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Comparative Analysis of Nuclear Energy Policies in Japan, South Korea, and China

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Abstract

Soon after the Fukushima nuclear accident, countries in East Asia, Japan, South Korea, and China, each took different path on nuclear energy. Japan recently announced nuclear phase-out policy after the accident but soon reversed its policy and decided to re-boot its nuclear program. South Korea also announced nuclear phase-out policy whereas China has been firmly elevating nuclear power generation. To thoroughly probe such differences in their recent nuclear energy policies, nuclear institutions in these countries will be meticulously compared and examined in the historical perspective. This paper will be divided into three phases in an overall historical sequence of nuclear development to analyze nuclear institutions, various actors, and their interactions. For such an analysis, a path dependence framework will be used and then argued that nuclear paths in these East Asian countries are showing an institutional pattern of increasing return under self-reinforcing sequences. These nuclear institutions are reproduced by a group of elites and functional consequences, and their outcomes are top-down path dependent leading to seemingly different nuclear energy polices. From such a conclusion, this study will hopefully contribute to better understandings of nuclear energy policies in different regions and to predict future energy paths around the world.

Keywords: Nuclear Energy Policy, Institutionalism, Comparative Historical Analysis, Path Dependency, Decision-making Process, East Asian Studies.

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I. Introduction

A decade has passed since a disastrous Great East Japan Earthquake and followed by the Fukushima Daiichi nuclear accident. Public acceptance on nuclear technology has significantly deteriorated, and decision-makers have begun to doubt feasibility of nuclear energy as a future energy source. The national energy policy has a profound impact on public health, safety, and environments, thus public acceptance toward power generating technology is an essential consideration in designing and implementing such a policy. With a recent increase in information inflow, the level of public knowledge in technical fields has also increased, and they have become more active in articulating their interests in specialized areas. On the international front, the Paris Agreement has confirmed renewable energy sources as a future energy source to fight against climate change, and so conventional fossil fuel energy source has lost its footing on the future energy mix. But the role of nuclear energy has become more ambiguous as it is considered as neither fossil fuel energy sources nor renewable energy sources. On the other hand, the future of nuclear energy source has some bright sides in the international environment. According to the International Atomic Energy Agency (IAEA), nuclear energy source has been recognized as a low carbon energy source that would contribute to climate change mitigation and sustainable development, and nuclear power capacity has been increasing among developing and fast-growing economies as it is more efficient than renewable energy sources[1]. Due to technical inefficiency and expensive costs in generating power from renewable energy sources, immediate replacement of fossil fuel sources may be almost impossible. On the one hand, developed countries have been benefited from their pre-built nuclear facilities while gradually limiting the use of fossil fuel energy sources and preparing for future renewable energy source. On the other hand, developing countries have engaged in ongoing nuclear energy projects to secure their power generations, which they may participate in global sustainable development blueprints. Thus, the use of nuclear energy may be beneficial to both developed and developing countries in providing a good intermittency to future energy sources while satisfying a

[1] International Atomic Energy Agency. "Nuclear Power and the Paris Agreement," pp. 1-3.

target from the Paris Agreement with the use of low carbon sources.

Despite such advantages, nuclear energy source historically has never been a dominant energy source. Even during its heyday, from the mid-1990s to the early 2000s, the share of nuclear in world's power generation was approximately 17.5%[2]. But since the mid-2000s, the share of nuclear energy has stagnated, and its share has only become about 10% of the world's power generation in nowadays. There would be numerous reasons that nuclear energy was not able to become a dominant energy source. Compared to traditional fossil fuel energy sources that can be mined or drilled, nuclear energy generation takes difficult and expensive processes, and requires tremendously expensive capital costs in constructing nuclear facilities, reprocessing plutonium, maintenance, waste disposals, etc. Though nuclear energy had been regarded as a future energy source since the 20th century; efficiency, safety reasons, or fierce public oppositions all served as a barrier against nuclear energy to be a dominant energy source. And in the 2010s, discourse on nuclear energy has perhaps confronted a critical juncture from the Fukushima nuclear accident in March 2011. Energy transition discourse has been also active in East Asia as these countries were closely affected by the aftershock of the Fukushima nuclear accident. Moreover, East Asian countries are industrialized and high demanders of energy sources, while resource-scarce countries like Japan and South Korea have been relying significant degree of nuclear energy source on their national power generations. After the Fukushima incident, Japan, as a victim of a disaster, initially pushed toward revolutionary energy transition including a plan for nuclear phase-out. South Korea and China immediately conducted safety assessment of their nuclear reactors amid arising public fears from radiation exposure and food safety due to geographical proximity. And these countries ultimately took different paths in their nuclear energy policies. Soon after the accident, Japan announced to withdraw from nuclear energy but later reversed this decision to continuously pursue nuclear energy source as a vital part of their power generation. And several years after the accident, South Korea announced nuclear phase-out policy which was one of main energy policies pledged by

[2] American Physical Society. "How has nuclear power changed since Chernobyl?" August 8, 2019.

the new South Korean administration. Different from these two countries, the Chinese administration was less swayed by external crisis and steadily increased the share of nuclear energy source from the nation's power generation. Such a difference among three countries is pronounced shown in the graph:

Figure 1. Japan's Nuclear Share Trend (IAEA Power Reactor Information System Country Statistics, 2020)

Figure 2. South Korea's Nuclear Share Trend (IAEA Power Reactor Information System Country Statistics, 2020)

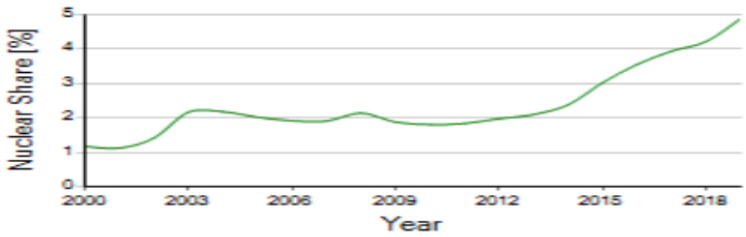

Figure 3. China's Nuclear Share Trend (IAEA Power Reactor Information System Country Statistics, 2020)

In this paper, research aims to explain pronounced differences in displayed trends in nuclear

in three East Asian countries by arguing that their paths have been shaped from historical perspective. Their current policies are products of their institutions developed and furnished over time through interactions among various actors. In a broader scope, policy itself is an institution with a plan to serve political and social purposes. And so, differences in policies inherently mean differences in institutions developed over time. Thus, nuclear energy policy has not been developed by a mere accident or shock but rather steadily constructed from the history. Therefore, this paper will examine and compare three countries with a path dependent approach that may offer explanation on differences in current nuclear energy policies across different countries. Path dependent approach would be the best choice to compare and perhaps explain different policy outcomes in different countries. These countries will be analyzed within institutional context that is distinct, historical, and empirical perspective. Another issue in this approach is upon different types of sequences and explanations, which analyze distinct institutional patterns and driving forces for such reproductions or changes in institutions. Within a path dependency framework, therefore, defining and elaborating nuclear institutions in a broader context, not limited to law or policy but expanded to actors and their interactions over time will be important.

Before analyzing literatures and frameworks, a brief explanation and characteristic of nuclear is necessary in understanding nuclear institutions. The origin of nuclear power technology was driven by the state's ambitions and external environments and ultimately affected technical aspect of nuclear power such as reactor type. And this has gradually impacted public acceptance and organizational development over time. It has been not so long that civilian economy began to integrate with the state authority on the energy sector. Nuclear energy at its origin was known to be developed from the study explosiveness from energy release by nuclear fission during wartime or the Manhattan Project, but after the war, civilian role on nuclear technology has expanded on energy supply and macroeconomic effects by energy policy[3]. With the national agenda to reconstruct after the war, energy sector has bloomed.

[3] Kohl, Wilfrid L.. "National Security and Energy." In Encyclopedia of Energy, edited by Cutler Cleveland. Elsevier Science (2004), pp. 193-206.

Especially nuclear sector experienced the most active transition to civilian integration among other energy resources. Although the idea of nuclear power's civil use was initially introduced during the wartime in the 1930s, a special circumstance hampered further development of civil integration of nuclear power technology. But shortly after the war, accumulated knowledge bloomed as the Soviet Union introduced the first nuclear power plant Obninsk in 1954, generating about 5 MW, and two years later, the U.K.'s Calder Hall nuclear power plant began its first commercial operation[4]. These early-stage reactors were initially designed for military purposes, but states have decided to operate reactors for dual purpose. For instance, Calder Hall plant served to generate and reprocess plutonium for the British nuclear weapon program. It was evident in Calder Hall plant's magnox reactor type, which is a gas cooled type with graphite moderators[5]. Such a graphite moderate does not require enriched uranium rather natural uranium fuel to produce plutonium and the core design facilitated extraction of a large stockpile of weapon-grade plutonium. Nevertheless, its efficiency to generate electricity is low due to limitations in design and usage of uranium fuel. Despite such a critical drawback in generating power, countries could not easily forgo nuclear power's dual capability and its strategic importance in the post-war era. Especially after the war, states adherently pushed toward nuclear development to rebuild the nation's footing and escape from identity crisis. Gabrielle Hecht referred nuclear technology as a path toward 'national glory'[6]. For example, France felt a sense of defeat after the war, which displayed poor military performance and its technological and economic development was far stagnated to its counterpart Germany[7]. Moreover, the state faced chaotic external situations after the Second World War with the rise of superpower competitions and colonial insurgencies from Indochina and North Africa[8]. The nuclear discourse between the French Atomic Energy Commission (CEA) and the Electricite de

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[4] AM Petro'yants. "A Pioneer of Nuclear Power." IAEA Bulletin Vol. 26 No. 4. December 1984.

[5] Ibid (IAEA).

[6] Gabrielle Hecht. The Radiance of France. The MIT Press (2009), pp.272-293.

[7] Ibid (Hecht), pp. 27.

[8] Jonathan Hunt. "The Radiance of France: Nuclear Power and National Identity after World War II by Gabrielle Hecht (1998)" *Not Even Past.* July 30, 2012.

France (EDF) reveal France's politically motivated justification of a gas-graphite that can breed the "maximum bomb-usable plutonium" over light- or heavy-water reactor in pursuit of military nuclear program[9]. The CEA's pursuit of gas-graphite reactor triumphed over the EDF's advocate of light-water reactor, as the French decision-makers positively evaluated the dual-use ability of gas-graphite reactors. Such a decision over reactor type was driven by domestic and external environments on French efforts to build the nuclear bombs and to flex its muscles on the post-ward period, and this French bomb was later used during the Algerian War of Independence[10]. As revealed in such anecdotes, the nuclear power generation originally stemmed from military aspirations after the Second World War. The United Kingdom's Calder Hall reactor was designed to supply plutonium for the British nuclear weapon program. And France also selected a gas-graphite program to regain the national glory amid internal and external disorders in the postwar period. Although the study suggests that cost assessment of Magnox nuclear reactors (gas-graphite) built between 1955 and 1972 are more expensive than other available alternatives including conventional plants like light-water reactors[11], countries' decision-making in introducing its commercial nuclear power was driven by maintenance of dual-capability shaped by external environments then affected decision-maker's strategic choice on nuclear power reactor.

Similar anecdote may be also found in East Asian countries case which the development of nuclear technology initially began from its dual-capability. Otherwise, some countries apparently expressed military aspirations from the initial stage of nuclear technology development. The former case may apply to Japan and South Korea when they initially decided to develop and import nuclear power technology. But the latter applies to Chinese case, which it initially invented nuclear weapon program and later developed into commercial use of nuclear technology. East Asian countries may have

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[9] Ibid (Hunt).

[10] Ibid (Hecht)

[11] Richard Green. "The Cost of Nuclear Power Compared with Alternatives to the Magnox Programme." *Oxford Economic Papers*. New Series, Vol. 47, No. 3. July, 1995, pp. 516-522.

been influenced by western countries that are predecessors of nuclear technology development. Such a nuclear-hedging behavior was more pronounced in Japan and South Korea to initially pursue nuclear energy sources while secretly pursuing weapon program with adapting weapon-related technologies or negotiating with other countries. From such a backdrop, the beginning of nuclear institutions can be assumed that will serve as an antecedent condition in nuclear paths in each country. And in the next chapter, previous literatures on institutions and comparative studies will be carefully visited, and their limitations for this particular research will be discussed.

II. Literature Review

1. Institutionalism

Institution has been a social-historical product to exercise powers and mobilize resources to shape policies in the modern political arena. While lexical definition of the institution is vague as it may refer to established law custom, or practice, it may embrace informal rules or relationships that may shape behavior of actors[12]. Although the definition of institutions varies by schools or scholars, it has a common and inclusive agreement on institution as law and custom. And more importantly, institutions may shape behaviors and preferences of political actors that heavily influence the political landscape. The past literatures on political institutions were dominated by the relationship between formal institutions and the state; however, the focus has shifted to relationships among individuals and their behaviors while institutions aim for survival and gaining legitimacy in an open environment[13]. The horizon of institution has been expanded, and scholars have interpreted the range of institution in slightly different manner. For example, Peter Hall defined as the structure of rules, procedures, and practices that shape relationship between individuals, while John Ikenberry extended to the structure of

[12] Stephen Bell. "Institutionalism: Old and New." pp. 1-2.

[13] Neha Patil. "New Institutionalism." Alcheton. February 2018.

state and the normative social order[14]. Institutions have evolved and affect wider range of aspects focusing on societal values and components. This was indeed a sign of withering of the old institutionalism and emerging new institutionalism.

The next question is how to compare and analyze these countries within a historical sequence. After setting a time frame, variables and their interactions would produce significant yet large-scale outcomes. In explaining institutionalism, institution itself can be both an independent and a dependent variable: it becomes a dependent variable when actors establish institution through a rational decision-making process, while it becomes an independent variable when actor's behaviors and preferences are influenced by an institution. In this paper, I will attempt to present both aspects of institutions, which nuclear-related institutions are initially established with certain motivations, and institutions ultimately shapes policy outcomes from various interactions between actors and forms structure of a polity's decision-making. In empirical study, Brigitte Weiffen conceptualized institutions both as dependent and independent variable when inter-democratic institutions, which are created by democratic idea, ultimately lead to peace among nations[15]. A similar causal mechanism may apply to this paper, in which nuclear institutions function both as independent and dependent variable. States, with a specific motivation, create and sustain nuclear institutions, and then, these institutions shape policy change in nuclear energy. In other words, institutions can interestingly be a catalyst for institutional or policy change whereas they can also be a constraining factor or even influenced by top-down policy change. Such a mechanism may be illustrated like following:

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[14] Kathleen Thelen and Sven Steinmo. Structuring Politics: Historical Institutionalism in Comparative Analysis. September 1992, pp. 2-5.

[15] Brigette Weiffen et al. "Democracy, Regional Security Institutions, and Rivarly Mitigation: Evidence From Europe, South America, and Asia." Security Studies (20:3), pp. 383

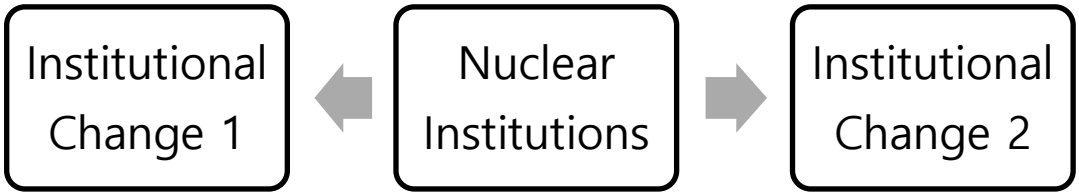

Figure 4. Nuclear Institutions as Both Independent and Dependent Variable

A direction of this paper could have been developed with an interpretation of nuclear institutions as both dependent and independent variables, but the paper mainly concerns with an institution as a dependent variable that is an outcome of the process of change. Within a new institutionalist perspective, various scholars have attempted to explain different mechanisms on the processes of institutional change. Douglas North, for example, insisted for gradual and continuous transformation of institutions. And similarly, Giovanni Capoccia studied endogenous institutional change that is triggered by a gradual process of reinterpretation and shifts in the social coalitions that lead to renegotiation processes[16]. On the other hand, Stephen Krasner argued for punctuated equilibrium theory that institutional change occurs abruptly by exogenous shock that is triggered by critical junctures. This concept of critical juncture, related to institutional genesis, allows transitions or dramatically changes altering path dependent institutions and shape new directions. Ruth Collier has elaborated critical junctures with a framework, which the antecedent conditions and the cleavage emerge prior to critical juncture, and after the transition, legacy and rival explanations emerge then legacy eventually ends[17]. And critical juncture may occur through various conditions, as they arose in different manners and timings. Alexander Gerschenkron argued that such a different timing brings different processes and consequences on political events or industrialization[18]. Gershenkron's argument

[16] Giovanni Capoccia. "Why Do Institutions Bite? Historical Institutionalism and the Politics of Institutional Change." *Comparative Political Studies* 49 (2016). pp. 1098

[17] Ruth Collier and David Collier. "Shaping the Political Arena: Critical Junctures, the Labour Movement, and Regime Dynamics in Latin Amercia." *Princeton University Press* (1991), pp. 30-31.

[18] Sven Steinmo. "What is Historical Institutionalism?" In Approaches in Social Sciences edited by Donatella Della Porta

may be significant in comparing three East Asian countries in this paper since they each industrialized in different period.

Empirically connecting to this paper, the Fukushima Daiichi accident had a profound impact for not only Japan's nuclear energy policy but also that of other countries. Such an exogenous shock further affected various realms such as safety regulation, public perception, health, and environments. From previous study, Sung Chull Kim has defined the Fukushima incident as a critical juncture for the development of Japanese nuclear power yet failing to bring a change in nuclear discourse in Japan[19]. And Soo-kyung Park also defined the Fukushima incident as a critical juncture that altered the nuclear path of South Korea[20]. While many previous studies have indicated the Fukushima nuclear accident as a critical juncture, a role of exogenous shock in institutional change has a clear limitation that preclude human agency and leaving institutional change as a product of the fate[21]. Moreover, focusing too much on exogenous shock may underestimate complexed endogenous relations within institutions. The Fukushima nuclear accident may have not generated exogenous shock for institutional change, but rather institutional changes in other countries may occur from incremental change from endogenous shock. Such a one-sided perspective on institutional change may generalize on the relationship between individuals and collective actions, it further undermines individual behaviorism and fails to provide accurate cause-and-effect relationship between institutions and individual acts. Sven Steinmo added that institutional change is "the product of changes in ideas by actors," which ideas provide creative solutions to collective action problems[22]. Actors, as a provider of ideas, can play a vital role in shaping institutions without relying too much on an exogenous shock, and there has been a growing attention

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and Michael Keating. Cambridge University Press (2008), pp. 164

[19] Sung Chull Kim. "Critical Juncture and Nuclear-Power Dependence in Japan: A Historical Institutionalist Analysis." Asia Journal of Peacebuilding vol. 1:1 (2013), pp. 88.

[20] 박수경, 장동현. "원자력 정책 변동 관한 연구: 후쿠시마 원전 사고 전후를 중심으로." 한국콘텐츠학회 (19:6). 2019, pp. 232-233

[21] Ibid (Steinmo), pp. 168

[22] Ibid (Steinmo), pp. 170

on the role and changes in institutions followed by energy transitions and changes in energy policies. For instance, Matthew Lockwood explained transition to sustainable energy sources in institutional perspective in which various actors interact with diverse political institutions[23]. Energy users, publics, or NGOs mainly interact with energy providers and policy makers under the institutional setting such as electoral systems and institutional arrangements like regulatory regime in aggregating interests. Sung Chull Kim defined nuclear power as an institution in four distinct ways: the relationship between the central and local governments, triangular relations between the government, politicians, and firms, technological nationalism; and the outside influence such as the United States pressure to Japanese nuclear development[24]. Another article by Soo-kyung Park indicates that institutional context in nuclear energy policies is shaped by policy paradigm, decision-making structure, and decree-law[25]. As explained by these scholars, perhaps, a contingent event did not solely contribute to dramatic alteration of nuclear path, while various actors and their interactions shaped new path within institutional context throughout the history.

While previous studies had put tremendous efforts to not only define institutions in both old and new styles, they also defined institutions in the context of nuclear energy. Those defined nuclear institutions will undoubtedly be a great asset to the study of this paper; however, they still lack some explanations on the main question of the paper. Although previous studies literally defined nuclear institutions and institutional change accordingly after the critical juncture period, they lack explanations on a fundamental question of why they change. Moreover, they lack analysis in the historical sequence in a longer term. Some of papers focused institutional change within a past decade or a few administrations in a narrower perspective. But this paper will attempt to glance from the initial development stage of nuclear power in each country. Assuming that Japan, South Korea, and China

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[23] Matthew Lock et al. "Historical institutionalism and the Politics of Sustainable Energy Transitions: A Research Agenda." Environment and Planning C: Politics and Space (35:2). 2017, pp. 315.

[24] Ibid (Kim), pp. 88-89.

[25] Ibid (박수경 et al.), pp. 223-225.

each began its nuclear development and institutional building around the 1950s and 60s, a time period is a little more than a half of the century in which seemingly broad but an analysis from the early stage is very essential to explain a critical nuclear path in each country. And lastly, the research in this paper will be significant in taking comparative perspective of three East Asian countries. Previous studies on nuclear institutions focused on analyzing just one country or comparing South Korea and Japan for a similar institutional pattern. Despite comparing three countries with a wide time frame may have a drawback in becoming too broad analysis, an interesting institutional pattern has been observed in all three countries that can hardly be neglected. As presented in an introduction section, three countries showed a distinct pattern in nuclear energy respectively and analyzing them in a common framework will be sincerely meaningful as a comparative historical analysis.

2. Comparative Historical Analysis

To thoroughly compare and analyze nuclear policies in different countries over time, the use of systematic and contextualized comparison is important. As Mahoney and Rueschemeyer defined comparative historical analysis method as the studies that juxtapose historical patterns across cases in a broader context[26]. In this sense, historical institutionalist approach may be included in a branch of comparative historical analysis if systematic and contextualized comparison element is analyzed. In fact, a common yet the most important goal in analyzing historically grounded cases is to answer, 'large-scale outcomes[27].' This is indeed the first feature of comparative historical analysis, which causal configuration leads to major and large-scale outcomes. Without the causal assumptions, testing hypotheses on locating similarities and differences is impossible to analyze cases. The second feature in comparative historical analysis is the unfolding of processes over time, which temporal structure of

[26] James Mahoney and Dietrich Rueschmeyer. Comparative Historical Analysis in the Social Science. Cambridge University Press (2003), Chapter 1 Comparative Historical Analysis: Achievements and Agendas, pp. 10

[27] Ibid (Mahoney et al.), pp. 7.

events strongly affect the end outcome. For example, nuclear energy policies may have been affected by the relative timing of major nuclear accidents. Social epistemology is strongly swayed by such a major event, where publics realize that their safety may be directly threatened and further affect decision-making processes in public sphere. And the final feature is associated with systematic and contextualized comparisons as aforementioned, it facilitates between theory and evidence in the research to discover new concepts and explanations and then becomes more powerful when employing small number of cases most commonly nation-states[28]. In this paper, cases of Japan, South Korea, and China will be compared, so small numbers of nation-states perfectly fit with macro-level analysis using the systematic and contextualized comparisons.

Nevertheless, there are three cleavages on historical comparative analysis presented by Mahoney and Rueschemeyer that serves as weaknesses compared to other approaches. Firstly, there is a difficulty in incorporating micro-level analysis into macro-level analysis of historical research. Although more studies actively incorporate both qualitative and quantitative methodology to present multiple causal analysis, dichotomous choice of research method is trivial in conducting research while the logic of inference is important[29]. At the same time, comparative historical analysis has been criticized for biased selection in dependent variables and sources. Although some degrees of secondary sources are also used in this paper, other sources from the international organizations were used to ensure credibility. Moreover, the validity argument is not strongly influenced by the secondary sources or instead use well-established historical interpretations for obviation of any systematic error[30]. Another cleavage is generated with the use of rational choice theory for general causal principals. Skeptics on comparative historical analysis argue that the method uses inductive method and undermine assumptions on rationality of actors[31], but historians often assume that actors are rational at the most of time. And the

[28] Ibid (Mahoney et al.), pp. 13-14.

[29] Ibid (Mahoney et al.), pp. 17.

[30] Ibid (Mahoney et al.), pp. 18.

[31] Ibid (Mahoney et al.), pp. 19-20.

topic itself is possible to apply rational choice model for systematic comparison of nuclear energy policies. For example, the cost of maintaining of nuclear power or of nuclear phase-out cost has been systematically compared based on assumptions on rationality of actors.

A main assumption is that if a major nuclear accident, for example of the Fukushima nuclear accident, occurs, and decisions will be required either to maintain nuclear power or to pursue nuclear phase-out. To rationalize a certain choice, detailed calculation may be made depending on cases and situations. In terms of energy security and efficiency, rational choice approach may display in numeric and further justified certain choice over others. For instance, renewable energy sources are yet expensive than other fossil fuel or nuclear energy sources due to technical problem. If actors attempt to maximize perceived benefits and utilities through institutions, such a numeric calculation may lead to a conclusion that a particular policy path is justified and rationalized. Such a method not only reduces uncertainty from actors and their decision-making processes, but it can also provide micro-perspective analysis that lacks in other new institutionalist approaches. Therefore, introduction of rational choice approach on nuclear energy policies will be an asset to supplement more micro-perspective aspects. Nevertheless, such a micro-level analysis has some drawbacks with sporadic numeric values that may lead to inaccurate estimation and outcome. And there is more general limitation on ex-ante policy analysis, which such utilities in economic benefits or risks do not solely lead to rational behavior of decision-makers. In other words, institutions or decision-makers may disregard what-seems like a rational choice in a numeric value. They sometimes make politically driven decisions that seem irrational. Thus, this result may only serve as a guidance to policymaking, while it may not serve as a deciding factor. Therefore, critics of the theory argue theory's empirical weakness, bounded rationality, and volatility in individuals. Although rational choice theory may provide an explanation on a certain choice and has a comparative advantage over some cases, it does not fully explain complex relationships between institutions and individual actors. But if nuclear institutions in Japan, South Korea, and China have incrementally changed, explanation based on rational choice approach may reveal drawback. Furthermore, an explanation on institutional change such as nuclear phase-out decision may not be

enough from cost-benefit analysis, but it is important to consider from multifaceted perspective to grasp better understanding on the issue. For such reasons, comparative historical approach, as a macro-perspective approach, would be more susceptible to conduct comparative analysis on nuclear energy policies in a wider and in-depth institutional context.

And lastly, comparative historical analysis has a drawback in lacking cultural analysis that can constructively interpret developments in social and political structures including developments of nuclear power in this paper. Nevertheless, cultural analysis is one of crucial elements in respect to nuclear matters due to inherent risks posed by nuclear power that is closely associated with people's perceptions. Likewise, risk perception is influenced by trust in institutions that regulate the introduction of new technologies that are unfamiliar to the publics[32]. And depending on the level of uncertainty on such technologies, risk perception and trust level on the authorities deteriorate. Similarly, the deficit model explains that the public hostility toward new technologies due to deficient knowledge[33], thus improving public awareness of science is a key step to promote public acceptance. On the other hand, the democratic model was later introduced to supplement the deficit model by adding values, norms, power relations, and trust as factors influencing public acceptance of science[34]. Understanding of public acceptance of science, therefore, has evolved over time as the level of public participation and engagement has accordingly grow. Moreover, an increase in trust not only reduces risks and raises benefits but it also improves overall level of trust in institutions[35]. But vice versa, trusts toward experts must be ensure if the level of social trust in experts or institutions is high, perceived benefits or risks will be amplified depending on the authorities' capabilities to shape favorable discourse. Institutional

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[32] Nicolas Bronfman, et al. "Understanding Social Acceptance of Electricity Generation Sources." Energy Policy 46 (2012), pp. 247.

[33] Yue Guo and Tao Ren. "When it is unfamiliar to me: Local acceptance of planned nuclear power plants in China in the post-fukushima era." Energy Policy 100 (2017), pp. 114

[34] Ibid (Guo), pp. 114-116

[35] Younghwan Kim, et al. "An International Comparative Analysis of Public Acceptance of Nuclear Energy." Energy Policy 66 (2014), pp. 476.

practice by the authority to manage risk has been a responsibility of regulatory regimes from a novel technology[36]. Although some studies suggest that the level of public knowledge and acceptance on nuclear technology is positively related to perceived benefits such as economic development and carbon dioxide emission whereas it is negatively related to perceived risks[37]. In other words, perceived risks on nuclear power stems from lack of public knowledge. On the other hand, lack of knowledge in specialized and yet clandestine technology such as nuclear power seems to be ubiquitous in every country, so perhaps publics often rely on experts, institutions, and authorities on such knowledge. As Gabrielle Hetch described, it inevitably gives too large authorities and power to experts who may influence the knowledge of publics and further the public acceptance, and they may manipulate uncertainty to shape favorable decision-making environment. And closed institutional structures and base-less belief systems engender a distorted view of the scope for public discussion and democratic involvement within nuclear decision-making and obscured risks posed by nuclear technology. Some solutions to reduce such gaps between the authority and publics would be institutional practices to foster communication. Irwin argues that the role of science is to emphasize denial of risk and uncertainty, while nuclear risk and uncertainty is largely dependent upon the public statements of scientists and engineers[38]. And if nuclear technology is perceived as inherent risks but essential for development, how decision-makers would legitimize such technology for the future? Such an agony began not so long ago; indeed, when nuclear technology was initially introduced to publics in the 1950s and 60s, public confidence was remarkably high with active promotion of novel technology in and outside the nation. However, a series of major nuclear accidents at the Three Mile Island in 1979 and Chernobyl in 1986 deteriorated public support toward constructing nuclear power plant. According to the OECD finding, such dramatic events can lead to sharp decline of on public support while public opinion is not volatile

[36] Ibid (Bronfman, et al.), pp. 247-249.

[37] Ibid (Guo), pp. 114

[38] Ibid (Barbara et al.), pp. 220

and takes longer time to recover[39]. Or even before such an accident, worsening public acceptance on nuclear power caused the NIMBY phenomenon, even before the TMI accident, the 1976 Gallup and Harris poll indicated that the majority of publics began to oppose nuclear power construction within five-mile distances of their local residencies[40]. More fundamental issue on worsening public acceptance on nuclear technology is perhaps its association with nuclear weapon program. For example, one of public polls indicated that about 60% of publics from the 1950s to 2010s linked nuclear technology to military program as they perceive nuclear technology is associated as nuclear weapons[41]. Such an association to nuclear technology to weapons is a part of moral perception, which publics are adamant to changes and their beliefs are often unchallenged[42]. Hore-Lacy argues that moral and ethical perceptions are contradictory conceptions as moral perceptions need no reasons whereas ethical perceptions need reasons to support justification and to carry out for actions[43]. Thus, publics have become more aware of ethical perceptions on nuclear technology such as safety, environmental issues, etc., while decision-makers also departed from traditional technocratic decision-making to match increasing public awareness on ethical perceptions. And such bilateral shifts in publics and decision-makers have larger implications in East Asia which signal that their decision-making processes have become more democratic and transparent. Allan has devised such a phenomenon as nukespeak, which is to shape nuclear discourse in preferred ways[44]. But if these devises do not exist, decision-makers must make decisions under uncertainty Giddens referred such an effort to interact and to communicate among agents as active trust[45]. In more recent years, institutions utilized such tools to enhance public understanding and reduce uncertainty on nuclear matters in cultural perspective, so cultural analysis has

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[39] Jonathan Baron and Stephen Herzog. "Public opinion on nuclear energy and nuclear weapons: The attitudinal nexus in the United States." Energy Research & Social Science 68 (2020), pp.2-5.

[40] Ibid (Baron et al), pp.2

[41] Ibid (Baron et al), pp. 3.

[42] Hore-Lacy, Ian. "Factors in Public Perception of Nuclear Energy" Uranium Information Centre, Melbourne, pp. 114-115

[43] Ibid (Hore-Lacy), pp. 115-118.

[44] Ibid (Barbara et al.), pp. 211.

[45] Ibid (Barbara et al.), pp. 212.

become important parts in newly emerging comparative studies. Public acceptance will be analyzed in the later part of this paper to supplement on lacking cultural analysis while a main emphasis will be on historical perspective.

On the other hand, such an analysis lacks causal analysis that is the most basic component in the comparative historical analysis. Every analytical paradigm has pros and cons in social science research, but the comparative historical analysis may mediate among diverse research methods. For example, the comparative historical analysis can ignore too much of subjectivity and supplement validity from the rational choice analysis while supplementing causal analysis and preventing to become too subjective[46]. Furthermore, the comparative historical analysis can relieve concerns being too broad from rational choice or cultural analysis while supplement too narrow statistical methods. Therefore, it can serve as a medium-ranged analysis not being too broad nor narrow, not immersed in subjectivity. In the next section, path dependency model, a main analytical framework and comparative historical analysis tool for nuclear energy policies in Japan, South Korea, and China will be explored in this paper.

III. Research Method

1. Path Dependent Framework

Among many other theoretical frameworks for historical comparison, path dependence seems to provide the most plausible explanations for outcomes from historical sequences along with institutional patterns or event chains. Nuclear energy policies in Japan, South Korea, and China were developed in different ways and produced different results in the end. To find and analyze reasons for different outcomes, the process of changes must carefully be analyzed. From the initial development of nuclear energy in these countries, various institutions and actors interacted to shape their current path. As James Mahoney described, path dependence is just more than 'history matters', it is a practice of

[46] Ibid (Mahoney et al.), pp. 25.

tracing certain outcomes or displaying contingent occurrences on historical events[47]. But in deeper analysis, their nuclear development path has been stable and showed a similar pattern of inertia. Such a pattern is not only displayed in nuclear technology development, but it widely applies to the introduction of new technology, where institutions adhere to old practices and disobey to new circumstances. And the power to adhere to old practices become stronger when the longer time piles up to customs.

Within a path dependence framework, two dominant types of sequences exist, including self-reinforcing sequences that produce long-term reproduction of institutional pattern; on contrary, reactive sequences are chains of temporally ordered and causally connected antecedent events, leading to the outcome[48]. And one distinct pattern in self-reinforcing sequences is 'increasing returns' that constantly increase benefits over time while once adopted, the pattern becomes consolidated and difficult to transform to a new pattern. In essence, past choices not only persist into the present, but they also affect future processes, and a big question is how this process, sequence, and temporality may be incorporated into social explanation[49]. For example of nuclear energy policies in Japan, South Korea, and China, they made decisions to adapt nuclear energy for power generation at a certain timing, and their past decisions may have affected their present struggles and future concerns on nuclear power. These three countries may have undergone distinct process, sequence, and temporality to shape nuclear path.

According to James Mahoney, path dependent analysis includes three features: causal processes, unpredictability, and inertia. The first feature reveals that early events in historical sequence is important as they affect later stage of outcomes. In other words, the order, method, and timing of events matter in historical sequence. Although the early stage matters, the second feature tells that the outcome cannot be determined by prior events or initial conditions, which make unpredictable but become stabilize over time. And the final feature reveals that pattern of continuing processes and then tacking outcome occur. Especially in self-reinforcing sequences, institutional pattern is reproduced

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[47] James Mahoney. "Path Dependence in Historical Sociology." Theory and Society, Vol. 29, No. 4 (2000), pp. 507-508.

[48] Ibid. (Mahoney), pp. 508.

[49] Ibid. (Mahoney), pp. 510.

whereas a pattern both reacts and counter-reacts to proceed to another event in reactive sequences[50]. Given such characteristics in path dependence framework, nuclear energy policies may have implications on causal processes that early stage of nuclear development strongly matter in later part of events. When decision-makers initially decided to pursue nuclear power as a national strategy, how nuclear power was introduced within a certain institutional setting matters in overall sequence of nuclear development. Thus, events at the early stage of the sequence are important as outcome of earlier events affect outcome of later stages. On the other hand, these final outcomes of sequence are not determined by initial conditions; in other words, initial nuclear energy policies cannot determine current or final nuclear energy policies on historical sequence. But even if new nuclear energy policy is introduced, along with path dependency, such a new policy is reproduced by a particular institutional pattern. With such a brief definition on path dependency, all causal sequences in the past may not be historically applied in this framework; however, nuclear energy policies in East Asian countries have great potentials to be historically explained by path dependency framework.

Among different sequence type of path dependent approaches, self-reinforcing sequence seems worth noting in technological development or enduring policy aspect. According to Mahoney's definition, directions become difficult or impossible to reverse direction over time[51], and because of 'increasing return,' institutions persist and tend to benefit from such an enduring process. And one of causes for such an increasing return process is critical junctures, which a particular option is selected among multiple alternatives while that a particular option is consolidated and cannot be returned to an initial point. And during this process of selecting a particular option at a critical juncture period, contingency that occurs unexpected and unpredictable outcome. While a contingent event is not just random or without antecedent conditions, it may include the assassination of particular individuals, natural disasters, market fluctuations, or even adoption of an inefficient technology[52]. Thus, contingency

[50] Ibid. (Mahoney), pp. 511.

[51] Ibid. (Mahoney), pp. 512.

[52] Ibid. (Mahoney), pp. 514

is very inclusive ranging from a particular choice from seemingly large and random process and challenging an initial prediction. After periods of institutional genesis, institutional reproduction occurs in path dependent institutions under self-reinforcing sequences. And institutions show a characteristic of 'lock-in' that institutional pattern becomes predominant under institutional reproduction mechanisms and unable to reverse its direction. Depending on the speed of triggering institutional reproduction, whether it is rapid or gradual, institutions can either solidify dominant position or become ephemeral against alternative options[53]. In fact, institutional reproduction is indeed paradoxical in its outcomes contradicting a classic theoretical framework and then reproduce such contradicting outcomes that were shaped during the critical juncture period.

In more detail, institutional reproduction can be divided into four different types of path dependent explanations: utilitarian explanation, functional explanation, power explanation, and legitimation explanation. In a utilitarian framework, actors rationally choose to reproduce institutions through cost-benefit assessments, and institutional change occurs upon actors' self-interest and learning process. In general, nuclear energy tends to be more expensive than traditional fossil fuel sources while is cheaper than renewable energy sources, so cost-benefit calculation will vary by country's institutions, their energy targets, and energy demand and supply. In East Asian context, they already have sufficient nuclear infrastructures so maintenance cost will be cheaper than nuclear phase-out or new energy source phase-in, unless new energy sources pass an infection point and become cheaper in power generation. Moreover, alternative fossil fuel sources or natural gas will be always cheaper than utilizing nuclear energy source without any regulations. Thus, institutional reproduction through rational cost-benefit assessment from utilitarian explanation is somewhat mixed in the East Asian context. In a functional framework, institutional reproduction occurs from functional consequences for a system, like integration, adaptation, or survival; and institutional change may occur from an exogenous shock

[53] Ibid (Mahoney), pp. 515.

pressuring the overall system to dismantle and leading to adapt to the new environments. In an empirical analysis, nuclear institutions in East Asian countries may reinforce and be reproduced for regime survival. So, despite exogenous shock such as regime turnovers or natural disasters, those institutions tended not to change. This explanation will be a worthwhile to analyze in detail because their institutions commonly seek for functional consequences, and they commonly confronted various types of exogenous shocks. A power framework, like a utilitarian explanation analysis, cost-benefit assessment is a basic assumption while it heavily emphasizes on role of actors. In this case, those actors are elites who cause institutional reproduction and benefit from such a power structure. However, when these elite groups lose power and rival subordinate groups gain power, institutions are likely to change in form of a sudden demise. This type of explanation seems the most plausible in the East Asian context as the role of actors have been crucial from an institutional genesis to reproduction in self-reinforcing sequence. And those institutions were often swayed by a group of elites who were constantly empowered by institutional reproduction processes. And the last type of legitimation framework likewise emphasizes a role of actors assuming their self-understandings on moral appropriateness. Thus, institutional change depends upon changes in actors' subjective perceptions and moral codes that may lead to decline in institutional stability or introduction of new thinking. In the East Asian context, moral appropriateness and values on nuclear institutions were highlighted especially after the Fukushima nuclear accident with respect to potential threats to environments from nuclear waste disposal issue. Moreover, increase in values of using renewable energy sources triggered potential changes in values of nuclear energy sources. In sum, institutional reproduction mechanism and institutional change mechanism vary, depending on different types of self-reinforcing sequences from various path dependent explanations. And another crucial question is how to apply these explanations on institutional reproduction and change mechanism of nuclear energy policies in three East Asian countries. From previous discussion of nuclear energy policies, their institutional patterns seemingly persist for reproduction. And empirically, functional and power explanations seem compelling in explaining institutional persistence in nuclear in the East Asian context, as institutional reproduction can be

analyzed in both functional consequence and powerful elite groups. On the other hand, utilitarian and legitimation explanation portray weakness in analyzing historical sequences of nuclear institutions in East Asian countries. Those explanations can feasibly analyze current nuclear path, but in a more comprehensive yet historical perspective, functional and power explanations largely influenced in various aspects of sequences and contingency.

A scope of study will be based on a small-N comparison, focusing on a small number of cases within delimited historical contexts. One of advantages in small number cases is that one can comfortably revisit theoretical concept while thoroughly analyzing cases and developing new theoretical frameworks[54]. Cases in this paper, Japan, South Korea, and China; for example, each industrialized and developed nuclear technology in different time frame. Dividing into right time frame by a significant incident would facilitate comparative analysis. For example, Sven Steinmo categorized into three phases in the taxation system: the historic compromise from 1880 to 1920; the postwar period until 1980; and tax reform in recent years for analyzing relevant institutions in Sweden, the United Kingdom, and the United States[55]. Another example is from the work by Ann Shola Orloff on sharp divergences in pension policy in Britain, the United States, and Canada within a certain time frame[56]. An important premise within Steinmo's argument is that these three states are democratic regimes, and the difference in structure of these democratic institutions led to different taxation policies in each state. On the other hand, three cases in this paper, Japan, South Korea, and China, are not democratic regimes. Although a regime difference may serve as a predicament in analyzing structures, Vipin Narang suggests that civic participations may be more active in non-democratic regimes such as China, in which civilians desire to involve in control of sensitive national strategy like nuclear power[57]. So perhaps,

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[54] Ibid. (Mahoney et al,) pp. 13.

[55] Edwin Amenta. "Review Work: Taxation and Democracy: Swedish, British, and American Approaches to Financing the Modern State by Sven Steinmo." pp.216-217.

[56] Ibid. (Mahoney et al,) pp. 8-9.

[57] Vipin Narang. "Nuclear Strategy in the Modern Era: Regional Powers and International Conflict." Princeton University Press (2014), pp.121-152.

regime type may not be a hurdle in selecting cases and choosing time frames on nuclear policies. Another categorization may be made on studies on nuclear energy policy. For example, historical cases affecting nuclear energy policy was divided into macro-, mid-range, and micro-level analysis of variables for policy formation and outcomes[58]. But in this paper, when comparing China, Japan, and South Korea, deciding accurate time frame unlike those of Sweden, the United Kingdom, and the United States would be difficult. East Asian countries each industrialized and developed nuclear technology at different time frame like previous Gerschenkron's argument with respect to different processes and outcomes from different timings. For example, the first commercial nuclear power plant operation in Japan, South Korea, and China began in the 1960s, 1970s, and 1990s respectively. Thus, analyzing these countries within a common time frame seem problematic, and arbitrarily dividing by period of important phenomenon or incidents rather than by certain time frames would be necessary.

The first phase will be an introduction of nuclear technology and institutions in each country. With diverse aspirations, each country began to express interests on nuclear technology and established relevant institutions for successful nuclear program. This period will be referred as 'early development stage' when various actors interact to develop nuclear program and finally succeeded in first commercial operation of nuclear power plant. The second phase would be the period of industrialization using nuclear energy sources. Since the first establishment of nuclear plant, countries relentlessly pursued nuclear program as a national strategy and reached the peak of nuclear power generation, which would refer to the 'period of acceleration', because countries in this period strived toward speeding up development for a national well-being. And the last phase is the period of stagnation, in which nuclear discourse is thoroughly discussed and seemingly institutional change was proposed especially after an exogenous shock. A period of critical junctures occurs in between each phases, in which nuclear energy is thoroughly discussed and consolidated in the end with an increasing return process. Actors in each historical sequence interact and then acknowledge benefits from nuclear institutions that they solidify

[58] Ibid (박수경 et al.), p. 223-225.

a particular option among energy choices.

However, such a division of historical sequence has a drawback that Chinese nuclear power never experienced a significant interruption that applies to the third phase. In other words, a skepticism on Chinese case is the existence of critical juncture periods in between the second and third phases. It is simultaneously doubtful if Chinese case fits for the third phase, but China faced minor interruptions in its nuclear path from various interactions among actors. And like other countries, China's nuclear path dependence has been stable despite different policy proposals. Therefore, scope of study will be limited by the early development stage, the period of acceleration, and the period of stagnation in conducting comparative analysis for three case studies.

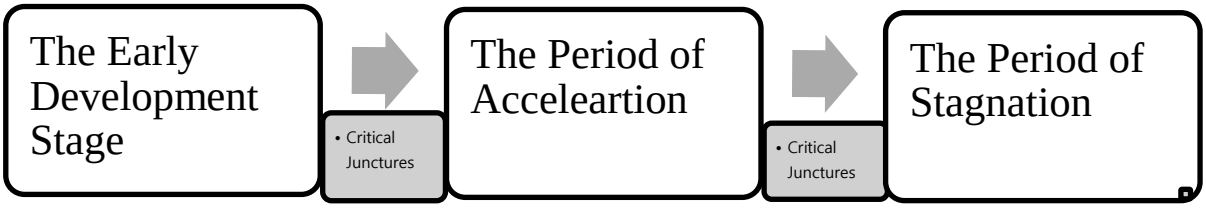

Figure 5. Development of Nuclear Path in Three Phases

2. Time Frame and Variables

When realizing the nuclear interests at the early development stage, countries were commonly affected by external influences. Western industrialized countries initially succeeded in developing nuclear program, and their influences led to establishment and development of nuclear institutions in East Asian countries. Along with external influences, countries were motivated by nuclear technology's dual-capability while researching and developing feasibility of nuclear energy sources. Without such motivations and national agenda to develop nuclear program, countries would have not been affected by external influences. Therefore, these two factors have crucially shaped the establishment of nuclear institutions at the early stage. And these nuclear institutions, at turn, ultimately lead to

institutional/policy changes in nuclear energy. And as an independent variable, nuclear institutions can be specified into several variables such as external environment, public acceptance, national energy mix, and government organization will be included in nuclear institutions that are shaped by the nation's motivation and that in turn generate policy changes on nuclear energy.

External environments largely affect decision-making process by shaping discourses and interacting with public domains. Whether it is a serious event such as war, major nuclear accident, or economic crisis or international cooperation such as NPT or climate change accord, a national agenda will likely to be affected. Such a discourse fundamentally arises due to risks of nuclear technology, and these risks are not only transnational effective but also directed toward publics. One of the biggest constraints in pursuing nuclear power would be risks. Public acceptance, therefore, is closely associated with external environments. Moreover, public acceptance on nuclear technology has fluctuated over time and commonly deteriorated in all these three countries affected the major incident. It is a crucial indicator not only to democratic regimes that decision-makings comprise of influences from various actors including civil societies, but it is also important to authoritarian regimes that make decisions among limited actors in a more top-down manner. Authoritarian regimes are exceptionally sensitive to internal threats and so centralizing control over critical structures and information is essential to those regimes to prevent threats[59]. In other words, gaining public support is essential to secure regime stability. Moreover, as Vipin previously argued, an authoritarian regime like China encourages under a special circumstance. In conclusion, public acceptance has been a core variable in nuclear policymaking process. And in terms of institutional context, energy mix and government organizations have been accordingly affected by the national agenda. These structures are very sensitive to institutional change driven by exogenous shock or interaction with other variables. With specified independent variables in nuclear institutions, nuclear path of Japan, South Korea, and China will be examined.

[59] Elizabeth Sauders. "The Domestic Politics of Nuclear Choics: A Review Essay." *International Security* Volume 44 Issue 2, Fall 2019, pp.168

IV. Analysis

1. Case Study

1-1. Phase 1

1-1.1. Japan

In East Asia, Japan is a forerunner in exploring civilian use of nuclear power technology by enacting the Atomic Energy Basic Law in 1955 to study nuclear technology for peaceful purposes and further established the Japan Atomic Energy Commission (AEC), Japanese Atomic Research Energy Institute (JAERI) to study nuclear matters, Atomic Fuel Corporation, and Nuclear Safety Commission to promote and oversee safe use of nuclear[60]. Although Japan was devasted by nuclear materials at the war, a decade later, it could successfully implement democratic and institutional approach to use nuclear materials. And two years after establishment of the Atomic Energy Basic Law, the Japanese authority further implemented regulation law to manage nuclear materials by the international rules and standards set by the IAEA or NPT. To further ensure public safety, they implemented prevention law along with regulation law, which is to prevent radiation hazards from publics[61]. In tandem with international efforts, Japanese authority formed the 'nuclear village' consisting nuclear industry, bureaucracy, politicians, business, media, and academia to promote 'safe, cheap, and reliable' nuclear energy[62]. Thus, along with external influences, Japan domestically formed solidarity to promote nuclear energy while ensuring public safety. Moreover, Japan succeeded in developing domestic Japanese Research Reactor-3 (JRR-3) in 1957 that served as a stepping-stone to commercialization of nuclear energy[63]. Prior to success of

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[60] Japan Atomic Energy Commission on the Atomic Basic Law.

[61] Yoshio Baba. "The Problems Facing Nuclear Power in Japan Emphasising Law and Regulations." Nuclear Law Bulletin 69 (2002), pp. 16-19.

[62] Jeff Kingston. "Japan's Nuclear Village." The Asia-Pacific Journal, Vol. 10:37 No. 1 (2012).

[63] Kiyonobu Yamashita. "History of nuclear technology development in Japan." AIP Conference Proceedings 1659 (2015), pp.1-3.

JRR-3, prior models of JRR-1 and JRR-2 were all constructed from the U.S. technology. Therefore, Japan's nuclear power was institutionalized by the law and regulation and further realized by successful construction of research reactors. Japan's initial development of nuclear technology was heavily influenced by the United States both in terms of technology development and public perceptions. Along with research development, Japanese authority expressed political gestures to soothe concerns and promote nuclear power throughout the 1950s and 1960s. One of the notable campaigns was Eisaku Sato's Three Non-Nuclear Principals to promote the peaceful use of nuclear technology. And during this period, Japan mainly depended on domestically produced coal while it gradually increased import of fossil fuel sources like crude oil in the 1960s. As a result, Japan was depending on oil more than 70% of its primary energy consumption by the early 1970s[64]. At the early development stage, nuclear energy was barely used to generate powers for many reasons. The foremost reason is inefficiency and lack of availability. The first commercial reactor began operation in 1966, and only a few reactors were added by 1970. At the same time, energy demand was not high as they could meet demands with domestic produced coals and fossil fuel imports.

Despite institutional solidity, advanced research facilities, political gesture toward peaceful use of nuclear technology, Japan's military aspirations toward nuclear program grew bigger as they began to introduce and use nuclear technology. Or perhaps, its motivation to build weapon program began even before institutional establishment during the war. One of evidence can be found in Japan's first commercial nuclear reactor. For example, Japan imported its first commercial nuclear reactor Tokai-1 from the United Kingdom in 1966, which was Magnox (gas-cooled) type reactor. As aforementioned in the earlier paper, Magnox type reactor was designed to generate and reprocess plutonium for British nuclear weapon program during the Second World War. And although there was cheaper options like light water reactors (LWR), boiling water reactors (BWRs) or pressurized water

[64] Katsunori Muraoka. "Energy Situations in Japan before and after the Fukushima accident." EPJ Web Conferences vol. 98 (2015), p.10

reactors (PWRs) during this period, importing more expensive and less efficient nuclear reactor still remains questionable decision. While its gas-cooled reactor type choice over light- or pressurized-water reactor type makes dubious on nuclear motivations, comparison to cases from the United Kingdom and French case over the choice of nuclear reactor for commercialization subtlety support political- and military-motivations behind pursuit of nuclear energy. Nevertheless, a decision related to importing Magnox reactor from the United Kingdom may provide valid explanation that it was inevitable since the United States limited exports of nuclear technology including the US-designed light water reactors[65]. Without helps from others, domestic nuclear development was impossible in Japan while its most reliable partner could not afford help. Then, the second option would be to import from the closet ally which may be the United Kingdom. And this would make more sense when the United States relaxed regulations on exports of nuclear technology, Japan cooperated with the U.S. to build light water reactors since late 1960s. And by the end of 1970s, Japan successfully received knowledge and technology from the U.S. vendors which enabled them to produce domestic nuclear reactors. On the other hand, further evidence reveals that Japan had pursued nuclear weapon program to some extent. For instance, at this similar period, Japan suggested a joint development of nuclear weapon program to West Germany in 1969[66]. Although this joint development was never realized with West Germany's decline, Japan sought for a path to regain its national glory like other western countries after defeated at the war. Moreover, the Prime Minister Sato directly ordered to study the feasibility of nuclear armament from various political, diplomatic, and technical perspectives, and the National Security Research Association accompanying officials from Defense Agency and Foreign Ministry published "Japan's National Security" detailing the possibility of converting nuclear reactors into nuclear weapon manufacturing facilities, of constructing plutonium reprocessing plants, and of isolated by neighbor countries[67]. Thus, the report organized by a private group within the government did not suggest a mere

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[65] Kennedy Maize. "A Short History of Nuclear Power in Japan." POWER. Mar. 2011.

[66] Robert Farley. "Imagine This: Japan Builds Nuclear Weapons." *The National Interest.* May 2019.

[67] Muto Ichiyo. "The Buildup of nuclear armament capability and the postwar statehood of Japan: Fukushima and the

abstract idea, but it outlined detailed plans for military options on nuclear technology and ultimately suggested that Japan is able to go nuclear at any time if it desires to do so. And a plan to develop weapon program became more difficult later as Japan signed the Non-Proliferation Treaty in 1970. Throughout the 1950s and 60s, earlier motivation in pursuing nuclear power and selecting nuclear reactor type seemed to be accord with nuclear power's dual purpose oriented toward strengthening security and military power.

As a result, public acceptance at this period deteriorated. At first place, institutional development was uneasy process with strong opposition from public, where one-third of population signed a petition to ban hydrogen bomb when Japan decided to allocate budget to establish atomic institutions and construct reactors was proposed[68]. Another public survey conducted by the U.S. Department of States in 1956 from Japanese public indicated that 39% of respondents believed nuclear technology would be more harm than beneficial in the long run[69]. Although there was a constant effort by Japanese authority to relax public oppositions, it was difficult for Japanese public to overcome traumatic experience from nuclear weapon in a short period. At this period, therefore, the Japanese government and industry launched numerous public campaigns to promote safety and modernity of nuclear technology by mingling with films and popular cultures. One example is that screening of a documentary film Blessing of Atomic Energy to Japanese public with the help of the U.S. Information Service Tokyo [70]. And another domestic effort is a production of Tetsuwan Atomu, a comic book where heroic main character using nuclear power peacefully to protect the world[71]. On the other hand, oppositions of nuclear program were also active in public campaign and assimilated in popular cultures.

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genealogy of nuclear bombs and power plants." Inter-Asia Cultural Studies Vol. 14:2 (2013), pp.194-195.

[68] John Swenson-Wright. Unequal Allies: United States Security and Alliance Policy Toward Japan, 1945-1960, Stanford University Press (2005), p. 181

[69] Craig Nelson. "The Energy of a Bright Tomorrow: The Rise of Nuclear Power in Japan." Origins Vol. 4, Issue 9 (2011).

[70] Yuka Tsuchiya "The Atoms for Peace USIS Films: Spreading the Gospel of the "Blessing" of Atomic Energy in the Early Cold War Era" International Journal of Korean History Vol. 19:2 (2014), pp. 107-135.

[71] Ibid (Nelson).

One notable example is a film Godzilla produced in 1954, which was to criticize the U.S. hydrogen bomb testing in the South Pacific region and the following Lucky Dragon Incident[72]. In 1954, by the U.S. hydrogen bomb testing in the Pacific region, 23 innocent sailors at a Japanese fishing boat Lucky Dragon #5 were affected by fallout of nuclear testing and suffered from radiation exposure. And in the film Godzilla, the monstrous creature was mutated and arose from the U.S. hydrogen bomb testing in the Pacific region and then destroy people and cities. Moreover, some critics argued that Godzilla's scaly skin is a reference to victims of nuclear bombing in Hiroshima and Nagasaki whose skins were flaked and burnt by nuclear explosion. Thus, a film clearly signaled a warning sign to risk and anti-nuclear rhetoric by referring to victims to nuclear bombing in Japan. And as opposed to active pro-nuclear campaigns from the Japanese government, the U.S. government, and nuclear industry, there were active anti-nuclear movements from public and private level at this early stage of nuclear development.

And finally in 1966, Japan's first commercial nuclear power plant Tokai-1, a gas-cooled reactor type, was imported from the United Kingdom, which could generate power up to 160MWe[73]. In prior to a commercial nuclear operation, Japan mainly depended on domestically produced coal while it gradually increased import of fossil fuel sources like crude oil in the 1960s. As a result, Japan was depending on oil more than 70% of its primary energy consumption by the early 1970s[74]. At the early development stage, nuclear energy was barely used to generate powers for many reasons. The foremost reason is inefficiency and lack of availability. The first commercial reactor began operation in 1966, and only a few reactors were added by 1970. At the same time, energy demand was not high as they could meet demands with domestic produced coals and fossil fuel imports, but with an increasing energy demands and other external influences, Japan enter the second phase of the period of acceleration in nuclear power program. In sum, Japan's institutional foundation was partly shaped by external

[72] Ibid (Nelson).

[73] World Nuclear Association. "Nuclear Power in Japan." September 2021.

[74] Ibid (Muraoka), pp.10-11.

influences from the United States, which actively encouraged peaceful use of atoms both in- and outside of Japanese soil. The United States pushed Japan to comply with international rules and regulations while it worked to improve public acceptance of nuclear technology on the Japanese soil. But contradictory to the United States' active influences on peaceful use of atoms, Japan's motivation seems to be driven by atomic weapon program from its reactor type choice and anecdotes from the inside of the government. But this shaped a favorable condition and institutional setting to develop nuclear program in earnest and later led to institutional changes to elevate nuclear energy sources.

1-1-2. South Korea

When western countries initially expressed interests in nuclear technology, Korea was annexed by imperialist forces. And when industrialized countries began to construct nuclear program, Korea just declared independence but soon went through a civil war. Such a complex nation-building processes delayed a commitment to development of advanced technology as a national agenda. South Korea naturally became a second mover in development of nuclear technology while internal situations hampered earlier development of advanced technology. For example, Japan began its first commercial operation in 1966 whereas South Korea began its first commercial nuclear reactor in 1978. On the other hand, they established institutional setting around the same time, where Japan introduced the Atomic Energy Basic Law in 1955 whereas South Korea introduced the Atomic Energy Law in 1959. Thus, it can be inferred that South Korea's early development stage was a more winding path. South Korea's interests toward nuclear energy began around the late 1950s by attaining the IAEA membership in 1957 and by establishing the Atomic Energy Law in 1959[75]. Institutionally, the Korean Atomic Energy Research Institute (KAERI) was established to study peaceful use of atoms, and Atomic Energy section was installed under the Bureau of Technical Education, the Ministry of Education to manage administration and to foster nuclear program and manpower[76]. President Syngman Rhee, who

[75] World Nuclear Association. Nuclear Power in South Korea. September 2021.

[76] 양맹호 et al. "광복 70년과 원자력." 한국원자력연구원. 원자력정책 Brief Report 2015-6, 2015, pp.7.

acknowledged the importance of nuclear energy from studying abroad experiences in the U.S., directly ordered state-funded studying abroad program to foster nuclear energy professionals, and the Ministry sent 237 students to the United Kingdom and the United States[77]. Like a Japanese case, South Korea was also heavily influenced the United States. In 1956, "Agreement for Cooperation between the Government of the Republic of Korea and the Government of the United States of America concerning Civil Use of Atomic Energy" was initially signed, which provided a legal basis and institutional platform to study and develop nuclear technology in South Korea. And a pledge of receiving assistance from the U.S. nuclear industry was enough to engage in active nuclear energy discourse.

For thorough research and development, South Korean government purchased 100kw TRIGA Mark-II research reactor in 1959 with funding from the U.S. and began its operation in 1962[78]. Although the construction for TRIGA Mark-II reactor was expected to be completed within four-to-five-month, domestic chaos such as April Revolution and May 16 Coup. And within the agency, numerous problems arose during construction including budget and manpower shortage, accident on internal cooling tower, and inter-agency scandals. Despite such drawbacks, introduction of research reactor paved a way to nuclear power generation by creating nuclear power task force and then introduced nuclear power generation blueprint to construct nuclear power plant by the early 1970s[79]. Furthermore, Korean Atomic Energy Research Institute (KAERI) served as a center for basic and applied science by studying radiation and radio-isotope and affected various sectors such as radio-therapeutics and radio-agricultural studies for seed improvement[80]. Thus, nuclear industry at the early stage of South Korea played an essential yet extensive role in developing medical and agricultural sector.

Like Japan's reactor type choice, military ambition in developing nuclear technology in early stage is also revealed by South Korean government's anecdote in building the Korean Atomic Energy

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77 오동룡. "李承晩 대통령, 초대 원자력과장 불러 "원자폭탄 만들 수 있나?"" 월간조선 Magazine 2016:02, 2016.

78 Ibid (양맹호 et al.), pp. 9.

79 오동룡."비망록을 통해 본 대한민국 원자력 창업 스토리 <3> 원자력, 통일벼를 낳다!" 월간조선 Magazine 2016:04, 2016.

80 임경순. "과학기술 – 원자력진흥." 행정안전부 국가기록원. 2006.

Research Institute (KAERI). In selecting location for this research institute, the Ministry of Defense initially decided to construct complex in Bakdal-ri, the Southern part of Gyeonngi province, and the President Rhee further recommended research complex to be located inside a naval base for security reasons[81]. However, the United States strongly opposed to this location and insisted research complex to be located near academic institutions where people can easily interact. As a result, the Ministry of Defense finalized the location of research complex to be nearby the Seoul National University. In light of South Korea's beginning of nuclear development, its introduction of pressurized water reactor over gas-graphite reactor type seems far from military-motivated nuclear reactor choice. On the other hand, gas-graphite reactor type became almost extinct in the 1970s due to inefficiency in power generation and global efforts to promote peaceful use of atoms. Furthermore, South Korea was banned to enrich and reprocess nuclear fuel to generate plutonium by the ROK-US Atomic Energy Agreement. Nevertheless, it does not mean that South Korea did not have ambitions over nuclear weapon programs nor related to its national identity. In 1969, the Nixon Doctrine that distorts the U.S. commitment in the international arena, and the Nixon administration notified South Korea that the US Armed Forces would withdraw by 1975. Since then, President Park Chung-hee at that time strongly insisted the need for self-defense with development of atomic bombs. Although the withdrawal of U.S. forces from the Korean Peninsula was never realized, South Korea was on the verge of developing the Plutonium bomb with detailed plans in technological and economic feasibility, expected budget, and estimated time for development completion. Then, the government carried out masterplan to develop weapon program by reaching agreements with the Saint-Goblin Nuclear (SGN) in France to construct nuclear fuel reprocessing site and the Canadian CANDU heavy-water reactor model that is viable to reprocess nuclear fuel to extract high purity Plutonium for weapon program. For example, Kori-1 in progress of construction at that time was a light-water reactor design which is not susceptible to extract high purity Plutonium from fuel reprocessing for development of weapon program. However, South Korea's

[81] Ibid (오동룡).

attempt to obtain nuclear weapon program was never realized with the U.S. reversal of its original plan to withdraw troops and the U.S. pressures to concede weapon development plan. In the end, South Korea breached nuclear fuel reprocessing site contract with French SGN and ratified the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). On the other hand, these series of incidents became achievement of Korean nuclear energy industry as imported Canadian CANDU heavy-water reactor was used in Wolsong-1 nuclear power plant serving as a kick-starter to Korea's nuclear power generation.

Organizational development related to nuclear power at early stage reveals South Korean authority's perception on nuclear power generation. It initially began from atomic energy section under the Ministry of Education in 1956 to study and research nuclear energy, and three years later, a section changed to atomic energy center to emphasize independence in nuclear technology research. And in the 1960s, the organization's responsibilities grew in preparation of nuclear power plant construction, where it jointly assessed construction site for nuclear power plant and analyzed economic and technical feasibility on nuclear power generation. Then, in 1967, President Park Chung-hee directly ordered to elevate nuclear power center into Atomic Energy agency as an external agency relevant to the Ministry of Science and Technology[82]. As the organization was promoted, it tried to take a driver's seat in nuclear power plant construction by finalizing site of the first commercial nuclear power plant in Kori region in Gyeongsanganm-do and by starting negotiations with foreign nuclear industries. However, a downside of the organization rapidly occurred when the Korean Electric Power Corporation (KEPCO) installed nuclear power generation sector and claimed for construction and management of nuclear power generation. For organizational dispute settlement, the committee was organized by the prime minister and decided that the KEPCO should be responsible for construction and management of nuclear power plants whereas nuclear power agency should focus on R&D, safety regulation, and manpower training. After losing power to be involved in nuclear power plant projects, the agency was

[82] Ibid (오동룡).

later abolished and merged to the Ministry of Science and Technology. Through such organizational development and struggle at the early development stage of nuclear technology, South Korean government's emphasis on nuclear power generation over time was pronounced.

With a long process of nuclear discourse and planning, South Korea finally achieved its first commercial operation by Kori-1 reactor in 1978. It was a pressurized water reactor (PWR) with 576 MWe type based on turnkey contract with the U.S. firm Westinghouse[83]. Unlike others' first reactor type choice, South Korea chose PWR reactor type. And it was turnkey contract, because South Korea at that time lacked nuclear knowledge and technology to completely design and construct nuclear reactor. But it is different from Japan's import of nuclear reactor, as the construction was carried at the Korean domestic soil. Perhaps, South Korea had a great passion adapt knowledge and technology and then later accomplish nuclear technology independence. In fact, Korean ministry of energy proposed 'nuclear power generation technology independence plan' by fostering manpower and localizing nuclear related equipment[84]. And the next nuclear reactor was non-turnkey contract based on the training and accumulated knowledge from the first reactor construction. Because South Korean government emphasized self-reliance of technology, the capability of domestic constructed nuclear reactor was essential for technology independence. Focusing on technology development and knowledge accumulation, South Korea could accelerate the development. On the other hand, a drawback from such a dazzling achievement is that public opinion was undermined in the early development stage. There had been public distrusts on institutions and negative perceptions on nuclear program, but the authoritarian regime at that period stubbornly drove nuclear development under a centrally planned economy.

At this early stage, South Korea had enough domestic produced coals and firewood and charcoal to meet energy demands, which the nation's dependency on foreign energy sources were only

[83] Ibid (World Nuclear Association). History of the nuclear sector of South Korea

[84] Ibid (양맹호 et al.), pp. 13.

about 15%[85]. But as energy demand rapidly increased during industrialization process, South Korea shifted to oil-centric policy to increase efficiency and promote sustainable development which later led to depend more on than half of energy source through oil by the early 1970s[86]. And just like other countries, South Korean industry was severely hit by oil crisis but unlike Japan or others, South Korea was not prepared to diversify energy sources and depart from heavily oil dependency. Then, by the late 1970s, South Korea was depending about 80% of the nation's power generation through oil and was hit even harder by the second oil crisis. And this time, South Korea decided to improve energy structure, and 20 years of research and institutional settings on atomic energy began to shine at a right timing. Therefore, external environments have affected countries to diversify energy structures to promote resilience and to achieve energy independence for reducing foreign dependency. At the Fourth Five-Year Plan for the Development of Power Resources in 1976, plans to depart from heavy oil dependency was announced, and one of solutions was to construct large-scale nuclear power plants which six new additional nuclear power plants were planned for construction[87]. The energy structure began to dramatically shift from oil-dependent economy to nuclear energy-emphasizing economy. And the newly created Department of Power Resources is retaining its legacy from what it becomes the Ministry of Trade, Industry, and Energy nowadays[88]. Thus, South Korea's early nuclear path was interrupted by domestic crisis and inner conflicts within institutions. But military ambitions and desire for energy independence strongly carried out development of nuclear program under the authoritarian rule. And the United States' involvement was crucial in shaping institutions at the early stage that have contributed to incremental development of institutions. For Japan and South Korea that have commercialized nuclear power generation without nuclear weapon program, the reactor type choice has significance in shaping the country's path. And especially, the meaning of the first reactor amplifies the significance of

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[85] 부경진, et al. "2012 경제발전경험모듈화사업: 에너지정책." 한국자원경제학회. 기획재정부. 2013, pp. 39

[86] Ibid (부경진 et al.), pp. 42.

[87] Ibid (부경진 et al.), pp. 59.

[88] 황은주. "석유는 돈이고, 무기다. 석유파동." 기록으로 만나는 대한민국. 행정안전부 국가기록원.

the nation's plan. Furthermore, achieving energy independence by domestic efforts mean much more than improving security or efficiency to such resource-scarce countries.

1-1-3. China

Compared to previous two cases from East Asia, China is a special case that is the one of few countries to develop and possess nuclear weapon program while it is the latest country to commercialize nuclear power among three East Asian countries. Thus, Chinese case would have exceptionally long development stage as its first commercial operation began in 1991 whereas Japan and South Korea began in 1966 and 1978 respectively. On the other hand, it does not mean that China's interests on nuclear and institutional setting emerged in later period, but it rather began in the 1950s like other countries. China was also heavily affected by external influences at the early stage. Although China did not directly engage in the Second World War, it quickly realized the necessity of possessing atomic bomb to confront imperialist adversaries. A series of events in the 1950s such as the Korean War or the Taiwan Strait crisis provoked China to develop weapon program from threats of atomic bomb. China actively cooperated with the Soviet Union in pursuit of nuclear weapon program, which the Soviet Union assisted in technology transfer while receiving support for Moscow's disarmament proposals. Thus, bilateral cooperation began from signing the agreement to foster peaceful uses of atoms including nuclear physics research and economic development[89]. Thus, the Soviet Union was initially reluctant to China's request on assistance in nuclear missile program, but the Communist Party of the Soviet Union Central Committee later allowed to send specialists in missile and nuclear technology to Chinese universities in 1957[90]. On the other hand, such a decision may have not been the Central Committee's decision but instead Khrushchev's personal decision to win Mao Zedong's political support. By 1958 and 1959, the Soviet Union and China made additional agreements including the New Defense

[89] Shen Zhihua and Yafeng Xia. "Between Aid and Restriction: The Soviet Union's Changing Policies on China's Nuclear Weapons Program, 1954-1960." The Institute for Far Eastern Studies. Asian Perspective, 36(1), 2012, pp. 97-98.

[90] Ibid (Zhihua, et al.), pp. 100.

Technology Agreement and Sino-Soviet cooperation on nuclear weapon program[91]. Nonetheless, this bilateral relationship ended very soon when Khrushchev decided to completely cut off assistances on Chinese nuclear program from a series of military incidents and displeasure over Chinese policies. Its initial motivation, therefore, is more straight-forward, undoubtedly driven by military ambitions. They initially planned a roadmap to develop weapon program within eight years but ultimately took about ten years while fourteen out of sixteen planned projects under Sino-Soviet nuclear projects were not completed or delayed when the Soviet Union. But Chinese authority was capable in resuming projects and successfully completing nuclear weapon programs with proper infrastructures, systems, and manpower.

In institutional perspective, the Second Ministry of Machine Building to develop nuclear technology, and more than 1,000 experts from the Soviet Union also worked at the ministry with Chinese workers[92]. With knowledge and work experience from Soviet experts, the ministry rapidly became sophisticated and modernized to function excellently and efficiently. And the Second Five-Year Plan in 1957 ensured China' commitment in developing weapon programs with plans to foster necessary technology and manpower. Other than the government ministry, a state-owned enterprise (SOE) plays a vital role in the Chinese context. The China National Nuclear Corporation (CNNC) was established as a SOE to oversee nuclear programs, which was mainly responsible for developing weapon programs to meet the state council's main interest. The Chinese regime further established the Beijing Nuclear Weapons Research Institute and began construction of the Baotou Nuclear Fuel Component Plant and the Lanzhou Gaseous Diffusion Plant in 1958 to produce enriched uranium for development of weapon program[93]. With such institutional efforts, China finally became the fifth country to possess nuclear

[91] Ibid (Zhihua, et al.), pp. 102-103.

[92] Ibid (Zhihua, et al.), pp. 104.

[93] William Burr and Jeffrey Richelson. "Whether to "Strangle the Baby in the Cradle": The United States and the Chinese Nuclear Program, 1960-64." *International Security*, Vol. 25:3 (2000), pp.58

explosive device by succeeding the nuclear test in 1964[94]. Then two years later, China succeeded in launching its first nuclear missile in 1966 and further launched its first nuclear submarine in 1970 in which possibly acknowledged military and civilian dual use for the first time[95]. Despite the early advancement of nuclear technology, domestic turmoil in the 1970s such as the Cultural Revolution ceased the development of high-tech state programs and delayed further commercial operation of nuclear reactor. China's nuclear decision-making process is very complexed as decision-making process is made by a few top authorities, and more nuclear-related information was not disclosed at the early development stage. Like other authoritarian rules, civil participation was strictly banned form the early-stage decision-making processes, in which the Chinese authority overturned nuclear objections raised in petitions by arresting signers and protestors[96]. While domestic turmoil and nuclear discourse hampered earlier commercialization of nuclear power generation, the authority approved the first construction of commercial nuclear reactor in 1981 and then its efforts finally bloomed in 1991 with its first commercial nuclear power plant, Qinshan 300 MW PWR[97]. For the success of commercial nuclear power plant, China launched two essential programs, the 863 Program and the 973 Program[98]. The former was also known as the National High Technology R&D Program, which was an institutional digestion of turning military knowledge into civilian uses. And knowledge of nuclear technology was a central piece in this initiative. China, with a successful development in atomic bomb and nuclear submarine, had a plenty of knowledge on nuclear technology and converted such knowledge for economic modernization by generating more efficient power. And the latter was a funding program for basic scientific research that boosted research projects for civilian use of nuclear technology.

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[94] Mark Hibbs. The Future of Nuclear Power in China. The Carnegie Endowment for International Peace Publications, 2018, pp. 58.

[95] Yun Zhou et al. "Is China ready for its nuclear expansion?" *Energy Policy* 39 (2011), pp.771.

[96] Ibid (Hibbs), pp.92

[97] International Atomic Energy Agency. "People's Republic of China" on Country Nuclear Power Profiles. IAEA Publication, pp.220.

[98] Ibid (Hibbs), pp. 83

The Chinese case is different from Japanese or Korean cases as it overtly developed nuclear weapon program and then pursued civilian use of its existing nuclear program. And certainly, China's initial motivation was to empower military capability to protect itself from outside forces. Such a motivation was common in other cases, which decision-makers consider nuclear power's military and civil dual use. Thus, the significance of introducing the nuclear program stemmed from military ambitions and self-protection amid chaotic internal situations. Nuclear power's symbolic pillar as a weapon of massive destruction and as a future energy source to accelerate economic growth seem very attractive option to decision-makers at that time. In East Asia, though three countries had different timelines for commercialization of nuclear power, they openly expressed interests in nuclear technology in the postwar period and enacted a law and institutionalized research of nuclear technology in the 1950s[99]. On this basis, these countries have achieved great success in economic development. On the other hand, such backdrops in the origin of nuclear technology have provoked inevitable politicization and dichotomy in the nuclear discourse. And China was heavily influenced by the Soviet Union at the early stage of development, where it received assistance in technological development and shaping institutions. This made Chinese case more special as it succeeded in developing nuclear weapon program as different to others whose motivations were less revealed. And Chinese case to some extent was similar to that of Korea, in which internal crisis delayed development of nuclear programs while authoritarian regime suppressed civil participation on nuclear institutions.

1-2. Phase 2

1-2-1. Japan

The second phase of acceleration of nuclear power generation began from the mid-1970s and lasted until the 2000s in Japan. This was not special case in Japan but rather it was a common phenomenon among developed countries, which they highlighted nuclear energy as future energy

[99] Though rumors that Japan and China carried development of nuclear weapon during WWII

source and accelerated since initial development of nuclear program. Though nuclear accidents such as the 1979 TMI accident or the 1986 Chernobyl accident hampered more rapid development, the aftershock of nuclear accidents did not last long enough to countries to phase-out and later peaked nuclear power generation in the late 1990s. Japan steadily increased shares of nuclear power generation, reaching the peak in 2007 with generating 320 TWh from nuclear energy[100]. Although Japan experienced a slight decline in nuclear power generation in the late 2000s due to decommissioning older reactors and decline in overall energy demand, Japan's commitment to nuclear energy was indeed steady before the Fukushima accident. During this period, Japan constructed and operated more than 60 nuclear reactors and achieved the world's first thermal reactor with mixed oxide core and the world's first third generation nuclear reactor. And from recipient of nuclear technology and knowledge at the early development stage, Japan has become one of leading nuclear technology nation in the 2000s by providing frameworks for joint research and development on nuclear energy technology under the U.S.-Japan Joint Nuclear Energy Action Plan.

Externally, the 1973 Oil shock triggered Japan to revisit its energy security to diversify energy sources by accelerating to construct nuclear power plants and gradually increase shares of nuclear energy source. And with the wave of industrialization, energy demands in Japan exploded throughout the 1980s and 90s. There have been several institutional changes since the development of nuclear-related institutions in Japan. For example, after the oil shock, the Agency for National Resources and Energy was created to seek diversification of energy sources including promotion of nuclear energy sources, which still play a significant part in Japan's energy resource management nowadays. And in 1967, the Power Reactor Nuclear Fuel Development Corporation (PNC) which was renamed from the Atomic Fuel Corporation from 1956 to study advanced reactor designs and to manage various reactor development projects[101]. And external influences to pursue peaceful use of atoms drove Japan to ratify

[100] The Federation of Electric Power Companies of Japan. "Why is Nuclear Energy Necessary in Japan?"

[101] World Nuclear Association. "Japan's Nuclear Fuel Cycle." January 2021.

Non-Proliferation Treaty (NPT) in 1976[102]. However, such organizational development and international cooperation became in vain with nuclear accident and followed by scandals.

Monju nuclear reactor was a sodium-cooled, mixed oxide fuel fast reactor that began operation in 1994. The Japanese authority proposed a development of fast breed reactors (FBR) as a national strategy and believed Monju plant as a pivot to a future of nuclear technology with data and knowledge gained from operations and testing from this FBR. However, a year after the operation, in 1995, hundreds of kilograms of sodium was leaked from the Monju reactor and caused fire when this leaked liquid sodium combusts with oxygen and moisture in the air. Fortunately, the accident did not cause damage to human life or radiation leak, but the main problem arose when the PNC, in responsible of the Monju power plant, decided to cover-up the accident by editing videos and reporting false information. Such a scandal immediately faced huge backfire from publics and could regain confidence in its fast reactor nuclear program. Such response from the PNC immediately caused public outrage. Sodium is not like radioactive materials that cause serious damage to public health; however, the PNC's response amplified public concerns by lack of explanations and manipulation of reports and footages of the scene of accident[103]. In the end, the PNC was bombarded not just by sodium leak accident not adhering to safety regulation but further by lack of effective communication and scandals that ultimately resulted in loss in confidence of the institution and later replaced by the Japan Nuclear Cycle Development Institute (JNC). Although the government intended to restart the Monju plant in 2000, relentless public protests and technical difficulty delayed the restart and finally began re-operation in 2010. Despite the restart, Fukushima accident further deteriorated public perception on the Monju plant, and the plant suffered from a series of minor incidents that ultimately led to a decision to decommission the Monju plant in 2016. Thus, the Monju nuclear power plant symbolizes nuclear power in Japan, which it had an ambitious plan to become a world's leader in advanced nuclear technology in the 1980s

[102] Steven Aftergood and Jonathan Garbose. "Nuclear Weapon program." Federation of American Scientists. 2012.

[103] Power Technology. "Scrapping Monju: the curtain falls on Japan's experimental fast breeder reactor." Jan 2017.

and 90s but later declined in power and trust in nuclear program. Despite such institutional drawbacks, the JNC basically played a same role including development of spent fuel management, mixed oxide fuel, and fast breeder reactor (FBR) which is equivalent to the project at the Monju nuclear power plant. And in spite of scandals and institutional restructuring, the government's trust was as firm as allocating $3.3 billion to the JNC in 1999, which is about the half of the Japanese government's nuclear energy research and development budget[104]. Therefore, the government response to institutional failure was superficially restructuring, but, transformation from the PNC to the JNC was a mere renaming as its responsibility has not changed. Other than the Monju incident, accidents in the Mihama steam and radioactivity exposures to workers at the Tokaimura facility leading death of two workers later for radiation poisoning[105] occurred in the 1990s that further exacerbated public acceptance on nuclear technology. And from a series of nuclear accidents, Japanese authority created the Nuclear and Industrial Safety Agency (NISA) under the Ministry of Economics, Trade, and Industry (METI), but it was not enough to prevent rapidly deteriorating public acceptance and further nuclear accidents.

Triggered by such accidents and scandals, anti-nuclear movement also became more active and organized as numerous nuclear reactors were constructed and began to affect people's lives more directly. For instance, Japan had to inevitably build its new light water reactors by coastlines in which reactors can easily supply water to generate powers, but these reactors negatively affected local fishing industry as wastes and heated water dumped from nuclear reactors caused temperature changes of water and killed large number of fishes[106]. Such a problem generated environmental concerns to wide range of population and led to creation of the most prominent anti-nuclear protest group called the Citizen's Center for Nuclear Information (CNIC) in 1973 that led numerous local movements, shared information,

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[104] Sato, Y.. "Japan Atomic Energy Research Institute in the 21st century." Japan Atomic Energy Research Institute, 2001, pp. 118.

[105] Ibid (Maize).

[106] Ibid (Nelson).

and circulate petitions[107]. And since the 1980s, anti-nuclear protests exploded both at local-level and urban areas with emergence of anti-nuclear groups such as the CNIC, No Nukes Plaza, Green Action Japan, etc. On the other hand, the Japanese government attempted to promote public acceptance through communication; for example, the Cabinet Office with NHK began to conduct opinion polls on nuclear power since the 1980s[108]. As opposed to the previous literature on a dramatic event exacerbating public perception, Japan's public confidence on nuclear power was relatively stable even after the Chernobyl accident. So, from the 1980s to 2010, Japanese public's negative reaction against nuclear power was generally about 20~30%, according to surveys conducted by seven different media, agency, and institution[109]. At this period, Japanese nuclear industry grasped huge financial success through acceleration of nuclear power plant constructions, but public distrust on nuclear institutions simultaneously grew. Indeed, public confidence and trust toward the institution similarly plunged with lack of transparency in crisis management. To alleviate such concerns, the government attempted to promote safety and communication to the publics. Despite a series of failures on nuclear energy governance in the 1990s, not much of lessons were learned and applied to handle bigger crisis in Fukushima in later period. Japanese nuclear path simultaneously was more solidified with continuation of institutions and actors who drove acceleration of nuclear energy construction and power generation.

1-2-2. South Korea

Since the first operation of Kori-1 nuclear reactor in 1978, South Korea accelerated nuclear development by starting construction of 26 nuclear power plants over these three decades, and South Korean nuclear industry grasped huge success with numerous construction projects and exporting advanced nuclear technology abroad. In prior to flourishment, in the early 1980s, the South Korean

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[107] Ibid (Nelson).

[108] Atsuko Kitada. "Public opinion changes after the Fukushima Daiichi Nuclear Power Plant accident to nuclear power generation as seen in continuous polls over the past 30 years." Journal of Nuclear Science and Technology, 53:11, pp. 1686-1700. May 4, 2016.

[109] Ibid (Kitada). See Figure 1. he long-term trends of negative opinions to NPG before the Fukushima Accident, pp.1687-1689.

government announced the Fifth Five-Year Plan for Development of Power Resources that emphasized plans to construct five additional nuclear power plants and building four nuclear power generation villages in Kori, Wolsong, Uljin, and Youngkwang. Moreover, introduction of the Ten-Year Plan for Nuclear Power Technology Independence in 1985 reveals South Korea's ambitious plan to achieve energy independence through nuclear technology. This policy proposal aimed to achieve nuclear technology independence rate by 95%, develop 1,000MW nuclear power plant with domestic productions, and achieve independence in nuclear fuel reprocessing technology[110]. Furthermore, the Comprehensive Nuclear Energy Promotion Plan was introduced in 1997, which was another five-year planning to oversee nuclear energy policies and to promote safety regulation standards. In the first plan, Nuclear Energy Safety Committee was established, the Periodic Safety Review (PSR) on nuclear reactors was introduced, and ensured transparency in selection process for nuclear power plant sites[111]. And later plans in the 2000s and 2010s focused more on technical development in fuel reprocessing and waste management, promoting security against disasters or terrors, and fostering international cooperation. All these approaches were taken to promote safety and ensure transparency in nuclear power plants and nuclear energy policies.

While South Korean nuclear industry was having a prime time in nuclear power generation and construction for plants during the acceleration period, but public acceptance on nuclear technology exacerbated with a series of anti-nuclear protests. The Chernobyl nuclear accident in 1988 increased awareness in nuclear safety issues, and more critically, cover-up of heavy water leak from Wolsong-1 nuclear power plant was disclosed, which led to anti-nuclear protests at a local-level from residents nearby nuclear power plants. And organizationally, Korean Atomic Energy Research Institute (KAERI) and Korean Nuclear Fuel Development Corporation were merged into Korean Energy Research

[110] Ibid (부경진 et al.), pp. 60.

[111] 문만용. "과학기술 – 원자력진흥종합계획." 행정안전부 국가기록원. 2016.

Institute[112], which was an effort to minimize the image of nuclear and to give more general image like energy research. The government believed capacity-building and active communication as vital areas to ensure public acceptance and established relevant institutions. In 1989, the law for assisting nuclear reactor neighboring area, and a year later, an open guidance for nuclear-related information was distributed to undisclosed nuclear energy policies and management of nuclear power plants[113]. And the government further attempted to promote public acceptance through various means including publishing 'White Paper for Nuclear Power Generation' annually and establishing Korean Nuclear Energy Foundation (KNEF) to improve public relations. From this series of confidence building measures and active communication, positive feedbacks for nuclear power plant improved from 72% in 1986 to 95% in 2005 while negative impressions decreased from 53% to 29% for same period according to public survey conducted by the KNEF[114]. In this acceleration period, in tandem with rapid and innovative development in nuclear technology, promoting public acceptance through safety measures and trust-building process have emerged as key part of success of nuclear energy industry. Similar to previous Japanese case, South Korea's acceleration of nuclear energy was also driven by institutions and actors nourished from the early stage of development. As a result, South Korea's nuclear path was consolidated after the period of critical junctures leading to the new period of acceleration.

1-2-3. China

Since the first commercial operation in the early 1990s, China's nuclear power generation was strangely sluggish unlike Japan or South Korea that immediately accelerated nuclear development. Nonetheless, China was active in nuclear research and development and commitment in military programs. And Chinese government tried to separate nuclear military and industry and deregulate its institutions in the 1990s. The most apparent example is a separation of the China National Nuclear

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[112] Ibid (임경순).

[113] Ibid (부경진 et al.), pp. 64.

[114] Ibid (부경진 et al.), pp. 64-66.

Corporation (CNNC) from the Ministry of Nuclear Industry, which was a central piece in developing China's first atomic bomb and nuclear submarine in the 1960s. From this institutional reorganization, the CNNC turned into a state-owned enterprise (SOE) in charge of construction of nuclear power plants in Shanghai region in the 1990s[115]. And the state council's creation of nuclear-related SOEs such as the China General Nuclear Power Holding Company Limited (CGNPC) and the State Nuclear Power Technology Corporation (SNPTC) meant for opening China's nuclear industry to cooperate with foreign nuclear industry. Along with these SOEs, China's structural division in the 2000s led to acceleration of its nuclear program.

China's strategic nuclear decision-making has a clear hierarchy and executed in a top-down process. The central authority generally approves nuclear projects based on preliminary studies and reviews by lower divisions. The National Development and Reform Commission (NDRC) and the National Energy Administration (NEA) are responsible for the authorization and final decision for nuclear projects, while the China Atomic Energy Authority (CAEA) oversees safety regulation and also reviews preliminary studies conducted by the National Nuclear Safety Administration (NNSA) and the State Environment Protection Administration (SEPA) that investigate, inspect, and review safety and environmental impact of planned nuclear power plants[116]. These organizational structures reveal that China's nuclear decision-making process is not totally fragmented and centralized; rather, each institution take expertized role to assess and review feasibility of each nuclear projects. However, one possible drawback from this vertical hierarchy from the center to the periphery is that decision-making process on nuclear program is sometimes dependent on personal preferences like it is in the crisis mode. A decision-making process in crisis mode is centralized across a few top party hierarchies, personalized upon the leader's preferences, and militarized to some extent[117]. Traditionally, the party leadership was deeply involved in energy-related decision-making and often more influential than SOE managements;

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[115] Ibid (Hibbs) pp. 16-17.

[116] Ibid (IAEA), pp. 218.

[117] Sebastian Heilmann, China's Political System. Rowman&Littlefield. 2017, pp.161.

for instance, top-level personnel could facilitate pre-authorization infrastructural work for nuclear projects with local and provincial governments and firms[118]. Such personal ties not only benefited pre-authorization stage of nuclear projects, but they also benefited formal approval process as those favored SOEs already preoccupied advantageous position in projects.

Another pillar of China's centralized decision-making and strategic policy coordination lie in role of technocrats. This process has been conventionally centralized among top party hierarchy with technocrats and almost look alike crisis mode that the top leader's ad-hoc decisions and personal preferences have been influential in nuclear development projects. Technocrats, whose careers in state industry and the economic bureaucracy, largely appeared in a decision-making process since the third-generation leadership with the wave of economic reforms and sophistication of science and technology[119]. And they served as a core pillar of Chinese nuclear decision-making throughout many years. Technocrats were involved in nuclear decision-making in the early stage of the second-generation leadership under Deng Xiaoping. Technocrats sought nuclear technology as a key to electricity supply to large population as well as boost economic growth in the 1970s, and with technocrats' assertion, the regime finally approved the construction of the first nuclear power plant in 1981[120]. And technocrats played a larger role in the third-generation leadership with the central authority's decision to accelerate nuclear development. Until now, they play a significant role in China's nuclear decision-making process; for instance, technocrats urged to establish the National Energy Administration (NEA) under a central government agency in 2008 to specialize the nation's energy policy[121], which has become the core part of the National Development and Reform Commission (NDRC). Therefore, technocrats have largely contributed to China's nuclear energy programs since the beginning up to now, and to some extent, their knowledge and expertise empowered the central authority in a decision-making process. With such

[118] Ibid. (Hibbs), pp.64

[119] Ibid. (Heilmann), pp.165

[120] Ibid. (Hibbs), pp.12

[121] Ibid. (Hibbs), pp.19

institutional context, China began its nuclear rise certainly from the Medium- and Long-term Nuclear Power Development (2005-2020) that planned 70 GWe nuclear power generation and 4% nuclear energy target out of total installed power generating capacity by 2020[122]. China overachieved its initial target in 2019 with generating 330,120 GW by nuclear power which is approximately 4.9% of its total power generation and became the world's third largest nuclear power generator after the United States and France[123]. And China's installed nuclear power capacity also skyrocketed from its operation in 1991 with 300 MWe to 45,498 MWe in 2019[124]. And this trend is likely to continue as stated in the 14th Five-Year Plan as China is leaping toward ambitious greenhouse gas emission target and non-fossil energy provision and plan to construct six to eight new nuclear reactors in 2020-2025[125]. And China's nuclear rise is a continuation path, which it planned to construct more advanced nuclear power plants and increase share of nuclear energy sources in the nation's power generation.

During this period, public acceptance also deteriorated in China like other countries that went through nuclear acceleration period earlier. A proper measurement on public acceptance did not exist in earlier period under authoritarian rule or even civil participation was suppressed. But in more recent days, data on public acceptance or stories of anti-nuclear protests in China are reported. According to the government survey reported on joint recommendations by the Chinese Academy of Engineering and French institutions in 2017, public support for nuclear power in China is only about 40%[126]. Moreover, another survey indicates that public's perceived risk is larger than perceived benefit and so public acceptance is moderately low in China[127]. And more intuitively, increase in anti-nuclear protests within China signal a deterioration of public confidence. For instance, shortly after the Fukushima accident,

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[122] Ibid. (Hibbs), pp. 29

[123] Ibid (IAEA). Nuclear Share of Electricity Generation in 2019.

[124] Ibid (World Nuclear Association). Nuclear Power in China.

[125] Reuters. "Factbox-China's 14th 5-year plan: Key commodities and energy themes to watch." October 2020.

[126] Ibid (Hibbs), pp.93

[127] Shanyong Wang et al. "Public perceptions and acceptance of nuclear energy in China: The role of public knowledge, perceived benefit, perceived risk and public engagement." Energy Policy, Elsevier, vol. 126, pp 352-360.

rumors on radiation leak in China led to panicked buying rush of iodized salt, and a further protest occurred against construction of nuclear fuel processing complex in the city of Jiangmen in 2013[128]. Another protest occurred in city of Lianyuang in Jiangsu Province in 2016, where residents violently clashed polices in opposition to building new nuclear fuel reprocessing site[129]. And an implication from rising anti-nuclear demonstrations in China is rural and urban disparity on nuclear perception. Urban population with relatively wealthy and information-dense publics generally support nuclear power for cheaper electricity rates and better air quality whereas rural population often objects to nuclear power and initiates demonstrations on the local level. Especially, rural population is directly exposed to risk as the most of nuclear power plant is being constructed in rural areas. Furthermore, information asymmetry in China intensifies fear of radiation among people in rural areas that they perceive nuclear power based on incorrect or unfounded information after the Fukushima accident. Due to closed political system in China, it is extremely difficult to identify public acceptance by survey and an impact of public acceptance in policy-making process. However, a few incidents within China reveal that public support of nuclear technology deteriorated especially in rural areas where information is unevenly distributed.

1-3. Phase 3

1-3-1. Japan

Fukushima nuclear accident undoubtedly triggered decline of nuclear power generation in Japan and contributed to stagnation of nuclear power generation in Japan. The government declared a nuclear emergency state, abandoned all nuclear construction plans, and suspended nuclear power operations[130]. The Japanese government halted operations of most nuclear power plants within a few months after the disaster and finally suspended the last remaining nuclear power operations in May

[128] Ibid (Hibbs), pp.92-93

[129] Ibid (Hibbs), pp.92-93.

[130] Lewis Glass. “In-Depth: Nuclear Energy in Japan.” June 2016, pp.1-5.

2012[131]. Among 54 idled nuclear reactors, the only exception was the Oi reactor in the Fukui Prefecture that was approved to reboot in July 2012, with concern of great deficit on electricity supply on the following summer. And more shockingly, the Enecan, the Energy and Environment Council under the Japanese government, announced the "Revolutionary Energy and Environment Strategy" suggesting nuclear phase out by 2040[132]. Because Japan has been relying 30% of its power generation from nuclear sources and planning to raise nuclear power share up to 50% by 2030, the new policy of nuclear phase-out seemed very radical transformation and revolutionary as the title suggests. As expected, this policy caused backlashes from political and business stakeholders concerning high energy costs and economic impacts if abandoning nuclear energy sources[133]. Furthermore, it was very doubtful on the effectiveness of policy proposal, as the authority postponed a decision on this energy transition until 2015 and pushed back nuclear phase-out by 2050[134]. And due to failures in handling crisis, the ruling party Democratic Party of Japan (DPJ) faced a crushing defeat against the Liberal Democratic Party (LDP) at the 2012 National Election, which ultimately led to a more dramatic policy reversal. Although the majority public polls were still favoring nuclear phase-out[135], this regime turnover meant that the former nuclear phase-out strategy would not sustain. On the other hand, a role of the nuclear village was crucial in reversal of nuclear energy policy. The METI shifted blames to the NISA and then replaced the NISA to the Nuclear Regulation Authority (NRA), a new autonomous safety regime, while appointing the new head of NRA as a former vice chairman of the JAEC, strong proponent of nuclear industry[136]. Moreover, the nuclear village such as the METI, the TEPCO, and other nuclear industries, targeted the Prime Minister Kan Naoto by openly blaming his crisis response and management and stonewalled his new anti-nuclear

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[131] Japan Atomic Industrial Forum. Current Status of Nuclear Power Plants in Japan. January 2019.

[132] Ibid (Japanese Atomic Industrial Forum).

[133] Hiroko Tabuchi. "Japan Sets Policy to Phase Out Nuclear Power Plants by 2040." *New York Times.* Sep. 2012.

[134] Ibid (Kingston), pp. 20.

[135] Linda Sieg. "Analysis: Despite 2011 disaster, pro-nuclear party could win power in Japan." *Reuters.* Nov. 2012.

[136] Ibid (Kingston), pp. 16.

energy initiatives. Followed by such a bureaucratic conflict, the NRA finally became an independent body as an external agency from the Ministry of Environments while completely departing from the METI. And when new Abe administration took in power, the nuclear village achieved its goal by realizing the expectation of nuclear restart from announcement of nuclear energy as a key base-load power source for the next 20 years in the 4th Basic Energy Plan in 2014[137]. And this has not changed until today, as of the 5th Basic Energy Plan in 2018 stressing the long-term importance of nuclear energy and proposing nuclear energy mix share by 20-22% in 2030[138]. The power dynamics among actors and ministries increasingly locked-in to increase returns for private corporations and the whole pro-nuclear community.

However, after the Fukushima incident, major media outlets conducted public surveys, and negative public reactions exceeded about 70%, though about 60% of publics still believed nuclear power generation is inevitable despite to high negative reactions, according to July 2011 survey by the Institute of Nuclear Safety System[139]. Strong anti-nuclear sentiments continued in 2012, when 81% of publics favored nuclear phase-out during public hearings at the Japanese government[140]. Therefore, publics still recognized the importance of nuclear power generation while the priority for power generation has slightly shifted. For instance, in 2011, risk of accident became the primary consideration in selecting energy sources for the Japanese publics rather than energy security, environmental concern, and economic consideration[141]. As this result suggests, publics less recognized economic factors in power generation and simultaneously, they were less aware of rising electricity rates from using alternative sources other than nuclear power[142]. Therefore, when Japan suspended nuclear operations,

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137 Ibid (World Nuclear Association). Post-Fukushima energy policy changes for Japan.

138 Ibid (World Nuclear Association). Post-Fukushima energy policy changes for Japan.

139 Ibid (Kitada), pp.1687-1694.

140 Ibid (Kingston). Other public polls conducted by Asahi, NHK, or government organizations generally indicated 70-80% publics supported nuclear phase-out policy in 2012.

141 Ibid (Kitada), pp.1694-1695.

142 Ibid (Kitada), pp.1696-1697.

public backlash on rising electricity rates was a surprise shock as expected. And this was the period in which public demonstrations became most active. Demonstrations involving thousands of anti-nuclear protesters frequently occurred throughout 2011 and 2012, and one of the largest protests involved 60,000 demonstrators marching to Meiji Shrine at Tokyo in September 2011[143]. Regardless large-scale active anti-nuclear demonstrations, the regime decided to restart nuclear program as public sphere was never considered in a decision-making process. On the other hand, such a decision was easy to make while Japan's nuclear path in pursuing nuclear program and connections among actors in nuclear industry have been very stable. There are two implications on such public perceptions at the post-Fukushima era: on the one hand, despite a horrendous disaster, people still recognized nuclear power as an important energy source. On the other hand, despite emerging active anti-nuclear protests, public voices were almost ignored as a decision was made to reboot nuclear program.

In sum, Japan's recent nuclear path after the Fukushima nuclear accident has been a roller coaster ride, but its nuclear institutions apparently persisted throughout this turbulent period. And such an environment was shaped by increasing return processes from institutions and group of elites. When new safety regime was created after the Fukushima nuclear accident, elites from nuclear village, formed from the early stage, exercised power to shape favorable decision-making environments and reproduce existing nuclear institutions. Despite a fierce resistance from subordinate groups like public demonstrations by CSOs, self-reinforcing sequences have become stronger in consolidating nuclear energy choices. In this perspective, Japan's initial proposal of nuclear phase-out policy after the Fukushima accident was a rash announcement perhaps driven by negative reactions and demonstrations. The DPJ administration proposed nuclear phase-out policy as a part of crisis management, but the newly elected LDP administration reversed the phase-out policy and put Japan's nuclear path back on track, which subordinate groups regained their powers to enforce institutional change. Both natural disaster and regime turnover generated exogenous shocks to Japan's nuclear path, creating critical junctures but

[143] VOA News. "Anti-nuclear Protesters March in Japan." September 18, 2011.

it is questionable whether new equilibrium has been shaped from such shocks. Otherwise, nuclear phase-out in Japan never existed as a break for nuclear power generation after the Fukushima accident was for a comprehensive safety check and reinforcement of regulations. New proposed policy could not sustain, while it led Japan to maintain nuclear power and reproduce institutions in a long term by fulfilling public concern on economics aspect and demonstrated public gestures to promote safety. And such a promotion of public safety and regulation is evidence of continuous and stable nuclear path, which countries have been constructing since the 1990s or throughout the whole historical sequences on nuclear development history.

1-3-2. South Korea

After the Fukushima accident, South Korean government immediately conducted an internal safety assessment and the IAEA Integrated Regulatory Review service check to ensure safety. Technically, it installed the coastal barrier to protect from tsunami, secured battery power supplies, enhanced passive hydrogen removal systems, and improved the seismic performance of automatic shutdown system[144] and institutionally, the authority established the Nuclear Safety and Security Commission, an independent regulatory regime directly responsible to the President[145]. And the South Korean administration was still confident in its domestic nuclear industry as the 7th Basic Plan for Long-term Electricity and Demand for 2015-2029 announced a new plan to construct 13 new reactors by 2029 and to implement 28 percent increase from current nuclear capacity[146]. Although South Korean nuclear institutions seemed unwavering even after the Fukushima nuclear accident, new change began to shape new environments in 2017.

Like Japan, the regime turnover perhaps was a critical juncture in South Korea's stagnation of nuclear power generation, in which the newly elected Moon administration closed the oldest nuclear reactor Kori-1 and proposed nuclear phase-out policy in 2017. And in the 9th Basic Plan for Long-term

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[144] Ibid (World Nuclear Association). Recent regulatory actions of South Korea

[145] Nuclear Safety and Security Commission. IAEA: Korea's safety regulation effectively improved.

[146] Ibid (World Nuclear Association). Energy policy of South Korea

Electricity and Demand for 2019-2034, it further announced that only 17 reactors will operate in 2034 from current 25 reactors and electricity generate share will decrease from current 19 percent to 9.9 percent in 2034[147]. But ironically, nuclear power generation in 2020 reached 160K GWh which was the third highest output since 2015 and 2016[148]. South Korea exceeded 160K GWh on annual nuclear energy production in 2015, 2016, and 2020, in which before and after nuclear phase-out proposal in 2017. While nuclear energy still consists about 30% of the national energy mix, a plan for nuclear phase-out has been kept pushed back from initially 2060 to 2070 and finally 2080. Like Japan's nuclear phase-out policy, South Korean policy is also 'kicking the can down the road' behavior that the administration is shifting responsibilities by ambiguous goals and too much long-term projects. Thus, such a proposal which seemed drastic institutional change had almost no impact on South Korea's nuclear path, and its ineffectiveness in a short-term caused backfire on the national energy policy.

Institutionally after the Fukushima nuclear accident, establishment and management of Nuclear Safety and Security Commission (NSSC) was passed in the National Assembly to introduce the NSSC as an independent presidential advisory body in 2011. Along with the NSSC, the Korea Foundation of Nuclear Safety was established to promote public safety on nuclear matters. On the other hand, the Korea Institute of Nuclear Safety was already responsible for management of public safety, and the NSSC was already established in 1997 as an advisory body under the Ministry of Science and Technology[149], so this was indeed reproduction of nuclear institutions led by various stakeholders within the government ministry. Another evidence of nuclear path dependency may be found on closing ceremony of South Korea's first nuclear power plant Kori-1, where President Moon announced phase-out policy as denuclearization process. On the other hand, it is a bifold concern as President Moon publicly announced to develop two nuclear-powered submarines for the ROK navy[150]. It is even more

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147 오찬종. "탈원전 지속…원전 비중 19%->9%." MK MBN, 2020.

148 산업통상자원부. "에너지원별 발전량 현황." E-나라지표, 2021.

149 정환삼. "원자력안전위원회." 행정안전부 국가기록원.

150 Navy Recognition. "South Korea Navy to acquire two Nuclear Power Submarine." *October 2019 News Navy Naval*

contradictory that if a nation is pursuing denuclearization in pursuit of peace but shutting down a peaceful use of civil nuclear program while developing military nuclear program. It seems very symbolic and contradicting that President Moon Jae-in to announce nuclear phase-out at the closing ceremony of Kori-1 whereas a former President Park Chung-hee stressed the strategic importance of Ballistic Missile Submarine during the groundbreaking ceremony of Kori-1 reactor in 1971[151]. Although their stances on nuclear technology are contradictory, their pursuit of nuclear-powered submarine is similar as their nuclear paths have been enduring. Formal institutions for developing this nuclear technology were initially introduced in 1994 under the Kim administration, and elites were fostered by dispatching to Russia to study nuclear technology and later leading the first nuclear-powered submarine in South Korea. In this sense, South Korea's nuclear path seems very enduring as despite anti-nuclear rhetoric and subordinate groups against anti-nuclear powered military program, nuclear path publicized in the 1970s was consolidated institutional persistence and led by elites promoted within institutions.

However, public acceptance slightly deteriorated with risk of nuclear accidents and domestic scandals. South Korea publics also perceived nuclear development is inevitable even after the Fukushima accident; according to public survey by the Korea Nuclear Energy Foundation (KNEF), 87.8% respondents recognized the necessity of nuclear development in 2011 which was only 2% decrease from the previous year[152]. On the other hand, safety issue and local acceptance of power plant both significantly exacerbated from the 2010 to 2011 survey. This may reveal that public awareness and anxiety have increased after the incident, but overall approval of nuclear has not changed. From the KNEF's public survey from 2000 to 2016, over 75% of respondents from the entire period approved the necessity of nuclear power[153], and more recent data on May 2019 also indicate that about 72% of

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Maritime Defense Industry. October 2019.

151 Ibid (오동룡).

152 이상복. "원자력 국민인식 역대 최악…"현재 수준 유지" 61.3%." 이투뉴스 Energy & Environmental News. January 2017.

153 Ibid (이상복).

respondents still approve nuclear power generation[154]. More interestingly, 93% of respondents recognized that merits from nuclear power are superior to demerits, and among merits, 77% responded for cheap electricity generation costs and 61% responded for green-house gas emissions[155]. Thus, this indicates that economic consideration was top priority for supporting nuclear power. On the other hand, foremost demerits of nuclear power became management of radioactive waste and risk of accidents as publics became more aware of risk and safety-related issues. Only about 34% of Korean respondents knew 'there hasn't been any radiation leak accident' in Korea, which was 6% increase from the previous 2018 survey. Overall, such figures indicate increasing public awareness on nuclear technology shifting from moral to ethical perceptions. Beside the Fukushima accident, nuclear scandal was a major cause of suspending commercial nuclear operation in South Korea. But according to the survey, about 45% of respondents recognized that they are not aware of nuclear scandals, and about 23% of respondents answered that they do not support nuclear power after nuclear scandals[156]. Therefore, results of public survey in South Korea shifted to focusing on safety issues such as waste management or risk of accidents. But publics were aware of the importance of nuclear energy source in the nation's power generation, which may not have led to serious public backlash after the Fukushima nuclear accident. On the other hand, a series of scandals on nuclear institutions in 2012, 2013, and 2020 betrayed trust within these institutions. During the internal safety probe, the Korean Hydro and Nuclear Power (KHNP) discovered that reactor parts were supplied with falsified safety statements from seven domestic companies and one foreign company[157]. For replacement of reactor parts with forged safety certifications, five nuclear reactors were suspended; furthermore, two additional nuclear reactors were shut down with discovery of control cables with falsified documentations[158]. As a result of these series

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[154] Ibid (이상복).

[155] 김소연. "국민 7명 원자력발전 '찬성' 脫원전 동의하지 않아." 원자력신문. November 2018.

[156] 조동준. "원자력에 대한 국민의 인식수준과 수용성 영향요인에 관한 연구." 서울대학교 행정대학원. 2015.

[157] Meeyoung Cho. "S.Korea to widen safety probe on certificates for nuclear reactor parts." *Reuters.* February 2014.

[158] Meeyoung Cho. "South Korea shuts more nuclear reactors over fake certificates." *Reuters.* May 2013.

of scandals, total 226 individuals, including a former CEO of the KHNP, were indicted with charged of fraud, briberies, and embezzlement[159]. Seven nuclear reactors were suspended, and planned constructions and commercial operations of new nuclear reactors were suspended. Thus, the Fukushima accident was perhaps indirect cause of South Korea's large nuclear power deficit throughout 2011-2013 while direct cause of this was the internal scandals. And another scandal occurred regarding Wolsong-1, South Korea's second commercial nuclear power plant. There has been alleged manipulation of economic feasibility of nuclear power plant by the KHNP for early closure of Wolsong-1 power plant[160]. Despite proposed change in nuclear energy policy in 2017, endogenous shock bombarded by internal scandals within nuclear institutions remained same as nuclear path in South Korea has been stable and continuous. As a result of declining public acceptance from nuclear accidents and scandals, massive public protests arose nearby Wolseong nuclear power plants led by various CSOs. Despite such public movements, anti-nuclear rhetoric posed by the government, or even various exogenous shocks, nuclear institutions persisted as they were formed from the early development stage.

Like a case in Japan, a regime turnover perhaps served as an exogenous shock that pressured institutions to change. But a validity of institutional change from such a policy proposal is skeptical, and the change seems to cause a stagnation period in nuclear power generation. Moreover, scandals from the nation's nuclear agency crucially affected diminishing trust in nuclear institutions during this period. Public acceptance also deteriorated and shifted toward public safety and risk of accidents leading to public demonstrations though publics recognize the necessity of nuclear energy sources. And high approval rating for nuclear power generation perhaps reveals that public domain was not appropriately integrated to proposal of nuclear phase-out policy. Given a recent trend on increasing public awareness on nuclear risks and increasing acceptance on nuclear technology, it is likely that political tensions are

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[159] 김강민. "데이터 분석: 원전비리 업체 89곳, 한수원에서 2조원 수주." *Korea Center for Investigative Journalism.* 2014.

[160] 남정민, 노경목. "멀쩡한 월성 1호기 경제성 조작해 폐쇄…" 한경 경제. July 2021.

leveraged and public opinions on nuclear policy would be even more polarized in South Korea. On the other hand, no significant change on energy structures or nuclear institutions took place as nuclear institutions developed from the early stage are maintaining their legacies. For example, the Korean Atomic Energy Research Institute (KAERI) from the Energy Law in 1959 is still responsible for nuclear energy research, and the Ministry of Trade, Industry, and Energy inherited legacies from the 1970s and 80s and still functioning for ministerial management in energy industry within the government, or even in the 2010s with the establishment of the Nuclear Safety and Security Commission and the Korea Institute of Nuclear Safety. Such institutional reproduction mechanisms were generated by various actors within institutions including leaders, bureaucrats, or researchers who shaped nuclear path to increase their benefits to ultimately causing self-reinforcing mechanism and resulting in top-down process of path dependency.

1-3-3. China

China's pursuit of nuclear power was barely affected by the Fukushima nuclear accident and firmly pushed safety checks, unlike Japan and South Korea that slowed down nuclear power generation during same period. After the Fukushima incident, China focused on ensuring the regime's stability and public safety when public perception on nuclear abruptly deteriorated after the Fukushima accident. Shortly after announcing the 12th Five-Year Plan to surge investments and construction on nuclear projects, China promptly suspended approvals for nuclear reactor constructions and conducted comprehensive safety checks[161], and the government announced follow-up the "12th Five Year Plan for Nuclear Safety and Radioactive Pollution and Control and Vision for 2020" to enhance new safety standards for existing and newly constructing nuclear reactors[162]. Major domestic nuclear power firms agreed upon cooperation mechanism for safety while the regime incorporated the IAEA's international safety standards and conducted the IAEA's Integrated Regulatory Review Service[163]. Under such a

[161] Ibid. (World Nuclear Association). Regulation and safety in China

[162] Ibid. (World Nuclear Association). Post-Fukushima check in China

[163] Ibid. (World Nuclear Association). Post-Fukushima check in China

thorough review and strict regulation on the international standard, China could quickly sway from nuclear safety discussion and further carry out new constructions as it planned in the Five-Year Plans. Moreover, to safeguard nuclear safety and regulation, the China Atomic Energy Authority (CAEA) signed a cooperation agreement with the OECD Nuclear Energy Agency (NEA), and the National Nuclear Safety Administration (NNSA) closely cooperates with numerous foreign and international agencies including the US Nuclear Regulatory Commission (NRC), OECD NEA, IAEA, Japanese and South Korean counterparts, and ASEAN +3 Forum on Nuclear Safety[164]. Earning strong international credibility is very important for the regime to claim its legitimacy and to ensure public safety in the international standard. Compared to other countries conducting nuclear safety assessment and review, China's ad-hoc response was relatively swift and effective in avoiding a long political nuclear discourse in resuming nuclear power operation. Perhaps, China's swift response was possible due to its unique crisis-mode decision-making process in pursuit of planned macro program and centralized policy coordination. Another crucial aspect in the regime's swift and resolute decision was largely due to support from regions and municipalities. When constructions for nuclear plants were delayed and on hold after the Fukushima accident, more than 16 provinces announced to construct nuclear plants as planned in the 12th Five-Year Plan[165]. Decision-making in such a crisis mode was oriented to top-down process with centralization and urgency, while support from the bottom indicate consolidation of the power. After reassuring safety of nuclear energy from the 12th Five-Year Plan (2011-2015), China leaped toward surging nuclear program with ambitious greenhouse gas emission target and non-fossil energy provision in the 13th Five-Year Plan (2016-2020). The regime further promulgated to commit to increase six to eight nuclear reactors every year, to start a new coastal power plant, and to complete various nuclear projects[166]. Thus, the regime's ad-hoc response to crisis as well as consolidating power to the central authority from local municipalities was critical in championing its mega development projects.

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[164] Ibid. (World Nuclear Association). Regulation and safety in China

[165] Ibid. (World Nuclear Association). Nuclear Growth.

[166] Ibid. (World Nuclear Association). Nuclear Power.

On the other hand, China's nuclear path was different from that of Japan or South Korea, in which they have constantly pursued nuclear development after the first commercial operation. That was a period of acceleration that with exploding energy demands from industrialization, nuclear development has become their national priorities. However, China strangely slowed down or even ceased its nuclear development after its first commercial operation in 1991. At that period, nuclear industry was substantially growing under the leadership of premier Li Peng; however, a successor Zhu Rongji favored petroleum sector and electric grid industry over nuclear industry, which ultimately led to decline in investment in nuclear industry, and Zhu further imposed a three-year moratorium on nuclear power plant construction in the end of 1990s[167]. But then, Zhu's successor Wen Jiabao championed China's modern nuclear energy program in 2005 with the Medium- and Long-term Nuclear Development Plan that completely reversed previous energy path. Thus, China's total net capacity only grew 300 MWe to 6,587 MWe from 1991 to 2005 for 14 years, whereas for next 14 years, its capacity since then skyrocketed to 45,498 in 2019[168]. Thus, Chinese nuclear energy policy moved back and forth within a decade, which partly hampered earlier nuclear development. On the other hand, the authority's determination to commit to nuclear macro programs and mega projects led to rapid growth and success in relatively short period.

Another slow-down process caused by public outrage in local villages in China, which ultimately led to cancellation of construction of nuclear facility. A few years after the Fukushima nuclear incident, the inflow of negative yet groundless information about the nuclear program arose in local villages in China. One pronounced case was a protest against nuclear plant construction occurred in the Southeastern city of Jiangmen in 2013[169]. A new uranium plant was worth 37 billion Chinese yuan project providing around half of China's enriched uranium fuel; however, the government cancelled the

[167] Ibid (Hibbs), pp.13

[168] Ibid (World Nuclear Association). Nuclear Power in China. See graph of nuclear power capacity.

[169] Ibid (Hibbs), pp.93-95

project in response to outbreak of demonstration[170]. but the central authority cancelled the plan to construct nuclear fuel processing complex due to outburst opposition from local residents. Therefore, local experiences have contributed in slowing down nuclear power development in China that was firm path even after the Fukushima incident. Although it was not major transformation or effect in the course of Chinese nuclear path, this meant China's nuclear decision-making process may have changed from top-down process to the bottom-up process. It was very different from the past Chinese response to anti-nuclear protests, which the central authority compulsively dissolved protests and arrested demonstrators.

For Chinese case, exogenous shock was similarly generated from the regime turnover influenced by leader's preferences as a strictly top-down process. And those nuclear institutions undoubtedly benefit a group of elites to sustain and reproduce for increasing return processes. On the other hand, Chinese case further displays functional explanation on its nuclear institutions. Unlike previous cases from Japan and South Korea, China's nuclear history sequences began from military institutions that were later reproduced for integration into a larger system, such as civil institutions. Moreover, China's difference in the regime type is related to functional consequences, for example, a priority is for survival which lead to emphasis on harmony and unity within institutions. It may be true that all regimes regardless of their types seek for survival, but a survival of regime and system would be a critical matter in dictatorship. In this sense, institutional reproduction in China was driven by functional consequences for a larger system From the early development stage, China becoming a nuclear-weapon state may be a contingent outcome in proximity of the Soviet Union and a special historical circumstance, but self-reinforcing processes led to integration into civil nuclear program, adaptation to new international environments, and ultimately fortify regime for survival.

1-4. Summary

[170] BBC News. "Protest prompts China to cancel Jiangmen uranium plant." 2013.

	Japan	South Korea	China
Early Development Stage	1950s – Mid 1960s · Influenced by the United States and imported first nuclear power reactor to operate in 1966. · Established Atomic Energy Basic Law and other nuclear institutions with military intentions. · Depended on domestic produced coal then imported oil. · Mixed public acceptance on nuclear technology.	1950s – Late 1970s Influenced by the United States in development and began first commercial operation in 1978. · Established Atomic Energy Law and other nuclear institutions with military intentions to some extent. · Depended on domestic produced coal then imported oil	1950s – Early 1990s Influenced by the Soviet Union in developing weapon program and began first commercial operation in 1991. · Agreed on a bilateral cooperation with the Soviet Union and created institutions and SOEs under the second FYP. · Depended mainly on coals.
Acceleration Period	Mid 1960s – 2010 · External environments shaped by the NPT, nuclear accidents (TMI or Chernobyl accident), and globalization. · Restructured existing nuclear institutions and established safety regimes. · Nuclear energy shares gradually increased and reached peak in the 2000s. · Public acceptance	Late 1970s – 2016 · External environments shaped by the NPT and nuclear accidents (Chernobyl or Fukushima accident), and globalization. · Restructured existing nuclear institutions and established safety regimes. · Nuclear energy shares gradually increased and reached peak in the 2010s. · Public acceptance deteriorated with domestic	Early 1990s – Present · External environments shaped by globalization, Fukushima accident, and Paris Agreement. · Restructured military institutions into civilian nuclear institutions and created safety regimes and SOEs. · Nuclear energy shares are gradually increasing. · Public acceptance deteriorated with safety concerns, and public

	deteriorated with domestic scandals and safety concerns then public protests arose.	scandals and risk of accidents then public protests arose.	protests arose.
Stagnation Period	2011 – 2012 / 2012 - Present · Proposed nuclear phase out policy but then reversed the policy and rebooted nuclear power plants. · New safety regimes were created, and institutions are back on track. · Nuclear energy shares ceased but slowly and gradually increasing. · Public acceptance exacerbated, and large-scale organized protests arose.	2017 – Present · Proposed nuclear phase out policy but no fundamental change in nuclear institutions. · New safety regimes were created, and institutions are maintained. · No significant changes in energy structure. · Public acceptance slightly deteriorated, and mixed discussions arose.	1991 – 2005 · Personal preference on nuclear energy source led to change in nuclear institutions
Types of Path Dependent Explanation	Self-reinforcing Sequences: Power Explanation: A group of pro-nuclear elites reinforced institutions to reproduce to increase returns. Seemingly institutional change was generated from gaining power of subordinate groups but re-gaining power of elites	Self-reinforcing Sequences: Power Explanation: Various actors including political leaders, bureaucrats, and researchers played the power dynamics for nuclear institutions to persist and increasingly locked-in for their benefits.	Self-reinforcing Sequences: Power/Functional Explanation: Top-down processes from elites reproduced nuclear institutions while institutions also persisted for functional consequences which integrated into civil nuclear program and

	rapidly brought path dependency.		propensity to regime survival.

There have been numerous similarities and differences on historical sequences of development of nuclear path in Japan, South Korea, and China. Initial conditions in these countries, from the early development stage, were heavy influences from external forces in developing institutions and shaping decision-making environments. Japan and South Korea were influenced by the United States, whereas China received assistance from the Soviet Union in developing nuclear weapon program. Although China was the only one to possess nuclear weapon capability among three countries, Japan and South Korea also had military intentions to develop nuclear weapon program at the early stage. Under such intentions, their reactor types or institutions were designed to serve dual-capability to some extent. Thus, publicity campaign of nuclear technology was active in this period, and especially in Japan, anti-nuclear movements arose in private spheres in respond to the government's campaign. However, such a civic participation was relatively inactive in South Korea or China under authoritarian regimes in which demonstrations were dissolved or protestors were arrested. In perspective of energy structure, these countries firmly believed nuclear energy source as a future energy source, so they planned to gradually depart from coal and oil sources to pursue nuclear energy source in desire to achieve efficiency and energy independence.

A period of critical junctures temporally occurred after the construction of first nuclear power plant, in which triggered countries to commit to construct their second and third nuclear power plants and gradually depart from heavy dependency on oil or traditional fossil fuel energy sources. Along with selecting nuclear energy as their future energy sources, external influences and industrialization from home and globalization from abroad drovec the acceleration of nuclear development in these countries. Although this acceleration period came in the 1970s and 80s for Japan and South Korea, China underwent an internal cataclysm that delayed its first commercial nuclear power operation until 1991. But in this acceleration period, institutions commonly persisted and then reproduced by creating safety

regimes to ensure public safety. In Japan and South Korea, nuclear accidents and domestic scandals shaped unfavorable conditions to accelerate nuclear program while public acceptance deteriorated in concern to public safety and fall in institutional trust. China also underwent a similar process of restructuring from military institutions to civilian institutions and strengthening safety regulations while faced arising public protests from deteriorating public acceptance due to nuclear accident.

Japan and South Korea faced the stagnation period, in which after reaching the peak to nuclear power generation, these countries were on the verge of abrupt change with a proposal of nuclear phase-out policy. A period of critical junctures was stimulated by the Fukushima nuclear accident and the regime change from the second to the third phase. Japan's change was triggered by the Fukushima nuclear accident while decision was reversed from regime turnover to the Abe administration, seemingly another exogenous shock. South Korea's change also occurred from regime turnover when the Moon administration announced nuclear phase-out policy though actual changes in nuclear institutions were barely observed. Indeed, nuclear institutions in Japan and South Korea persisted for benefits, which can be summed up for an increasing return process. And among different types of institutional reproduction, the power explanation may best fit for these two cases as elite groups formed from the initial development stage, and their roles greatly contributed to persistence of nuclear institutions. Because these elite groups did not lose their powers to subordinate groups, changes in nuclear institutions have not yet occurred and endured throughout historical sequences. On the one hand, China's acceleration to nuclear program is currently underway, and so stagnation after peak never occurred yet. On the other hand, China experienced a serious interruption to its nuclear program after the first nuclear operation in the 1990s when Zhu Ronji delayed Chinese nuclear program, until 2005 when new leader Wen Jiabao set the acceleration of nuclear program as China's new national agenda. Therefore, these countries commonly faced abrupt changes in nuclear institutions from change in the regimes and followed by leader's individual preferences. For such a case, an elite group strongly influenced in change of nuclear institutions in China. It would be precipitate to deem these institutional changes as a mere exogenous shock, as these countries have carefully paved different paths throughout

the history through such a persistence. Moreover, Japan and South Korea's change by proposal of nuclear phase-out policy lacks substances with ambiguous goals in a long-term which make more skeptical to validity of institutional change. Furthermore, they have maintained legacies from the past institution that produced continuous outcome in their current institutions that clearly fit for path dependency. And China, in spite of discontinuity in the 1990s, has gradually changed from military to civilian nuclear institutions and aiming for its original nuclear path toward the topnotch of nuclear power. Within path dependency framework, three East Asian countries commonly experienced institutional reproduction for self-reinforcing sequence may be explained by the power explanation that a group of actors especially elites formed and persisted institutions. On the other hand, China's case is more special, which previous reversal of nuclear path was generated by exogenous shock and then later persisted for functional consequences. China's non-democratic regime type seems to prioritize regime survival that mainly trigger institutional reproduction, and transformation of an overall system seems impossible compared to other countries. In sum, Japan and South Korea has endured institutional legacy from the early development stage, and their proposal of changes is aligned to adaptation to the future. After reaching peak in power generation, it is natural for countries to stagnate in power generation, and introduction of new renewable energy source after nuclear energy source naturally led reproduction of energy structures not only in Japan or South Korea but also in many other countries pledged to fight climate with new energy transitions. But in reality, a proposed revolutionary change was not realized from self-reinforcement of their nuclear history sequences and rather benefited from increasing return process. Whenever critical junctures outbreak for genesis of institutional patterns, powerful elite groups induced nuclear institutions to reproduce in a same old-fashioned institutional pattern.

V. Conclusion

Ten years have passed since the Fukushima nuclear accident, and numerous policies were proposed, modified, or even reversed during this period. But more fundamental question was what

drove different nuclear paths among different countries? For example, Japan, South Korea, and China each seemed to take different nuclear paths in recent years: Japan announced nuclear phase-out policy but soon rebooted its nuclear program; South Korea also announced nuclear phase-out policy while still depending on nuclear energy; and China has planned to play a leading role in the world's nuclear power generation. To probe different paths among these three countries, the beginning of nuclear institutions within these countries will be a good starting point. They commonly began to express nuclear interests with pursuit of developing military capabilities with dual capability of nuclear technology. Each countries had their own anecdotes of nation-building process, where failures and drawbacks from the past led countries to rebuild national footing and technological prowess. Japan experienced humiliating defeat in the Second Word War with traumatic experience of victimized by atomic bomb. South Korea experienced the colonial rule and civil war. And China also went through the civil war and external threats from imperial forces. These experiences ultimately led countries to strengthen military power against external threats and to achieve independence in energy sources for self-sufficient prosperous economy through nuclear technology. Nuclear technology served as a symbolic pillar to overcome such difficulties, and they committed to establish institutions with assistance from external forces at the early development stage. And then, public awareness naturally increased, which managing such a domestically and internationally sensitive technology through a strict regulation and transparency has been a key to success. And so various institutions have been established to nationally promote nuclear technology and protect public from any risks. Throughout such a historical sequence, nuclear path in each country was very dependent characterized by a long-term institutional reproduction led by a group of elites. With such an institutional pattern of increasing return, nuclear energy option was more consolidated over time by various interactions among different actors in each country.

Within a path dependent framework, persistence in nuclear institutions in Japan, South Korea, and China was observed. From the initial development stage through the period of acceleration and stagnation, countries undertook a common yet distinct path in nuclear institutional development through various interactions among actors. Such persistence and interactions may explain current nuclear path

of each country, and ultimately answer the mystery of large-scale outcomes. Explanations from cultural analysis or rational-choice theory may have answers to a same question over these three cases, but some drawbacks are supplemented from a path-dependent framework. On the other hand, beside power explanation on institutional reproduction, functional explanation seems plausible in analyzing this institutional pattern in terms of regime survival and adaptation. Otherwise, institutional reproduction derived from a more complexed self-reinforcing process that caused increased benefits and solidification of such a distinct institutional pattern.

Reinstating an initial research question of driving factors of different different nuclear paths in three East Asian countries, interesting comparison and contrast have been observed. Initial conditions were similar in three countries from the early development stage to nuclear acceleration period, which critical junctures occurred for solidification of nuclear paths. And during this period, various interactions and processes shaped nuclear paths that consolidated institutional pattern paved by a group of elites at the initial development stage. Despite of shocks including accidents, scandals, regime turnovers, or public protests; this institutional arrangement was barely waving and rather self-reinforcing to form a long-term reproduction of nuclear institutions. Initially, recent institutional changes in these countries seemed to be an abrupt change but probing through a beginning to the end revealed that large-scale outcomes in these countries were lacking substances while benefiting from older institutional patterns. Furthermore, they have maintained institutional legacies from earlier periods and reproduced institutional practices in emphasizing safety regulation to adapt new decision-making environment encompassing public spheres. Furthermore, politicized nature of nuclear technology contributed to a more radical and polarized reaction when new nuclear energy policy was proposed. Given thorough study of nuclear path in this paper, it would be interesting to observe future institutional changes on nuclear energy or the path of new energy sources. As these countries have been encouraging more active civil participation, reducing any risks with active communication, and strengthening safety regulations, it is predictable that the future decision-making environments will incrementally change in this path. And by learning from these past experiences, countries, with

interactions among diverse stakeholders, may develop more stable and robust future path of energy sources. Last but not least, this study will hopefully contribute to the study of future institutions related to not only nuclear energy but also new energy source and emerging technologies.

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국문초록

후쿠시마 원전 사고 직후, 일본, 대한민국, 중국 등 동아시아 국가들은 각기 다른 원자력 정책을 펼쳤다. 일본의 경우, 탈원전 정책을 발표하였다가 이후 무효화 결정을 내리고 원자력 발전을 늘려가고 있으며 대한민국은 최근 탈원전 정책을 발표한 반면 중국은 원전 굴기 정책을 펼치며 굳건히 원자력 발전 비중을 늘려가고 있다. 이러한 다른 원전정책들의 추진 배경을 알아보기 위해 각 나라들의 원자력 제도들을 역사적 관점으로 경로 의존성 틀을 이용해 비교 분석할 것이다. 결론적으로 각 나라들의 원자력 경로들은 수확체증 과정을 통해 제도가 지속되고 재생산되었으며 권력과 기능성에 기초하며 설명이 가능하다. 이러한 결론을 바탕으로 이 연구가 역사적으로 다른 원자력 정책의 배경에 대한 이해를 돕고 미래의 에너지 정책 및 경로 예측을 돕길 희망한다.

주제어: 원자력 정책, 제도주의, 비교역사분석, 경로 의존성, 의사결정 과정, 동아시아 지역연구.