Fukushima nuclear disaster in 2010 March
H: Large-scaled shut-down

Figure 5.1: Time Sequence of Nuclear Development in Japan



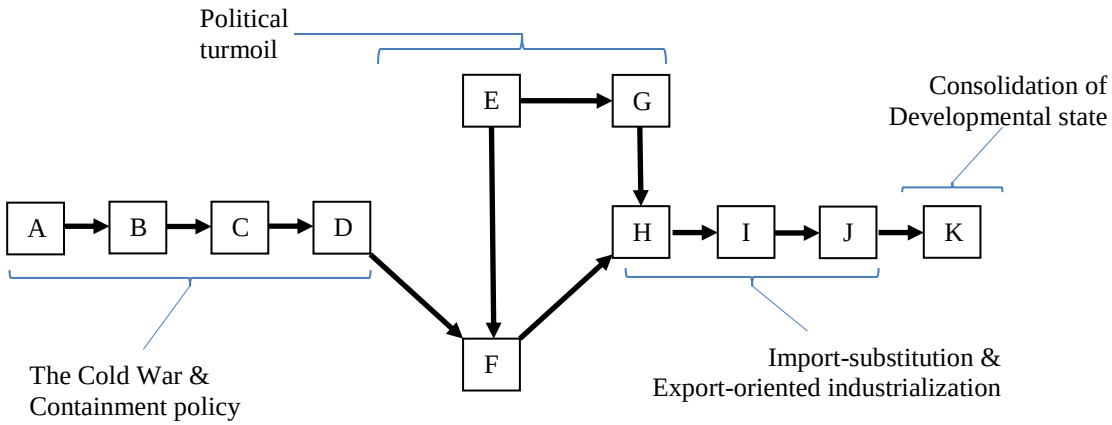
Key:
A: A-bombs in Nagasaki & Hiroshima
B: Korean War
C: Division between North / South Korea
D: Phoenix Project began in 1960 under Rhee Syngman's administration
E: Park Chung-hee's military regime
F: Nixon's visit to China in 1972
G: India's first nuclear test in 1974
H: Proliferation crisis & Re-negotiation of US-Korea nuclear cooperation
I: Panmunjom axe murder incident in 1976
J: Park's assassination in 1979 & Chun Doo-hwan's negotiation with U.S.
K: The completion of the self-reliance project in mid 1990s
L: Nuclear exports to UAE in 2000s

Figure 5.2: Time Sequence of Nuclear Development in South Korea



Key:
A: A-bombs in Nagasaki & Hiroshima
B: Division between ROC (KMT) / PRC (CCP)
C: Korean War
D: Hsin-Chu Project began in 1960s under KMT administration
E: INER & CSIST set up in 1967
F: ROC lost UN membership & replaced by PRC in 1971
G: Nixon's visit to China in 1972
H: India's first nuclear test in 1974
I: Proliferation crisis & Re-negotiation of US-ROC nuclear cooperation in 1977
J: Local protest against the 4th NPP began at 1986 and the first opposing political party Democratic Progress Party (DPP) set up
K: The flee of an INER high-ranking official to U.S. and the exposition of secret nuclear weapons project in 1988
L: DPP won the president election and stop the construction of the 4th NPP in 2000
M: Reactivation of the construction of the 4th NPP in 2001
N: Pro-nuclear KMT won the president election in 2008
O: Fukushima nuclear disaster in 2010 March
P: "Sun Flower Movement" against pro-China & pro-nuclear KMT administration
Q: DPP won the general election in 2016 and settled "Non-nuclear homeland" policy

Figure 5.3: Time Sequence of Nuclear Development in Taiwan



Key:
A: A-bombs in Nagasaki & Hiroshima
B: Division between ROC (KMT) / PRC (CCP)
C: Korean War
D: First nuclear weapons test in 1964
E: Cultural Revolution, 1966-1976
F: Reactivation of reactor research in early 1970s
G: Deng Xiaoping's market-oriented economic reform
H: Qinshan & Daya Bay Projects started in 1980s
I: Commercial operation of Qinshan phase I in 1994
J: Exports to Pakistan in 2000s
K: Reorganization of nuclear bureaucracy in mid 2000s

Figure 5.4: Time Sequence of Nuclear Development in China

4. Comparison of Four Paths

To reconcile the theoretical inconsistences caused by the deviant cases, this research conducts a comparative analysis of the four sequences to identify the structural conditions and critical events that changed the direction of nuclear development.

As shown through the general trends of the four sequences, we first examine three most conspicuous structural conditions: the Cold War milieu, the consolidation of developmental state,

and the division system. Then, by examining the series of events constituting the structural conditions, we determine the critical events that led to the divergent consequences.

Cold War and U.S. Hegemony

The first structural condition is the Cold War rivalry and the accompanied U.S. hegemony. Japan, South Korea, and Taiwan were in the same condition, while China was on the reverse side.

To contain the post-WWII expansion of the Soviet regime and mobilize for the Korean War, the United States soon included Japan, South Korea, and Taiwan under its umbrella of the containing Communism policy. In addition to the large amount of economic and military support, the United States also integrated them into the export-oriented market economy that made them further depend on the market access allocated by the United States (Cumings 1984; Halliday 1980). Meanwhile, nuclear technology was used by the United States as a diplomatic measure to attract the recipient countries to join the containment of Communism (Doel and Harper 2006; Hecht 2006; Krige 2006; Krige and Barth 2006; Miller 2006). The United States' East Asian allies that were enthusiastic about nuclear technology were unsurprisingly enlisted as the candidates to obtain the technological assistances. In other words, the nuclear development in Japan, South Korea, and Taiwan was a part of the hegemonic plan led by the United States for countering the Soviet Union (Cumings 1984; Halliday 1980; Hayes 1988; Kelly 2014; Kelly 2015). Compared to the unequal exchange generated by the international trades between the core and the peripheral, the states of the East Asian allies under the U.S. hegemony kept more autonomy from the patron because of the security need to contain the expansion of the Communist regime (Koo 1987; Woo-Cumings 1998).

Whereas the long-term interest of the United States was to maintain the dependent relationship and monopolize the supply market of nuclear technology, the interest of the East Asian allies was to achieve indigenization of nuclear technology. Indigenization is a push-and-pull between the patron and the clients. To achieve this goal, Japan used its economic power: the Japanese firms signed the licensing agreements with the American firms, gradually acquiring the capability of manufacturing components (Lester 1982:419). However, in addition to being expensive, the licensing agreement required a higher capability of R&D which was relatively lacking in the less-developed countries. Thus, it was not suitable for Taiwan and South Korea that had fewer human resources than Japan at the initial stage of the nuclear development (Chu 1982). As an alternative, South Korea and Taiwan sought to diversify the sources and bargained the nuclear cooperation agreements with the United States. As seen in the latter discussion of the interaction between the structural conditions, the re-negotiation of South Korea was successful, but Taiwan failed, which separately led to the divergence of these two paths.

On the other hand, with the history of being on the other side against the US-led world until the normalization of the US-China relationship in the early 1970s, China failed to build connections to the United States, and this vacuum even lasted after the market-oriented economy reform. Compared to the nuclear cooperation between the United States and its East Asian allies, the USSR assistance to China was relatively short-lived and centered on the development of nuclear weapons. Although the U.S. suppliers planned to sell China the reactors in the late 1970s and early 1980s, the U.S. congress finally vetoed the proposal due to the worries regarding exporting sensitive technologies to the former enemy during the Cold War (Xu 2010). The Chinese government thus turned to trade with France for its project of the first foreign imported NPP.

In short, the effects of the Cold War milieu and the U.S. aid were double-edged. On the one hand, the U.S.-aid generated from the Cold War rivalry gave the recipients early advantages in developing nuclear power. On the other hand, to maintain the regime of containing Communism and the monopoly of nuclear technology, the United States may block its client's attempts to seek autonomy.

Thus, the Cold War rivalry and the U.S. aid partially explain the discrepancy of deviant cases. For Taiwan, although it shared the early advantages from the U.S. supports of nuclear technology, it failed to re-negotiate with the United States to obtain further assistances to upgrade the nuclear industry. For China, its low efficiency relative to its East Asian neighbors indicates the absence of unconditional supports such as the US-aid. However, by alternating its sources of nuclear technology to multiple countries such as France, Canada, and Russia, China was also in a far distance from the U.S. hegemony and relatively autonomous to expand its influence in the global network of nuclear transactions.

Consolidation of Developmental State

The second structural condition is the consolidation of the developmental state. Again, Japan, South Korea, and Taiwan were in a similar condition. Although the same condition appeared in China, it was delayed to the mid-2000s, even after China's completion of export-oriented industrialization in nuclear development.

We find that the nuclear development in Japan, South Korea, and Taiwan demonstrated the configuration of bureaucratic structure in agreement with the prototype of the developmental state. Considering the nodal agency, the institutions shouldering the state-planning for the economic growths—the Ministry of International Trade and Industry (MITI) in Japan, the

Economic Planning Board (EPB) in South Korea, and the Council for Economic Planning and Development (CEPD) in Taiwan—were also in charge of the planning and management of the nuclear business.

In addition to the existence of nodal agency for the coherent planning, the nuclear development was also influenced by the organizational integration of nuclear technocracy. There was an inherent contradiction of functioning between the nuclear regulatory sector's roles of regulating the nuclear safety and advocating the nuclear power generation (Campbell 1988). The East Asian developmental states overcame this institutional contradiction. Japan, for instance, overcame this contradiction by fusing the regulatory and industrial sectors together with each other through the "revolving doors" in the personnel arrangements, forming the government-industrial complex called "Nuclear Village," consisting of not only the electric power companies but also the Diet, the MITI, and the nuclear scientists and experts (Kim 2013; Kingston 2012a; Kingston 2012b; Kingston 2013; Low and Yoshioka 1989; Low, Nakayama, and Yoshioka 1999; Pickett 2002; Vivoda and Graetz 2015). This kind of organizational arrangement that integrated the regulatory bureaucrats, the electric power companies, the research institutes, and the business groups was also seen in South Korea (Jasanoff and Kim 2009; Kim and Byrne 1990; Kim and Byrne 1996; Valentine and Sovacool 2010). In Taiwan, although the INER has been transformed from a military to civilian agency and re-affiliated to the nuclear regulatory authority, it kept subcontracting the research projects and funded by Taipower Company.

In contrast, the nuclear development in China experienced a series of complicated reorganization and thus was involved in the political struggle between the factions within the CCP, through the post-reform period until the late 2000s (Xu 2008; Xu 2010; Zhou, Rengifo,

Chen, and Hinze 2011). The National Development and Reform Commission (NDRC), which was directly subject to the State Council, directed the management and planning for the general economy, and the nuclear power sector was included in the jurisdiction of the NDRC. However, being subordinated to the general goal of economic development, the nuclear development faced the competitions of the other energies and the strategical arrangements serving other purposes such as the international trades and the currency policy; thus, it occasionally had to yield the priority to different projects (Xu 2008). In addition, there were significant debates regarding the pace and methods of developing nuclear energy. In short, there were organizational disintegration and internal competitions in the nuclear development in China, at least in the early phases.

In addition, although having the similar organizational integration of state apparatus, Taiwan did not achieve the same level of technology transfer. On technology transfer, South Korea was greatly benefited by using the "component approach," which requested the local large business groups as the sub-contractors or suppliers of related equipment for more efficiently acquiring the foreign technologies. Although Taiwan also adopted the component approach and strived to form the joint ventures for acquiring the technologies, its efforts ended in a total fiasco, illustrating that there were no appropriate agents capable of performing these tasks. This difference correlated with the condition that Taiwan had less giant business groups and lower concentration of capital than South Korea (Koo 1987). In the process of developing nuclear power, Taiwan lacked the involvement of large business conglomerates, such as Hyundai, Daewoo, and Samsung in South Korea, and Mitsubishi, Hitachi, and Toshiba in Japan. These large business groups—called chaebols in Korean, and zaibatsu or kereitsu in Japanese—played the important role of supporting the government's need to invest or involve specific fields of

industries. With the sufficient state capacity to discipline or sanction the chaebols, the South Korean state induced the business groups to join the investments that the state needed and meanwhile deterred them from rent-seeking or being inefficient (Chang 1994; Chibber 2014). In other words, large business groups are useful policy tools for increasing investments and gathering capital for state projects if the state has sufficient capacity to discipline the large business groups. Although the class structure in which the large business group equivalent to chaebol or zaibatsu was absent may be helpful for the KMT government in Taiwan to control and concentrate political power, it also made the Taiwanese developmental state less competitive than South Korea in the sector of heavy industry.

Thus, the configuration of developmental state and it timing explains the discrepancy of the two cases. For China, its low efficiency corresponds to the absence of developmental state throughout most of the process. For Taiwan, although it shared most organization features of the other developmental states, the lack of state-disciplined large business groups in developing nuclear power made the key technology transfer fail.

Division System & Security Dilemma

The last structural condition is the tension of sovereignty dispute. The impacts of this condition concentrated in South Korea, Taiwan, and China.

As both China and Korea were divided into two opposing regimes soon after the WWII, the divisions locked all the involved states into a long-term process of war mobilization. As soon as the WWII ended, the Korean Peninsula was divided into the Republic of Korea (i.e., South Korea) supported by the United States and the Democratic People's Republic of Korea (i.e., North Korea) supported by the Soviet Union. In 1949, as the Chinese Communist Party defeated

the KMT government led by Chiang Kai-shek, the KMT government soon fled to Taiwan but kept claiming itself as the solely legitimate regime ruling China. When North Korea invaded South Korea and triggered the Korean War in 1950, the United States not only sent its troops to East Asia, but also signed agreements of nuclear cooperation both Taiwan and South Korea.

However, the stalemate of the Vietnam War by the 1970s made the American public discontented with the troop deployment in East Asia and led the administration to look for alternative routes to confront the Soviet Union. President Nixon first proposed the plan of troop withdrawal and then attempted to normalize the U.S.-China relationship to divide the solidarity of the Soviet forces. While upset by the changing U.S. foreign policy and shocked by the fall of Saigon, South Korea and Taiwan strategically turned to utilize the threats of nuclear proliferation for ensuring their security. By knowing the ambiguity between developing nuclear weapons and civilian nuclear energy, they used it as a hedge to bargain with the United States (Kang and Feiveson 2001; Kroenig 2009a; Kroenig 2009b; Kroenig 2010; Monteiro and Debs 2014; Pollack and Reiss 2004; Reiter 2014; Snyder 1984).

Despite using the same strategy, the United States made more compromises with South Korea than Taiwan. By examining the events and processes of negotiation, we can determine that the distinction was their sovereign status in the inter-state system. Compared to South Korea, Taiwan confronted a more difficult international environment where it was deprived of the formal recognition of most countries in the world (Wakabayashi 1997). For the normalization of the US-China relationship, Nixon worked to include Communist China into the United Nations as a formal member. In 1971, the UN General Assembly passed the resolution for recognizing the PRC as the solely legitimate representative of China while expelling the government of Chiang from the UN.

On the other hand, in contrast to the United States' leaning to China, the triangular relationship between the two Koreas and the United States remained unchanged. The tension between the United States and South Korea was finally released by a series of contingent events illustrating the urgency and necessity for the United States to assist South Korea's defense against North Korea, which was consistently hostile to both South Korea and the United States (Choi and Park 2008; Choi 2014; Hong 2011; Kim 2001).

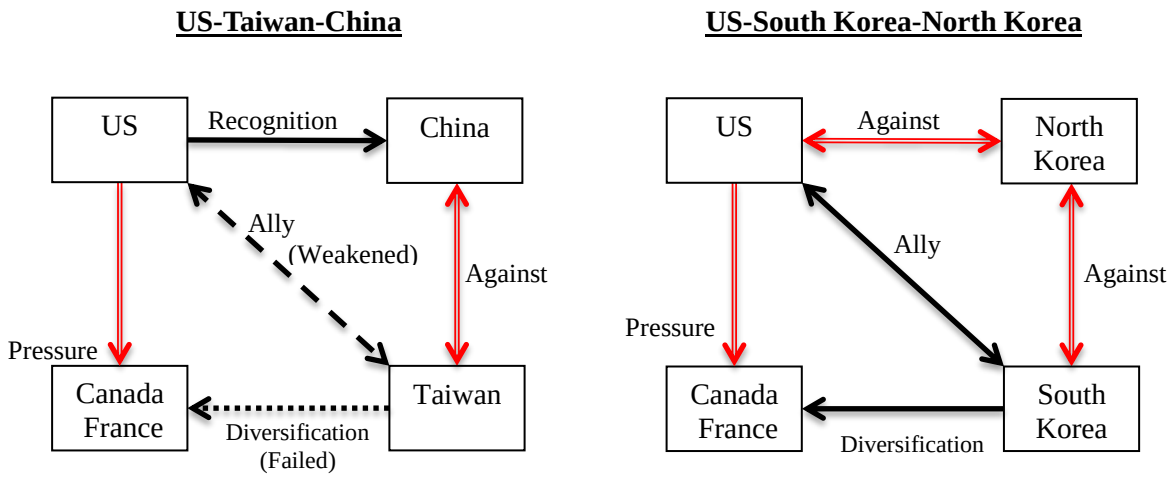


Figure 5.5: Comparison of Triangular Diplomatic Relationships

In short, although both South Korea and Taiwan were impacted by the division system, Taiwan suffered strict sanctions in the crisis of non-proliferation. As represented by Nixon's visit to China and the ROC's expulsion from the United Nations, the series of diplomatic events damaged Taiwan's bargaining power and diversification strategies by impairing its status of sovereignty. From this breaking point, the nuclear development in Taiwan went into a route divergent to the typical developmental state model represented by South Korea.

On the other hand, although China also belonged to the ROC/PRC division system, its nuclear development was not directly influenced by its status of sovereignty. Instead, the temporary suspension of developing civilian nuclear energy was made by the political turmoil. The reactivation of civilian nuclear program was the direct product of the market-oriented economic reform.

5. Conclusion

The event history analysis and the network analysis in the last chapters illustrate that the structure of the global nuclear development follows the organizing principle of the capitalist world economy, maintaining the unequal exchange between the core and periphery. On the other hand, they also indicate that the limited and scarce upward mobility can only be found in the cases of the East Asian developmental states (or called the "strong semi-periphery" in the literature of the world systems analysis). However, they also show that Taiwan, as a typical case of developmental state, had a low efficiency of constructing nuclear power plants and failed to achieve import-substitution industrialization of nuclear industry. Another deviant case, China, had the greatest core-ness in the post-Cold War nuclear transactions network, but also had lower efficiency inconsistent with its ambitious expansion. Both deviant cases seemingly challenge the validity of the developmental state theory and the world systems theory. Based on the comparative sequence analysis, we can identify the factors making the discrepant cases and thus reclaim the validity of our theoretical perspectives.

First, we find that Taiwan's state autonomy in developing nuclear power was limited by its failure to bargain with the United States. This failure in turn came from Taiwan's impaired status of sovereignty caused by the contingent events emerging from the changing geopolitical

interests. As the United States changed its diplomatic relationship with Communist China during 1970s and thus caused the KMT government to lose its membership of the United Nations, Taiwan's ability to bargain for U.S. support fell sharply. This finding agrees with the theoretical argument of this research that the embedded autonomy of the developmental state has been generated from the network position of the world system, and the agency of the developmental state to overcome the structural constraints must come from the practices of diversification strategy.

Second, China's low efficiency shown in the event history analysis and highest centrality power during the post-Cold War period shown in the network analysis were both made by its delayed development and sharing no technological lock-ins from U.S. aid. We find that the consolidation of developmental state has been the organizing principle of China's nuclear policy, but it was postponed to the recent decade rather than in the early stage of nuclear development. In other words, instead of making our theoretical perspectives invalid, the case of China indicates that the time orders of structural conditions do matter, and the unanticipated low efficiency reflected the postponed occurrence of the developmental state.

CHAPTER SIX

CONCLUSION

To obtain a systematic understanding of the global nuclear power development, we tested the western-centered perspective and based our investigation on two alternative theories: the world systems theory and the developmental state theory. By combining the event-history analysis, the network analysis, and the comparative historical analysis for pushing forward such understanding, this research determines the general trend underlying the global nuclear development and explains the factors leading to the divergent consequences of developing nuclear power in the given countries. We summarize the major questions, empirical findings, and theoretical implications in the following paragraphs.

1. Questions and Findings

First, to test the theoretical perspective over-emphasizing Western democracies and presupposing the inherent connection of anti-war grievances to anti-nuclear movements, this research reexamined the relationship between democracy and the development of nuclear industry. In contrast to the anticipated results, the quantitative analysis in chapter 3 first rejects the hypothesis regarding the effect of democracy on the nuclear development, showing a slightly positive correlation between the two. The comparative analysis in chapter 5 indicates that this result is due to the covert of the multi-faceted power structure made by the measurement counting solely the institutions of formal democracy. As halted by the growth coalition sharing the vested interests of developing nuclear power and the techno-nationalism legitimating the nuclear industry, the public contentions over nuclear power are thus removed from the political

arena of the democracies. Thus, this result indicates that democracy and democratization are not necessarily the anti-thesis of the nuclear development.

Second, as inspired by the world systems theory and the concern regarding foreign dependency, the first question asks whether developing nuclear power is a developmental strategy for catching up or a trap of under-development established by the advanced countries. On the one hand, the countries importing or expecting to import the nuclear technology are certainly motivated and attracted by the conveniences such as the energy sufficiency or even the potential military uses of nuclear power. On the other hand, the imported technology, which is a form of international trade, can be used by the exporters to bait a dependent relationship caging the receivers into an unequal exchange favoring the former. The quantitative analysis shows that the effects of foreign dependency on the nuclear development are negative in general. The event-history analysis in chapter 3 demonstrates a negative correlation between the construction efficiency of NPPs and the foreign dependency. The network analysis of the global nuclear reactor transactions in chapter 4 indicates that the importing countries seldom can achieve the import-substitution industrialization, being illustrated in the lasting high in-degrees, ongoing zero out-degrees, and continually low centrality degrees. However, both analyses also stress that the initial dependency in the East Asian countries are often offset or even reversed. The comparative historical analysis in chapter 5 checked the situation. The cased-based investigation shows that as contingent with the geopolitics under the Cold War rivalry, the diversification strategy, if properly adopted, can give them better bargaining power for more efficient and effective technology transfer.

Third, considering the affinity between the nuclear program and the state planning, we assume that the developmental state, which is the most representative of the state-led economy,

provides the most productive environment for developing nuclear power. Our findings confirm that the developmental state is the most powerful explanation. The developmental state explains the most variation and consistently shows the positive association with the nuclear development. In the quantitative analyses of chapter 3 and 4, Japan and South Korea, which are most often cited as the prototypical developmental states, show the highest efficiency of constructing NPPs and the upward mobility in the network of global nuclear reactor transactions. The historical narratives shown in chapter 5 also stress that the features of the developmental state such as the power concentration of the nodal agency and the organizational integration of the rational bureaucracy can be found in the traces of nuclear development in these two countries.

Two deviant cases are generated from the structural analyses combining both alternative theories: Taiwan and China. Although being subject to the same category of the developmental state, Taiwan shows a different pattern in developing nuclear power, which has a far lower efficiency of constructing NPPs than Japan and South Korea. China shows low efficiency in the event history analysis, but it has the largest growth of centrality power in the network analysis. The case-based comparison in chapter 5 shows that although there were many efforts for Taiwan to consolidate the developmental state, it lacked big business conglomerates essential for efficiently gathering the capital and completing the technology transfer. In addition, Taiwan's state autonomy and capability for pursuing the diversification of nuclear technology were constrained by its impaired sovereignty due to the changing international contexts. Second, although the Chinese government has been approaching to the developmental state during the process of developing nuclear energy, its relative inefficiency illustrates that there might be a different environment for the late-comers in the post-Cold War period from those during the Cold War. In short, the deviant cases help determine the composition of the developmental state

and show that the maximal efficacy of the developmental states to overcome the negative effect of foreign dependency is generated from the local contexts fixed with the specific time-space relationship during the Cold War.

The importance of the Cold War milieu is also inspired by an additional theoretical concern with war mobilization. In the quantitative analysis, as referring to not only the material military resources but also the specific socio-political conditions, the war mobilization is operationalized in two forms: the possession of nuclear weapons and the time period experienced under the Cold War. When considering the effect of possessing nuclear weapons, it is hypothesized that there shall be technological spillovers from the military R&D to the civilian uses. When considering the effect of the Cold War milieu, it is hypothesized that the political exception generated under the urgent situation of the Cold War rivalry may help eliminate the disfavoring conditions such as the public discontent or the requirement of due process. In short, it is hypothesized that the effects of the war mobilization are generally positive. However, in chapter 3, the quantitative analysis demonstrates contradictory results, indicating that the impact of possessing nuclear weapons is negative but impact of the Cold War milieu is positive. Instead of directly discarding the results as errors, the cased-based investigation conducted in chapter 5 reconciles the contradiction by a strong interpretation based on the narratives of how each East Asian country progressed in the development of nuclear weapons. The investigation first stresses that although only China formally owns and manufactures nuclear weapons, all the East Asian countries have been involved in developing nuclear weapons. In addition, it indicates that the impact of nuclear weapons is not simple linear but curvilinear, being positive as the driving motivation for developing nuclear power at the early stage but negative as in conflict with the international non-proliferation regime at the latter stage. In addition, as collaterally supported by

the measurement of the changing centrality degrees in the network analysis in chapter 3, we find that the technological cooperation between the supplier of the nuclear technology and the recipients is contingent on the patron's diplomatic relationship to the Communist counterparts of the recipients. Overall, the impacts of the war mobilization represented in the form of the military considerations regarding nuclear weapons are initially positive, then declining, and finally negative as the non-proliferation regime has been gradually consolidated.

2. Theoretical and Methodological Implications

The above findings provide productive feedback to improve the theoretical understandings regarding nuclear development.

The first theoretical implication is the reconciliation between the world systems theory and the developmental state theory. First, the network analysis of the world system elaborates the embeddedness that empowered the East Asian countries' state autonomy and capacity to develop nuclear industry, showing both the structure of global unequal exchange between the core and periphery and the agency of the developmental states (which are also called strong periphery by many world systems analysts). By applying the advanced technique for quantitative analysis to operationalize the world system, the network analysis can establish a parsimonious model to draw clear border lines between the positions and the blocs in the world system, supplementing it with a more concrete measurement (Lloyd, Mahutga, and De Leeuw 2009). While the positions in the world system can be more specifically recognized, more and more questions related to the dynamics of positioning are raised in the network analysis, especially the debate regarding the mobility in the world system (Clark 2008; Clark 2010; Clark and Beckfield 2009; Kim and Shin 2002; Mahutga 2006; Nemeth and Smith 1985; Smith and White 1992). With this concern, it

indicates that while most countries remain in their positions and illustrate the persistence of the inequality between the blocs, the East Asian countries that are largely on the tier of semi-periphery show the significant upward mobility exceptional to the anticipation of the dependency theory and world systems theory. The network analysis of this research, on the one hand, indicates the constant structure of the core-periphery relationships; on the other hand, it provides a clear map showing where the limited changes of node power happen and depicts the dynamics of diversification. In contrast to the exogenous explanation, the theory of the developmental state provides a compatible explanation stressing the developmental strategies endogenous to the countries. For instance, as the network analysis demonstrates a paradoxical result that the developmental states are initially dependent on the United States for developing nuclear power but finally become independent and thriving in the nuclear industry, the narratives about the technology transfer help clarify that the early trade flows also carry the comparative advantages from the earlier technological lock-in of the LWRs (Cowan 1990). The diversification strategies are also implemented timely, thereby offsetting the negative effects of the foreign dependency. In short, by adding the idea of agency to the world systems theory and coupling the developmental state with a structural analysis based on a concrete positioning, the analyses based on the two theoretical strands reciprocally enhance the explaining power of each other.

The second theoretical implication is that the dialect between the coercion and capital (Kentor 2000; Tilly 1992) can be illustrated in a variety of forms and linked to the dynamic process of developing nuclear power instead of being fixed and static. With the clarification of the interaction between the military and civilian uses of nuclear development in the East Asian cases, we find that each state switches between the paths of coercion intensive, capital intensive,

and capital-coercion trade-off rather than adhering to a single strategy. While stressing the accumulation of coercion represented in the development of nuclear weapons at the initial stage, these states either reluctantly cover the military considerations with the accumulation of capital shown in the development of nuclear energy or radically denounce the military uses for trading more civilian technological assistances after the non-proliferation regime has been settled. On the one hand, this process zigzagging between coercion and capital highlights the theoretical uniqueness of the military resources that cannot be reduced to the economic capital, as shown in the military considerations of nuclear weapons (Mann 2012). On the other hand, the dynamic of switching strategies also indicates that there are conversions of different forms of power (Bourdieu 1994; Mann 2012) along with the process of developing nuclear power. In short, to enhance the understanding of the nuclear development, the process of developing nuclear power needs to be analyzed as a series of conversions of different forms of power rather than a monotonous accumulation of single types of resources. It also demonstrates the importance of the local contexts; when considering the convertibility of different forms of power, the resources can become constraints in some specific contexts, and vice versa.

The last theoretical implication refers to the delimitation of the developmental state. As discussed in chapter 2, although the developmental state is often specified as a certain number of countries in East Asia, it is more often depicted as a complex configuration consisting of many institutional conditions, such as the state planning for the economy (Amsden 1989; Johnson 1982; Wade 1990; Woo 1991), the bureaucratic rationality (Evans 1995; Evans and Rauch 1999), the nodal agency for coordinating the production activities (Chibber 2002; Chibber 2003), or even a general balance of political power (Chibber 2003; Chibber 2014; Haggard 1990; Haggard 2004; Kang 2002). However, following the theme of state planning and intervention, scholars stress

that more and more countries perform the strategies once exclusive to the developmental state, emerging as a new type or variant of the developmental state (Beeson 2009; Block 2008; Block and Keller 2011; O'Riain 2000; O'Riain 2004). In other words, the recent efforts to renew the ideal type of the developmental state instead blur the theoretical border of the given idea, though exponentially increasing the number of the candidate cases. To clarify the scope of the developmental state for restoring its applicability, we conduct the comparative analysis to make its contour more clear and profound with more detailed distinction. Through the comparative analysis, although state involvement has increased everywhere in recent decades, the effects of the earlier generation of the developmental state on the nuclear development are mingled with the concerns of the national security (Koo 1987; Woo-Cumings 1998) and the political exception to the democratic accountancy (Cumings 1984; Cumings 1999), which are all generated or legitimated under the urgency of the Cold War rivalry. It indicates that the specific historical contexts of the war mobilization play an important role in the consolidation of the developmental state, involving both the international alliance providing abundant aids and the domestic political environment halting public contentions under the urgency of the Cold War rivalry. In short, in addition to the state involvement, the developmental state is also characterized by its embeddedness in the Cold War milieu, which is not mentioned or emphasized in the recent renewal of this idea.

In conclusion, we find that nuclear power in general is inseparable from dependency and war preparation. In most situations, importing nuclear technology may not help the developing countries achieve self-reliance in nuclear power generation. Instead, it simply intensifies or prolongs the dependency of the developing countries on the vendor countries. Achieving

self-reliance in nuclear energy requires restricted conditions such as the Cold War rivalry and the developmental state, which are not easy to reproduce or desired.

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