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Nuclear Supply Dynamics: Effects of Export Competition on Nuclear Nonproliferation

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Abstract

Nuclear Supply Dynamics: Effects of Export Competition on Nuclear Nonproliferation

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In commercial nuclear trade, buyer-dependent profit-oriented nuclear export competition has promoted the spread of nuclear weapons technology and weapons-grade fissile materials. Even today, the existing international nuclear export control regime such as Nuclear Suppliers Group is still too weak to maintain consistent export policies for nuclear nonproliferation and nuclear security. Moreover, the export control regime is traditionally governed by nuclear weapons states encountering a transition, as new nuclear power plants are mostly supplied by emerging nuclear suppliers. Under such a power transition, disagreements on export practices between new and old suppliers may deepen. In addition, nuclear transactions would evolve from point-to-point transfers to a system of complex trade networks, and the non-binding global regime has no control over every detail of nuclear export. The regime can also face a dilemma over the choice between the erosion of technical barriers to proliferation and the denial of sensitive technology transfer.

Despite the importance of supply-side dynamics in nuclear proliferation, the majority of past studies have focused on the demand-side aspects. Limited

studies on the supply-side dynamics to date have identified at least two important challenges. First, various statistical analyses have yet failed to generate reliable quantitative datasets with no success in yielding a critical causal relationship among decision-making components. Second, case studies only looked at the impact of excessive competition among suppliers, without attempting to develop an understanding about underlying mechanisms. With the advent of new suppliers, it is necessary to investigate an evolving spectrum of export competition based on structured and focused case studies. The present dissertation is aiming at suggesting a set of positive reformative strategies for an improved nuclear export control regime.

A systems-thinking model is employed to address two critical questions: 1) what types of supply-side feedback influence nuclear suppliers to decide nonproliferation conditions of supply, and 2) how political and business competition among suppliers, in turn, affects the feedback structures. The proposed reformative strategies can strengthen the types of feedback that can reinforce nonproliferation, or can weaken the feedback to proliferation. Three export cases of 1960-70's representing different competition levels were studied: 1) a strong export competition between Canada and the United States to India; 2) a monopolistic case of the Soviet Union to North Korea; and 3) a moderate competition between the United States and Canada in export to South Korea. As a result, a new supply dynamics model for nuclear export decision-making has been developed; it was tested via the three cases and a new cooperation case between the United States and India.

The nuclear supply dynamics model shows that suppliers' pursuit of economical, strategic, and political benefits produces the four types of feedback among suppliers. A nuclear export decision can be politically driven based on consideration of market importance and nonproliferation requirement. In the risk-taking feedback scenario, a supplier can compromise conditions of supply in order to avoid negotiation deadlock with a recipient;

otherwise, the supplier must risks losing its competitive position. In the lack of vigilance feedback scenario, a supplier can be distracted to attract markets while it deals with no vigilance with unattractive recipients. In the consensus-building feedback scenario, a supplier can build consensus with other suppliers on conditions of supply to avoid being the only party in negotiation conflict with a recipient, and thus to seek its competitive position. Finally, in the external constraint feedback scenario, if a supplier tries to loosen conditions of supply, other suppliers constrain it from doing so to keep their competitive positions. The first two types of feedback can loosen conditions of supply, while the latter two can strengthen the conditions.

Under high competition, Canada and the United States compromised safeguards conditions of supply to India that was the largest democracy and business economic market – the risk-taking feedback was dominant. Under low competition, the Soviet Union as well as other suppliers was indifferent to proliferation risks in North Korea where market attractiveness was trivial and Soviet political influence seemed credible – the lack of vigilance feedback was superior. Under moderate competition, the United States persuaded Canada to build consensus on stringent conditions of supply while constraining France from supplying South Korea with sensitive reprocessing technology – the consensus-building and external constraint feedback were prominent. In summary, the nuclear supply dynamics model predicts that a high competition renders suppliers to discount recognized proliferation risk, whereas a low competition may also increase potential proliferation risk due to lack of vigilance of suppliers. It is expected that a moderate competition results in healthy feedback among suppliers, allowing them to pay due attention to strict nonproliferation conditions of supply.

Case-specific supplier behaviors have been preserved up to date with continuing pursuit for gaining strategic advantages and economic profits. The United States lifted a ban on India permitting the unaccepted nuclear weapon

state legitimate access to civil nuclear technology and materials without requiring her ratification of NPT. This recent example highlights that strong strategic and economic stake of the supplier led to pursue the market at the expense of negative impact on the international nonproliferation regime while most nuclear transactions still rely on specific bilateral arrangements.

Such a bilateral negotiation process between a supplier and a recipient is usually exclusive; few interaction opportunities are allowed for other nuclear suppliers. There is no way that other suppliers can legally require a disclosure of nuclear negotiation processes. In addition, nuclear suppliers are sharing scant political, strategic, and economic benefits, although interdependence among suppliers is important to maintain a power balance and prevent a supplier from violating the global nuclear export guidelines.

Therefore, today's nuclear export systems need to be upgraded so as to facilitate transparent interactions with each supplier, and to create more political, strategic, and economic benefits shared by nuclear suppliers. The upgraded strategy can assure the consensus-building process and reinforce the external constraint mechanism, while preventing both special concessions to win intense competition and lack of vigilance in a monopolistic trade. Practicable approaches for more supply-side interaction and more benefit-sharing include: building a global negotiation framework based on nonproliferation conditions of supply while classifying other business conditions; running more interaction programs for a global code of conduct; establishing a multinational consortium for reactors, fuels, components, enrichment, reprocessing, and storages; and forming higher diplomatic, economic, and technical interdependence among suppliers.

Keywords: Nuclear nonproliferation, Nuclear security, Nuclear Suppliers Group, Nuclear export controls, Export competition, Conditions of supply
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I dedicate this dissertation to
my parents for their love

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Chapter 1 Introduction

In commercial nuclear trades, buyer-dependent nuclear export practices might have facilitated the spread of nuclear weapons and weapons-grade fissile materials. The preference in the spread of nuclear energy may result from nuclear suppliers' pursuit of political benefits, strategic advantages, and economic profits. Moreover, nuclear transfer has often caused international debates and regional tensions because of the inevitable technical connection between atoms for peace and atoms for war. A few countries, Israel, India, Pakistan, and North Korea, have manufactured nuclear weapons by acquiring foreign assistance for nuclear materials and technology. So far, about 27 countries have tried to obtain enrichment and reprocessing; nearly 80% of them have succeeded in importing at least the core components – which is not a legal violation, but far exceeds the number one really needs. In many cases, geopolitical and economic interests have triumphed over nonproliferation interests. More dangerously, a few states are operating illicit nuclear trade networks outside the nonproliferation regime.

Unfortunately, the risk of proliferation is still embedded in the global nuclear industry. The existing international nuclear export control regime is still too fragile to maintain consistent export policies. Most nuclear transactions still rely on specific bilateral arrangements. Historical lessons suggest that it is difficult to persuade proliferating countries to abandon nuclear weapons programs in which they have already made huge investments. Nevertheless, a few studies have elucidated upon the significant increase in proliferation risk and terrorist threats in today's nuclear business practices. Proactive nonproliferation assurances preceding nuclear exports are deemed necessary to ensure acceptably low proliferation risk in nuclear trades. To encourage nuclear suppliers' participation in these assurances, the export approach must not overly compromise on permitting the politically and economically competitive market mechanisms. Concerned parties must identify and reinforce positive nonproliferation functions of the competitive nuclear market, if any, based on geopolitical and economic self-interests, while regulating the negative functions. This may bridge the gap between nonproliferation interests and geopolitical or economic interests. This chapter describes a birds-eye view of the study, including objectives, significance, and background.

1.1 Objectives: reforming nuclear export controls

The purpose of this dissertation is to suggest a set of positive reform strategies to shape a global nuclear export regime. The goals are to minimize proliferation risk and prevent terrorist intervention while enabling suppliers and demanders to seize upon desirable business opportunities. As such, this study identifies supply-side interaction (i.e., interaction among nuclear suppliers, or supply-side feedback) determining nonproliferation conditions of supply, and explores supply-side competition's influence on the interaction. The reform strategies are required to strengthen positive reinforcements of nonproliferation, whereas weakening negative feedback that accelerates proliferation. Supply-side competition based on geopolitical and economic self-interest is a key explanatory variable that influences interplay among suppliers. Integrating competitive market mechanisms into nuclear export controls would accommodate peaceful uses of nuclear energy, while simultaneously monitoring inconsistent export policies. The main focus here is on how a supplier interacts with other suppliers for the purpose of nonproliferation of a recipient, and how the interaction among suppliers affects the recipient's decision.

1.2 The dual-use nature of nuclear energy and the transition of nuclear export environment

Article IV of the Nuclear Non-Proliferation Treaty (NPT) underlines "the inalienable right" of all parties "to facilitate, and have the right to participate in, the fullest possible exchange of equipment, materials and scientific and technological information for the peaceful uses of nuclear energy." Under the provision, global interests in nuclear energy are being renewed to address unprecedented climate changes since the turn of the 21st century. As of March 2012, 61 nuclear power plants are under construction in 13 countries (IAEA 2011:6-7). Although this is than the 233 reactors being concurrently built in 1979, this new nuclear wave involves larger numbers of buyers and sellers, and a more regionally diverse spectrum (Schneider et al. 2011:233).

After the 2011 Fukushima accident, this new nuclear demand suffered a setback in public perception, but it is likely to remain unchanged in the long term. In April 2011, 65 countries participated in the International Atomic Energy Agency (IAEA) technical cooperation program to build their first nuclear power plants. As of mid-2012, 6 of these countries significantly pulled back on their nuclear power programs, including Thailand, Cuba, Kuwait, Malaysia, Qatar, and the Philippines. However, most countries decided to continue on (Schneider et al. 2011:41-49). Over 20 countries have set up specific plans for construction and operation of a first nuclear power plant in the next 20 years.

Despite its potential for clean energy, nuclear power has unfortunately caused proliferation of nuclear weapons, threat of nuclear terrorism, accumulation of nuclear wastes, and destructive nuclear accidents. In particular, doubts have been raised about the solidity of nonproliferation regimes against the surging wave of nuclear power expansion (Rauf and Simpson 2004). Regarding the dual-use nature of nuclear energy, Hannes Alfvén, Nobel Laureate in Physics, said: “Atoms for peace and atoms for war are Siamese twins.” Peaceful and military programs share identical scientific principles, need the same fissile materials, and use similar engineering processes. In addition, the advancement of inspection systems has yet to catch up with the complexity of nuclear facilities and trade networks.

Until now, the NPT and its several interlinked arrangements, as shown in Figure 1.1, have performed significant roles to formalize nonproliferation norms and to establish mutual trust among states. The arrangements include an export control system, nuclear test ban treaties, a safeguards system, nuclear security assurance, prevention of production of fissile materials, and nuclear weapon-free zone. Although many countries are still dissatisfied by the global regime, the long-standing efforts can manage to keep the number of nuclear weapon states at no more than nine.

Out of the many important efforts, managing nuclear trades is the most challenging part of nuclear nonproliferation. For example, the mutual trust based on NPT membership was eroded when North Korea, Iraq, and Libya received nuclear materials and technology for nuclear weapons within the NPT. As illustrated in Figure 1.2, there are even more cases in which nuclear transfers for peaceful purposes were diverted to nuclear weapons development. French assistance to Israel was intended for the development of nuclear weapons. India, Pakistan, and South Africa received nuclear materials, equipment, and technology. These countries were not members of the NPT at that time; however, the number of proliferation cases has increased within the NPT regime. As mentioned, Iraq, North Korea, and Libya represent such cases, while Iran is an especially controversial case (Anthony et al. 2007:7).

After having experienced nuclear diversion, especially the 1974 India nuclear test, the international community strengthened global nuclear export controls. However, the reaction of a global regime is always slow to catch up with rapidly changing market situations. Ian Anthony et al. commented that "the very significant role that export controls have recently been given in nonproliferation strategies was arguably an overdue development (Anthony et al. 2007:6).” Such concerns are quickly growing due to the transition of nuclear trade environment under the weak structure of a global regime.

Although nuclear trades should be carefully managed by responsible suppliers, the current nuclear export control regime is not legally binding, and the disagreement between rule-makers and real exporters is surging. The export regime is still led by nuclear weapons states, whereas many new nuclear power plants are exported by emerging nuclear supplier states. Together, the United States, Russia, the United Kingdom, France, Canada, and Germany installed almost 90% of global nuclear capacity prior to the Chernobyl accident. These suppliers began losing their markets during the long depression after the accident. New nuclear suppliers constructed nearly 70% of nuclear capacity installed after the accident. Consequently, the disagreement on export practices between rule-makers and rule-followers may soar with the advent of new supplier states.

Table 1.1 shows the emergence of nuclear suppliers from both inside and outside the nonproliferation regime. There are two related watershed events in the post-Cold War era. The key event outside the regime is that A. Q. Khan of Pakistan operated a small illicit nuclear trade network. Khan supplied uranium enrichment technology to North Korea, Iran, and Libya. Inside the regime, South Korea agreed to sell 4 nuclear power plants to the United Arab Emirates in 2009. South Korea, Japan, China, and India are strong potential competitors in nuclear power plants market currently dominated by the United States, Russia, France, and Canada.

During the Cold War, the existence of only two superpowers constrained risky nuclear technology transfer after the failures of counter-proliferation. They had a clear superiority to buyers in terms of military, political, and economic capabilities that increased their leverage power. Moreover, these traditional suppliers could offer a comprehensive package of both nuclear power plants and nuclear fuels. They countered proliferation attempts by controlling technology, ensuring security, offering economic assistance, isolating diplomatically or economically, or using military force.

Under the power transition of the nuclear market, the new supply dynamics may challenge the traditional nuclear nonproliferation regime. Besides, international nuclear trade practices have been changed from point-to-point nuclear transfers to a system of complex transactions (Hibbs 2011:54). Most new suppliers, which are not major world powers, need a multilateral export regime that helps to monitor all nuclear trades and impose pressure on risky attempts. They are required to cooperate if they want to build political and economic capabilities that provide recipients with incentives to keep nonproliferation high on the national agenda.

Uranium producers (Namibia, South Africa, Argentina, and Brazil), U.S. allies (Japan, Canada, Australia, and South Korea), proliferators (India, Pakistan, North Korea and Iran), and China have recently sought to develop enrichment or reprocessing (Warrick 2008), in potential competition with the traditional suppliers. The United States, Russia, the United Kingdom, France, Germany, and the Netherlands together supply 90% of enriched uranium demand. About 90% of the nuclear power plants in operation or under construction require enriched uranium fuels – except for heavy water reactors. Several countries are considering reprocessing as a solution for nuclear wastes. France is helping China to construct a large-scale wet reprocessing pilot plant while South Korea is developing pyroprocessing. In addition, the United States, France, India, Israel, Japan, North Korea, Pakistan, Russia, Germany, the United Kingdom, Argentina, and Brazil all have experience in reprocessing spent nuclear fuels.

Nuclear technology in the market has also changed. For example, gaseous centrifuge enrichment is gradually being distributed, while gaseous diffusion enrichment is being phased out. Also, there is a growing demand for small modular reactors for developing countries in which the capacity of the electric grid is insufficient for large-scale reactors. Nuclear reprocessing is being re-explored in several countries in efforts to find technical solutions for spent nuclear fuels. It is challenging to securely manage these new kinds of nuclear transfers, as well as phasing-out industries regarding materials, equipment, facilities, technologies and human resources.

Table 1.1 Nuclear supply market in transition

	Inside the NPT	Outside the NPT
Breaking events	South Korea agreed to sell 4 nuclear power plants to the United Arab Emirates in 2009	A. Q. Khan of Pakistan operated a small illicit nuclear trade network
New rising actors	South Korea, Japan, China, Brazil, Argentina, Australia, South Africa	India, Pakistan, North Korea, terrorist groups
Important factors	Safety, security, physical protection, spent nuclear fuels, public acceptance	Legitimate approval from the international community to get engaged in global economy
Main concern	New proliferation attempts with civil nuclear assistance	Fixation of unacceptable nuclear weapons states

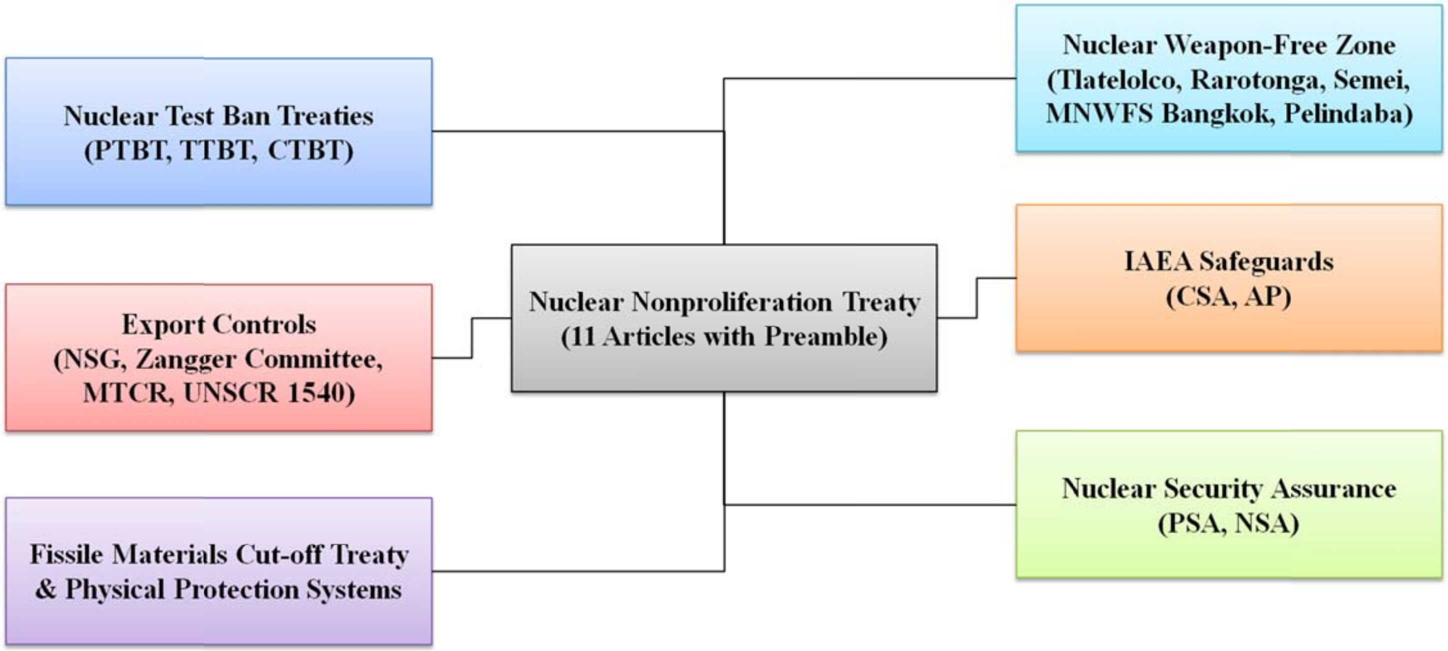


Figure 1.1 International arrangements of nuclear nonproliferation with the NPT

PTBT: Partial Test Ban Treaty
CTBT: Comprehensive Test Ban Treaty
TTBT: Threshold Test Ban Treaty

NSG: Nuclear Suppliers Group
MTCR: Missile Technology Control Regime
UNSCR: UN Security Council Resolution

PSA(NSA): Positive (Negative) Security Assurance
CSA: Comprehensive Safeguards Agreement
AP: Additional Protocol

Italic Red: nuclear export that contributed to spread of nuclear weapons

Bold Black: other nuclear exports that are significant or controversy

* Two export cases were intended for nuclear weapons, not nuclear power (China & Israel)

** A. Q. Khan stole centrifuge blueprints from URENCO Netherlands (Pakistan)

*** Albright and McGreal argued that Israel also helped South Africa to develop nuclear bombs

Figure 1.2 History of peaceful nuclear transfer that contributed to spread of nuclear weapons or fissile materials

1.3 The dilemma: the erosion of technical barriers versus the regime of sensitive-technology denial

Before this study attempts to identify causes and proposes solutions, we must consider a fundamental question – whose is to blame for nuclear proliferation? The most plausible answer would be that both demanders and suppliers contributed to the spread of nuclear weapons and fissile materials. The demanders might be compelled to develop nuclear weapons to achieve a national agenda. On the other hand, the suppliers want to promote nuclear exports in order to pursue political and economic interests. Nevertheless, unlike those for the demanders, the global regulations for nuclear suppliers are deficient. Because of the non-binding global export rules, procedures, and verification, the legal enforcement of supply-side nonproliferation is also unsatisfactory. The lack of a supply-side focus may result from scant self-examination on the part of the suppliers, or the weak influence of demanders on the supplier community.

The core of the current nuclear export regime is technology denial. The technology denial regime limits the spread of enrichment and reprocessing by denying the import requests of recipients. This approach does not give the states an option to manufacture and deploy nuclear weapons in a short period of time without depending on foreign resources. No Nuclear Suppliers Group (NSG) member has exported enrichment and reprocessing to states that have no such capabilities since the group's formation. A few major suppliers, mostly enrichment and reprocessing technology holders, have governed the export regime, while other suppliers are passive. Because most recipients demand a nuclear power plant before enrichment and reprocessing, the regime to inhibit proliferation is rather reactive, not proactive.

However, the technology denial regime has resulted in severe opposition from the demander community and the minor suppliers group. They tend to believe that nuclear transfer is not a trust-based trade and that a few suppliers have made exceptions in the export control regime for their own interests. Such exceptionalism causes inconsistent, buyer-dependent, and careless supply policies without effective or reliable constraints from other suppliers. Consistent technology denial is not a solution, but a temporary measure to delay the proliferation issue. While maintaining the current thorough criteria of technology export, it is also required to reform the nuclear export regime to encourage positive interaction among suppliers. The supply-side interaction has to involve all nuclear suppliers for materials, equipment, and technology, not just sensitive technology holders. With this in mind, this study will attempt to identify what types of natural interaction or feedback among suppliers is based on geopolitical and economic self-interests in the nuclear market.

The solidarity of the technology denial regime is very doubtful because technical barriers to proliferation have been largely eroded during the past 60 years. J. Robert Oppenheimer, the scientific director of the Manhattan Project, claimed that nuclear weapons are not too hard to make and that they will be universal if so desired. Nuclear energy created the first situation in which the United States managed perilous technology by solely controlling scientific knowledge (Wellerstein 2010). However, the unprecedented effort failed to limit technology access to permitted actors. Many actors have pursued nuclear capability as a form of an insurance policy or a bargaining chip. Terrorist groups are developing, smuggling, and stealing nuclear materials and technology. Controlling access to nuclear weapons technology has grown increasingly difficult. There are already many different supply routes for nuclear materials, equipment, and technology for nuclear proliferation.

Peter D. Zimmerman, an American nuclear physicist, has shown that there are no technical barriers to nuclear proliferation (Zimmerman 1993). First, the principles and design details of nuclear fission weapons were declassified in 1965 through the Los Alamos Primer. The primer, a secret report until 1965, was reprinted and updated by Robert Serber, a physicist in the Manhattan Project (Serber 1992). There are two types of nuclear bombs: a gun assembly and an implosion device. A gun assembly for highly enriched uranium is straightforward. In addition, the more complicated implosion type for weapons-grade plutonium or highly enriched uranium is widely understood.

As shown in Table 1.2, nuclear bombs consist of several technical components such as fissile materials, reflectors, tampers, moderators, safing, arming, fuzing, firing, detonators, and initiators. Most materials for the components are widely available in the open market, with the exception of nuclear weapons materials. Neither safing, that avoids unwanted explosion, nor arming, that unlocks the safing system, pose a technical challenge. A conventional barometric fuze that causes detonation at a pre-set altitude is suitable for commanding the detonation sequence of a missile's firing system. Moreover, off-the-shelf high-voltage voltage-current pulse generators are perfectly adequate for exploding the bridge wire detonator with adequate simultaneity (Zimmerman 1993).

Second, the principal technical barrier to nuclear proliferation – the production of a significant quantity of nuclear materials – has been eroded. Countries can secure fissile materials by producing them indigenously, purchasing them from the open or black market, or by smuggling. The last two routes are plausible approaches for terrorists. In the current business system, it is difficult to purchase weapons-grade fissile materials in the open market. For this reason, countries may approach an illegal nuclear trade network or find nuclear assistance outside the nuclear nonproliferation regime. Moreover, many handbooks and best-practice guides contain physicochemical properties, handling know-how, and standard engineering procedures of nuclear materials.

Third, nuclear-related dual-use technologies have become essential components of daily life. Distributed nuclear power might improve technical expertise and infrastructure as the foundation for a weapons program (Warrick 2008). Digital computers, high-speed cameras, and non-destructive tests decrease the number of experiments required to design nuclear arsenals. More directly, hot cells and nitric acid are required for medical and industrial isotopes generation as well as wet reprocessing. Despite the different quality, aluminum tubes used in enrichment centrifuge are commonly used in everyday life. Many states have small research reactors that produce radioactive isotopes or support training programs.

Fourth, the black market may offer a cost-effective and fast route to secure fissionable materials, radioactive isotopes, equipment, and technology. The black market is particularly dangerous because this route could provide complete products to technically incapable countries or non-state actors. For example, the international community was greatly surprised by the global nuclear black market of A. Q. Khan. Khan formed and operated a secret proliferation network based on Pakistani uranium enrichment technology. Khan's network exported centrifuge technology to North Korea, Libya, and Iran (Albright and Hinderstein 2005).

However, the international community still has time to fix the export regime. The technology denial regime may be effective when technical barriers are high, but its sustainability comes into question with the erosion of technical barriers. In the long term, we no longer say "absolutely no" to recipients, we must require that they meet certain criteria. At the same time, consistent and responsible nuclear suppliers have to provide recipients with political and economic incentives to keep their nonproliferation commitments. To achieve this goal under the legally non-binding export environment, an interaction-based global export regime is required. The global nuclear export regime has to promote positive interaction and cooperation among suppliers, and accommodate geopolitical and economic self-interests into nonproliferation interests.

Fortunately, political and market incentives encouraging collaboration with other suppliers exist. Anthony et al. commented that “few countries possess all the elements of a full nuclear fuel cycle, and the great majority rely on foreign sources for at least some items that are critical for the development of a civilian or military nuclear programme (Anthony et al. 2007:1).” This means that only a few suppliers can provide full nuclear export packages. With that in mind, this dissertation provides the reform strategies for a global nuclear export regime based on instinctive interaction among suppliers that pursue political and market incentives or self-interests.

Table 1.2 Components and materials for nuclear weapons

Components	Materials for the components
Nuclear materials	Weapon-grade plutonium, highly enriched uranium
Reflector	Natural uranium, depleted uranium, Be-9, Th-232
Tamper	Usually same materials of reflectors
Moderator	Be-9, B-10, HP Graphite
High explosive	PBX, HMX, PETN, RDX
Neutron source	Po-210, Ra-226, Cf-252, Am-244, pulsed neutron tube (deuterium, deuterium-tritium)
Initiator	Exploding-bridge wire detonator, electro-explosive devices, slapper detonator
Safing	Employing physical protection or keeping fissile materials separately
Fuzing	Radar, a barometric altimeter, an infrared rangefinder, delivery time setting using Newton’s laws
Firing	Off-the-shelf high voltage voltage-current pulse generators
Arming	Physically, providing necessary energy to unlock safing

Chapter 2 Review of the State of the Art

This section emphasizes two arguments through a literature review as a rationale for this study: 1) the necessity of this research, and 2) the appropriateness of methodology used in this study (Bolker 1998). Since the 1970s, a number of engineers, scientists, and political scientists have devoted many resources and passionate dedication in order to answer several questions related to why, when, and how states decide to go or forgo proliferation, and what technical systems and institutional measures inhibit the diversion of civilian nuclear programs to military purposes. The review discusses both arguments developed by political scientists and assessments conducted by engineers and scientists. The list of literatures consisted in the review is likely incomplete. There is a bulk of publication on this field, but finings based on the selected studies may be sufficient to support the rationale of this study.

Nuclear engineers have published quantitative system-level assessments that focused on identifying diversion pathways and thief routes, designing technical and institutional barriers, and finding the acceptable proliferation resistance level of nuclear systems. The assessments considered technologies, materials, safeguards, physical protection, and other technical means used to deter, detect, assess, delay, and prevent the theft, undeclared production or diversion of nuclear materials. On the other hand, political scientists developed state-level analyses have concentrated on exploring national or international policies that impact social, political, diplomatic, economic and security conditions determining a state's decision to pursue, or not pursue, nuclear weapons. Also, they investigated how much these policies relatively affect nuclear proliferation or nonproliferation. However, there is still a gap in the literature as well as the export control system to sufficiently ensure that exported nuclear items are used for peaceful purposes only without infiltration of nuclear terrorists.

2.1 State-level theory of nuclear proliferation and reversal: two different views of trade actors

There are three ways to classify proliferation cases. The first way is based on two fundamentally different views on the consequences of nuclear proliferation: nuclear optimists and nuclear pessimists (Feaver 1995; Montgomery and Sagan 2009). As an expansion of the realist view, nuclear optimists have argued that the spread of nuclear weapons could deter states from attacking other nuclear weapon states with nuclear strikes or other significant means due to the fear of nuclear counterattack (Green 1966; Waltz 1981; Mearsheimer 1990; Powell 1990; Waltz 1990; Mearsheimer 1993; Sagan and Waltz 1995; Waltz and Sagan 2003). On the other hand, nuclear pessimists have claimed that the use of nuclear weapons could not be entirely prohibited due to inevitable human errors or miscalculations that occur as part of the very fact that nuclear weapons exist (Feaver 1992; Miller 1993; Sagan 1993, 1994; Karl 1996; Feaver et al. 1997). These scholarly debates were, are, and will be indeterminable disputes, but the view of nuclear pessimists provides the rationale behind nuclear disarmament and nuclear nonproliferation.

The second way is to classify proliferation is through the two necessary conditions for nuclear proliferation: motivation and capability. Many scholarly debates have described a state's motivation for both proliferation and reversal. In other words, they explained willingness to initiate, explore, pursue, acquire, or abandon nuclear weapons. Simultaneously, other scholars have measured a state's nuclear capability – i.e., the opportunity to successfully manufacture nuclear weapons within a given time period. Proliferation motivation drives nuclear capability-building while nuclear capability influences a proliferation decision by reducing thresholds or tolerance regarding the decision to pursue a nuclear option. One extreme line of thought that emphasizes nuclear capability is technological determinism: "once a country acquires the latent capacity to develop nuclear weapons, it is only a matter of time until it is expected to do so (Singh and Way 2004:862)."

The third way to classify proliferation cases, used here, is to investigate two different trade perspectives influencing nuclear proliferation processes or decisions. The two perspectives are demand-side and supply-side approaches. Both approaches could shape motivation and capability, which are important input conditions for nuclear proliferation. The demand-side approach has primarily answered three questions: why states proliferate, why states do not proliferate, or why states give up nuclear options. On the other hand, the supply-side approach has mainly explored why states provide other states with nuclear assistance, and how to prevent sensitive nuclear items from being used for the development of nuclear weapons.

2.1.1 Demand-side approach of decision-making on nuclear weapons development

The demand-side approach explains the spread of nuclear weapons by stating that recipient states want to develop nuclear weapons for their own security, domestic politics, norms, symbolism, and psychological factors. Ogilvie-White Tanya (1996) identified strengths and weaknesses of existing theories for explaining nuclear proliferation and reversal. Due to the complexity of nuclear proliferation, she concluded that the "nuclear proliferation process itself must be viewed as the consequence of a combination of internal and external pressures and constraints, involving influential organizations, groups, and individuals, and their ideas, beliefs, and interests… None of the existing theories of nuclear proliferation provide a satisfactory explanation of the proliferation dynamics [alone] (Ogilvie-White 1996:55)."

The realist view has persisted as one of the strongest explaining variables for nuclear proliferation and reversal (Powell 1990; Waltz 1990; Frankel 1993; Mearsheimer 2001; Waltz and Sagan 2003). William Epstein (1977) considered a security risk as a dominant factor in deciding whether to pursue or forgo a nuclear weapon program, while recognizing other political and economic incentives as less important factors (Epstein 1977). Following Epstein's view, Bruce Bueno de Mesquita and William H. Riker (1982) concluded that the frequency of bilateral conflicts maximizes during a certain middle point and then decreases to zero when all states have nuclear weapons, as the number of nuclear states increases in the hypothetically designated geopolitical system (De Mesquita and Riker 1982). This conclusion supported the nuclear optimists' view. Kenneth Waltz and Scott Sagan (2003) argued that states live in a self-help anarchic environment where they are forced to develop a self-defense capability including nuclear weapons to maintain the balance of power (Waltz and Sagan 2003).

Scott Sagan (1996, 1999) has questioned the realist view. He critically tested a realist hypothesis that "states will seek to develop nuclear weapons when they face a significant military threat to their security that cannot be met through alternative means; if they do not face such threats, they will willingly remain non-nuclear states (Sagan 1996, 1999)." As answers to the question, Sagan proposed three models: a security model, a domestic politics model, and a norms model. In the traditional realist view, the security model suggests that security risks cause nuclear weapon acquisition, eventually leading to a proliferation chain reaction. Although he found the security model was still significant, he suggested historical evidence that the security model cannot describe. On the other hand, the other two models could explain the evidence. In the domestic politics model, nuclear weapons are political objects creating internal debates between advocators and opponents. Critical players in the internal debates are politicians, nuclear authority staffers, and military professionals. The NPT was reinterpreted as a system that supports domestic opponents who discourage the government from pursuing nuclear weapons. The norms model focused on the symbolic meaning of nuclear weapons as a way to showcase a state's modernity and identity to the global society. He argued that some proliferation attempts were not from a leader's cold calculations but from a strong desire for a state's identity. Thus, he emphasized that nuclear disarmament would be essential to dilute the meaning of a "nuclear weapon club," reinforcing nuclear pessimists' view.

T.V. Paul focuses on the reasons why governments relinquish nuclear weapons or give up a nuclear weapon program (Paul 2000). He discusses the effects of nuclear power and nonproliferation norms while finding the security environment as a determining variable for nuclear disarmament. In his explanation, developing nuclear bombs ironically renders states vulnerable to external attacks – the traditional security dilemma. Other scholars also hold a similar view in that nuclear proliferation causes a negative security impact by threatening adversaries and loosening ties with key allies (Reiss 1988; Davis 1993; Davis and Frankel 1993; Reiss 1995).

Etel Solingen (1994, 1998, 2007) repeatedly argued that export-oriented industrialization strategies, for example those of Japan, South Korea, Taiwan, Egypt (under President Anwar El Sadat), South Africa, Brazil and Argentina, would make states reluctant to initiate proliferation because of the huge potential loss of international investments and economic benefits (Solingen 1994, 1998, 2007). Liberalizing regimes probably help enhance market competitiveness and positive reputations within the international community by forming an attractive environment for foreign investments. Such a regime may think of a nuclear option as a path to slowed economic growth and to lost international prestige. On the other hand, autarchic coalitions may pursue isolated economic development regimes that make states more likely to initiate proliferation if they have enough motivation.

The role of individual leaders was emphasized by Mitchell Reiss (1988, 1995), especially regarding nuclear reversal, as they seek to retain political power and win public popularity (Reiss 1988, 1995). He reported a few examples including F. W. de Klerk of South Africa, Carlos Menem of Argentina, Fernando Collar of Brazil, and Nursultan Nazarbayer of Kazakhstan. Jacques Hymans (2006) invoked leaders' conceptions of national identities to explain why states pursue or abandon nuclear proliferation (Hymans 2006).

Maria Rost Rublee (2008) focused more on psychological factors to describe the nearly universal signing of and compliance with the NPT, as well as the reasons why only four states have acquired nuclear weapons (Rublee 2008). David Krieger (2005) pointed out that many states have not pursued nuclear weapons due to low technical capability, secure alliances, the NPT norms, nuclear weapon free zone agreements, perception of negative consequences, and national self-image (Krieger 2005). Asal and Beardsley (2007) concluded that "nuclear weapons provide more than prestige, they provide leverage. They are useful in coercive diplomacy and this must be central to any explanation of why states acquire them (Asal and

Beardsley 2007:296).” Kurt Campbell et al. (2004) argued that the changes in international circumstances lead to quickly build proliferation experiences and potential nuclear capabilities, if sufficient motivations are present (Campbell et al. 2004).

Sonali Singh and Christopher R. Way (2004) quantitatively simulated decision-making processes on whether a state moves toward the next step or goes back to the previous step, within four different stages from “no interest” to “explore”, “pursue”, and “acquire” (Singh and Way 2004). There were three groups of determinants including technological determinants (i.e. industrial and economic capabilities), external determinants (i.e. external security threat), and internal determinants (i.e. democracy, democratization, global democracy, economic openness, economic liberalization, dissatisfaction, symbolic motivations). The relative importance of these factors was determined by historical datasets. They concluded that greater development allowed states at the low development stage to have greater ability to acquire nuclear bombs, while advanced states reacted in the opposite way. They also found that economic interdependence and liberalization were positively correlated with nuclear nonproliferation. On the other hand, they did not find support for the effectiveness of extended nuclear deterrence to reduce proliferation risk.

Dong-Joon Jo and Erik Gartzke (2007) quantitatively measured “whether a state possesses nuclear weapons” or “whether a state has an active nuclear weapons development program (Jo and Gartzke 2007).” They classified specific data into two groups: opportunity, mainly the potential to build nuclear weapons; and willingness, the eagerness of a state to possess nuclear weapons. They considered the degree to which nuclear weapons knowledge is diffused and released into more open dimensions with time. Economic capabilities were positive variables to possess nuclear weapons but not to initiate proliferation. Democracies were negatively associated with initiating proliferation, but displayed the opposite behavior in acquiring nuclear weapons. Conventional security risk is strongly related to both initiation and acquisition, whereas diplomatic isolation and domestic unrest have no effect. Global and regional powers are more likely to pursue and acquire nuclear weapons. Jo and Gartzke also found that extended nuclear deterrence reduces the probability of acquiring nuclear weapons, but it has no effect on the initiation of the program. Interestingly, they argued that the longer a state does not pursue nuclear weapons, the less likely it proliferates. The longer states have nuclear weapons programs, the less likely they are to acquire nuclear weapons.

2.1.2 Supply-side approach of decision-making on nuclear materials and technology export

The supply-side approach describes the spread of nuclear weapons in that suppliers want to offer nuclear assistance to boost their own economic profits, strategic advantages, and political benefits. Nuclear assistance may help recipient states to develop nuclear weapon capability or ease a proliferation decision. Some studies emphasized the necessity of nuclear assistance to build the nuclear weapon capability of less industrialized countries (Beaton and Maddox 1976; Mozley 1998). In that respect, the Atoms for Peace program faced an inevitable dilemma: that civilian assistance might provide a stepping-stone to proliferation, if a proliferation motivation exists (Meyer 1986). There is a large body of demand-side publications on nuclear proliferation, but only a small volume of studies on supply-side considerations of nuclear proliferation.

Stephen Meyer (1986) evaluated a quantitative “nuclear propensity” that is defined as the time-dependent extent of a nation’s explicit predisposition toward initiating the manufacture of nuclear weapons (Meyer 1986). In his motivational hypothesis, political and military conditions are needed to motivate a proliferation decision, even if a state has enough nuclear capability. He argued three motive incentives: 1) security incentives, 2) domestic politics incentives, and 3) external incentives. These incentives were subdivided into 15 motive conditions: nuclear threat, latent capacity threat, overwhelming conventional threat, regional power status/pretensions, global power status/pretensions, pariah status, domestic turmoil, loss of war, regional nuclear proliferation, defense expenditure burden, nuclear ally, legal treaties enforce, risk of unauthorized seizure, possible nuclear intervention, and peaceful reputation.

After a long drought, there has recently been a surge of interest in the supply-side studies of nuclear proliferation. The following compares the major research works from Matthew Kroenig (Kroenig 2007, 2009a, b) and Matthew Fuhrmann (Fuhrmann 2008, 2009a, b), and discusses the correspondence among scholars on civilian nuclear cooperation and the proliferation of nuclear weapons (Bluth et al. 2010).

Matthew Kroenig examined why states provide sensitive nuclear assistance, and has argued that sensitive nuclear assistance contributes to nuclear proliferation by advancing technical abilities (Kroenig 2009a, b). He defines sensitive nuclear assistance as “the international transfer of the key materials and technologies necessary for the construction of a nuclear weapons arsenal to a non-nuclear weapon state”. The definition corresponds to the practical consensus about enrichment and reprocessing as sensitive nuclear assistance (Kroenig 2009b).

Explaining upon Kroenig’s research focus from sensitive assistance to all kinds of nuclear assistance, Matthew Fuhrmann examined why states provide civilian nuclear assistance, and whether civilian nuclear assistance increases the likelihood of both the onset of a nuclear weapon program and the acquisition of nuclear weapons (Fuhrmann 2009a, b). He measured civilian nuclear assistance as the number of nuclear cooperation agreements, although he noted that “a large percentage of nuclear cooperation agreements are subsequently canceled and do not result in the transfer of nuclear material or technology” (Bluth et al. 2010:189).

Kroenig concluded that “states that receive sensitive assistance will be more likely to acquire nuclear weapons” (Kroenig 2009b:166) and that civilian nuclear assistance has no effect to proliferation. However, civilian nuclear assistance and NPT membership may decrease the probability that a state will acquire nuclear weapons (Bluth et al. 2010). On the other hand, Fuhrmann concluded that "all types of civil nuclear assistance raise the risks of proliferation" (Fuhrmann 2009a:8). Civil nuclear assistance contributes to the initiation of a nuclear weapon program and the manufacture of nuclear weapons. Fuhrmann's paper warns the sellers of civilian nuclear technology – including the United States, Russia, France, Canada, Republic of Korea, Japan and others.

Kroenig based his arguments on technical and strategic reasons that were later backed by statistical analysis (Kroenig 2009b). First, nuclear assistance with a proven design helps scientists and technicians to readily overcome the learning curve and concentrate on reproducing the proven design. Second, nuclear assistance "can reduce the amount of trial and error needed to successfully operate nuclear facilities." Third, nuclear assistance "can help states to economize on the costs of nuclear development." Fourth, sensitive nuclear assistance "can help a state to avoid international scrutiny" by reducing the time required to manufacture nuclear weapons.

Fuhrmann argued that nuclear assistance could reduce the expected costs of nuclear weapon programs by increasing technical nuclear capability (Fuhrmann 2009a). Regarding motivation perspectives, he emphasized that nuclear assistance "inspires greater confidence among leaders that the bomb could be successfully developed" within relatively short periods of time. This mitigates "considerable political and economic costs such as international sanctions, diplomatic isolation, and strained relationships with allies." Also, nuclear assistance stimulated "scientists [to] convince the political leadership that producing a nuclear weapon is technologically possible and can be done with relatively limited costs." He noted that this description is still effective in the absence of a security threat.

This connection between nuclear assistance and proliferation raises a significant question regarding why states provide nuclear assistance. Kroenig (Kroenig 2009a) offered three strategic reasons. First, "the more powerful a state is relative to a potential nuclear recipient state, the less likely it will be to provide sensitive nuclear assistance to that state." Second, "states will be more likely to provide sensitive nuclear assistance to states with which they share a common enemy." Third, "states that are dependent on a superpower patron will be less likely to provide sensitive nuclear assistance."

The first reason may be important when a nuclear transfer threatens the original supplier by increasing the recipient's nuclear capability. There are several historical contradictions in which the more powerful states provide sensitive assistance to the weaker states, although many of them can be explained by the second reason. Conversely, powerful states might be more likely to provide sensitive assistance to weak recipients whose nuclear advancement would not pose a danger to them. In the second reason, sensitive nuclear assistance would impose strategic costs on rivals. For example, France provided Israel with nuclear items for its rivalry against Egypt; China supplied Pakistan with nuclear assistance against India. The third reason is supported by that superpowers want to maintain a hegemonic non-proliferation structure that could be threatened by the spread of nuclear technology. Thus, superpowers often appear at the forefront of counter-proliferation. This increases the potential economic, security and diplomatic costs of proliferators that are largely dependent to superpowers.

Fuhrmann offered five reasons why states trade in dual-use weapons of mass destruction technologies (Fuhrmann 2008) or why states sign civilian nuclear cooperation agreements (Fuhrmann 2009b). First, “suppliers are more likely to export nuclear technology to their military allies than non-allies.” Second, “suppliers export less nuclear technology to states with which they are engaged in militarized conflict.” Third, “suppliers are likely to export nuclear technology to enemies of enemies.” Fourth, “suppliers are likely to export nuclear technology to states that are enemies of the most powerful states in the international system.” Fifth, “democratic nuclear suppliers are more likely to offer peaceful nuclear assistance to democracies than to non-democracies”.

Fuhrmann’s second argument is straightforward; he explained the first and the third arguments by stating that providing nuclear assistance can strengthen allies and alliances as well as relationships with enemies of enemies. His fourth argument may be closely related to the third argument while his fifth argument may be closely related to the first argument. These fourth and fifth arguments are specific versions of the previous two arguments. He suggested that suppliers ignored the proliferation risk induced by providing civilian nuclear assistance due to economic and strategic gains. However, Christoph Bluth et al. has commented that nuclear suppliers did not share Fuhrmann’s view on increasing proliferation risk through civilian nuclear assistance (Bluth et al. 2010).

The studies of the two scholars can raise issues related to nuclear proliferation and nuclear assistance based on statistical analysis. Sensitive assistance was measured by export and import of enrichment and reprocessing facilities; civilian assistance was measured by the number of research reactor trade and the number of nuclear cooperation agreements. However, nuclear assistance cannot be simply measured by using statistics. It is a much more complex interaction between suppliers and demanders. These studies lacked engineering and business discussions about nuclear power programs. More importantly, statistics may raise another issue by showing a positive correlation between nuclear assistance and proliferation, but it is difficult to provide detailed causality and specific solutions.

Bluth et al. concurred that statistical analysis cannot suggest any meaningful causation, because the number of cases of nuclear proliferation is small (Bluth et al. 2010). They showed that many civil nuclear technology recipients did not attempt to proliferate. At the same time, they asserted that membership in the NPT could explain the scarcity of attempts to proliferate in Japan, Qatar, Saudi Arabia, and South Korea. The NPT is closely related to the United Nations Security Council's rights to impose severe economic sanctions that increase political and economic cost of nuclear proliferation. Bluth and Kroenig expressed skepticism on Fuhrmann's argument, because it cannot explain the situation of providing access to nuclear power technology in exchange for the renunciation of nuclear weapons. Bluth et al. claimed that a decision to proliferate requires technical cooperation, as opposed to technical cooperation initiating a nuclear weapons program.

Interestingly, David Boyle focused on proliferation risk involved in education and training related to nuclear program (Boyle et al. 2010). He emphasized that providing education is insufficient to judge whether assistance contributes to proliferation, while the content of education is important. His argument is that the content of the education leads states to be less or more likely to proliferate. He emphasized that the United States should develop properly designed and administrated assistance programs, because that tends to reduce proliferation risk.

There are several studies that consider the relationship between supply-side competition and nuclear proliferation. Jennifer Scarlott (1992) argued that “inconsistent application of nonproliferation policy can encourage a problem country to use the threat of nuclear proliferation as a foreign policy tool” (Scarlott 1992). The inconsistent applications may be explained by supply-side competition. Mark J. Moher (1985) commented that a supplier under high competition would think “if we do not supply, someone else will, therefore why not us” (Moher 1985). For the global nuclear control regime, Fred McGoldrick (2011) commented that “NSG guidelines are essential to ensuring that civil nuclear trade is not diverted to nuclear weapons or terrorist use and that suppliers do not compete in the international market by minimizing nonproliferation controls” (McGoldrick 2011).

2.2 System-level assessments of proliferation risk

Since the nuclear holocaust in Hiroshima and Nagasaki, the world has experienced consecutive nuclear proliferations following the U.S. in 1945: the Soviet Union in 1949, the United Kingdom in 1952, France in 1960, China in 1964, and Israel circa 1967 (Broad 2008). Meanwhile, the IAEA safeguards, which had insufficient authority to control a chain reaction of proliferation until the ratification of the NPT in 1970, were expected to enter a new era after that. However, the Indian nuclear test in 1974, with material and facilities supplied for peaceful purposes, dashed these hopes (Kang 2005). In 1977, fear of nuclear weapons proliferation led U.S. President Jimmy Carter to ban domestic commercial reprocessing. He tried to encourage other states to follow the U.S. nonproliferation policy (Xoubi 2008).

The Carter administration commissioned two studies: 1) the Nonproliferation Alternatives System Assessment Program (NASAP) between 1976 and 1980, conducted by the U.S. DOE (U.S. DOE 1980); and 2) the International Nuclear Fuel Cycle Evaluation (INFCE) from 1977 to 1980, carried out by 8 working groups from 66 countries and 5 international organizations (Skjoldebrand 1980). These studies sought to discover how to reform nuclear energy systems toward proliferation resistance. The NASAP concluded that the light water reactor once-through fuel cycle (or open fuel cycle) is the most resistant fuel cycle among all options. However, both studies concluded that “no technological arrangements would be immune to proliferation in the face of a state determined to obtain a weapons capability” (PRPPWG 2006b). A similar conclusion was reached by a U.S. study group sponsored by the Ford Foundation (Keeny 1977). Similarly, Harold A.

Feiveson (1978)'s review studies concluded that no fuel cycle can constitute a silver bullet against diversion of civilian nuclear power program (Feiveson 1978). These conclusions particularly emphasized that the connection between civilian nuclear power and weapons proliferation is a problem that technology cannot handle alone.

There are two methodological categories of proliferation resistance assessments of a reactor system, a commercial fuel cycle, or transportation and storage of nuclear materials: attribute analysis and scenario analysis. Attribute analysis quantifies proliferation resistance based on various attributes related to nuclear power systems, whereas scenario analysis compares proliferation risk involved in specific pathways to develop nuclear weapons. As one of the attribute analyses, multi-attribute utility calculates proliferation resistance by aggregating quantified metrics with relative weighting factors. The most utility models concentrate on only technical aspects of proliferation issues. The comparative studies of proliferation resistance assessments may be well performed by attribute analysis. Also, the relative weighting factors heavily depend on expert views. As an example of a scenario analysis, probabilistic risk analysis determines proliferation resistance. Almost every proliferation study using the probabilistic risk analysis suffers from the lack of available data for the target system, especially the causal probabilistic relationships of events leading to failures. This scenario analysis has an advantage of examining details of selected systems, but it is difficult to compare diverse alternatives.

2.2.1 Attribute analysis on nuclear proliferation vulnerability of materials and technology

Motivated by the NASAP and the INFCE, several scholars attempted to develop quantitative assessments for measuring proliferation risks (Liner et al. 1977). Ioannis A. Papazoglou et al. (1978) delineated the proliferation pathways for nuclear power systems, scoring them by multi-attribute utility analysis (Papazoglou 1978). There were two sets of five technical attributes with different levels of importance for both crisis and non-crisis situations. The minimum value among pathways was considered as the proliferation resistance of a fuel cycle system.

Carolyn D. Heising et al. (1980) used multi-attribute analysis to quantify the relative proliferation risk of a once-through cycle, a light water reactor-breeder cycle and, a thorium converter-breeder cycle (Heising et al. 1980; Heising 1982). Pre-defined utility functions produced dimensionless numerical values that would be multiplied by the relative importance factors. The summation of these calculated values gave one single risk indicator for each fuel cycle alternative. The relative weighting factors were generated by conducting surveys of experts.

Shahid Ahmed and A. A. Husseiny (1982) expanded attributes and ranked proliferation risks of 14 alternative routes, based on five acquisition factors: resources, difficulty, cost/schedule, and risks, weapons capability (Ahmed and Husseiny 1982). Each attribute had a unique utility curve that gave the expected utility value from zero to unity. P. Silvennoinen and J. Vira

(1981, 1986) assessed the risk of clandestine military construction and a diversion from a civil program (Silvennoinen and Vira 1981, 1986). They developed two time-dependent models based on utility theory and fuzzy measure theory. After that, there were few studies until the mid-1990s due to the small number of possible alternatives (Heising 1982).

The studies on Management and Disposition of Excess Weapons Plutonium of U.S. National Academy of Science, conducted in the mid-1990s, revived system-level activities regarding the assessment of proliferation risk. The analysis described intrinsic proliferation barriers to acquisition of the plutonium from its storage site, diluents and fission products, and nuclear weapons (Kang 2005). The studies provided the basis for future activities like Technical Opportunities for Increasing the Proliferation Resistance of Global Civilian Nuclear Power Systems (TOPS) (NERAC 2000b; PRPPWG 2006a).

Krakowski used the pair-wise comparison method to determine weighting factors for the multi-attribute utility approach (Krakowski 1996, 2001). Using the electrical circuit model, Won Il Ko et al. (2000) attempted to develop quantitative models linked with multi-attribute utility theory, based on factors suggested by plutonium deposition studies (Ko et al. 2000).

To improve the proliferation resistance of civilian systems, the U.S. DOE established TOPS from 1999 to early 2001 to draw short-term and long-term areas of technical research. They specially underlined the necessity of research and development related to high burn-up fuels, thorium/uranium fuels, non-fertile fuels, and advanced fuel cycle concepts.

The task force developed the barrier framework first, and identified both intrinsic and extrinsic barriers to a proliferating state (NERAC 2000a, b). TOPS attributes, however, involved a great deal of subjectivity, uncertainty, and inapplicability to quantitative assessments. It suggested proliferation resistance assessments as an essential part of the engineering design. This task force also required the strengthening of existing institutional measures like safeguards and export controls to manage new proliferation resistant technologies.

In recent years, two vigorous international studies have been ongoing: 1) International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), and 2) Proliferation Resistance and Physical Protection Working Group (PRPPWG). Since 2000, the INPRO has created innovative nuclear energy systems that ensure economic competitiveness and safety while addressing nuclear waste and minimizing the connection between civil uses and military diversion (Gowin and Kupitz 2001). This approach is oriented toward bottom-up evaluation within a hierarchical structure. This method first defines intrinsic and extrinsic indicators and their limits, and then assesses the fulfillment of requirements and basic principles (IAEA 2004; Hurt 2005). The INPRO method has been tested by member states via their planned nuclear generation reactor system (IAEA 2009a, b).

In 2004, using a refined attribute analysis, William S. Charlton reported an intrinsic time-dependent multi-attribute utility analysis to the Blue Ribbon Commission. This compared proliferation resistance of fuel cycle options (Waltar et al. 2004). The method tracks the material flow of a unit mass of nuclear materials from input to output into disposal, especially focusing on the fuel cycles associated with light water reactors. He concluded that a closed fuel cycle has potential advantages if reprocessing can be thoroughly managed and safeguarded, while proliferation resistance of the once-through cycle decreases with time (Charlton 2004; Charlton et al. 2007). The approach has five metrics: attractiveness level, concentration, handling requirements, type of accounting system, and accessibility. The relative weighting factors were developed by a multi-organization working group.

2.2.2 Scenario analysis of overall nuclear system responses to nuclear proliferation

In parallel with the INFRO, the Generation IV International Forum has developed since 2001 the next generation nuclear energy systems with the goal of making them the most unattractive diversion path or theft route (OECD/NEA 2010). The form covered the broadest range of issues including proliferation resistance, i.e. diversion, misuse, clandestine replication, abrogation, and physical protection, i.e. sabotage, theft of materials for nuclear weapon and radiological dispersal devices (Takaki et al. 2005). This approach evaluates the system response against identified pathways and threats to specific targets by measuring technical difficulty, cost, time, fissile material type, detection probability, and detection resource efficiency (PRPPWG 2006b). Threat scenarios encompassed motivations of states based on socio-political information. The method has been applied to the Example Sodium Fast Reactor case study (PRPPWG 2009) and efforts have been made to develop a mutual understanding with the INPRO approach (Gen-IV International Forum 2009).

The Japan Atomic Energy Agency is focusing on a quantitative proliferation resistance assessment for a commercial fast reactor system through the consideration of technical and material barriers (Inoue et al. 2004). However, D. Grant Ford noted that this assessment cannot avoid subjectivity and duplicability of some attributes (Ford 2010). The Simplified Approach for Proliferation Resistance Assessment of Nuclear Systems was developed by combining this Japanese method and the TOPS. This divided diversion has four stages: diversion of fissile materials, materials transportation to a facility site, materials transformation into a weapons-usable form, and weaponization (Greneche et al. 2006). The method assesses the resistance caused by barriers from the current stage to the next, based on the barriers' effectiveness scored by expert groups.

Brookhaven National Laboratory is developing a probabilistic methodology for evaluating proliferation resistance of several diversion pathways (Yue et al. 2005). This method requires defining the failure rates of each diversion process step during possible event sequences. Similarly, Sandia National Laboratory's risk-informed probabilistic analysis is capable of simulating a dynamic analysis that can compare outcomes of feasible proliferation pathways (Blair et al. 2002). In addition, Pacific Northwest National Laboratory produced probabilistic results to assess proliferation resistance of fuel cycle systems by using the Bayesian Network (Coles et al. 2009). Fuzzy theory was applied to evaluate proliferation resistance of technologies (Li 2006) and efficiency of safeguards (Matsuoka et al. 2002).

2.3 Research rationale from a gap in the literature

Several international studies have strongly encouraged scholars to assess the proliferation risk of specific nuclear fuel cycle systems, and develop state-level theories about nuclear proliferation and reversal. Nuclear engineers have published quantitative system-level assessments that focused on identifying diversion pathways and thief routes, designing technical and institutional barriers, and finding the acceptable proliferation resistance levels of nuclear systems. On the other hand, political scientists developed state-level analyses that focused on national or international policies that impact social, political, diplomatic, economic, and security conditions determining a state's decision to pursue, or not pursue, nuclear weapons.

However, there are still missing gaps in the literature. The missing gaps should be filled by further studies on how to prevent peaceful nuclear technology from being used for the development of nuclear weapons. First, such studies require more supply-side analysis. So far, despite the importance of supply-side aspects in nuclear proliferation, the majority of past studies have focused on the demand side. Koenig also found that "scholars have explained why states want nuclear weapons… but have not examined the supply side of nuclear proliferation" (Kroenig 2009a:113). The lack of a supply-side focus may result from scant self-examination on the part of the suppliers, or the weak influence of demanders on the supplier community.

Second, future studies require in-depth case studies. Many statistical analyses have not succeeded in analyzing reliable quantitative datasets and finding critical causal relationships among decision-making components. Some scholars have commented that statistical analysis cannot suggest any meaningful causation because the number of cases of nuclear proliferation is small. Also, they can see only averaged values, rather than a broad spectrum of causes-results.

Third, future studies require more examination of various competition levels. Most existing case studies only looked at the impact of excessive supply-side competition, without attempting the development of an underline mechanism. Most cases of nuclear export have not occurred in a context of high supply-side competition. With the rise of new suppliers, it is necessary to investigate an evolving spectrum of competition based on structured and focused case studies.

Fourth, future studies require bringing causal components into a single map of a system-wide method. This will allow us to bring complex components and interactions into a causal relationship. Moreover, such system thinking will help us to understand how every factor interacts with others and within an overall system.

Table 2.1 Considering factors for state-level and system-level proliferation risk assessment

	Papazoglou, 1978	Silvennoinen, 1981	Ahmed, 1982	NAS, 1995	Ko, 2000	NAS, 2000
Technical difficulty	Status of info/ Radioactivity/ Existence of criticality problems	The ease of accessibility to & unaccountability of the flow of source material	Technical difficulty/ Risks to personnel/ Availability of info/ Accessibility of fissile mass	Chemical form/ Radiological hazard/ Containment (deep burial)	No. of process steps/ Shielding/ Remote operation requirement/ Radiation dose/ Physical barrier (container)	Mass, bulk, radiation/ Difficulty in disassembly and separation of Pu
Detectability	Warning period	Detectability of weapons development	Risk to project detection/	Mass and bulk/ Containment/ Institutional barriers	Measurement uncertainty	Acquisition signatures/ Processing signatures
Material quality	RgPu, WgPu, HE-U233, or HE-U235	Quality of the separated material	Rate of weapons grade fissile mass production/ Weapon reliability	Isotopic composition	Mass of diverted material for one SQ	Deviation from WgPu (barrier against use)
Resource	Direct and operating costs/ Nuclear energy cost/ Sanctions	Minimum cost/ Marginal cost of modifying a civil nuclear facility	Costs/ Facility requirements/ Instrumentation/ Human resources			
Time required	Weapon development time	Minimum time required	Year to completion		Lead time to set up process/ Time to process one SQ	
Others					Transport of special nuclear material	

Table 2.1 Considering factors for state-level and system-level proliferation risk assessment (continued)

	TOPS, 2001	NPAM, 2003	Charlton, 2004
Technical difficulty	Critical mass/ Spontaneous neutron/ Heat/ Radiation/ Difficulty in material separation/ Remote handling/ Concentration/ Difficulty and time of operations/ Complexity and safety of modifications/ Manual versus automatic, remote operation/ Frequency of operational opportunity to divert/ Availability and access to information	Chemical form/ Failure probability of facility barriers	Physical barrier/ Size & weight/ Radiation Dose/ Fuel load type/ Separability
Detectability	Passive and active detection capability/ Hardness of radiation signature/ Uniqueness/ Uncertainties / Type of material and processes/ Form of material/ Effectiveness of observable environmental signatures/ Minimum detectability limits/ Ability to detect illicit activities/ Response time/ Precision and frequency of monitoring/ Degree of incorporation into process and operation/	Warning time/ Detection probability	Frequency of measurement/ Uncertainty of measurement/ Unidentified movement/ % of processing with item accounting
Material quality	Amount of potentially weapons useable material	Material attractiveness	DOE attractiveness level/ Heat/ Even numbered Pu/ Inventory/ Concentration
Resource	Cost of modifications/ Facility throughput/ Dual-use skills and knowledge/ Applicability of dual-use skills/ Availability of dual-use information/ Need for specialized equipment/ Degree of enrichment/	Costs	
Time required	Time required to modify/ Time materials in a facility or process are available to proliferant access	Production time	
Others	Remoteness/ co-location of facilities/ Administrative steps for access/ Physical protection and security arrangements/ Existence of effective back-up support/ Effectiveness of access control and security		

Table 2.1 Considering factors for state-level and system-level proliferation risk assessment (continued)

	Stephen Meyer, 1984	Sagan, 1996	Singh, 2004	Jo, 2007
Security risks	Nuclear threat/ Latent capacity threat/ Conventional threat/ Loss of war/ Possible nuclear intervention	Security threat/ Proliferation chain reaction	Enduring rivalry/ Frequency of dispute involvement	Conventional threat/ Nuclear threat/ Diplomatic isolation
Internal factors	Domestic turmoil/ Defense burden/ Unauthorized seizure	Advocators' lobby/ Nationalists		Domestic unrest
Norms	Peaceful reputation	Symbol of nuclear weapons/ NPT	Dissatisfaction/symbolic motivations	NPT membership/ NPT population
International prestige	Regional power status/ Global power status/ Pariah status	Int'l isolation/ Desire for int'l prestige		Major power/ Regional power
Latent capacity	Technical and industrial weapons production capability		GDP per capita/ Industrial capacity (steel production and electricity generating Capacity)	U deposits/ manpower / Iron & steel production/ Energy consumption/ Electricity production capacity/ HNO_3 production capacity/ Degree of knowledge diffusion
International interdependence	Nuclear ally		Exports and imports among GDP/ Change in trade ratio/ Alliance with great power	Nuclear defense pact
Political opposition	Legal treaties enforce	Domestic debates	Democracy/ Democratization/ Percentage of democracies	Democracy

Chapter 3 Research Design

This dissertation attempts to suggest reform strategies for a global nuclear export regime. Its goals are reducing proliferation risk and preventing terrorist infiltration in nuclear trades. To achieve the research purpose, two research questions have been explored to develop realistic, effective, legitimate, and evidence-based policy recommendations. The two questions are intended to reveal critical interdependent interactions among nuclear suppliers. Answers to these questions may fill an existing gap in the literature. To date, most research has focused on the demand side of nuclear proliferation, not the supply side of nuclear proliferation. This study suggests a new nuclear supply feedback model that determines nonproliferation conditions of supply. To test the model, three nuclear export cases in the 1950-70s were carefully selected and thoroughly investigated to answer the questions. Based on the case studies, the causal relationships of the nuclear supply mode have been confirmed. To visually describe the complex causalities, this study utilized the causal loop diagram of system thinking. This allowed researchers of the case studies to effectively elaborate supply-side feedback that reinforces nonproliferation or accelerates proliferation. This chapter describes research questions and approaches while justifying methodology and case selection.

3.1 Research questions and approaches

Nuclear export is not a single-stage game, but a multistage game. The commonality of a long-term vision between suppliers and demanders is deemed necessary to reduce the potential risk of nuclear proliferation and terrorism in nuclear trades. However, case-specific nuclear assistance has contributed to the exploration, pursuit, or acquisition of nuclear weapons. In the worst-case scenario, peaceful nuclear transfer was diverted to the manufacture of nuclear weapons. To elucidate the connection between nuclear power and nuclear weapons, thus study's research questions focus on two perspectives: interaction or feedback among nuclear suppliers, and the importance of the role of nuclear power plant suppliers.

First, the supply-side weaknesses of nuclear nonproliferation can be more effectively supplemented by interdependent feedback among nuclear suppliers based on self-interest. This is because a recipient has limited influence on the supply side, or may be due to a supplier with unreliable self-examination procedures. Under weak nonproliferation conditions of supply, recipient countries are less likely to voluntarily make or adhere to high-level commitments of nuclear nonproliferation and nuclear security. With limited time and national resources, the recipient countries primarily aim to create nuclear capability as soon as possible.

Thus, nuclear suppliers are responsible for ensuring that nuclear trading for peaceful purposes does not inadvertently contribute to nuclear weapon proliferation and terrorist intervention. The responsibility of nuclear suppliers to commit to nonproliferation during nuclear trade is significant. That commitment will encourage recipients to establish long-term nonproliferation treaties and thus assure non-terrorist use. Moreover, the feedback from one supplier to another might determine whether an overall nuclear export regime moves forward – to obtaining more nuclear power without nuclear proliferation – or backward.

Second, all nuclear suppliers, including sensitive technology holders, are required to be more active, proactive and cooperative. They share equal responsibilities in preventing recipients from developing nuclear weapons or supplying terrorists. Nuclear export control regimes in the past have focused on limiting the spread of enrichment and reprocessing technology; any nuclear suppliers without such technologies are rather passive in the export regime. The engagement of nuclear power plant suppliers is critical, since most recipients initially demand nuclear power plants rather than enrichment or reprocessing. Also, a nuclear power plant, as a primary source of revenue, is an effective, proactive and insensitive tool regarding the establishment of interdependence with recipients. This interdependence constitutes economic and political barriers to nuclear proliferation.

The participation of all suppliers in creating an effective nuclear export regime is important, with an increasing role for emerging nuclear suppliers. Six suppliers – the United States, the Soviet Union, the United Kingdom, France, Canada, and Germany – supplied nearly 90% of installed global nuclear capacity before the Chernobyl accident, whereas new nuclear suppliers have constructed about 30% of new installations of nuclear capacity after the accident. Such a disparity between regime-governors and real exporters may increase, in turn increasing proliferation vulnerability of nuclear trade. Until now, international nuclear trade has been based on bilateral agreements, not legally binding treaties. This has resulted in inconsistent supply decisions that might encourage some suppliers to depart from existing export norms in the name of self-interest – or stimulate a few recipients to exploit proliferation as a foreign policy tool.

Despite the importance of supply-side entities in nuclear proliferation, there has been scant research regarding the supply side. To fill this gap in the literature, it is important to compare the differences in how nuclear suppliers behave in cases of nuclear proliferation versus cases of nuclear reversal. This comparison allows us to identify supply-side feedback that influences nonproliferation conditions of nuclear supply. The export approaches of nuclear suppliers should aim at reducing the risk of nuclear proliferation and terrorist intervention, while preserving a mutually beneficial partnership with a recipient. To discover strategies that would reform the nuclear export regime and satisfy these criteria, the first research question is:

> What types of supply-side feedback influence nuclear suppliers to determine nonproliferation conditions of nuclear supply?

In order to more specifically investigate how the interaction among nuclear suppliers changes in different situations, supply-side competition has been chosen as an explanatory variable. The competition includes both political and economic aspects, resulting in substantial variations for the supply-side interaction. Nonproliferation conditions of nuclear supply were influenced by the supply-side interaction. The supply-side competition is a variable that reflects the mutual interactions of nuclear suppliers based on self-interest, and allows us to formulate reform strategies for an international nuclear export regime based on market mechanisms. To improve our understanding of complex, interdependent types of feedback among nuclear suppliers, the second research question is:

> How political and business competition among nuclear suppliers affects the feedback structures?

Among several research steps shown in Figure 3.1, this study first describes the rationale for nuclear export case selection in the following sub-section. The next section describes a hypothetical feedback structure of nuclear supply, with unchanged nuclear market characteristics. The selected cases confirmed that nuclear suppliers have made different commitments and implementation efforts regarding "*recipients proliferated*" to "*recipients tried but failed*." Three in-depth historical export cases from the 1950s-1970s are explored using qualitative observation, in order to reveal causal relationships for the two research questions. The causal relationships are tested and modified by applying them to a current trade case. Based on the causal mechanism, reform strategies for a nuclear export regime are suggested by enhancing existing market feedback that reinforces nonproliferation.

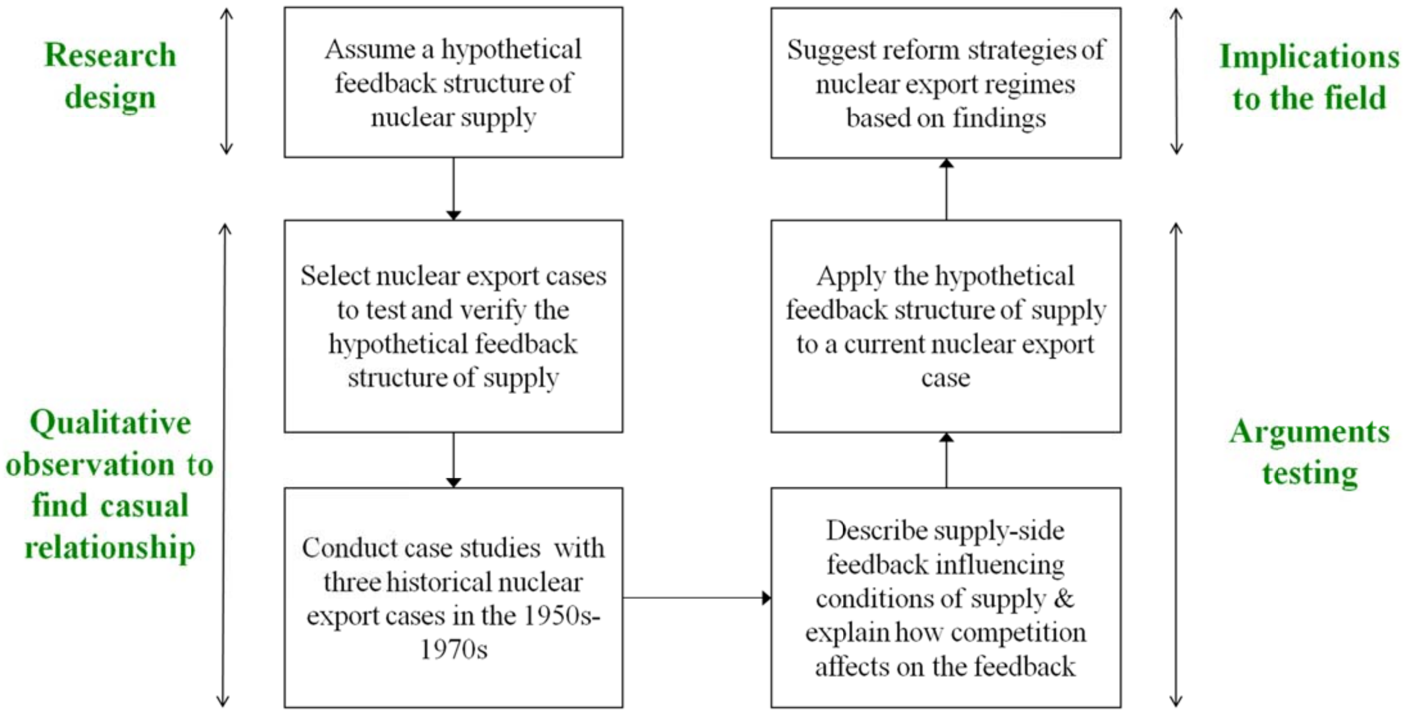


Figure 3.1 Research process flowchart

3.2 Methodology

Two research methods have been combined to analyze complex nuclear export decision-making processes: a combined method of "controlled cases compassion" and "system thinking." The controlled comparison of nuclear export cases significantly improves understanding of focused problems and carefully identifies causal relationships based on historical evidence. The system thinking integrates causalities, interactions, or feedback among involving factors into a single system, expresses the findings in an intelligible diagram, and predicts possible outcomes of policy suggestions based on the causal relationship. This section briefly explains two methods to help readers fully understand the following chapters.

3.2.1 Controlled comparison of cases

A controlled comparison of cases is conducted to explore how the different results – as dependent variables – can be produced by the different causes – as independent variables (Van Evera 1997). As schematically illustrated in Figure 3.2, the descriptive method of controlled comparison conducts simultaneous paired qualitative observation in two or more cases on the same issues. This method allows us to compare how different independent variables result in different dependent variables if other key background conditions, such as control variables, are well-controlled and constant across the cases so as not to disturb the causal relationship. Discovery of the causal relationship was achieved by using the process tracing technique. It helps shed light on the specific and intricate correlation of independent and dependent variables, with connected, intervening variables. The process tracing technique requires the comprehensive data to trace the decision-making processes (George and Bennett 2005:205-217). Hence, it is critical to use historical evidence to reveal suppliers' export decision-making processes.

The controlled comparison of cases using the process tracing technique has been selected for four reasons. First, the number of recipient countries pursuing nuclear weapons capability is small; the number of nuclear suppliers is even smaller. Thus, it is too difficult to obtain statistical data sufficient to produce meaningful and reliable outcomes. Second, it is all but impossible to measure the amount and level of nuclear materials and technology export. Most studies have measured only what they can easily measure. This situation has long plagued large-n statistical analyses. Third, inferring the causal relationship with specific evidence is made possible by a careful analysis of the qualitative case studies approach (Van Evera 1997:53-55; Gerring 2007:48). The intervening variables that logically connect independent and dependent variables are found by the qualitative approach with in-depth investigations, while the statistical analysis suffers from identifying such intermediate steps. Fourth, it is possible to provide specific policy recommendations by carefully looking at significant and contentious nuclear export cases. The case studies provide more policy options or levers for each intermediate step of the causal relationship than those of statistical correlations, which are not causalities.

Casual relationship

$$A \rightarrow p \rightarrow q \rightarrow r \rightarrow B$$

where A is an *independent variable*
B is a *dependent variable*
p, q, r are *intervening variables*
causality valid if α, β, γ are constant across cases

- *Independent variables* (A) frame the casual phenomenon of a casual hypothesis
- *Dependent variables* (B) frame the caused phenomenon of a casual hypothesis
- *Intervening variables* (p, q, r) frame intervening phenomenon in casual relationship
- *Control variables* (α, β, γ) remain at constant/comparable variables across cases

Figure 3.2 Arrow diagram of casual relationship from controlled comparison of cases

3.2.2 System thinking and causal loop diagrams

Based on the selected case studies, the system thinking provides a tool for better understanding of complex structures and assists in the policy making process. Professor Jay Forrester of the Massachusetts Institute of Technology (MIT) developed the method over fifty years ago to understand the dynamic behavior of an integrated industrial system over time (Forrester 1961). To date, it has been used for population, ecological, economic, engineering, and political systems. Peter M. Senge, Director of the Center for Organizational Learning at MIT's Sloan School of Management, asserted that "reality is made up of circles but we see straight lines" (Senge 1990:73). That way of thinking limits us in understanding a complex system and thus in making the right decision.

First, explaining the nuclear export decision-making process is required to fully understand how every factor interacts with others and with an overall system, i.e. the "big picture," rather than breaking the system into constituent parts and focusing on individual factors. Nuclear export is a complex dynamic process. It displays the different conclusions of system thinking from the traditional analysis that focuses on separating components due to strong positive or negative feedback from internal or external sources. Second, the visualization technique of system thinking improves communication effectiveness. This is useful in presenting the complex causal relationships of nuclear export in a dynamic environment. Third, system thinking makes it easy to retrace the steps from desired results to possible factors producing those results. Creating more possible factors and strengthening their impact could result in straightforward policy recommendations.

A causal loop diagram is a feedback loop explaining “a closed sequence of causes and effects, that is, a closed path of action and information” with all its constituent components and their interactions (Richardson and Pugh III 1981; Kirkwood 1998:8). The diagram illustrates how elements interact with each other and affect an overall system. The feedback effects have to be emphasized in nuclear export because the causal relationship moves both ways, as does a closed system.

A system is an interdependent group of elements that causes patterns of behavior. The elements include items, events, conditions, or decisions while the two types of arrows indicate the causal influences between the elements. A sign, either + or -, on the arrow represents positive or negative influence on a causal link between two elements. A causal link from one to another is positive if a change in one produces a change in another in the same direction. A causal link from one to another is negative if a change in one produces a change in another in the opposite direction.

Figure 3.3 shows an example of a causal loop diagram that expresses a new product adoption model. There are two feedback loop diagrams: a positive or reinforcing loop, and a negative or balancing loop. The positive loop “reinforces change with even more change” or causes exponential increases or decreases, while the negative loop “seeks a pre-set goal” and reaches an equilibrium plateau (Kirkwood 1998:10). In the right-side positive loop, high adoption rate increases the number of people adopting the new product, which further increases adoption rate due to the word-of-mouth impact. In the left-side negative loop, high adoption rate decreases the number of potential adopters, and further decreases adoption rate due to market saturation. The positive loop consists of an even number of negative causal links; the negative loop contains an odd number of negative links.

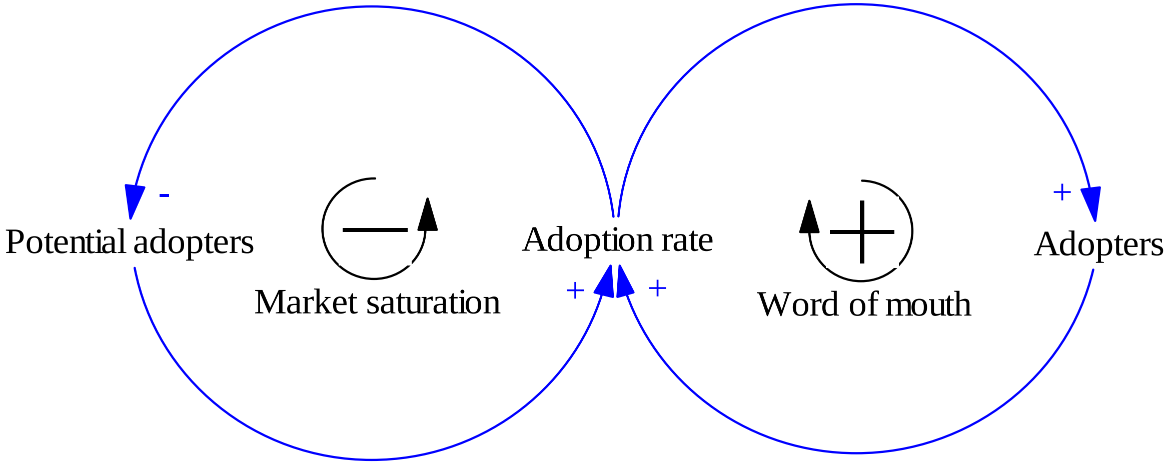


Figure 3.3 Example of causal loop diagrams for security dilemma

3.3 Case selection

A few studies have offered a full-scale comparative analysis of nuclear suppliers' decisions regarding nonproliferation conditions of supply. The literature review reveals that most existing supply-side studies have statistically explored why nuclear suppliers provide nuclear assistance. In addition, it is worthwhile to examine another specific question – why do nuclear suppliers provide nuclear assistance to recipients lacking sufficient nonproliferation commitment and implementation? It is worth noting that a number of countries have received nuclear assistance, but not every country has attempted to proliferate or succeeded in acquiring nuclear weapons. The different conditions of supply between recipient states "*proliferated*" and "*tried but failed*" is one of the critical factors in bifurcating non-weapon states into those with nuclear weapons programs and those with healthy commercial nuclear power programs.

Three nuclear export cases in the 1950s-1970s were selected as main foci of this study, while one recent case was additionally selected to test the nuclear supply model developed from the previous cases. Independent variables are "*market attractiveness of recipients*" and "*political importance of recipients*." A dependent variable is "*nonproliferation conditions of supply*" to recipients. Such a combination allows us to analyze different types of feedback among nuclear suppliers, along with recipients' economic and political conditions. Control variables are "*recipients' technical process of concern*" and "*significance of nuclear assistance recipients received*" as well as “*proliferation motivation of recipients*.” After describing a statistical overview of nuclear proliferation, the rationale of case selection is justified in the following sub-section.

3.3.1 Statistical overview

More than 60 years after the atomic destruction of two Japanese cities, 30 countries have explored, 16 pursued, 13 acquired, and 4 relinquished nuclear weapons (Bleek 2010:159). Among the 13 states, the United States is a unique country that developed nuclear bombs without importing nuclear technology in the Manhattan Project during World War II. Three states – Belarus, Kazakhstan, and Ukraine – suddenly became nuclear weapons states after the Soviet Union collapsed in 1991, but eventually decided to abandon nuclear weapons. South Africa, which completed its first nuclear device in 1979, voluntarily terminated the nuclear weapons program in 1990 and signed the NPT the next year. Currently, there are four unofficial nuclear weapons states: Israel, India, Pakistan and North Korea. Among all nuclear weapons states, Israel and North Korea are the only two countries that possess nuclear weapons without commercial nuclear power plants.

Thirty countries are operating over 440 commercial nuclear power plants worldwide while more than 60 new nuclear power plants are under construction in 14 countries (IAEA 2011:6-7). Italy, Kazakhstan, and Lithuania have shut down all their nuclear power plants and terminated their commercial nuclear power programs. Japan is at a crossroads after the

Fukushima accident. In the wake of the Japanese nuclear crisis, Germany decided to shut down all of its 17 nuclear reactors within 10 years. After Germany's nuclear phase-out, the United States, Russia, France, South Korea, Canada, and Japan remain as the major nuclear power plant vendors, while China and India are seeking to export nuclear materials and technology. These countries are all survivors of the depression after the Chernobyl accident in 1986, except for South Korea, Japan, China, and India, which are newly emerged nuclear vendors. In the 1980s, the United States, the Soviet Union, France, Germany, Japan, Canada, Sweden, and Switzerland all had their own nuclear power plant technology. On the other hand, the United Kingdom, once a major vendor, no longer maintained its supply capability at that time.

Among countries receiving research reactors as listed in Table 3.1, excluding Belarus, Kazakhstan, Ukraine, and the United States, approximately 40% of them explored, 20% pursued, and 13% acquired nuclear weapons. About 27 states have tried to secure sensitive nuclear assistance such as reprocessing and enrichment; nearly 80% of them have succeeded in receiving partial or full assistance. Half of those that received enrichment or reprocessing then acquired nuclear weapons, although a few of them did not attempt to proliferate at all. On the other hand, no country could manufacture nuclear weapons if it failed to obtain partial sensitive assistance – at least education, equipment, or technical advice. The number of countries that proliferated through the black market is still small, but all of the current proliferation cases involve an illicit nuclear trade network.

Regardless of industrial or military uses, most recipients of enrichment and reprocessing technology are expected to maintain their technical capability after they secured that technology. Despite there is no current plant in operation, these countries might construct and operate enrichment or reprocessing facilities without significant technical difficulties. Almost all countries that tried to develop enrichment and reprocessing technology received related nuclear assistance even before beginning operation of their first nuclear power plant. All those countries have attempted to proliferate, regardless of the different levels of significance of their programs. Interestingly, enrichment and reprocessing have been mostly exported by the United States, the Soviet Union, and France. Overall, nearly 15 countries have the operational or potential capability of uranium enrichment; almost 20 countries could potentially reprocess spent nuclear fuels. The next section excludes those less focused nuclear export cases listed in Table 3.1. It then justifies case selection, and presents independent, dependent, and control variables.

Table 3.1 Database of nuclear assistance and proliferation record

Countries	Proliferation record			History of nuclear power, fuel cycle and nuclear assistance				Current nuclear capability		
	Explore	Pursue	Acquire	1st research reactor	Enrichment assistance	Reprocessing assistance	1st NPP	Nuclear power capacity (MWe)	Enrichment	Reprocessing
USA	1939-	1942-	1945-	1942	Initiating the Manhattan Project	Initiating the Manhattan Project	1957	100,747	Operational	Operational
Russia (USSR)	1942-	1943-	1949-	1946	Domestic	Domestic	1954	21,743	Operational	Operational
UK	1940-	1941-	1952-	1947	Participating in the Manhattan Project	Participating in the Manhattan Project	1956	10,137	Operational	Operational
France	1945-	1954-	1960-	1948	USA	USA	1959	63,260	Operational	Operational
China	1956-	1956-	1964-	1958	1958-1960 (USSR)	1958-1960 (USSR)	1994	8,438	Operational	Operational
Israel	1949-	1955-	1967-	1960	Domestic	1959-1965 (France)	-	-	Operational	Operational
India	1948-	1964-66, 72-75, 80-	1974-	1956	Domestic	Domestic (declassified UN documents)	1969	3,987	Operational	Operational

Table 3.1 Database of nuclear assistance and proliferation record (continued)

Countries	Proliferation record			History of nuclear power, fuel cycle and nuclear assistance				Current nuclear capability		
	Explore	**Pursue**	**Acquire**	**1st research reactor**	**Enrichment assistance**	**Reprocessing assistance**	**1st NPP**	**Nuclear power capacity (MWe)**	**Enrichment**	**Reprocessing**
South Africa	1969-91	1974-91	1979-91	1965	1968-1972 (Germany)	-	1984	1,800	Potential	-
Pakistan	1972-	1972-	1987-	1965	1975 (stole from the URENCO Netherlands), 1980s (China)	1960-1970s (France, UK, Belgium) – *failed*, 1974-1982 (France), 1990s (China)	1972	425	Operational	Operational
Ukraine	-	-	1991	1960	-	-	1978	13,107	-	-
Belarus	-	-	1991	1962	-	-	Cancelled	-	-	-
Kazakhstan	-	-	1991	1967	-	-	1973	-	-	-
North Korea	1962-	1980-	2006-	1965	1997-2002 (Pakistan)	1950s (USSR) – *limited*	Cancelled	-	Operational	Operational

Table 3.1 Database of nuclear assistance and proliferation record (continued)

Countries	Proliferation record			History of nuclear power, fuel cycle and nuclear assistance				Current nuclear capability		
	Explore	Pursue	Acquire	1st research reactor	Enrichment assistance	Reprocessing assistance	1st NPP	Nuclear power capacity (MWe)	Enrichment	Reprocessing
Yugoslavia	1949-62, 74-87	1953-62, 82-87	-	-	-	1966 (Norway) - *failed*	-	-	-	-
South Korea	1970-75	1970-75	-	1962	-	1972-1976 (France) -*failed*	1978	17,705	-	-
Libya	1970-2003	1970-2003	-	1981	1997-2001 (Pakistan)	-	-	-	-	-
Brazil	1966-90	1975-90	-	1957	1979-1994 (Germany) - *failed*	-	1982	1,884	Potential	-
Iraq	1976-91	1976-91	-	1967	1980s (German)	1976-1978 (Italy)	-	-	-	-
Iran	1974-79, 84-	1989-	-	1967	1984-1989, 1995 (China), 1987-1995 (Pakistan)	-	2012	915	Potential	-
Germany	1939-45	-	-	1957	Domestic	Domestic	1966	20,480	Operational	Potential

Table 3.1 Database of nuclear assistance and proliferation record (continued)

Countries	Proliferation record			History of nuclear power, fuel cycle and nuclear assistance				Current nuclear capability		
	Explore	Pursue	Acquire	1st research reactor	Enrichment assistance	Reprocessing assistance	1st NPP	Nuclear power capacity (MWe)	Enrichment	Reprocessing
Japan	1941-45, 67-70	-	-	1960	-	1971-1974 (France)	1966	46,823	Operational	Operational
Switzerland	1945-69	-	-	1957	-	-	1969	3,238	-	Potential
Sweden	1945-70	-	-	1954	-	-	1972	9,036	-	Potential
Norway	1947-62	-	-	1959	-	-	-	-	-	Potential
Italy	1955-58	-	-	1959	-	-	1964	-	-	Potential
Egypt	1955-80	-	-	1961	-	1980-1982 (France)	-	-	-	-
Australia	1956-73	-	-	1958	-	-	-	-	-	-
Indonesia	1964-67	-	-	1964	-	-	-	-	-	-
Taiwan	1967-76, 87-88	-	-	1961	-	1975 (France)	1978	4,927	-	-
Canada	-1969	-	-	1947	-	-	1971	12,569	-	-
Argentina	1978-90	-	-	1958	Domestic	Domestic	1974	935	Operational	Potential
Romania	1978-89	-	-	1957	-	-	1996	1,300	-	-

Table 3.1 Database of nuclear assistance and proliferation record (continued)

Countries	Proliferation record			History of nuclear power, fuel cycle and nuclear assistance				Current nuclear capability		
	Explore	Pursue	Acquire	1st research reactor	Enrichment assistance	Reprocessing assistance	1st NPP	Nuclear power capacity (MWe)	Enrichment	Reprocessing
Algeria	1983-91	-	-	1989	-	1986-1991 (China)	-	-	-	-
Armenia	-	-	-	-	-	-	1979	375	-	-
Austria	-	-	-	1960	-	-	Cancelled	-	-	-
Bangladesh	-	-	-	1986	-	-	-	-	-	-
Belgium	-	-	-	1956	-	1940s-1950s (USA)	1974	5,902	-	Potential
Bulgaria	-	-	-	1961	-	-	1974	1,906	-	-
Czech Republic	-	-	-	1957	-	-	1985	3,678	-	-
Spain	-	-	-	1958	-	-	1969	7,450	-	-
Hungary	-	-	-	1959	-	-	1983	1,889	-	-
Netherlands	-1975	-	-	1960	Domestic	-	1969	487	Operational	-
Finland	-	-	-	1962	-	-	1977	2,696	-	-
Slovenia	-	-	-	1966	-	-	1983	666	-	-
Mexico	-	-	-	1968	-	-	1990	1,300	-	-
Slovakia	-	-	-		-	-	1972	1,762	-	-

Table 3.1 Database of nuclear assistance and proliferation record (continued)

Countries	Proliferation record			History of nuclear power, fuel cycle and nuclear assistance				Current nuclear capability		
	Explore	Pursue	Acquire	1st research reactor	Enrichment assistance	Reprocessing assistance	1st NPP	Nuclear power capacity (MWe)	Enrichment	Reprocessing
Poland	-	-	-	1958	-	-	Cancelled	-	-	-
Serbia	-	-	-	1959	-	1960s (Norway, Czechoslovakia)	-	-	-	-
Greece	-	-	-	1961	-	-	-	-	-	-
Turkey	-	-	-	1962	-	-	-	-	-	-
Syria	Suspected	-	-	1996	-	-	-	-	-	-

Reference: (Levite 2003; IAEA 2005; Kroenig 2009a; Bleek 2010:169).

3.3.2 Rationale for case selection

Four nuclear export cases – three in-depth and one brief – are selected as a plausible comparative analysis, not a deterministic test, on what types of supply-side feedback influence the decisions regarding nonproliferation conditions of supply, and how supply-side competition affects the types of supply-side feedback. The three cases range from the 1950s to the 1970s. They presented different competition levels: strong competition among Canada, France, the United States, and the Soviet Union in exporting to India; the Soviet Union's monopoly on exports to North Korea; and moderate competition among the United States, Canada and France to South Korea. More comprehensive data is available for these historical cases than for that of recent cases. Based on feedback structures of nuclear supply, a new supply dynamics model for decision-making regarding conditions of supply has been developed. The model is tested in the context of a new nuclear cooperation agreement between the United States and India.

There are two independent variables and one dependent variable. It is vital to include a wide spectrum of both independent and dependent variables with a relatively small number of cases. The abovementioned three export cases could provide a set of rich data to solve the research questions. The cases are required to reflect the current situations of policy concern related to nuclear export.

As one independent variable, "*political importance of recipient*" is assumed to be determined by five political conditions:

1) Recipient's regime type
2) Recipient's geological location
3) Recipient's regional and global status
4) Recipient's proliferation record
5) Supplier's political urgency

As another independent variable, "*market attractiveness of recipient*" is assumed to be decided by five economic conditions:

1) Recipient's market size
2) Recipient's market growth rate
3) Recipient's entry barriers
4) Recipient's technology level
5) Supplier's economic urgency

The independent variables have three levels – low, moderate, and high. These inputs result in different supply-side competition levels from high to low. It is difficult to quantify, measure, or compare the two independent variables or competition levels across the cases. For this reason, this study has chosen a spectrum of cases – a highly competitive case, a monopolistic case, and a case with competition in between. The selection of extreme nuclear export cases could minimize the chance that other elements will significantly influence the effect of supply-side competition or the political importance and market attractiveness of the recipient.

As a dependent variable, "*nonproliferation conditions of supply*" is assumed to be decided by nuclear suppliers' four indicators:

1) Safeguards on recycled fissile materials
2) Re-export requirements for nuclear technology and materials
3) Incentive to reduce proliferation benefit or increase proliferation cost (diplomatic, economic, strategic, or political)
4) Assistance for a recipient to set up national export control and physical protection systems

For the three historical cases, the dependent variable has the same three levels of low, moderate, and high. Of course, there are a number of other indicators for the nonproliferation conditions of nuclear supply, but the above three indicators are clear, explicit, and representative. It is too soon to conclude whether the recent nuclear export case had a negative impact on the nuclear nonproliferation regime. Still, it is possible to make convincing projections about the consequences of the case based on the current conditions of the three indicators.

Three control variables are fixed for this study to minimize other influencing factors on the dependent variable, aside from the two independent variables or supply-side competition. The nonproliferation conditions of nuclear supply could be also changed according to "*security risk of recipient*" and "*materials or technology traded to recipient*" as well as "*technical process of concern*." First, the security risk of recipient country could intensify a nuclear supplier's concern about the proliferation probability of the recipient, thus strengthening conditions of supply. Second, nuclear items traded to a recipient help it to develop technical level, influencing potential proliferation concern. Third, as a recipient wants to import more sensitive technology, a supplier requires more strict conditions of supply, if other influencing factors are the same.

All three recipients in the selected cases faced serious security threats from neighboring adversaries. North Korea and South Korea allow for an even greater control of other variables, given their geopolitical, strategic, and cultural similarities. The three recipients received civil nuclear assistance, whereas no reprocessing and enrichment technology was transferred. In all three cases, reprocessing spent nuclear fuels is a technical process of concern.

With two independent variables, nine combinations are possible as shown in Figure 3.4. For the historical cases, three significant combinations were selected – (low, low), (moderate, moderate), (high, high) at (market attractiveness, political importance). These combinations are comprehensive enough to reveal how political importance and economic attractiveness cause supply-side competition, and how the competition influences nonproliferation conditions of supply with different competition levels.

Each case has been distinct from others to overcome difficulty of quantitative measurement and to minimize unexpected influences on causal relationships from other factors. For the case selection process, Stephen Van Evera claimed to "select cases with extreme high or low values on the study variable and explore them for phenomena associated with it. If values on the study variable are very high, its causes and effects should also be present in unusual abundance, standing out against the case background. If values on the study variable are very low, its causes and effects should also be conspicuous by their absence (Van Evera 1997:24-25).” The moderate case between two extreme cases allows us to explore how findings in two extreme cases can be applied into other cases.

There are certain criteria for selecting these nuclear export cases as case studies. First, nuclear exports shall be originally intended for peaceful use, not military purposes. Second, a recipient shall attempt to proliferate once, to compare suppliers’ behavior regarding states that acquired or abandoned nuclear weapons. Third, consequences of export cases shall be significant – either the recipient actually made bombs or else completely gave up its program. Fourth, suppliers’ influence shall impact proliferation or nonproliferation decisions of recipients. Fifth, the level of materials and technology provided shall be high enough to facilitate nuclear power plants, enrichment or reprocessing. Sixth, selected cases shall include wide combinations of independent and dependent variables within a relatively small number of cases.

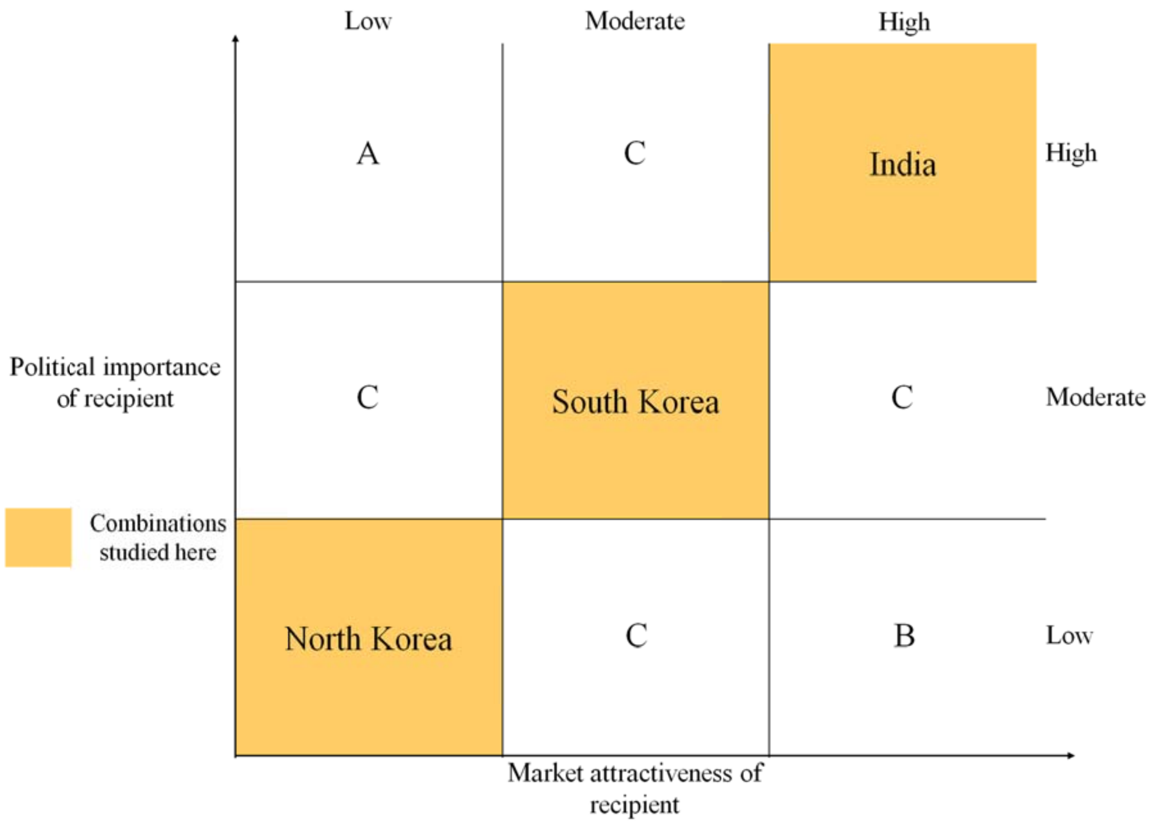


Figure 3.4 Possible combinations of independent variables

Many cases of high political interest – (low, high), A shown in Figure 3.4 – are less related to civilian nuclear program that necessarily emphasizes economic benefit. Thus, the case selection excluded those export cases that were exclusively motivated by building a nuclear weapons program. Between 1959 and 1965, France helped Israel construct the Dimona plutonium reprocessing plant, and might have provided a nuclear bomb design (Cohen 1998:73-75; Cirincione et al. 2005:225). In addition, the Soviet Union gave China designs and components for the Jiuquan plutonium reprocessing plant and the Lanzhou uranium enrichment plant – although the Soviet Union did not fulfill a promise to give a prototype atomic bomb (Lewis and Litai 1991).

In the 1980s-1990s, China reportedly provided Pakistan with a nuclear weapon design, enough highly enriched uranium for two nuclear bombs, and assistance in developing the Kahuta uranium enrichment plant and the Chasma reprocessing plant (Shuey and Kan 1995; Kroenig 2010:199). Moreover, Pakistan supplied Iran, North Korea, and Libya with designs and key components of gaseous centrifuge enrichment technology, and perhaps a nuclear weapons design. In the mid-170s, A. Q. Khan smuggled enrichment design and equipment from the Netherlands for nuclear bombs while working at the URENCO Company (Albright and Hinderstein 2005; Corera 2006).

There are only a few substantial economic-interest dominated cases – (high, low), B shown in Figure 3.4 – because the inevitable connection of nuclear energy to military plans provokes strong political and strategic attention. In many cases, France and Germany exported nuclear materials and technology for economic profit. Among these, particular cases in Latin

America are excluded. Only limited influence from nuclear suppliers was required for Brazil and Argentina to abandon their programs. They did so because of mutual consensus on prevention of self-destructive security dilemmas as well as domestic financial crisis. Although Germany agreed to supply Brazil with ten reactors, a reprocessing plant, and an enrichment plant in 1975, Brazil built only two reactors; it cancelled the reprocessing plant in 1985 and the enrichment plant in 1994 (Spector and Smith 1990:242-266; Kroenig 2010:198). Moreover, economic profit was a main driving force that the A. Q. Khan network of Pakistan exported uranium enrichment technology to Libya, Iran, and North Korea. The network, which was out of Pakistani government controls, pursued the economic interest of the individuals who involved in the network.

In addition to politically or economically biased cases, other nuclear export cases were also excluded from this study. France constructed the ToakiMura reprocessing facility for Japan from 1971 to 1974 and assisted in constructing the Rokkasho-Mura reprocessing plant, but Japan did not attempt to proliferate (Reiss 1988:113-115). France also provided Pakistan with the two reprocessing plants at Chasma and Pinstech; Chasma was suspended due to U.S. pressure in 1978 and only Pinstech was completed in 1982 (Spector and Smith 1990:90-117). However, Pakistan eventually chose a highly enriched uranium path. France supplied Egypt with hot cells in the early 1980s, and Italy constructed a radiochemistry lab containing hot cells for Iraq in the late 1970s, but the levels of technology transfer was rather limited (Weissman and Krosney 1981:161-174; Bhatia 1988:61).

China provided Iran with calutrons for electromagnetic isotope separation and enrichment in the 1980s (Albright et al. 1997:359-360). China exported hot cells to Algeria for a plutonium reprocessing facility (Albright and Hinderstein 2001). Nevertheless, these cases are rather insignificant compared to the nuclear export from China to Pakistan in terms of proliferation consequences and transferred technology level. Taiwan is a similar case to South Korea. Both contacted France to introduce reprocessing plants in the 1970s, but gave up these plans under U.S. political and economic pressure. The two countries eventually retained peaceful nuclear power programs. South Korea was selected from the two because nuclear suppliers in South Korea could halt reprocessing deals even before minor components, like hot cells, were transferred (Weissman and Krosney 1981:152-153; Spector and Smith 1990:342-344). Moreover, the two Koreas have close control variables, which allow us to find a strict causal relationship between independent and dependent variables.

Based on the case studies, a new feedback structure of nuclear supply has been developed to describe the decision-making process that determines nonproliferation conditions of supply. Three export cases are selected with different competition levels: a strong competition between Canada and the United State in export to India; a monopolistic case of the Soviet Union to North Korea; and a moderate competition between the United State and Canada to South Korea. The feedback structure has been tested on a new nuclear cooperation agreement between the United States and India.

India is a non-official nuclear weapon state, having conducted 1974 and

1998 nuclear tests. In the 1950s-1970s, Canada exported to India a research reactor and two heavy water-moderated nuclear power plants. For the research reactor, the United States supplied heavy water (Perkovich 1999). The transferred research reactor was used to produce weapons-grade plutonium for the 1974 nuclear test. India developed a reprocessing plant based on the declassified documents on plutonium reprocessing during that period. The suppliers hesitated to reinforce conditions of supply to avoid negotiation conflict with India. There was serious concern about weak safeguards on recycled plutonium. At the time, India was the second-largest democratic country and enjoyed international prestige as a leader of non-aligned movements. Its geological location was important for the democratic world's goals to restrain China. The Indian economic market was huge enough to attract nuclear suppliers wanting to export their nuclear power plants. Nuclear nonproliferation policies of the United States and Canada were weaker than those of them right after the 1970s. Military disputes with China and Pakistan threatened India, especially after China conducted its nuclear test in 1964.

North Korea was among states with nuclear weapons that received the least nuclear assistance from suppliers. North Korea conducted nuclear tests in 2006 and 2010, and formed a secret nuclear trade network with Pakistan and Iran. The Soviet Union provided a training program of plutonium reprocessing in the 1950s, but did not provide completed plants or products. The Soviet Union also assisted North Korea in constructing a small research reactor (Wit et al. 2004). Despite no complete or significant assistance, North Korea continued to import nuclear-related items from the Soviet Union.

Although North Korea imported gaseous centrifuge technology from Pakistan, its two nuclear tests were based on weapons-grade plutonium. The Soviet Union preferred to focus on competitive or attractive markets to gain more benefit while being indifferent in North Korea. North Korea had insufficient economic attractiveness or political importance compared to other communist countries. At that time, the Soviet Union was reluctant to participate in the international nonproliferation regime that the United States had initiated. North Korea shares its south border with its primary adversary, South Korea, while Japan is located right next to North Korea.

South Korea tried to secure reprocessing technology from France for both a nuclear weapon project and a nuclear power program in the 1970s, but failed. Instead, South Korea secured nuclear power plant technology from the United States and France and became a nuclear power plant vendor. Canada also exported 4 nuclear reactors to South Korea. France provided South Korea with a nuclear fuel fabrication plant rather than a reprocessing plant. The United States and Canada requested South Korea to accept strict safeguards requirements and re-export obligations as well as security assurances and economic assistance to reduce proliferation benefit and increase cost. In the 1970s, South Korea's economic growth rate was impressive, and this promoted an active nuclear power program. Its political importance was non-negligible, although Japan was a primary ally for the democratic countries. The United States and Canada enhanced their commitment to any recipient's nonproliferation status after the shocking Indian nuclear test in 1974. South Korea felt insecure due to the alliance of North Korea, China, and the Soviet

Union, especially in the 1970s when the United States lowered its security guarantee for Asian allies.

In January 2005, the United States signed an agreement on civilian nuclear cooperation with India. The agreement allows India to import nuclear materials, equipment, and technology from foreign countries. India had been a target of the international nuclear export control regime due to its unexpected 1974 India nuclear test. After the U.S.-India nuclear agreement, many suppliers reached cooperation agreements to conduct nuclear business in the massive Indian market. The major supplier's nuclear deals with the recipient outside the nuclear nonproliferation regime indicate that their nonproliferation and nuclear security commitments decreased for those cases. It may be difficult to firmly determine the consequences of the recent nuclear export case to India on nonproliferation and nuclear security. Nevertheless, it is significant to test whether previous negative or positive results in the above three cases could be reproduced by such activities.

Table 3.2 Independent, dependent, and control variables of selected nuclear export cases

Cases		Independent variables		Dependent variables	Control variables		
		Political importance of recipient	Market attractiveness of recipient	Nonproliferation conditions of supply	Technical process of concern	Recipient's civil nuclear assistance received*	Recipient's security risk of recipient
Long cases (1950s-1970s)	Canada, USA to India	High	High	Low	Reprocessing	Received	Serious (China & Pakistan)
	USSR to North Korea	Low	Low	Low	Reprocessing (enrichment)	Received	Serious (USA & ROK)
	USA, Canada to South Korea	Moderate	Moderate	High	Reprocessing	Received	Serious (USSR, China, DPRK)
Short case (2000s)	USA to India	High	Moderate	Low	Reprocessing & enrichment	Received	Serious (China & Pakistan)

* Sensitive nuclear assistance includes highly enriched uranium, weapons-grade plutonium, reprocessing, enrichment, bomb drawings, and nuclear test data except for such nuclear assistance to recipients that already have such capabilities; otherwise, it is civil nuclear assistance

Chapter 4 Nuclear Decision-Making Model for Conditions of Supply

The nuclear supply dynamics model features the most important interactions (or feedback) in decision-making regarding nonproliferation conditions of nuclear supply. The supply feedback model was built based on two contrasting characteristics of the nuclear power market: competitive and regulated. The dynamics model explains interaction from one supplier to another. Pursuing economic, strategic, and political self-interests under a geopolitically and economically competitive environment produces four types of supply-side feedback. Among the feedback, two were shown to weaken conditions of supply to win political and economic competition, whereas the others strengthen the conditions to regulate the competition.

It is assumed that a supplier wants to win the competition and maximize own political, strategic, and economic benefit. The first interaction is *the risk-taking feedback*: a supplier hesitates to reinforce conditions of supply to avoid negotiation conflict with a recipient; otherwise, it loses its competitive position. The second is *the lack of vigilance feedback*: a supplier prefers to focus on attractive markets to gain more benefit while being indifferent in unattractive ones. The third is *the consensus-building feedback*: a supplier builds consensus on conditions of supply to avoid negotiation conflict with a recipient all alone and keep its competitive position. The fourth is *the external constraint feedback*: if a supplier loosens conditions of supply, a group of other suppliers constrain it from doing so to maintain their competitive advantages. This chapter describes a hypothetical nuclear supply dynamics model with the detailed causal relationship.

4.1 Competitive, regulated, political nuclear market

Nuclear suppliers typically pursue economic, political, and strategic benefits from nuclear trade, forming an intensely "*competitive*" environment. To prevail, suppliers may provide recipients with diplomatic, economic, political and military incentives. Loosening nonproliferation conditions of supply is one of the significant incentives that would attract key recipients. Simultaneously, nuclear suppliers prevent other suppliers from offering more attractive incentives and obtaining the benefits of nuclear trade.

This market, which basically entails trading deadly technology, was initially formed due to the strong competition between democracy and communism. To maximize the benefits of nuclear trade, some suppliers have made unacceptable exceptions in the international nuclear export control regime. Also, they have focused on those countries with more attractive markets. These inconsistent nuclear supply policies caused the failures of counter-proliferation exemplified by India's nuclear test in 1974 and Iraq's proliferation attempt in 1992.

To inhibit the uncontrolled spread of nuclear technology, suppliers have agreed to establish multilateral nuclear export regulations. In the "*regulated*" nuclear market, global rule-makers include the NPT, the NSG, the Zangger Committee, United Nations Security Council Resolution (UNSCR) 1540, and Missile Technology Control Regime (MTCR). To avoid competitive disadvantages arising from the regulations, suppliers request that other suppliers agree to conditions of supply – multilateral regulations are less risky than unilateral regulations and share the cost of negotiation with recipients. Moreover, they restrain others from violating the rules and from offering recipients more attractive incentives.

The rule-making process is reactive and controversial. For example, the NSG was established in response to the India nuclear test. The Iraq attempt led NSG members to adopt new export guidelines that require the Comprehensive Safeguards Agreement (CSA) and that control export of dual-use items. However, these export control systems cannot prevent risky nuclear exports, if suppliers choose. These routes to escape from nonproliferation pressure were caused by a “*political*” nuclear market.

The struggle between advocates for market competition and advocates for nonproliferation makes the nuclear market political. The former group considers political and economic interests to be the highest priority. Those in the latter group are concerned about side effects from competition, i.e. nuclear proliferation. The nuclear export regime is a compromise between these opposing interests. Thus, the nuclear export control regime is still imperfect and changing; this will not change. Therefore, it is important to infuse the nuclear market with enhanced nonproliferation assurances while still allowing pursuit of market opportunities. To achieve both goals, we need to understand the interaction among nuclear suppliers based on natural supply mechanisms – competitive and regulated.

Despite a long market depression ever since the 1979 Three Mile Island accident and the 1986 Chernobyl disaster, fundamental characteristics of the nuclear market remain unchanged; it is still competitive, regulated. The global nuclear export regime is also political; this is a product of compromises between market competition and nonproliferation regulation. Nuclear trade still relies on a bilateral agreement between a supplier and a recipient. The interaction patterns among suppliers, drawn from existing export cases, will still meaningful in the current market.

4.2 Feedback loosening conditions of supply

Two supply-side feedback systems would accelerate proliferation by loosening nonproliferation conditions of supply. The risk-taking feedback is strong in high-level competition, while the lack of vigilance feedback is conspicuous in low-level competition. In the first type of feedback, nuclear suppliers worry about jeopardizing bilateral relationships with important political partners or losing attractive economic markets by other competitors, if they require strict conditions of supply. In the second type of feedback, nuclear suppliers have no concern regarding proliferation risk of export to unattractive recipients, resulting in lack of vigilance, while they focus on attractive markets. Competition is the best variable that reflects incentives of exporting in a market and thus explains interactions among suppliers.

4.2.1 The risk-taking feedback

In the risk-taking feedback, a supplier hesitates to reinforce conditions of supply to avoid negotiation conflict with a recipient; otherwise, it loses its competitive position. This shows how the cost of negotiation with a recipient influences a supplier to determine nonproliferation conditions of supply. This feedback, illustrated in Figure 4.1, is significant regarding competition with other suppliers; the weaker conditions a supplier determines, the more competitive advantages it gains. The negotiation conflict increases when a supplier requests strict nonproliferation conditions. A high negotiation cost weakens the supplier's competitive position. The cost of negotiation includes increased time delay to market entry, deterioration of political relationships, and actual economic expenses of negotiation. The competitive disadvantages cause the supplier to be concerned about losing a profitable economic customer or strong political partner. The supplier might fear that its ability to influence the recipient to accept trade deals will disappears. For this reason, the supplier ignores internal and external warning. Thus, the supplier loosens conditions of supply lest its competitive position becomes unstable. Decision-makers in the supplier state think: if we do not supply what the customer wants, others will win them over with weaker conditions, and then why not us? Therefore, the higher negotiation cost of the supplier causes the stricter the conditions of supply. The reduced conditions conversely drive the feedback to the enhanced conditions. This feedback forms a balancing loop in which a change of a variable results in a reverse change of the variable.

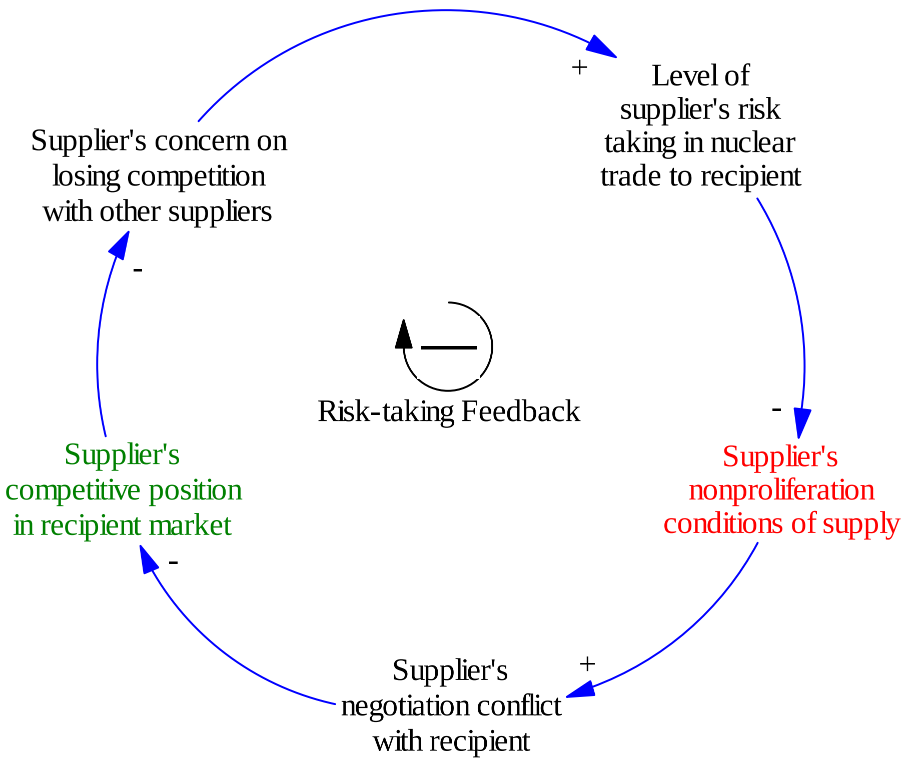


Figure 4.1 Causal loop diagram of risk-taking feedback

4.2.2 The lack of vigilance feedback

In the lack of vigilance feedback, a nuclear supplier prefers to focus on attractive markets to gain more benefit while being indifferent in unattractive ones. This considers the relationship between lack of vigilance in nuclear exports and nonproliferation conditions of supply. Figure 4.2 represents the feedback that is particularly strong under weak competition. To gain more benefits, a supplier focuses more on competitive market, while overlooking proliferation risks in an unattractive recipient. The weaker conditions of supply a supplier requests, the stronger external concern on nuclear trades to a recipient will be. The external concern is rather weak because other suppliers have no interest in an unattractive market. If other suppliers do question the trades, the supplier denies the recipient's request for nuclear technology. The supplier obtains low trade benefits from the economically or politically unimportant recipient, and thus tends to withhold technology transfer. Without technology transfer, the supplier underestimates the nuclear capability of the recipient. Thus, the supplier lacks vigilance on proliferation risk in the recipient. It neither applies strict conditions of supply nor offers the recipient any incentives to reduce proliferation benefit. Supplier decision-makers believe that if we do not supply it, others will not either, the recipient has no internal capability, and thus we do not need worry. Hence, the greater lack of vigilance produces the weaker conditions of supply. Weak conditions bring a lack of vigilance that loosens the conditions. This feedback is reinforcing a change of variable results in the same direction as change of the variable.

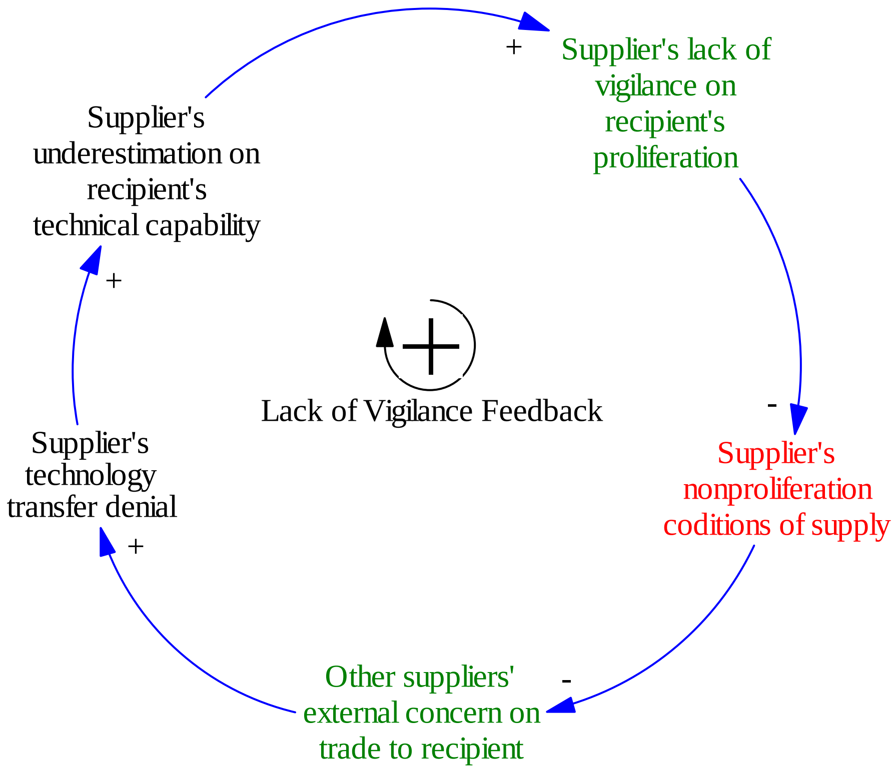


Figure 4.2 Causal loop diagram of lack of vigilance feedback

4.3 Feedback strengthening conditions of supply

The other two types of supply-side feedback strengthen conditions of supply regarding nonproliferation by enhancing nonproliferation conditions of supply. These types of feedback result from two fundamental characteristics of the nuclear market – regulated and competitive. The consensus-building feedback considers the rule-making process for conditions of supply. For this type of feedback, a few initiators usually interact with many other suppliers to set up the agreed rules to avoid negotiation conflict with a recipient all alone. On the other hand, the external constraint kind of feedback reflects monitoring and punishment systems among suppliers based on the agreed-upon standards. Many parties constrain a few violators of the consented standards to keep their competitive position in the recipient market.

4.3.1 The consensus-building feedback

In the consensus-building feedback, a supplier builds consensus on nonproliferation conditions of supply to avoid negotiation conflict with a recipient all alone and keep its competitive position. This reflects that a situation in which a nuclear supplier persuades others to strengthen consensus on the conditions. The attempts would be initiated by internal nonproliferation advocates or external nonproliferation pressures. This feedback, shown in Figure 4.3, is significant in managing the concern of a supplier regarding losing the market via the high competition. Requiring a recipient to accept the strict conditions of supply diminishes the supplier's competitive position due to competitive disadvantages caused by lengthy negotiation conflict. The reduced competitive position encourages the supplier to request that other suppliers agree to the same stringent conditions, comply with the consented standards, and verify each other, in order to avoid political and economic disadvantages. Thus, a group of suppliers take collective action such as safeguards on recycled plutonium, re-export requirements, security assurances, and economic assistance. If other suppliers agree to build consensus on conditions of supply, the original nuclear supplier does not need to worry about competitive disadvantages due to negotiation with the recipient for nonproliferation conditions. This feedback counterbalances the risk-taking feedback that weakens the nonproliferation conditions in nuclear trades. Consequently, the weaker competitive position, due to negotiation conflict, results in the supplier's stronger effort to establish mutually agreed-upon conditions of supply. In the consensus-building feedback, a change of a variable eventually causes a reverse change of the variable.

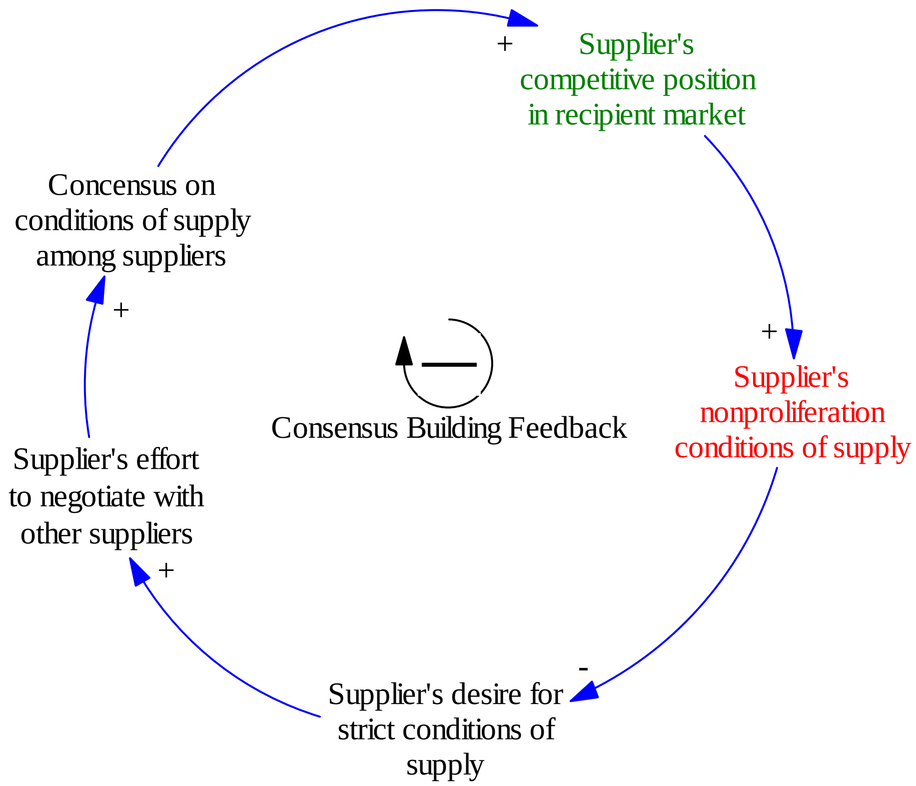


Figure 4.3 Causal loop diagram of consensus-building feedback

4.3.2 The external constraint feedback

In the external constraint feedback, if a supplier loosens conditions of supply, a group of other suppliers constrain it from doing so to keep their competitive position. Figure 4.4 illustrates this feedback that becomes more powerful when a supplier takes advantage of the conditions of supply to gain market advantage. The weaker nonproliferation conditions of supply result in stronger proliferation concerns of external sources. Other suppliers worry that the supplier could improve its competitive position in a recipient market by reducing the conditions of supply. Thus, other suppliers demand that the supplier complies with the mutually agreed-upon conditions of supply. The stricter the agreed conditions are, the stronger the external influence. Interdependence among suppliers is critical for this feedback mechanism. The supplier no longer ignores internal and external warnings about proliferation risk in nuclear trades. This external feedback is significant in low levels of competition case, because this is the only effective feedback system that reinforces the nonproliferation conditions of supply. When a nuclear supplier tries to reduce nonproliferation conditions of supply, others will prevent it from making special exceptions for a recipient state, in order to maintain their competitive political and economic advantages. Thus, the stronger the restraints other suppliers apply to the supplier, the more stringent the conditions of supply. This external constraint feedback produces a balancing loop in which a change of a variable results in a reverse change of the variable.

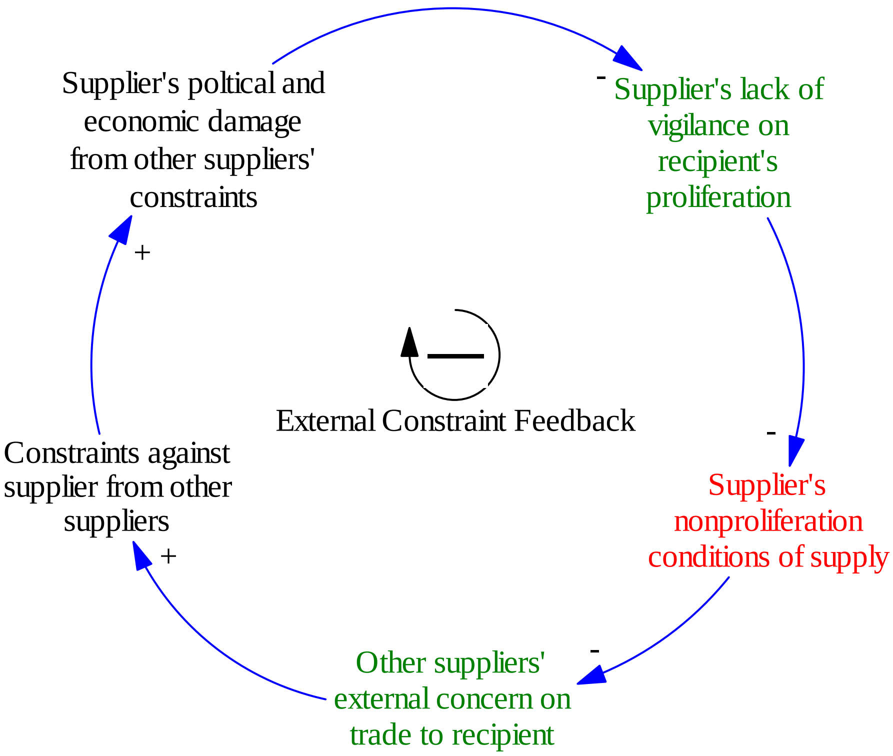


Figure 4.4 Causal loop diagram of external constraint feedback

4.4 Inter-linkages and other influencing factors

Risk-taking versus consensus-building

Under high competition, negotiation conflict with a recipient is fatal for a supplier because other suppliers vigilantly await an opportunity to join the recipient market. If no consensus on conditions of supply was established among suppliers, a safe choice for the supplier is not to unilaterally reinforce them, but to multilaterally do so.

Lack of Vigilance versus external constraint

Under low competition, a supplier is confident to control a recipient without accepting requests on technology transfer while carefully observing attractive (or competitive) ones. A self-satisfied supplier is difficult to break lack of vigilance unless other suppliers impose effective external constraints (diplomatic, strategic, and economic) on it.

Risk-taking versus lack of Vigilance

Negotiation conflict with a recipient brings a supplier's careful attention to a nuclear export case; some level of competition is required to prevent lack of vigilance. In other words, an uncompetitive case (with lack of vigilance) is unlikely to cause serious negotiation conflict because a recipient has no best alternative for nuclear imports.

Consensus-building versus external constraint

Consensus over conditions of supply provides suppliers with legitimate to constrain another supplier from loosening the conditions. External constraint imposed on the supplier of concern is reliably effective if it has large interdependence among other suppliers on economic, technical, political, diplomatic, security perspectives.

Other influencing factors on the feedback structure

First, global environment has been changed by several significant events such as India's nuclear test in 1973, Iraq's nuclear attempt in 1992, the end of Cold War, the event of 9/11 in 2001, and Pakistan's black nuclear market in 2004. However, there are several export cases that cannot be explained by global environment alone:

1) North Korea was less highlighted until the end of the 1980s;
2) U.S.A. kept exporting fuels to India & allowed Japan to reprocess;
3) U.S.-Pakistan nuclear cooperation in the early 1990s;
4) Russia exported nuclear power plants and fuels to India, Iran;
5) Recent U.S.-India deal weakens CSA & AP as conditions of supply.

Global-level strategic competition was strong during the Cold War, while regional-level economic competition became more important in the post-Cold War. While global environment is still a significant influencing factor, supply-side competition would provide explanations from a different angle that fills a missing gap.

Second, vested rights have been given to India and Japan that are typical high competition cases. A few scholars have argued that accepting vested rights is critical to decide who obtain sensitive technology. However, it is only a consequence, not a reason. The rights have been granted by major suppliers to gain political and economic benefit. Nuclear suppliers worry about serious negotiation conflict if suppliers made them to give up rights for technologies. This behavior is well explained by the feedback structure this paper suggests.

Third, a few people might think that roles of suppliers in a recipient's proliferation are limited. If a recipient is so desperate, suppliers have no ways to prevent the recipient from developing nuclear weapons. However, suppliers can offer incentives to reduce proliferation benefit and increase cost, which influences the recipient's desperation to proliferate.

Chapter 5 Analysis of Nuclear Export Cases

Three nuclear export cases have been selected to test the nuclear supply decision-making model that determines nonproliferation conditions of supply. They demonstrate different supply-side competition levels: strong competition between Canada and the United States in exports to India; a monopolistic case of the Soviet Union trading to North Korea; and moderate competition between the United States and Canada in exporting to South Korea. For each case, this dissertation identifies what types of basic interaction among nuclear suppliers influence conditions of supply, and how export competition affects the basic structure of interaction. Under high export competition, Canada and the United States took proliferation risks in nuclear trade to India by loosening safeguards as conditions of supply. Under low competition, the Soviet Union, as along with other suppliers, was indifferent to proliferation risks in North Korea while focusing on more attractive markets. Under moderate competition, the United States urged Canada to join it in issuing strict conditions of supply, while constraining France from supplying South Korea with reprocessing technology.

As a result, it has been postulated that high export competition leads suppliers to take potential proliferation risk in nuclear export, that low competition results in suppliers' indifference to potential proliferation risk, and that moderate competition causes healthy supply-side interaction that reinforces conditions of supply. These different consequences result from the different effects of export competition on the basic structure of interaction among suppliers. The structure consists of the four types of interaction:

1) The risk-taking feedback: a supplier hesitates to reinforce conditions of supply to avoid negotiation conflict with a recipient; otherwise, it loses its competitive advantages over rival suppliers;
2) The lack of vigilance feedback: a supplier prefers to focus on attractive markets to gain more benefit while being indifferent in unattractive ones;
3) The consensus-building feedback: a supplier builds consensus on conditions of supply to avoid enduring negotiation conflict with a recipient all alone and keep its competitive position;
4) The external constraint feedback: if a supplier loosens conditions of supply, a group of other suppliers constrain it from doing so to keep their competitive position.

This chapter describes the detailed analysis of three nuclear export cases one by one while the next chapter explains cross-case comparison.

5.1 Exports from Canada and the United States to India: high attractiveness, high competition, high risk-taking

India conducted nuclear tests at Pokharan in 1974 and 1998. India called the first test a peaceful nuclear explosion; the second test demonstrated India’s capability to deploy nuclear weapons. The 1974 nuclear detonation was a bitter experience for Canada and the United States, as they had assisted India in developing a nuclear program under high competition with the Soviet Union. Canada also competed with the United States and France for the Indian nuclear market. The high competition among the suppliers was caused by the economic attractiveness and political importance of India. The competition led suppliers to be willing to take India's proliferation risk, despite internal and external warnings.

In the high export competition scenario, suppliers were concerned about negotiation conflicts with India where competitors awaited an opportunity to join for the market. In contrast, efforts to create mutually agreeable conditions and offer collective security assurance failed. In the nuclear decision-making model for conditions of supply, the risk-taking feedback defeated the consensus-building feedback. The lack of vigilance feedback was negligible because so many suppliers paid attention to the attractive market; the external constraint feedback was trivial since suppliers had little influence to others' decision on conditions of supply.

The first section describes how nuclear assistance contributed to India's nuclear program. The following explains what types of supply-side feedback determined nonproliferation conditions of supply in nuclear exports of Canada and the United States, and how supply-side export competition influences conditions of nuclear supply.

5.1.1 Nuclear assistance and nuclear program

India began nuclear research 3 years before it achieved independence from Great Britain in 1947 and 1 year before the first-ever nuclear test by the United States in 1945 (Barnaby 1993:68). Homi J. Bhabha, a father of the Indian nuclear program, proposed a three-stage nuclear development plan in 1954 that the Indian government adopted in 1958 (Venkataraman 1994:158). First, separated plutonium would be produced from heavy water reactors loaded with natural uranium fuels. The first-stage power reactors would be constructed with Canadian assistance. Second, a mixture fuel of plutonium and thorium would be loaded into sodium-cooled fast breeder reactors, producing U-233 enriched uranium. Third, either sodium fast breeder reactors or heavy water thermal breeder reactors would be fueled with a combination of U-233 enriched uranium and thorium (Bhatia 1979:90; Gopalakrishnan 2002:372). The plan was intended to maximize utilization of thorium, which was abundant in India. Nevertheless, it could not avoid accumulating a stockpile of weapon-grade plutonium and enriched uranium.

For the 1974 nuclear test, India used a plutonium implosion-type bomb. Producing this type of bomb requires natural uranium, conversion, fuel fabrication, heavy water, research reactors, reprocessing, and the steel structure of the nuclear bomb. India designed and constructed its first research reactor, which became operational in 1956. Great Britain supplied India with detailed engineering drawings for this swimming pool-type reactor. The British also provided 80%-enriched uranium fuels without safeguards. In compensation, Bhabha informed that India would consider purchasing a British power plant in the future (Abraham 1998:84-85).

In 1955, Canada agreed to offer India a 40MWt heavy water research reactor, the so-called CIRUS (Canadian India Reactor United States), at less than half of the total cost under the Colombo Plan (Reiss 1988:218-219). Canada supplied half of the initial natural uranium metal fuels; the United States sold ten tons of heavy water (Bhatia 1979:89-90; Chellaney 1993:6). The other half of the initial fuels was indigenously manufactured. The reactor was able to generate high-quality plutonium due to low discharged fuel burn-up – more plutonium-239, less plutonium-238 – and the use of metal fuel for easier reprocessing. Later, the CIRUS, capable of producing 10kg of plutonium per a year, was used to supply weapon-grade plutonium for the first nuclear test (Moher 1985:41-42; Cirincione et al. 2005:194-195).

Based on previous experience, India has indigenously operated the Dhruva research reactor since 1985. This reactor is moderated by heavy water and fueled by domestic natural uranium. India procured heavy water from Norway and the Soviet Union for the research reactor, although India was not a member of the NPT and a main target of international control (George and Bennett 2005:71). In addition, India is operating two more research reactors, a fast breeder reactor and a U-233 fueled light water reactor. These research reactors have helped India to train manpower and produce plutonium, as well as develop an advanced nuclear power system.

In December 1958, India decided to build a reprocessing plant using PUREX (plutonium-uranium extraction) technique. This plant could produce fissile materials for one or two explosive devices per year. The decision was influenced by the Chinese appeal to develop nuclear weapons in May 1958 (Reiss 1988:220). A U.S. company, Vitro International, provided a blueprint of the plant site while India acquired core reprocessing techniques from the declassified documents of the United Nations (Kroenig 2010:202). In 1955, the United States began declassifying numerous papers on nuclear matters such as reprocessing, and they were available to foreign scientists (Wohlstetter 1977:30). In the 1955 U.N. Conference on the Peaceful Uses of Atomic Energy, French scientists opened up the plutonium extraction process (Weiss 2010:258). In the 1960s, the United States supplied plutonium to India for research purposes. In 1964, India produced its weapon-grade plutonium at the Trombay plant with spent nuclear fuels from the CIRUS for the first time (Perkovich 1999:64).

In addition, foreign assistance helped India to develop a commercial nuclear power plant. In the 1960s, India imported the first two BWRs (Boling Water Reactors) at Tarapur from the United States, under the condition that India would use only U.S. fuels for these reactors. However, India switched its fuel supplier to France in 1980s. In August 1963, the United States urged India to accept the IAEA inspection of the U.S.-originated fuels. Plutonium separation from them must be pre-approved by the United States. The United States also offered substantial financial loan for the plants (Chellaney 1993:318-327).

In 1963 and 1966, Canada agreed to export two CANDU (CANada Deuterium Uranium) plants to India – RAPP (Rajasthan Atomic Power

Project) I and II. The Canadian heavy water reactor technology was a reference system for India's localized nuclear power plants. The 1963 Canada-India agreements enabled free exchange of technical information including plans, working drawings, blueprints, and on-the-job-training for CANDU reactors. For RAPP I, Canada provided half of the initial fuels and loaned nearly 50 percent of the total cost.

After the 1974 nuclear test, India paid the consequences by having difficulty securing heavy water from Canada or the United States, so India imported it clandestinely since the early 1980s (Barnaby 1993:71-72). For example, between 1982 and 1987, 130-150 tons of heavy water were transferred from China to India through a German nuclear materials broker, Alfred Hempel (Tong 1992:105-106). The German government permitted the sale while ignoring both U.S. and British warnings (Leventhal 1992:179).

A research reactor and a reprocessing plant were critical for producing weapon-usable fissile materials. India almost autonomously developed the reprocessing plant, while receiving significant assistance for the research reactor in terms of funds, fuels, moderators, design, and construction. Nuclear assistance reduced technical barriers and accelerated India's overall nuclear program. Since India obtained much assistance without committing to high-level safeguards, Canada and the United States had little leverage to stop India's proliferation. Now, India has formed a relatively large-scale nuclear power program including mining, milling, refining, conversion, fuel fabrication, reprocessing, heavy water production, power reactors, research reactors, uranium conversion, and enrichment.

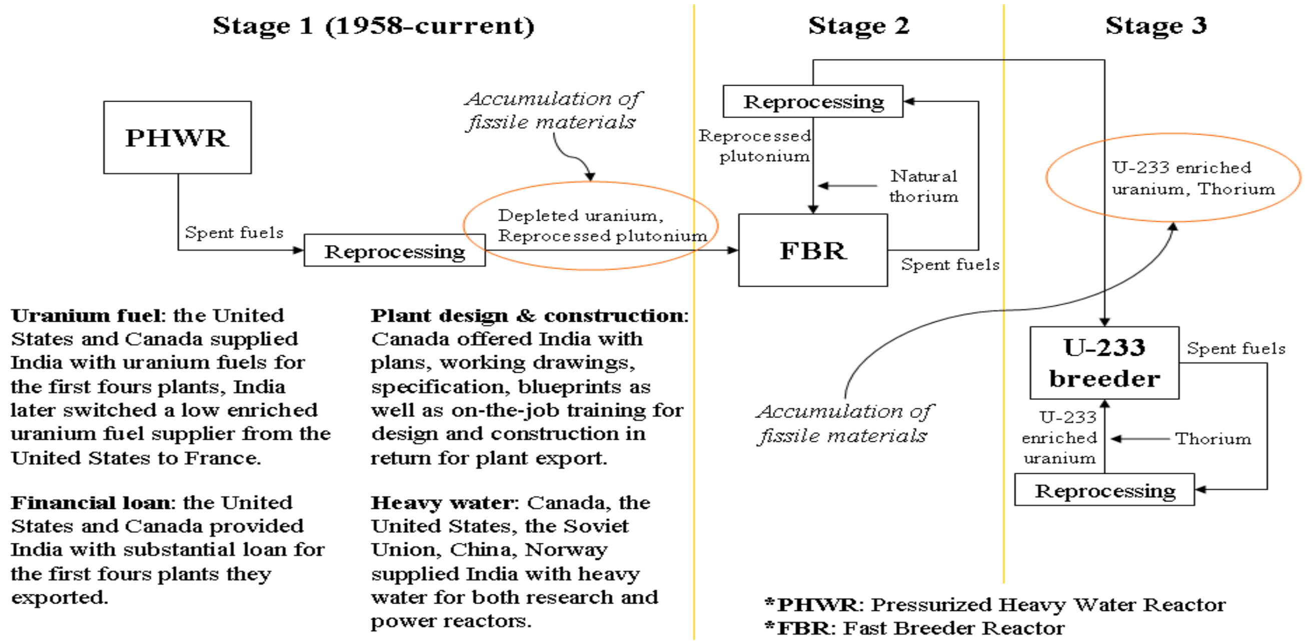


Figure 5.1 Suppliers' nuclear assistance and India's three-stage nuclear development plan

5.1.2 Nuclear exports from Canada and the United States

It is striking that decision-makers in Canada and the United States recognized the proliferation risk in nuclear technology transfer to India beforehand, yet promoted nuclear exports regardless by ignoring internal and external warnings. They were satisfied with a low level of nonproliferation assurance on India's nuclear program. Bhabha, who led the Indian nuclear program for nearly twenty years, was a staunch advocate of developing a nuclear bomb or cultivating, at least, a latent nuclear weapons capability. In a 1948 public statement, Jawaharlal Nehru, the first Prime Minister of independent India, said: "I think we must develop it [nuclear energy] for … peaceful purposes .... Of course, if we are compelled as a nation to use it for other purposes, possibly no pious sentiments of any of us will stop this nation from using it that way" (Perkovich 1999:20).

Moreover, India's nuclear development plan inevitably meant the accumulation of weapon-grade plutonium and U-233 enriched uranium. India also explored peaceful nuclear explosions from the very beginning. In addition, India faced a competitive security environment because of its shared borders with China and Pakistan. Under internal pressure, Prime Minister Lal Bahadur Shastri formalized this ambition as an official policy after the 1964 Chinese nuclear test (Reiss 1988:208). Moreover, India balked at accepting either bilateral or international safeguards with sufficient levels of inspection and verification.

Considering these issues, why then did Canada and the United States hesitate to confront India while avoiding the cost of negotiation and ensuring high proliferation risk in nuclear export to India? First, anticipated high economic profits gave the suppliers a strong motivation to promote nuclear deals with India, with its huge market size and growth rate. In particular, the Canadian government and industry wanted to achieve market dominance in the emerging nuclear field via heavy water reactor technology. Canada hoped that success in the Indian market would expand Canadian nuclear markets to many other developing countries. Canadian officials reasoned that if it had failed to achieve the Indian market due to strict conditions of supply, other suppliers would have jumped in with weak conditions. Hence, it avoided the cost of negotiation with India.

Second, India's political importance in the Cold War environment led Ottawa and Washington to overlook proliferation risks in New Delhi in order to win political advantage against Communism. The Atoms for Peace program stimulated the two suppliers to offer nuclear assistance to India. They believed that close diplomatic ties with India could offer considerable strategic benefits because India was the largest Asian democracy that geopolitically pressured the Soviet Union and China. Moreover, India's security was threatened by China. Canada, as a middle power, also hoped that India would help it to restrain radical policies from the two superpowers and connect their voices to the Third World (Kapur 2007:35). If their relationships with India were jeopardized, the Soviet Union might have established nuclear bilateral cooperation. Thus the political importance of India was another reason to avoid the cost of negotiation with India.

Third, the nonproliferation policies of Canada and the United States were not solid enough to resist economic and political temptation. The global nonproliferation norms were newly emerging; there was no consensus regarding the baseline of conditions of supply. In a context of high competition, there were weak incentives to build consensus on conditions of supply with competitors. When a Canada-U.S. consortium exported the CIRUS to India, each country paid little attention to the other's conditions. The United States, a minor supplier, thought that Canada, a major supplier, was responsible for the potential risk. Canada believed that the IAEA could handle India's nuclear issues, although its inspection authority was very limited at that time. An attempt to offer collective security assurance failed due to different interests of suppliers. Efforts at consensus-building were ineffective in the face of contrasting interests under high competition, since suppliers had limited interdependence.

Entering the Indian nuclear market: 1955-1961

It was Canada to approach India about providing civil nuclear assistance. In March 1955, AECL (Atomic Energy of Canada Limited) President Bill Bennett was pressured by Canadian staffs of the Colombo Plan to export a nuclear power plant to India. However, a Canadian nuclear power plant was still under development and unavailable to the global nuclear market. Instead, Bennett proposed supplying a heavy water research reactor. Lester Pearson, then Secretary of State for External Affairs, welcomed this idea by calling it "a most important gesture, the effects of which might be very great indeed"

(Bratt 2006:89). For Canada, the CIRUS reactor could be a showcase for future sales of large-scale commercial nuclear power plants if the transaction was successful (Kapur 2007:35). Moreover, the massive Indian market was a perfect testing site for Canada to break into the international nuclear market, including the Third World, as a credible and capable nuclear supplier.

In order to win the Indian market, heavy water-moderated Canadian reactors had to compete with light water-cooled American reactors, graphite-moderated Soviet reactors, and gas-cooled British reactors. Late to the game, Ottawa was eager to attract the VIP customer by offering what it wanted, to offset its competitors' competitive advantages. Particularly, the United States and the Soviet Union could provide conventional security assurance, nuclear deterrence, and economic assistance. Moreover, France vigilantly awaited an opportunity to replace India-Canada nuclear cooperation with India-French cooperation. All competitors established well-known proven industrial nuclear capability surpassing that of Canada's.

Such strong competition among suppliers weakened Canada's competitive position. Canadian officials commented that "the United Kingdom and the United States are showing great interest in the development of atomic energy in Asia… makes it perhaps all the more imperative why Canada should assist in making comparable advances in this field" (Lonergan 1989:74; Bratt 2006:90). To overcome its competitive disadvantages, Canada needed to offer more attractive terms of transfer agreement regarding the CIRUS. Negotiation conflicts with India would give others the opportunity to seize India's market.

In addition to economic aims of the First World suppliers, India was a political bridge to the Third World. Canadian Prime Minister Louis St Laurent and Pearson “attached the highest importance to Canadian-Indian relations, viewing India as a necessary bridge between … the First World of Western industrial democracies and the Third World of developing and impoverished states (Bothwell 1984:74; Bratt 2006:91-92).” Canada also considered India an important middle power partner and ally with which to maintain global peace and confine Communism.

India was the largest democracy in Asia and a leader of the nonaligned countries. The Western countries wanted to prevent India from communizing. Nehru defined Communist attacks and unfavorable economic situations as two threats to Indian democracy and advised the Western countries that “the best defense against communism was to raise living standards.” Pearson took Nehru’s advice and justified the Colombo Plan as a mechanism to confront the spread of Communism. He argued that “Communist expansionism may now spill over into Southeast Asia” (Bratt 2006:92).

In October 1955, Canada requested that Bhabha agreed to the repatriation of spent fuels from the CIRUS (Bratt 2006:93). Both Bhabha and Nehru considered the repatriation request a challenge to Indian sovereignty. To resolve the disagreement, Pearson and Escott Reid, High Commissioner to India, met Bhabha in India. They tried to persuade him to accept international safeguards regarding the reactor, nuclear fuels, and subsequent plutonium. While arguing that India reliably monitored plutonium without international safeguards, Bhabha proposed to avoid mentioning any arrangements for nuclear fuels in a bilateral agreement. If so, both parties could not technically violate any rules in upcoming IAEA regulations. Pearson accepted Bhabha's suggestion, and that accelerated the reactor sale, while Reid questioned Bhabha's intention (Touhey 2007:13).

The Canadian Cabinet approved export of the CIRUS in December 1955, although the issue regarding the fuels was unresolved. Nehru and Reid officially signed the reactor transfer agreement in April 1956. Canada gave up its request for the repatriation of irradiated fuels and the related international safeguards. The agreement contained only one safeguards-related reference: "The Government of India would ensure that the reactor and any products resulting from its use would be employed for peaceful purposes only (Blanchette 2000:74)." Canada was allowed to inspect the reactor only if India used Canadian fuels, but India would be seen able to manufacture them indigenously.

The AECL, a main beneficiary of nuclear exports, provided India with much nuclear information. Iris Lonergan commented, "AECL gave out technical information rather selectively and appeared to place more trust in Indian fellow scientists than in Canadian diplomats. The lack of technical knowledge in External Affairs about nuclear technology and safeguards severely hampered the Canadians and was one of the determining factors for the mishandling of the spent fuel ownership and disposal question" (Lonergan 1989:171).

Canada suggested that the IAEA should resolve the irradiated fuel issue. Finch commented: "Government excuses about the absence of the

IAEA … served two functions: first, it diminished the Canadian responsibility; and second, it implied that everything was under control since the IAEA was created" (Finch 1986:78). According to Bratt, "it was completely unrealistic of Canada to believe that the Indians would cooperate with the IAEA" (Bratt 2006:95-96). India had rejected the IAEA safeguards from the initial negotiation process of the Statue of the IAEA.

Jules Leger, the under-Secretary of State for External Affairs, pointed out that "this could presumably be surmounted, especially if we assume that a country like India will acquire a reactor from some source [friendly or adversary] and will be producing this material" (Bratt 2006:93). Canada justified the export of the CIRUS by this logic: if we don't supply it, other suppliers will do so without safeguards – so then why not us? The costs of negotiation would diminish Canada's competitive position and it would lose India to other suppliers.

The United States also avoided the cost of negotiation with India for the export of heavy water. In 1955, India asked the United States to supply heavy water for the CIRUS reactor. Isador Rabi, Chairman of the U.S. Atomic Energy Commission's General Advisory Committee, expressed his concerns about inappropriate safeguards on the heavy water sale to Gerard Smith, the U.S. State Department's atomic energy adviser (Clausen 1993:34; Perkovich 1999:31).

The United States initially requested India to accept a U.S. safeguards proposal for heavy water. In response, Bhabha said such a proposal was an insult to India. Lewis Strauss, Chairman of the U.S. Atomic Energy

Commission, consequently advised President Dwight D. Eisenhower to reduce the safeguards on the heavy water. Eisenhower, who launched Atoms for Peace, had been inclined not to push strict safeguards for non-sensitive heavy water, in order to avoid endangering mutual relations with the key political partner.

Even the Soviet Union was trying to establish a close diplomatic relationship with India by promoting arms exports and providing foreign aid. The Soviet Union competed with the United States to attract India, a key strategic partner. Thus Washington had to take further steps to strengthen bilateral cooperation with India in order to establish a future economic market and increase U.S. influence in South Asia.

American officials believed that Canada, a major supplier for the CIRUS, was responsible for India's nonproliferation of India. According to Leventhal's note, an American official said "this is a Canadian problem, not ours" in response to the 1974 India nuclear test (Leventhal 2005:1). However, the United States also supplied India with heavy water for the CIRUS without requiring a reliable inspection framework. These excuses allowed the United States to keep conducting trade, including nuclear fuels, with India after the 1974 test.

The agreements regarding the Canadian research reactor and the American heavy water stated that nuclear materials and technology would be transferred for "peaceful purposes only," but they did not specify this terminology. After conducting its nuclear test, India claimed that it was for peaceful purposes. No rule had been violated because "peaceful uses only" was an ambiguous concept; the NPT even included an article about peaceful nuclear explosion.

As illustrated in Figure 5.2, India’s high market attractiveness and political importance caused strong competition among suppliers to establish close diplomatic and economic relationships. Competition diminished the relative positions of Canada and the United States in the Indian market. Fearing the loss of that important customer, the advocates for nuclear export urged national leaders to ignore internal or external warnings and promote nuclear deals with conditions that India could accept. As a result, there was no strict safeguard provision in the 1959 Canada-India CIRUS agreement, other than India’s commitment to use the reactor and fissile materials for peaceful purposes only (Bhatia 1979:92). The nuclear deal under a close bilateral relationship was essential and urgent, so nations avoided the strict safeguards that would mean lengthy negotiations. Such calculations were repeated in subsequent negotiations for safeguards as conditions of nuclear supply from Canada and the United States.

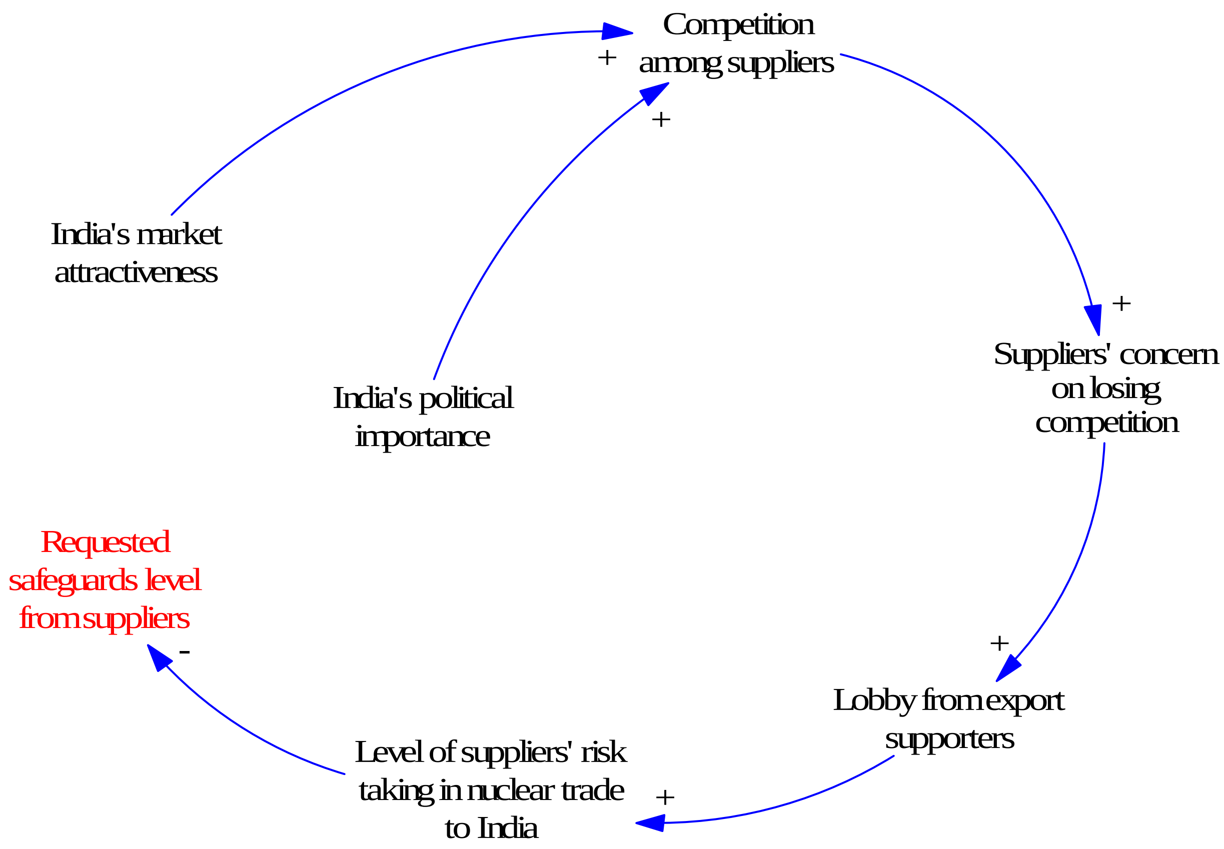


Figure 5.2 Suppliers' decision making logic on prerequisite safeguards for CIRUS export

U.S. competition with the Soviet Union: 1961-1963

No safeguards were imposed on the Trombay reprocessing plant that India claimed to indigenously design and construct. Barnaby explained that "only four of India's nuclear power reactors – two at Rajasthan and two at Tarapur – and none of the research reactors are under safeguards. Safeguards are applied to: the Hyderabad fuel fabrication plant only when it is making fuel from safeguarded material; the Tarapur fuel fabrication plant only when it is making fuel from plutonium produced in safeguarded reactors; and to the Tarapur reprocessing plant only when it is reprocessing spent fuel from safeguarded reactors" (Barnaby 1993:72).

There are opposing views of the reprocessing plant. Matthew Kroenig argued that "a U.S. firm, Vitro International, prepared blueprints for the construction of the physical site at the Trombay reprocessing facility in 1961, but … The sensitive technologies … were developed autonomously with the aid of declassified documents on plutonium reprocessing made available by the U.N" (Kroenig 2010:202). On the other hand, Leventhal commented that "the reprocessing plant where India had extracted the plutonium from CIRUS spent fuel … in fact had been supplied by an elaborate and secret consortium of U.S. and European companies" (Leventhal 2005:1).

Competition with the Soviet Union certainly motivated the United States to export nuclear power plants to India. In February 1961, Bhabha announced that India was interested in importing nuclear power plants. Before the negotiations began, Bhabha intentionally stated that India was pursuing nuclear cooperation with the Soviet Union. This encouraged

Canada and the United States to accelerate exports of nuclear products with minimum safeguards. In October 1961, India signed a cooperation agreement for peaceful uses of nuclear energy with the Soviet Union (Appadorai and Rajan 1985:273). Under the U.S. Mutual Defense Assistance Act of 1951, "the United States was required to deny military, economic, or financial assistance to any country trading such material [sensitive nuclear materials] with the Soviet Union" (McMahon 1994). To prevent Soviet-India cooperation, the United States gave India what it wanted.

As a leader of the Third World as well as of countries still subjugated by colonialism, India emerged as a new key political partner of many countries (Reiss 1988:205). The competition made India a difficult partner for the United States. Nehru, who conceptualized principles of nonalignment, believed that this policy would bring India complete political freedom and economic benefits. India thus resisted being a full ally with either the United States or the Soviet Union. Under the Cold War environment, India enjoyed being courted by two superpowers.

In the negotiation for the two Tarapur BWRs, U.S. Secretary of State Dean Rusk recognized the proliferation risk of India based on its geopolitical situation. In 1960, Nehru and Bhabha occasionally indicated that India would be able to manufacture nuclear weapons in the future. During a meeting with retired Major General Kenneth Nichols, a Westinghouse representative, Nehru first asked Bhabha if he could develop an atomic bomb. After Bhabha said he could, Nehru asked how long it would take. The required time, Bhabha estimated, was only a year. Then, Nehru asked

Nichols if he agreed with Bhabha's estimation. Nichols said there was "no reason why Bhabha could not do it." At that point, Nehru told Bhabha: "Well, don't do it, until I tell you" (Nichols 1987:351-352; Weiss 2010:257). It is unclear if Kenneth reported this conversation to the U.S. government.

In 1960, a Soviet diplomat warned an U.S. official that India could make nuclear weapons from the plutonium produced in the natural uranium reactors. Since this was coming from a main competitor, the United States apparently paid little attention. The United States forged on and exported two 160MWe BWRs; their construction began in 1962 and they became operational in 1969.

The 123 Agreement between the United States and India was reached in 1963. The agreement stipulated that India was required to use U.S.-origin nuclear fuels only for the two BWRs. The United States continued to supply nuclear fuels to India even after the 1974 nuclear test. However, in 1982 India began using France as a supplier instead, after the United States asked it to accept full-scope safeguards as a condition of supply (Barnaby 1993:70). France, a non-member of the NSG, was willing to supply India with nuclear fuels without imposing such safeguards. The United States had little influence to prevent the switch.

As a superpower, the United States did not sufficiently engage with India's security environment. In response to the 1964 Chinese nuclear test, President Lyndon Johnson announced that the United States would offer security assurances for non-nuclear weapons states against nuclear threat (Perkovich 1999:87-92). In 1964, M.R. Masani, General Secretary of the

Swatantra Party, called for a U.S. nuclear umbrella at a press conference. Indian Prime Minister Lal Bahadur Shasrti also discussed nuclear assurances with British Prime Minister Harold Wilson (Bhatia 1979:121). In April 1967, the India cabinet expressed concern about ineffective security assurances under the NPT to Moscow, Paris, Washington, and London. They hesitated to cooperate in this matter because of lack of political will based on different interests (Perkovich 1999:136).

Hesitation in improving conditions of supply for RAPP I: 1964

In the negotiation for the first CANDU plant, Canadian politicians, diplomats, and external affairs officials became suspicious about India's possible non-civil intentions. Many of them gradually came to support the IAEA safeguards; Canada requested India to accept them. The proliferation concern was largely intensified after the Indian defeat by China in the 1962 border war (Reiss 1988:206). In the Parliament Debate, some Indian politicians insisted on changing the existing policy against nuclear bomb development. The Prime Minster rejected this idea, but this debate became heated after the 1964 Chinese nuclear test (Sagan 1996).

Two main Canadian goals were: adopting the IAEA safeguards for the new CANDU plant and upgrading the existing safeguards for the CIRUS reactor up to the IAEA level. Some Canadian officials asserted that Canada had to use the CANDU sale as leverage to obtain these two nonproliferation targets. Canada would not export the CANDU plant unless India signed more strict safeguards agreements for the CANDU and the CIRUS (Bratt

2006:98). Moher pointed out that the “bilateral political relationship [between Canada and India] may be unable to withstand the test of such lengthy periods” (Moher 1985:40).

The AECL and its private partners opposed the renegotiation of safeguards for the CIRUS plant. They wanted to avoid increasing negotiation conflict with India to survive in the highly competitive market. For example, the AECL competed with General Electric, which offered extraordinarily favorable financial terms for light water reactors (Bothwell 1988:362; Bratt 2006:97). The Department of Industry, Trade, and Commerce supported these private sector companies. The Department of External Affairs worried that India would import nuclear reactors from the United States, the Soviet Union, or France.

Chester Ronning, Canadian High Commissioner to New Delhi, thought that India would not develop nuclear weapons until China tested its nuclear bomb. However, he was concerned Canada would not be able to prevent India from developing nuclear bombs if India wanted to do so. Nonetheless, he advised that Canada continue to promote the CANDU export project with India, because further debates on safeguards could cause “[a] very bad effect upon our relations with India, especially, after such lengthy negotiations” (Touhey 2007:15-16).

The AECL was an imperative entity to the export of nuclear power plants. Bratt noted that “it is necessary to export nuclear equipment and technology because Canada’s domestic market is simply not large enough … [compared to] the United States, which have much larger domestic markets.

Exports are crucial to Canada's nuclear equipment suppliers because these sales allow them to maintain the necessary infrastructure needed to produce components" (Bratt 2006:20-21). The AECL even provided India with a blueprint of CANDU to attract it. This decision diminished Canada's technical leverage on India's nuclear program.

Eventually, Canada dropped its demands and the CIRUS reactor remained without appropriate bilateral and international safeguards. For the CANDU plant, Ottawa did manage in the 1960s to achieve "rights to inspect and verify disposition of Canadian fuel; right to inspect premises of reactor; and right to obtain records of all fuel used in reactor and guarantee of prior notification of disposition of product of nuclear fuel" (Touhey 2007:16). However, fissionable materials produced in the reactor were not subject to bilateral safeguards (Barnaby 1993:72). In 1966, the bilateral safeguards agreement was replaced by the IAEA agreement, but fissionable materials produced by India were still not safeguarded components. India also accepted no retransfer of nuclear materials, equipment, and technology without Canadian approval.

Canada's early frustration on India's nuclear issue led it to abandon the responsibility for pursuing nonproliferation engagements. In the 1960s, Canada had overestimated India's technical capability to manufacture nuclear weapons. For this reason, Canada considered itself unable to stop India from developing nuclear weapons. This early frustration led many to conclude that no effort could make a difference regarding India's nonproliferation environment. The frustration was intensified by Canada's concern about its bilateral relationship with India. If a supplier had pressed India to sign high-level safeguards, it would have jeopardized the bilateral relationship, eventually leading India to find another supplier.

As shown in Figure 5.3, the growing proliferation concern increased Canada's desire for more stringent nonproliferation assurances. However, separated plutonium was not subjected to inspection, and Canada was reluctant to resolve the safeguards issues of the previous sale. A Canadian negotiator confessed: "We knew that reactor was naked. Here was a chance do something about it. But the commercial people kept saying that if we didn't give the Indians what they wanted, they'd get it elsewhere" (Pringle and Spigelman 1981:277; Bratt 2006:98). The weak nuclear export regime provided insufficient chances to interact with others and little incentive to agree to common conditions of supply. Again, desire for economic profit and political benefit trumped concerns over nuclear proliferation.

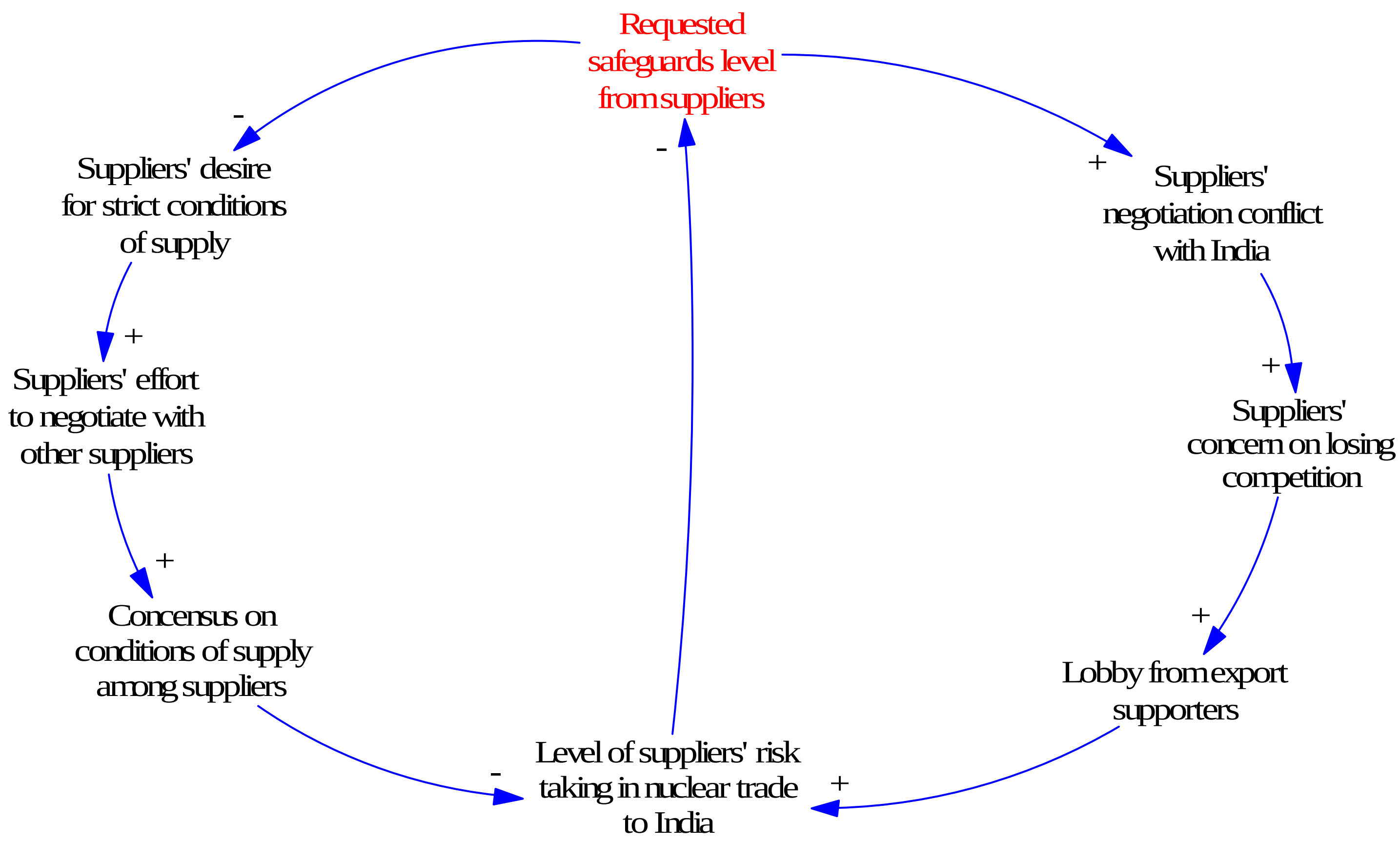


Figure 5.3 Suppliers' decision making logic on safeguards for Canadian RAPP I and II

Bilateral relation first strategy for RAPP II: 1966

India's reactions to the NPT were quite different from that of Canada during the negotiations for the RAPP II. Canada and India disagreed on the legitimacy and benefits of the NPT regime. In May 1964, India announced that it would not sign the NPT. Six months later, Prime Minister Shastri, who personally opposed nuclear weapons development, approved the exploration of peaceful nuclear explosions for tunneling, excavation, and other non-military purposes (Reiss 1988:216). This decision was largely influenced by strong internal desires after China's nuclear test. However, there was no distinguishable technical difference between peaceful nuclear explosions and nuclear bombs.

Denis Healey, the British defense minister, told his Canadian counterpart that the Indians "were making all necessary preparations for a test explosion sometime before the end of the year [1965] in a form which could be justified as being for peaceful purposes" (Touhey 2007:20). That information was incorrect, but revealed the potential dangers of India's nuclear program. In the same year, American intelligence also warned Canada that India might use Canadian technology to develop nuclear bombs (Bratt 2006:108).

Becoming the advocates for the multilateral nonproliferation regime, Paul Martin, Secretary of State for External Affairs, argued that Canada had to urge India to participate in a tight international safeguards system when offering financial loans for the second nuclear power plant. The proposed safeguards requirements met the NPT guidelines that included the IAEA's authority to monitor nuclear facilities as well as fresh and reprocessed nuclear materials, regardless of their origin (Bratt 2006:109). He also added "We will never have a better lever to apply with the Indians that their present application for credit financing of RAPP II" (Touhey 2007:24).

India insisted that it would not accept safeguards on subsequently produced plutonium. Concerned about negotiation conflicts, the AECL claimed that "it would be a great pity if Canadian industry were denied the opportunity to participate in this work by reason of the application of a political decision on safeguards of doubtful merit" (Bratt 2006:107). India also threatened Canada by noting that it could import nuclear power plants from France. Bratt explained India's behavior: "India calculated, as it had in the past, that this would result in the Canadian nuclear industry pressuring the Canadian government to ease up on its safeguards demands in order to preserve its sale to India" (Bratt 2006:109).

Canada decided to finance the second nuclear power plant with the same level of safeguards as RAPP I – no leverage action – in 1966. Canadian leadership hesitated to use the financial loan to insist on strict safeguards. Pearson, then Prime Minister of Canada, said "if we persist now we are likely to get into serious trouble with India" (Touhey 2007:24-25). The Canadian Cabinet approved the second CANDU sale in December 1966. Eventually, both parties agreed to place two CANDU plants under the IAEA safeguards no later than one year after each reactor reached criticality – these still did not affect separated plutonium (Moher 1985:41).

In 1968, Ottawa approached Washington and Moscow with the idea to provide India with a joint security guarantee. This idea failed due to the refusal of the Soviet Union, which wanted to build an independent relationship with India (Touhey 2007:30-32). There were no follow-up measures. Pearson abruptly retired as Prime Minister in 1968, at the final stage of the NPT negotiation. This intensified an internal chaos; the new Trudeau government was not interested at all in the India nuclear issue.

5.1.3 Assessment, summary and lessons

When Canada and the United States exported nuclear products to India, the desires for economic and political benefit overwhelmed nonproliferation concerns. Not only was nuclear trade not a product of credible alliances or strict bilateral relationships, but it was exploited as a means, despite high risks, to establish political and economic partnerships. Canada and the United States had recognized the proliferation risk in nuclear transfer to India from the start, but promoted nuclear exports regardless. Selling nuclear materials, equipment, or services was important, preventing the establishment of relationships with their enemies was critical, but countering nuclear proliferation was a less urgent agenda.

Figure 5.4 illustrates the decision-making process regarding nuclear exports from Canada and the United States. India’s economic attractiveness and political importance caused intense competition among suppliers. Competitors included the United States, the Soviet Union, the United Kingdom, Canada, and France. Canada and the United States were particularly threatened by the possibility of losing India to other eager competitors. They lobbied national decision-makers to ignore external and internal proliferation warnings and loosen demanded levels of safeguards as a condition of nuclear supply.

Once insufficient safeguards were imposed on nuclear exports to India, proliferation concerns became stronger, resulting in a desire for more stringent nonproliferation assurances. With consensus-building feedback, some diplomats and officials in Canada attempted to strengthen the required level of safeguards for nuclear reactors. However, such requests increased Canada's negotiation conflicts with India and had a negative impact on Canada's competitive position. Thus Canada chose to reduce conditions of supply to eliminate serious concern on losing India by other competitors.

In the context of high competition and weak nuclear export regimes, it is difficult to expect that nuclear suppliers will cooperate with competitors to set up consented conditions of supply on the customer. Nonproliferation policies cannot resist political and economic temptation. The bilateral safeguards agreements of Canada and the United States with India did little to clarify Indian nuclear intent, detect internal activities, and respond to proliferation attempts. After about 10 years later from the initial nuclear cooperation, Ottawa and Washington had little influence in preventing New Delhi from developing nuclear explosives.

The anticipation of major economic profits gave the suppliers a strong motivation to promote nuclear deals with India, which market size and growth rate were huge. Thus, they avoided the costs of negotiation with India.

Moreover, India's political importance in the Cold War environment led Ottawa and Washington to overlook proliferation risks in New Delhi in order to win a political edge against Communism. In addition, the global nonproliferation norms were newly emerging; there was no consensus over the baseline of conditions of supply. Efforts at consensus-building were ineffective in the face of conflicting interests of fiercely competing suppliers with limited interdependence.

In this case, concerns on negotiation conflicts overcame desires for consensus-building for agreed conditions and offer collective security assurances. The lack of vigilance feedback was negligible because suppliers focused on the attractive market; the external constraint feedback was trivial since suppliers had little leverage to influence other suppliers' decisions.

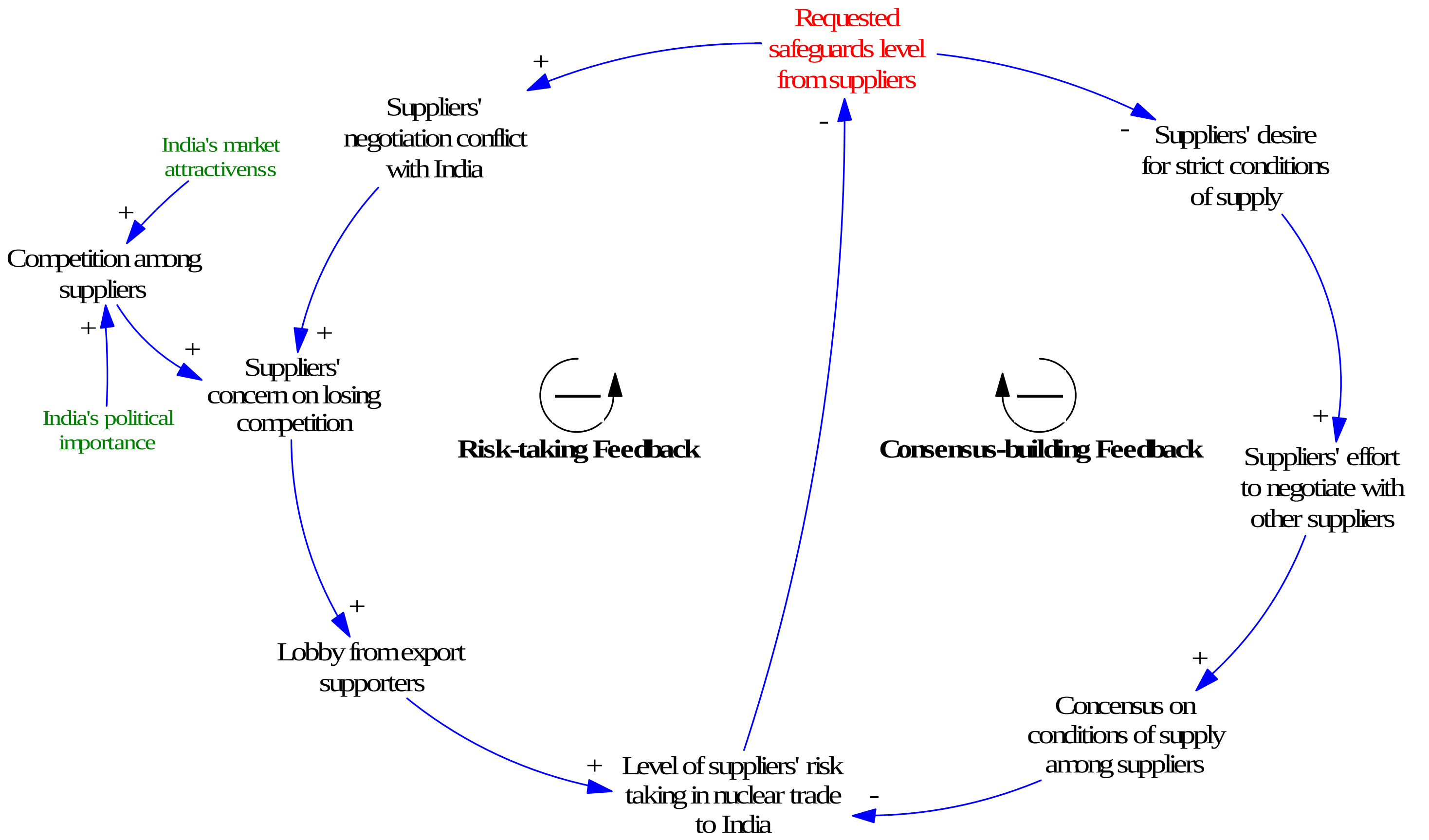


Figure 5.4 Canada and American export decision making logic on nonproliferation assurance

5.2 The Soviet Union to North Korea: unattractiveness, low competition, lack of vigilance

North Korea tested nuclear explosive devices in 2006 and 2010. Its nuclear development dates back to right after the ceasefire that ended the Korean War from 1950 to 1953. The case of nuclear trade between the Soviet Union and North Korea shows how lack of vigilance in nuclear assistance contributes to nuclear proliferation. The Soviet Union gave North Korea nuclear assistance for its own political benefit in the 1950s-1960s, but it was limited to basic research only.

The lack of vigilance feedback mainly influenced Soviet decisions on nonproliferation conditions of supply. To the Soviet Union, North Korea was less attractive and important than China and Eastern Europe, where supply-side competition was strong. North Korea's technical capability might have been underestimated because no supplier wanted to provide significant assistance to the unattractive market. On the other hand, the external constraint feedback balanced the lack of vigilance feedback. Competitors constrained the Soviet Union from exporting nuclear materials and technology with insufficient safeguards. Unfortunately, the feedback was weak in North Korea because the competitors focused on more attractive partners. With little attention from suppliers, the risk-taking feedback and the consensus-building feedback were trivial in this case.

In the following sections, we discuss how foreign nuclear assistance contributed to North Korea's nuclear capability. The next section elaborates upon why the Soviet Union overlooked proliferation risk in exporting nuclear knowledge to North Korea.

5.2.1 Nuclear assistance and nuclear program

The Soviet Union was a major nuclear supplier in the 1950s-1960s, whereas China had insufficient supply capability at that point. In 1954, North Korea's Department of Nuclear Defense was established under the Ministry of the People's Armed Forces. One year later, the Nuclear Physics Research Institute was established in Yongbyon. Pyongyang asked Moscow to help it to establish nuclear infrastructure. In 1956, North Korea joined the Joint Institute for Nuclear Research, designed as an international nuclear research platform at Dubna for the Communist world (Zhebin 2000:28-29).

From the late 1950s to the early 1970s, the Soviet Union trained over 300 North Korean scientists. In 1956, about 30 North Korean specialists may have learn plutonium-reprocessing techniques under the Soviets (Karouv 2000:17). Moreover, Choe Hak Kun, who became the Minister of Atomic Energy Industry in 1986, studied at Moscow University and worked at the Dubna Institute (Lee 1998:113-114). With Soviet–trained human resources, Kim Chaek University of Technology introduced its first nuclear course in 1964 (Hong 1994:27). In the 1970s, Kim Il Sung University and Kim Chaek University of Technology established their own nuclear education programs. The Soviet-assisted Yongbyon nuclear research complex provided on-the-job training.

From 1947 to 1950, Moscow assisted Pyongyang in investigating uranium deposits in exchange for 9,000 tons of uranium (Hong 1994:27; Chang 1999:114). In the 1970s, Kim Il Sung mandated further investigation of uranium deposits throughout the country (Ham 2009:67). China helped the survey team to discover a large amount of commercial-grade uranium deposits. According to Soviet officials, Romania might have sold nuclear materials to North Korea in the 1970s-1980s.

In 1959, North Korea signed two cooperation agreements on peaceful uses of nuclear energy with the Soviet Union and China. The agreement included the conduct of geological studies, the training of North Korean engineers, and the establishment of Yongbyon nuclear research (Zhebin 2000:30). For the Yongbyon center, the Soviet Union provided a 0.1MWt critical assembly, a B-25 betatron, X-ray and K-60,000 cobalt irradiation facilities, and a number of hot cells (Ham 2009:66). North Korea also obtained Soviet blueprints for several auxiliary facilities, such as a waste storage site and a special decontaminating facility (Karouv 2000:15-16).

In the early 1960s, Moscow supplied North Korea with an unsafeguarded 2MWt IRT research reactor with 10% enriched uranium fuels. This reactor reached its first criticality in 1965. It could theoretically produce 4-14kg plutonium for 31 years of its operation (Dreicer 2000:283). North Korea might also have loaded additional fuel rods made of natural uranium to produce weapon-grade plutonium. North Korea indigenously upgraded the power of the reactor to 4MWt in 1974 and to 8MWt in 1977. The Soviet Union reportedly provided 40% and 80% highly enriched uranium to support these increases of reactor power.

After Moscow refused to supply a 100MWt reactor, Pyongyang began building a 5MWe reactor based on a declassified British Magnox-type design. It used natural uranium metal fuels and reached the first criticality in 1985. The reactor is "very crude in quality … but suitable for the production of plutonium" (Mack 1991:87). North Korea also possessed sufficient natural uranium and graphite deposits (Senge 1990:22). In the mid-1980s, North Korea began the construction of 50MWe and 200MWe Magnox-type nuclear reactors that were suspended by the 1994 Geneva Agreed Framework.

North Korea began to study nuclear fuels in the early 1970s. A fuel fabrication plant was completed between 1985 and 1987. To produce yellow cake (U_3O_8) from domestic mines, North Korea has operated a uranium milling plant with an annual capacity of 210MTU since the early 1980s (Choe 1992). A conversion was simultaneously developed from yellow cake to uranium hexafluoride (UF_6), which is required for enriching uranium.

With Soviet-origin hot cells and Soviet-trained scientists, North Korea examined gram-scale extraction of weapon-grade plutonium from the irradiated fuels of the IRT reactor in the mid-1970s (Hibbs 1992:15; Niksch 2010). Pyongyang began the construction of a reprocessing facility at Yongbyon in 1985 with an annual capacity of 100MTHM (Fialka 1989). At that time, it was the second-largest plant in the world, second only to the U.S. plant at the Hanford site (Reardon 2010:134). The plant was designed with consideration of spent nuclear fuels from not only the 5MWe (20-25MWt) reactor but also incomplete 50MWe and 200MWe reactors. For wet reprocessing, North Korea imported TBP solvents. China shipped 20 tons of TBP to North Korea in 2002; there might be many undetected exchanges.

In 2010, Pyongyang unveiled its demonstration-scale enrichment facility to the world. The facility has 2,000 cascades of centrifuges, probably of a Pakistani P-2 design, theoretically producing enough enriched uranium for enough one or two uranium bombs a year (Sanger 2010). Pakistani President Pervez Musharraf admitted that A. Q. Khan provided 13 centrifuge units, blueprints, an instruction manual, two UF_6 calibrators with natural uranium and 0.3% uranium tails, special oils for centrifuges, technical advices, and a list of required items (Cheon 2004:6).

In 1987, North Korea imported an annealing furnace from West Germany for the melting/refining of uranium and for treating maraging steels (Squassoni 2006:4). It tried to purchase Japanese electrical-frequency converters in 1999 and 2003 to achieve a stable electricity supply for centrifuges, in order to achieve high rotational speed (Zhang 2009). In the early 2000s, it bought uranium feed and withdrawal components for centrifuges from China, Russia, and Europe. In late 2002, North Korea procured Russian high-strength aluminum alloys of 150 tons, enough for about 2,600 centrifuges.

Until the 1960s, North Korea built basic research infrastructures and developed human resources with Soviet support. Kim Il Sung fostered indigenous nuclear fuel cycle capability in the 1970s while establishing domestic education programs. By the end of the 1980s, North Korea had constructed demonstration plants for several frontend and backend fuel cycle processes. In the 1990s, North Korea became more focused on developing uranium enrichment capability, after pressure mounted on the plutonium route. Nuclear trade, assistance, and cooperation enabled North Korea to pursue the development of a full nuclear fuel cycle including conversion, reprocessing, and enrichment. These processes were finally exploited for nuclear tests in 2006 and 2009.

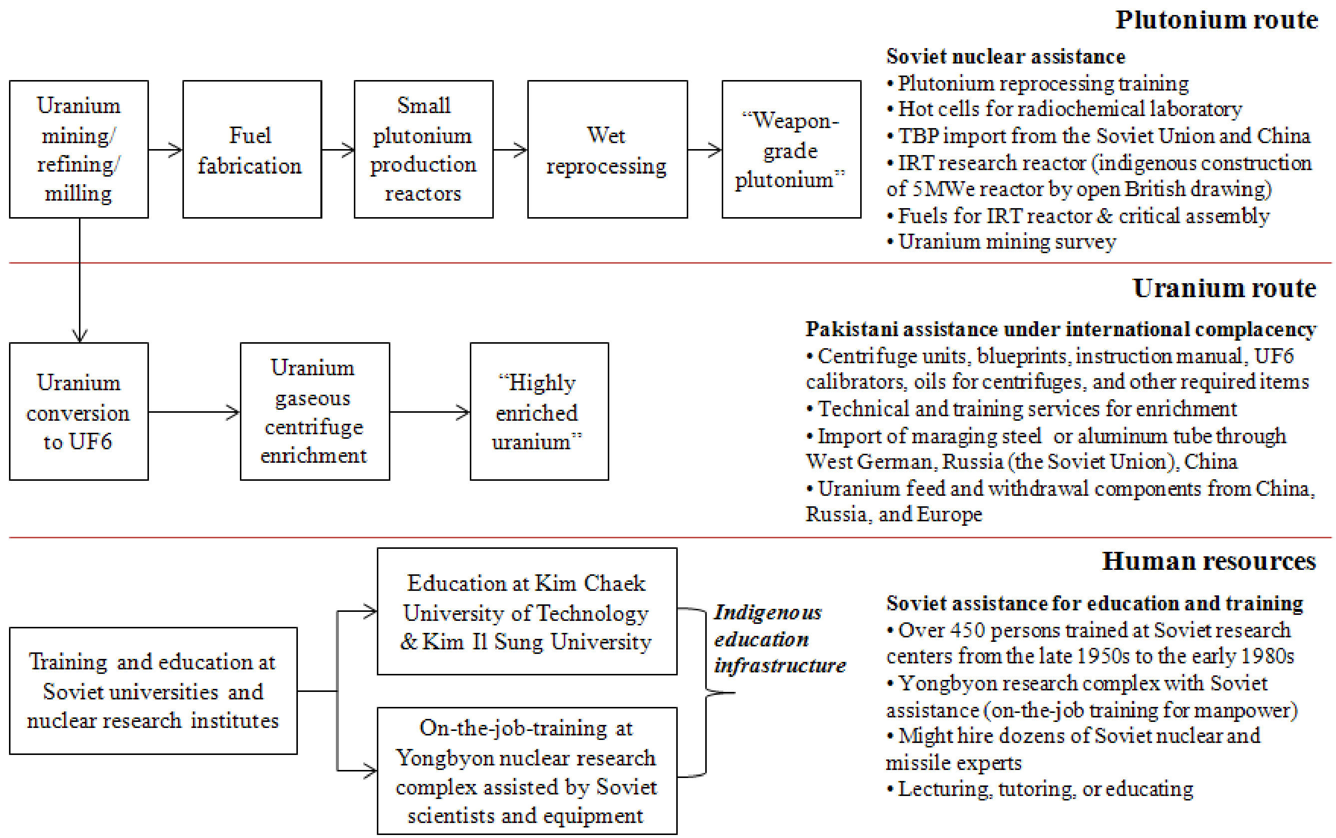


Figure 5.5 North Korea's two routes for nuclear materials production and foreign nuclear assistance

5.2.2 Nuclear exports from the Soviet Union

The Soviet Union overlooked proliferation risks in nuclear technology transfer to North Korea, resulting in weak nonproliferation conditions of supply. Although the Soviet Union did not supply a full-scale reprocessing plant, it provided manpower training for reprocessing, hot cells, and other required dual-use items. Until the mid-1980s, the Soviet leaders were politically confident that they could prevent North Korea from developing nuclear bombs. The Soviet Union also underestimated North Korea's nuclear capability, because very few other suppliers were interested in exporting nuclear items to North Korea's impoverished market. After Kim Il-sung, founding leader of North Korea, revealed his ambition to develop nuclear weapons, the Soviet Union and China denied the requests, but established no follow-up plans to eliminate the nation's proliferation motivation. No other suppliers actively warned or specifically questioned the Soviet Union about – a leader of the Communist world – about the potential risks of nuclear proliferation in North Korea. Many competitors were a lot more sensitive to nuclear issues in China and Eastern Europe.

There was enough proliferation motivation for North Korea; it faced a security threat by sharing its south border with a military alliance of South Korea and the United States. Insufficient security assurances from the Soviet Union and China intensified North Korea's desire for nuclear weapons as self-sufficient security mechanism. After the Korean War, North Korea's insecurity was intensified by the deployment of nuclear weapons in Guam, Hawaii, Okinawa and South Korea (Norris et al. 1999). The number of nuclear weapons in South Korea and Okinawa increased to nearly 1,400 in 1961 and about 2,600 in 1967. At that time, the United States retained the right of first nuclear strike to repel any attack on South Korea (Harrison 2002; Suh 2009).

These actions of the suppliers raise a question: why did the Soviet Union fail to recognize proliferation risk in North Korea? Why was it so confident it could control North Korea, and reject the requests of nuclear technology transfer? First, North Korea was economically unattractive for the Soviet Union and other nuclear suppliers. Nuclear suppliers had little incentive to sell sensitive nuclear products that required special nonproliferation constraints and required unnecessary negotiation efforts. The economic unattractiveness caused low supply-side competition. North Korea was a country to which allies gave economic assistance, not a market where they sold expensive industrial products. Because North Korea had to develop nuclear capability almost itself, the Soviet Union underestimated North Korea's technical capability. Moreover, North Korea largely relied on the Soviet Union for economic matters, making Soviet leaders confident of their political control. The Soviet Union was not concerned about losing the market in North Korea since others were not interested in competing. This overall indifference caused low external constraints.

Second, the political importance of North Korea was less significant than those of China and Eastern Europe. In the mid-1950s, the Soviet Union initially promoted nuclear assistance to North Korea in response to the U.S.

Atoms for Peace program that approached South Korea. Meanwhile, the Soviet Union provided nuclear assistance to Eastern Europe and China, regions where it really needed to maintain its influence. Eastern Europe was a highly important region in terms of coping with the Western world and the NATO alliance. In addition, Yugoslavia was a leader of the non-aligned movement. China was a difficult ally and competitor that required special attention. Of course, Moscow needed to maintain close links with all its important allies. But it had lower motivation to focus on Pyongyang. The low incentive resulted in lack of vigilance in North Korea's nuclear efforts.

Third, the Soviet nuclear exporters initially were overconfident about bilateral relationships with allies. Thus there was no effort to address allies' concerns or create regulation to control other import routes. Early on, the Soviet Union hesitated to participate in the international nonproliferation regime that the United States initiated. It was skeptical about multilateral control and proposed that the United States take care of its own allies. After China announced its nuclear intentions in 1958, the Soviet Union changed the focus of its nuclear export policy from political control to technology control. It cancelled many nuclear exports to its allies. This was the simplest way to avoid proliferation, but there was no additional help in removing proliferation motivations such as security threats and internal disorder. With no consistent export procedures, Moscow continued with its case-specific exports for political and economic benefits. This facilitated the loss of control over North Korea.

Nuclear cooperation against common enemies: 1950s

In 1954, the Soviet Union promoted an active worldwide assistance program for nuclear energy to improve political relationships with China, Eastern Europe, North Korea, and other Communist allies (Potter 1985:469). This program provided friendly foreign countries with nuclear information, expertise, manpower, materials, equipment, and technology. This Soviet nuclear export campaign was in response to the U.S. Atoms for Peace program. In January 1955, a Soviet Council of Ministers declared a large foreign assistance program that included nuclear exports. Nikita Khrushchev, First Secretary of the Communist Party of the Soviet Union from 1953 to 1964, was willing to take proliferation risks in nuclear transfer in exchange for political benefits (Duffy 1979:3). Right after the declaration, the Soviet Union signed nuclear cooperation agreements with China, Czechoslovakia, East Germany, Poland, Rumania, Bulgaria, Hungary, and North Korea (Polach 1968:4). In March 1956, the Soviet Union established the Joint Institute for Nuclear Research. By 1971, more than 3,000 Communist scientists had been trained by the Soviet Union (Duffy 1979:4).

During the Cold War, Moscow and Pyongyang shared common enemies – Seoul and Washington. On February 3, 1956, the United States signed an agreement for peaceful uses of nuclear energy with South Korea, and had provided it with a nuclear umbrella since the Korean War. The nuclear cooperation of these enemies stimulated the Soviet Union to strengthen its diplomatic ties with North Korea. Despite the bilateral cooperation that was launched with North Korea, there was no comprehensive outreach other than human resources development until the end of the 1950s. In 1959, the Soviet Union signed another cooperation agreement on nuclear energy with North Korea. This new agreement allowed North Korea to receive more substantive assistance, including the acquisition of a small research reactor.

Over the decades, several adversaries with nuclear capabilities had threatened the Communist world – either directly to the Soviet Union, or indirectly to its allies. Israel and South Africa were indirect threats, while West German was a direct threat. According to Gloria Duffy, "between 1955 and 1957 when the Soviets first promised to transfer nuclear technology to China, they might well have intended to share knowledge of nuclear weapons manufacture to increase the power of their socialist ally" (Duffy 1979:5). Subsequently, the two Germanys warranted more serious Soviet attention than the two Koreas in a similar situation. The Soviet Union tried to prevent West Germany from acquiring nuclear weapons; this was a one of the top Soviet foreign policies in the 1960s. After that, South Africa also received special Soviet attention. Duffy said that "the Soviets seem to see South Africa as moving ever more steadily toward the capability to make nuclear weapons… South Africa is near the top of the list of revanchist countries about whose nuclear plants the Soviets voice alarm" (Duffy 1979:2).

On the other hand, North Korea was a lesser item on the Soviet national agenda. In fact, North Korea was one of the most minor beneficiaries of Soviet nuclear assistance program. Starting in 1955, the

Soviet Union offered 2MWt research reactors fuelled with 10% enriched fuels to many Communist countries. North Korea imported a small research reactor in the early 1960s as one of the last recipients of this reactor transfer program. In this period, other allies gained many more benefits from Soviet cooperation. For example, Czechoslovakia was supposed to receive a 150MWt heavy water-moderated reactor. Hungary and East Germany were promised small light water reactors using enriched uranium fuels (Potter 1985:469). In particular, the Soviet Union offered the most significant nuclear largesse to China, including a gaseous diffusion uranium enrichment plant (Kroenig 2009a, b). Some of these deliveries were cancelled, however, after China expressed its intention to develop nuclear weapons in 1958.

Although the Soviet Union supplied nuclear technology to many of its allies, it paid little attention on how Soviet-origin nuclear items were used in countries inside and outside the Communist bloc. The Soviet Union supplied nuclear assistance without safeguards in the early stages. First, the Soviet Union did not fully recognize the inevitable technical connection between nuclear power and nuclear weapons, with such a low technical barrier between them. Second, Soviet leaders likely thought that a safeguards system would increase the conflicts of negotiation with recipients; there were only a few precedents of strict safeguards in nuclear business practices until the NPT was formalized. According to Potter, “the Soviet leaders failed to apply safeguards to… nuclear exports, perhaps because they were confident that they would be able to control the nuclear programs of their allies” (Potter 1985:469). In addition, one Soviet leader, Khrushchev, was willing to take the proliferation risk to gain political clout among friendly allies and to compete with Western adversaries. The Soviet initiative of nuclear exports to North Korea, one of the east borders of the Communist world, is understandable in this global competitive ideological environment.

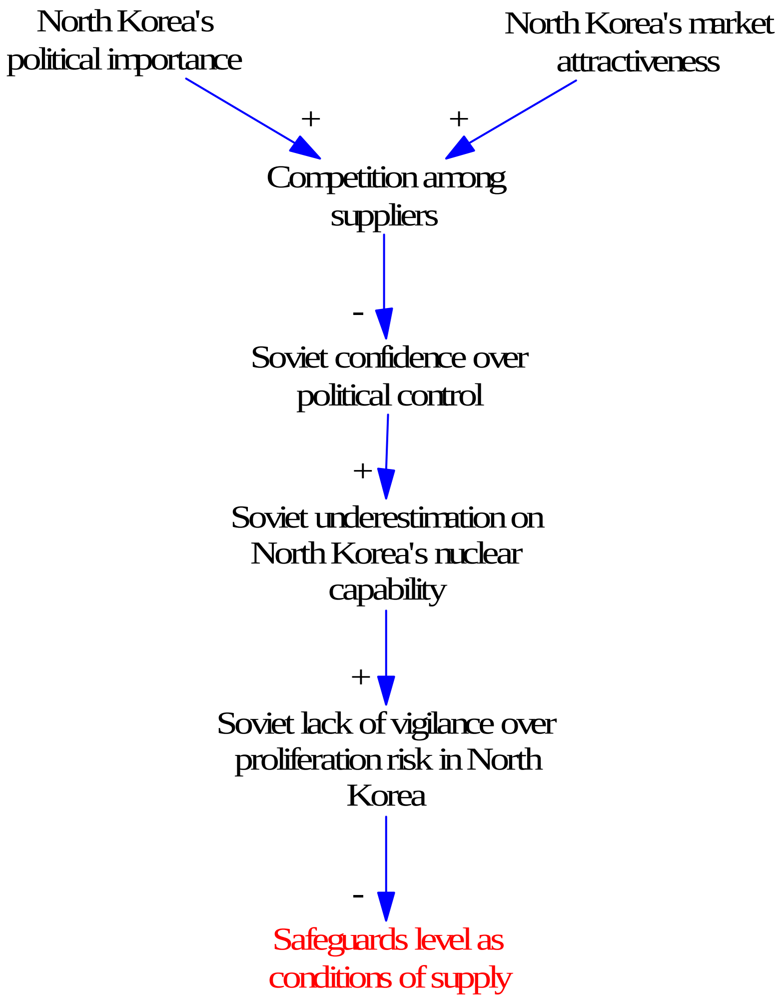


Figure 5.6 Soviet decision making logic on prerequisite safeguards for nuclear assistance

1958 Chinese nuclear shock, but continuing lack of Soviet vigilance over North Korea: 1960s-1970s

Regarding proliferation prevention, the Soviet Union experienced a very bitter failure before tightening its export controls. That failure is the 1958 declaration that China intended to develop nuclear weapons. In 1964, China conducted its first nuclear test based on Soviet-transferred nuclear technology. In response, the Soviet Union changed its export control policy from political control to technology control. Many on-going reprocessing and enrichment programs in Eastern Europe were suspended due to Soviet pressure. The Soviet Union cancelled trade deals to supply a 100MWt reactor to Hungary and a 150MW reactor to Czechoslovakia. In 1967, Moscow rejected Pyongyang's request for a 100MW reactor. Kim Il-sung reportedly threatened Moscow to suspend economic relations unless it supply a nuclear power plant, but it was not a serious threat (Solingen 2007:128). In addition, the Soviet Union restricted nuclear reactor exports to more proliferation-resistant light-water reactors with bilateral safeguards. It also requested that most recipients of Soviet reactors returned spent nuclear fuels. These countries included Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, Rumania, and North Korea (Potter 1985:470).

Simultaneously, the Soviet Union hesitated to accept multinational arrangements on nuclear export controls. Soviet nuclear export controls were managed based on political influence that served as primary nonproliferation leverage until the end of the 1970s. In 1963, V. S. Emelyanov, Deputy Chairman of the Soviet Council of Ministers State Committee on the

Utilization of Atomic Energy, told a European nuclear energy official that "there would be no proliferation problem if all countries would follow the policy of the USSR and each take care of its own." This policy suggested the United States monitored Japan, West Germany, France, and other democratic allies while the Soviet Union supervised China, East Germany, Czechoslovakia, and other socialist allies.

Duffy pointed out that "outside of advocating the NPT … the USSR seemed relatively unconcerned with pressuring countries other than directing clients to refrain from developing reprocessing or enrichment capabilities, stockpiling plutonium, or testing atomic devices" (Duffy 1979:12). The Soviet Union maintained tighter export controls over nuclear technology to its direct clients by denying requests for sensitive technology transfer. Duffy also commented that "[the Soviet Union] did not export nuclear secrets to allies for fear that such allies as Yugoslavia might obtain weapons and turn them on the USSR itself (Duffy 1979:2)." In that sense, North Korea was not a major client or ally that had to be well managed under the Soviet Union's nonproliferation responsibility. The Soviets thought North Korea was under their full control and had no technical capability to manufacture nuclear weapons.

Meanwhile, the Soviet Union jumped into the global nuclear power market beyond the Communist world to overcome its economic depression. The Soviet Union had initially moved exported uranium enrichment services to Western Europe and nuclear reactors to developing countries. From the mid-1970s, the Soviet Union began to export nuclear reactors, structural components, and enriched nuclear fuels outside the Communist bloc (Duffy 1979:14-15). Potter noted that "by the mid-1970s, the Soviet Union had begun to market nuclear technology and services abroad more aggressively. The Libyan [outside the communist bloc] deal may therefore have been regarded by Moscow as an important step in establishing its viability as a nuclear supplier for developing world" (Potter 1985:478).

After the Soviet Union expanded its international nuclear market, other suppliers urged it to join international nonproliferation regimes including the Zangger Committee, the London Suppliers Group, and the Nonproliferation Treaty Review Conferences. The Soviet Union began to closely cooperate with the United States to strengthen export controls for nuclear technology. For Moscow, the international monitoring system was an effective tool to expand nuclear energy business beyond the socialist bloc without receiving serious proliferation questions from other suppliers. West Germany's signing of the NPT in 1969 helped the Soviet Union to convince socialist countries to sign the NPT as well and allow the IAEA safeguards. Under such Soviet pressure, North Korea joined the IAEA in 1974 and signed a partial safeguards agreement for a 2MWt research reactor.

However, North Korea's compliance with the stringent policy could not last long. No nuclear supplier wanted to replace the Soviet trade position with North Korea. North Korea was an economically unattractive country where the Soviet Union worried about nuclear trade from other competitors. Thus, there was no short-term risk of nuclear proliferation that required sufficient level of nuclear capability.

North Korea was experiencing economic difficulty due to its imbalanced economic policy. Since 1957, Kim Il Sung prioritized heavy industries to increase military capability, rather than agriculture and light industry. Concerned about South Korea's growing military, Kim launched a weapons modernization program in 1962, including missile technology as well as a nuclear arsenal (Chang 1999). While North Korea allocated 20-25% of its Gross National Product to defense (Mack 1991), it had no concrete plan to embark on economic reforms (Lee 2009). In the 1970s oil crisis, this imbalance policy resulted in a food shortage, an energy scarcity, and lack of foreign currency (Eom 2009). This was exacerbated by decreasing trade with fraternal socialist countries that supplied food and coal at low prices (Mack 1991). Multiple floods reduced annual coal production and quality, hampering electricity generation and industrial products (Joo 2008; Eom 2009).

The Soviet Union had warning signs of Kim Il-Sung's desire to develop internal nuclear capability, but ignored the risk. When agreeing on a transfer of a small research reactor in the early 1960s, North Korean officials sought Soviet expert opinions on whether it could produce nuclear weapons, while demanding further Soviet nuclear assistance (Solingen 2007). Kim Il Sung sent a delegation to China to obtain assistance in developing nuclear weapons after China conducted its first nuclear test in 1964 (Oberdorfer 2001). In 1974, Kim asked Prime Minister Zhou Enlai to help him to develop an internal nuclear program (Choi 2010). Both requests were denied by the Chinese leaders. Despite these attempts, the Soviet Union never delivered on its promise that it would take back all spent nuclear fuels of the IRT research reactor in North Korea. The IAEA safeguards on the IRT reactor were too weak to effectively monitor North Korea's nuclear program and quickly respond to violations.

Moreover, Pyongyang's diplomatic ties with Moscow and Beijing began to deteriorate respectively after the 1953 death of Stalin and the Cultural Revolution. Khrushchev criticized Kim's personality cult; the Soviet Union supported an opposing party of Kim Il Sung. During the Cultural Revolution, China instigated anti-Kim Il Sung forces because of Kim's revisionism. Although Moscow and Beijing agreed in 1961 to offer immediate military assistance against any armed attack on North Korea, Kim Il Sung doubted them. North Korea's security apprehension was intensified by the Soviet withdrawal from Cuba in 1962 (Bin 2009).

From the Soviet perspective, it made more sense to focus on economically and politically competitive markets such as Eastern Europe, especially since the traditional Western suppliers were expanding their business to Eastern Europe. Romania tried to buy a CANDU reactor from Canada. Yugoslavia purchased a 600MWe PWR from U.S. Westinghouse. Finland agreed to import uranium from Australia in the late 1978.

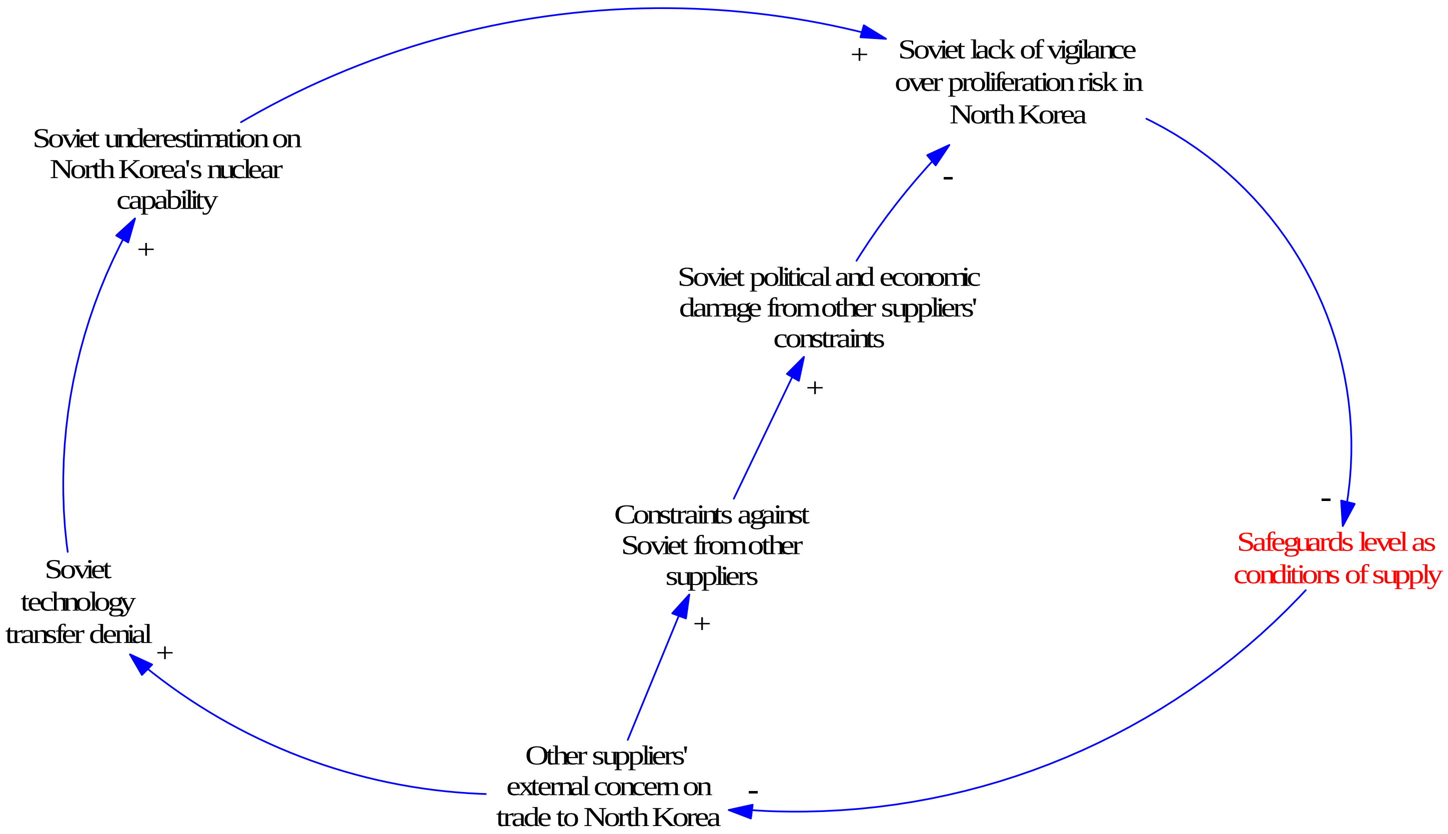


Figure 5.7 Soviet decision making logic on nonproliferation assurance for nuclear trade to North Korea after 1958

Soviet view of North Korea: politically controlled and low technical capability

Obviously, Moscow did not intend to allow Pyongyang to have nuclear weapons. Moscow wanted to keep its authority among the Communist allies. A stronger North Korean nuclear capability would threaten that. Based on observations of the 1950s-1970s, there appear to be two reasons for Soviet lack of vigilance regarding North Korea's nuclear program: Soviet confidence in its political control and underestimation of North Korea's technical capability. This section elaborates upon the two reasons.

First, the Soviet Union thought that it already had full control over North Korea's politics and economy, considering there were no other competitors. Kaurov explained the cooperation between North Korea and the Soviet Union with three principles: "(1) its voluntary nature; (2) mutual respect for state sovereignty and noninterference in the initial affairs of the other side; (3) friendly mutual assistance" (Karouv 2000:15). It was no until the 1980s that the Soviet Union took coercive actions against North Korea. Until then, Moscow was generally indifferent to North Korea's internal situations, including the nuclear program.

In the late 1940s and 1950s, more than 90% of North Korean trade was conducted with Communist countries, and the Soviet Union was the largest. In spite of the North Korean regime's strong pursuit of political and economic independence, its economy remained dependent on the Soviet Union. Kim Il-Sung considered nuclear cooperation with the Soviet Union and China as a success of his regime. Yet, he desired military and economic self-sufficiency that required minimizing dependence upon other countries. In 1969, approximately 70% of North Korea’s total trade dealt with the Soviet Union and Eastern Europe. Although Pyongyang contacted the Western world for importing machinery and equipment in the mid-1970s, North Korean exports still depended on the Soviet Union, 55.9% in 1989 and 56.8% in 1990. Imports also relied on the Soviet Union: 63.5% in 1989 and 57.7% in 1990.

Second, the Soviet Union underestimated North Korea’s technical capability due to limited foreign nuclear assistance. North Korea did not receive a large-scale nuclear reactor, a reprocessing plant, an enrichment facility, or a bomb design from the Soviet Union. There were other Communist allies that much closer to achieving nuclear weapons capability. This perception persisted after the collapse of the Soviet Union. Right before the 2006 North Korean nuclear test, a Russian official told an American official that North Korea had no capability to denote a nuclear bomb.

Moreover, the Soviet Union might fail to fully recognize that the trivial assistance could degrade technical hurdles of nuclear proliferation if it continued for several decades. This is despite that many nuclear suppliers denied North Korea’s requests for nuclear assistance and even the Soviet Union continuously reduced its assistance (Usui 1991). Kim’s regime repeatedly contacted East Germany in 1963, 1967, and 1981 and Czechoslovakia in 1979, to no avail (Solingen 2007). Kim Il-sung also may have contacted East Germany, Romania, and Pakistan, but only Pakistan responded.

Determined, Pyongyang indigenously produced a small plutonium production reactor, a reprocessing plant, and other nuclear fuel cycle processes. Despite low quality, they were capable enough to produce weapon-grade fissile materials (Bluth et al. 2010). The experience gained from the Soviet-origin IRT-2000 reactor was used to indigenously develop an engineering-scale reprocessing plant and a 5MWe research reactor. The IRT-2000 in North Korea was operated without an appropriate inspections from 1965 to 1977 (Dreicer 2000). North Korea secretly examined reprocessing techniques for weapon-grade plutonium from this reactor by loading natural uranium samples. An INFCIRC/66 trilateral agreement was achieved among the Soviet Union, North Korea, and the IAEA in 1977, but the inspection authority of the agreement was very limited and could not draw an overall picture of the North Korean nuclear program.

In the meantime, North Korea turned from the Soviet Union to the black market network for enrichment technology. Countries in this network include Pakistan, Iran, and Libya (Albright and Hinderstein 2005). North Korea also developed a uranium route in parallel since the late 1970s without receiving serious demands for nonproliferation commitments.

According to a Russian expert, Moscow discovered that Pyongyang's enrichment ambitions went beyond commercial grade in 1985. In 1986, the Swedish uncovered URENCO enrichment equipment such as autoclaves, desublimers, and steel containers that North Korea tried to import through Pakistan (Hibbs 1991). The Soviet Union seriously considered the potential proliferation risk in North Korea for the first time, and aggressively urged

North Korea to join the NPT. North Korea accepted the Soviet request in 1985 in exchange for four light water reactors (Mack 1991). This deal was cancelled in 1991 because of the economic troubles of the Soviet Union (Lee 1990).

The four power plant exchanges required various nonproliferation conditions of supply. First, Soviet-origin nuclear materials, equipment, and devices “shall not be used for the production of nuclear weapons or nuclear explosive devices, nor shall they be used to attain any military goal… they will be safeguarded by the IAEA.” Second, North Korea was restricted from providing third parties with information, materials, equipment, or technology that the Soviet Union provided. Third, North Korea would ensure physical protection of materials, and equipment to meet IAEA regulations.

However, this agreement did not address any equipment import and technical assistance from other suppliers. Also, there was no timetable for the construction of the nuclear power plant (Zhebin 2000:33). In October 1986, Kim asked the Soviets to assist in building an underground nuclear reactor (Ko 2002) and perhaps in developing advanced weapon systems as well. Soviet President Mikhail Gorbachov refused to help North Korea. In the 1980s, Moscow declined to supply nuclear fuels to a research reactor at Kim Il Sung University.

In addition, internal economic issues of the Soviet Union were now very urgent, so that it did not have the ability to constrain North Korea from acquiring nuclear weapon capability. Also, it did not approach others for cooperation on this issue. At the end of the 1980s, Mikhail Gorbachev enforced glasnost and perestroika policy to improve diplomatic relations and economic cooperation with capitalist countries, including South Korea. In response, the North Korean Foreign Ministry said that this new relationship “will leave us no other choice but to take measures to provide … for ourselves some weapons for which we have so far relied on the alliance” (Mack 1991). North Korea even declared that this threat would encourage it to develop nuclear weapons (Boulyche 1994; Eom 2009).

The nuclear risk of North Korea came under international attention only after a SPOT satellite discovered a secret nuclear program at Yongbyon in 1989 (Oberdorfer 2001). The United States and the Soviet Union pressured North Korea to sign the IAEA safeguards agreement. Gorbachev threatened to suspend nuclear fuels supply unless Kim accepted the IAEA inspection. Nevertheless, North Korea refused to ratify the Comprehensive Safeguards Agreement (CSA) until April 9, 1992. The two Koreas reached a Joint Declaration of the Denuclearization of the Korean Peninsula on January 20, 1991. The United States declared it would withdraw tactical nuclear weapons, fulfilling North Korea’s first prerequisite. On January 30, 1992, North Korea concluded a comprehensive safeguards agreement more than six years after signing the NPT. In October 1994, North Korea and the United States signed the Geneva Agreed Framework under which Pyongyang agreed to dismantle its nuclear program in return for two light water reactors. Construction on these was completely terminated on January 8, 2006 (KEDO 2006).

By repeatedly freezing and resuming nuclear facilities in a proficient manner, Pyongyang maintained a nuclear program for long periods. By selling its nuclear program, North Korea received extensive economic aid from China, South Korea, the United States, Japan, and the United Kingdom – ironically, this helped accelerated purchases of components and materials for an enrichment facility. In October 2002, North Korea's clandestine enrichment program in cooperation with Pakistan was revealed. It was a direct violation of the 1994 Geneva Agreed Framework. An American intelligence official called it: "a perfect meeting of interests – the North had what the Pakistanis needed, and the Pakistanis had a way for Kim Jong Il to restart a nuclear program we had stopped" (Sanger and Dao 2002). In addition, high-level U.S. government officials suspected that Pakistan has been sharing nuclear warhead-design information and nuclear test data with Pyongyang since 1997.

Despite limited support, North Korea succeeded in detonating nuclear bombs based on a plutonium implosion-type design. This was the result of a national effort of over 50 years with little outside influence. With just one indifferent primary nuclear supplier, North Korea developed a nuclear program without serious external engagement in nonproliferation attempts. The international society was also indifferent to this economically unattractive, politically unimportant, and supposedly incapable small country. Until the early 1990s, it was unclear who was really supposed to be in charge of North Korea's nuclear nonproliferation. This responsibility question is still asked even today.

5.2.3 Assessment, summary and lessons

Soviet lack of vigilance allowed North Korea to develop nuclear weapon capability without serious external constraints. Political confidence caused the Soviet Union to overlook proliferation risks in nuclear technology transfer to North Korea. The confidence was intensified by underestimating North Korea's long-term potential for technical capability development. Soviet nuclear exports to North Korea did not result from a long-term vision of bilateral partnership, but it rather on an instant reactive decision to compete with regional adversaries. Protecting Soviet influence on Eastern Europe and China was urgent, and putting more effort into fully controlling North Korea was pointless.

The decision-making logic for nuclear assistance is described in Figure 5.8. A globally competitive environment between Capitalism and Communism was an initial driving force of Soviet nuclear exports. However, North Korea's economic attractiveness was trivial, so there was low market competition among nuclear suppliers. With low supply-side competition, the Soviet Union was not threatened by other nuclear suppliers that were not interested in jumping into an unattractive market. For this reason, confident Soviet leaders produced national export controls with lack of vigilance on North Korea's nuclear program. Underestimation on North Korea's nuclear capability intensified such lack of vigilance. Thus, the lack of vigilance feedback loop was dominant in this low competition case.

A scenario in which North Korea developed nuclear weapons was considered a low probabilistic event. While the Soviet Union required North Korea to sign low-level safeguards, it offered no motivations for North Korea to reduce proliferation. Since the beginning, North Korea's nuclear program was largely biased toward a nuclear fuel cycle that was a money-consuming weapon-making activity rather than a commercial and profitable nuclear power plant business.

Other nuclear exporters questioned the controls of the Soviet Union in the nonproliferation conditions of supply, especially after it jumped into the global nuclear power market. Due to its external constraint feedback, the Soviet Union strengthened the conditions of supply and participated in the international nonproliferation regime. It denied its allies' requests for nuclear assistance and urged them to sign the international safeguards. This feedback was strong in an attractive market where other suppliers closely watched Soviet nuclear exports. The Soviet Union had to carefully manage this attractive market to keep its competitive advantages.

In contrast, North Korea was an unattractive market where no supplier wanted to sell major industrial products. Nuclear assistance that the Soviet Union provided to North Korea was less significant than those for other allies. The Soviet Union saw no need to request stringent conditions of supply for the rather minor nuclear items North Korea imported. Other suppliers also had no motivation to tackle Soviet nuclear export controls on North Korea because there were more controversial countries that had higher proliferation risks. Thus, the external constraint feedback in the nuclear exports from the Soviet Union to North Korea was weak. Nuclear suppliers were rather indifferent to North Korea's nuclear program.

North Korea's nuclear program remained outside of international monitoring system for over 20 years. The Soviet Union, a primary supplier, was not that concerned about North Korea's indigenous programs and cooperation activities. As a result, international concern over North Korea's nuclear program did not fully emerge until 1985 (Cirincione et al. 2005:244). The first comprehensive IAEA inspection did not happen until 1992, after 38 years of unsafeguarded nuclear development. Soviet lack of vigilance was not a direct cause of North Korean nuclear proliferation, but it certainly helped North Korea to develop nuclear capability without asking serious questions about proliferation for a long time.

The lack of vigilance feedback dominated this low competitive export case. Once a supplier lacks vigilance, it is extremely difficult to overcome it alone. Unfortunately, the external constraint feedback was not strong enough to balance out the lack of vigilance. Other suppliers were also indifferent to this unattractive or uncompetitive market. Therefore, the risk-taking feedback and the consensus-building feedback were trivial in this case.

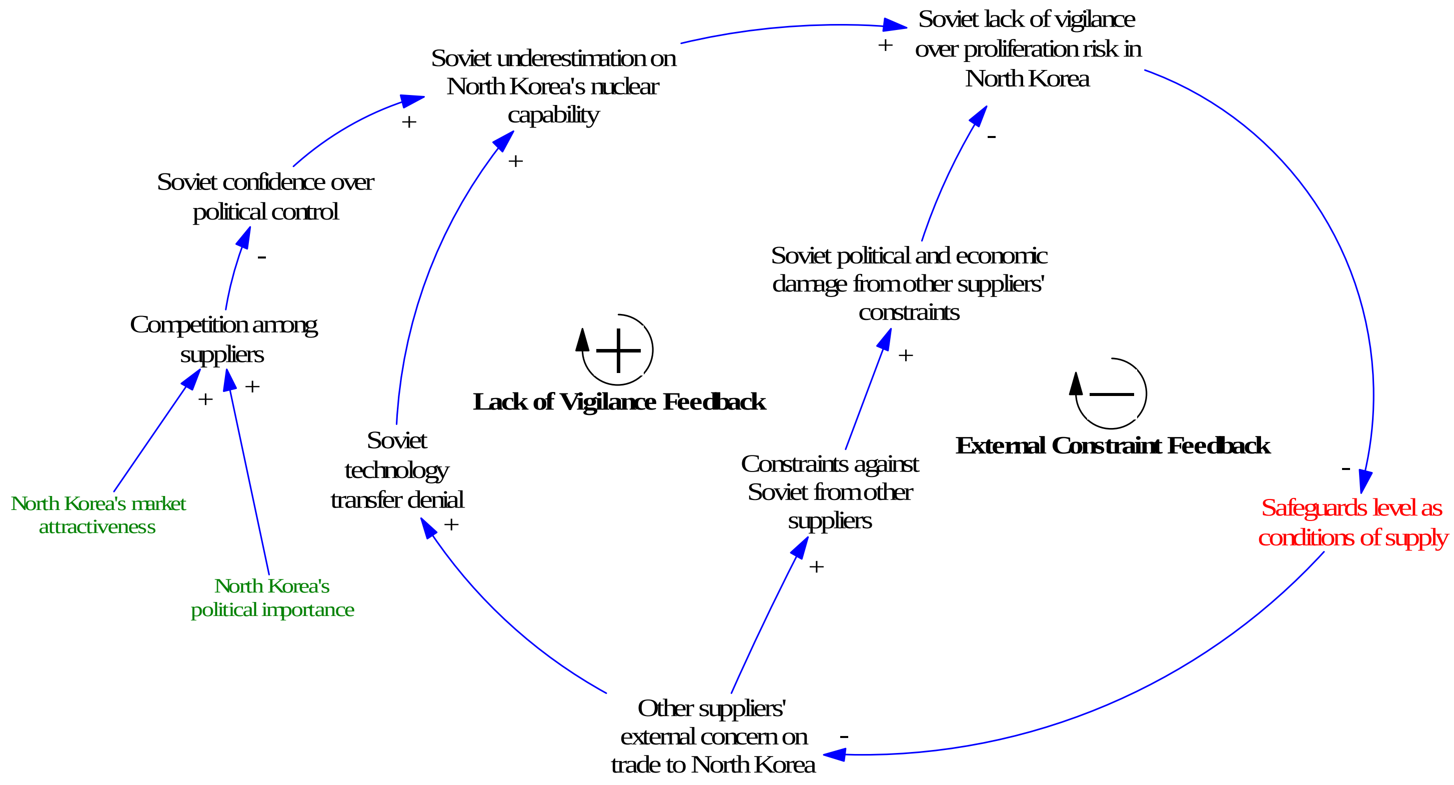


Figure 5.8 Soviet export decision making logic on nonproliferation assurance

5.3 The United States and Canada to South Korea: modest competition, nonproliferation feedback

In the 1970s, South Korea attempted to import a French reprocessing plant and a Canadian heavy water research reactor to develop nuclear weapons. South Korea's nuclear weapon program was eventually suspended because of the security assurances and economic pressure from the United States. Moreover, South Korea's high expectations for nuclear power changed the cost-benefit matrix of nuclear weapons. Market competition among the United States, Canada, France, and the United Kingdom was moderate in South Korea – weaker than India and stronger than North Korea. Healthy competition produced supply-side interaction that strengthened nonproliferation conditions of supply.

To avoid being the only one to absorb the costs of negotiation with South Korea, the United States urged other suppliers to establish consensus over conditions of supply. They were willing to use their leverage to pressure South Korea into nonproliferation compliance. Interdependence between the suppliers and the recipient, as well as collective actions among the suppliers, increased their negotiating power in the nuclear trade. In other words, the consensus-building feedback balanced out the negotiation cost feedback. The lack of vigilance feedback was prevented by the external constraint feedback. Under U.S. pressure, France supplied a fuel fabrication plant instead of a reprocessing plant.

The following section describes how assistance contributed to South

Korea’s nuclear program and how supply-side export competition strengthened conditions of supply.

5.3.1 Nuclear assistance and nuclear program

In February 1956, the United States and South Korea signed the Agreement for Cooperation between the Government of the United States of America and the Government of the Republic of Korea Concerning Civil Uses of Atomic Energy in Washington, D.C. In 1958, the South Korean government officially launched a national nuclear program by enacting the Atomic Energy Act and founding the Atomic Energy Department under the Ministry of Education. In the same year, the Korea Atomic Energy Research Institute was also established.

From 1955 to 1964, the South Korean government officially sent 237 trainees to national laboratories or universities in the United States and the United Kingdom, using funds from the government and international organizations. Among these, 127 people were sponsored by the government, 80 by the IAEA, 3 by the Colombo Plan, and 27 by other overseas aid (Choi et al. 2008:26). International education experts were instrumental in establishing the domestic education programs.

In the 1960s, the government invited international experts via the IAEA for domestic lecture programs at research institutes, universities, or public outreach. Between 1979 and 1988, the special lecture program at the national research institute offered 36 courses by 247 foreign lecturers on introductory and advanced nuclear power technology to 1,511 students. For long-term human resources development, the Korean government launched undergraduate nuclear engineering programs at Hanyang University in 1958 and Seoul National University in 1959. This was about ten years later, making the return of the first wave of graduate students from their overseas studies (Choi et al. 2008:26).

The General Atomic of the United States exported in 1958 a 100kWt research reactor (TRIGA MARK-II) under close supervision of the ROK-U.S. Atomic Energy Agreement. This reactor reached its first criticality in 1962. At that time, South Korea had no right to access irradiated nuclear materials, and had to return these to the United States. Half of the amount was financed by the United States for the research reactor, based on the U.S. policy to fund research reactors built in democratic countries. In 1969, the General Atomic again agreed to export a 2MWt research reactor (TRIGA MARK-III). In the same year, South Korea indigenously upgraded power generation level of TRIGA MARK-II from 100kWt to 250kWt. Nuclear fuels for the research reactors were also supplied by the United States.

Before 1964, the nuclear program concentrated on medical and agricultural uses of radioactive isotopes. From 1964 to 1966, however, Korea embarked upon site evaluations and selection for its first nuclear power plant. Several IAEA evaluations and foreign consulting sessions were continuously completed, from consensus-building to final plant location decisions. In addition to site selection, specialists from the IAEA and the United States provided critical reviews, feedback and assessments on the

Korean energy plan. This reduced the risk of internal and external investments and attracted more investors.

The United States and France exported light water cooled reactors and Canada provided heavy water cooled reactors (Choi et al. 2009). In 1968, South Korea invited bids for the first nuclear power plant based on a new 20-year nuclear power development plan. In the same year, the country signed the NPT. In 1971, the first plant construction was commenced on a turnkey basis with Westinghouse. Korea then faced the next urgent task of securing foreign currency for plant construction. South Korea only could afford $45 million, which fell $135 million short; the United States and the United Kingdom provided the rest.

The first three plants were contracted on a turnkey basis, which meant limited domestic participation. From 1978 to 1980, the country ordered six more PWR units from the United States and France. From the fourth to the ninth nuclear power plant, these projects were contracted on a non-turnkey basis. To establish standardized plant design, South Korea built the plant units with the same authorized power, 950MWe, from the third unit to the ninth unit. The total project scope was divided into several main contracts. Foreign main contractors were obliged to bear the contract liabilities with local sub-contractors under their supervision. All foreign companies were required to work with domestic industry to ensure a certain level of localization.

Korea gradually established localized nuclear technology for design, engineering, and producing components through “on-the-job training” and "on-the-job participation" under the direction of foreign suppliers. Private enterprises were also involved in developing components of the nuclear power plant under the thorough quality assurance and control administration of foreign suppliers. The localization portion increased with time. All of the localized components were required to pass inspection in accordance with the same standards applied to imported components. Ultimate responsibility for plant performance was placed on the main contractors, who promoted suppliers' active participation in quality control of sub-contractors. This contract scheme greatly helped to not only to expand the localized portions of work, but also to speed up the nuclear technology transfer.

With the national success of its heavy and chemical industry, South Korea in 1989 committed to its first locally constructed nuclear power plant, based on accumulated experiences and technology. South Korean companies became main contractors while foreign companies assisted as sub-contractors. Now, local companies performed most design and engineering, construction, and maintenance services. Domestic suppliers supplied the most nuclear power plant components. This tenth nuclear power plant was commissioned in 1995.

Long-term contracts for nuclear fuels were signed with 7 reputable companies from the United States, Canada and Australia. Between 1983 and 1987, instead of conducting high-risk exploration, Korea invested in uranium mines in Canada and the United States. Korea also diversified its suppliers of enrichment services for PWR plants by contracting with France, Russia and the United Kingdom.

In the 1970s, South Korea tried to introduce a French reprocessing plant, a Canadian heavy research reactor, and a Belgium Mixed Oxide Fuel (MOX) plant for both nuclear power program and nuclear weapons development. Both trade deals were terminated by external pressure to maintain nuclear nonproliferation. Instead, France exported a fuel fabrication plant to South Korea. Based on this assistance, South Korea localized PWR fuels fabrication. Moreover, PHWR nuclear fuels were localized and manufactured in South Korea. Now, all nuclear fuels are indigenously supplied to both PWRs and PHWRs.

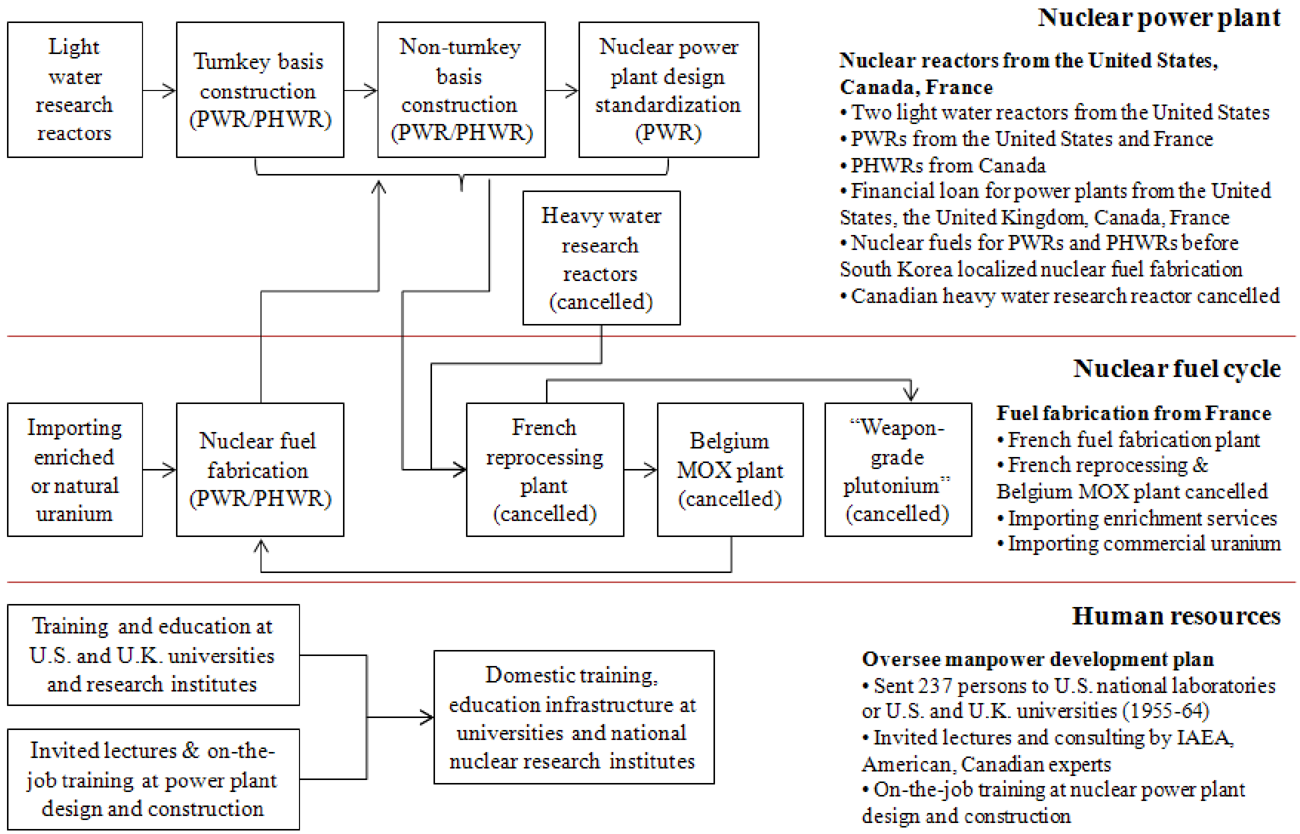


Figure 5.9 South Korea's nuclear development and foreign nuclear assistance

5.3.2 Nuclear exports from the United States and Canada

South Korea's economic attractiveness and political importance caused moderate competition among nuclear suppliers including the United States, Canada, France, and the United Kingdom. The United States and Canada were concerned about proliferation risks in South Korea, especially after it attempted to import a French reprocessing plant and a Canadian research reactor. These processes are critical for weapon-grade plutonium for nuclear bombs. Moreover, South Korea was seriously threatened by North Korea and its Communist allies because U.S. President Richard M. Nixon withdrew U.S. forces in South Korea in 1969. South Korean President Chung Hee Park also desired to develop nuclear weapons as independent security mechanisms.

In the South Korean case, the United States and Canada required strict nonproliferation conditions of supply for nuclear power plants. They shared knowledge and information about South Korea and established consensus over conditions of supply. The U.S. Embassy in Seoul played a critical role in verifying South Korea's intentions. The United States also gave a conventional security guarantee to eliminate proliferation motivation. It constrained France from selling a reprocessing plant to South Korea, but recommended it to export a fuel fabrication plant. However, the United States simultaneously gave reprocessing rights to Japan before it signed the NPT and kept exporting enriched fuels to India even after that country conducted a nuclear test.

Why did the United States and Canada cooperate to strengthen nonproliferation conditions of supply and prevent France from exporting reprocessing technology, while making exceptions for Japan and India? First, the United States and Canada were already dominant nuclear suppliers who held large shares in the global nuclear market. Although the rapidly growing electricity market in South Korea was large enough to import nuclear power plants, the suppliers were not very desperate. They were willing to set up consensus on conditions of supply and demand South Korea to accept them. Despite potential negotiation conflicts with South Korea, they were not concerned about losing a customer or a political partner to other competitors. Because of active consensus-building between Western suppliers, South Korea could not find an alternative for nuclear imports. The supply-side consensus allowed the United States, Canada, and France to share the South Korean market without compromising nonproliferation goals.

Second, it was the United States that first approached South Korea to provide nuclear assistance under the Atoms for Peace program. It launched the program to prevent the spread of Communism and increase U.S. global influence. South Korea was an important element of regional stability and strategic balance in Northeast Asia. When South Korea tried to develop its plutonium production capability, the main U.S. mission was to prevent this, while maintaining a bilateral relationship. Nevertheless, the United States and Canada did not give special consideration to nonproliferation conditions of supply for South Korea. Japan was the most important strategic ally in Northeast Asia to maintain a power balance with the Soviet Union and China.

Moreover, Washington and Ottawa were confident they could persuade Seoul to remain with a peaceful nuclear program, because Seoul had no alternative supplier for nuclear energy.

Third, internal nonproliferation advocates in the United States and Canada increased after the 1974 India nuclear test. The United States began to reinforce denial of requests for technology transfer. In addition, it offered bilateral arrangements to reduce proliferation motivations, such as security assurances and economic assistance. This was only possible because suppliers collaborated to raise nonproliferation conditions of supply. Otherwise, the U.S. efforts might have flailed as others gave South Korea what it wanted. Thus, promoting consensus-building and using external constraints were important. That is, the United States requested other suppliers to adopt identical conditions of supply while preventing them from weakening the conditions. South Korea had no other choice; it abandoned proliferation activities and accepted global standards.

Founding nuclear cooperation via Atoms for Peace: 1950s-1960s

Shortly after U.S. President Eisenhower delivered the Atoms for Peace speech in 1953, the United States approached South Korea to offer nuclear assistance (Choi et al. 2008:14-15). Since then, South Korea has developed a nuclear research program with the United States as a primary political and economic partner. The United States provided assistance for mainly political reasons. Unlike India, South Korea was not an economically attractive country to which the United States could potentially export its industrial products or nuclear power plants in a short time. South Korea's economic situation was desperate after the Korean War.

The Eisenhower administration likely believed that an undeveloped national economy was the main cause of the spread of Communism in the Third World, and that economic assistance – including nuclear aid – could shape such a nation's political culture in the long-term. Rostow asserted that this would convince people of superiority of capitalism over Communism, and thus contain the Communist bloc (Rostow 1960; Park 2001:57). In South Korea, there was a strong national Communist movement, and even North Korea initially expected an internal Communist revolution in South Korea as a likely scenario for unification between the two Koreas. On January 5, 1957, President Eisenhower announced that "a country could request American economic assistance and/or aid from U.S. military forces if it was being threatened by armed aggression from another state."

In 1954, Walker Lee Cisler, President of Detroit Edison in the United States, visited Seoul to persuade South Korean President Syngman Rhee to consider a nuclear power plant as a future energy supply mechanism. By the end of World War II, he was in charge of the reconstruction project for the European electric gird, and was an energy aide-de-camp to U.S. President Harry S. Truman. He advised Korean President Syngman Rhee to launch a management organization for a nuclear power program and a national research institute. He also recommended developing human resources as soon as possible.

When Rhee launched the nuclear program in 1955, he considered atomic energy for power production as a primary purpose. Although he did not develop any concrete study or military program for nuclear weapons, he also seemed to have an interest in atomic energy for nuclear weapon development (Park 2004). With a scarcity of natural resources, top priorities of the Korean government were the development of energy independence and a stable supply of electrical power. Prior to the Korean War, nearly ninety percent of electricity infrastructure was located in North Korea. When North Korea blocked the supply of electricity to South Korea right before the Korean War, total electricity capacity in South Korea dropped to about 127,000kW, far below demand (Budiansky 1992:2-3).

One of the reasons why President Rhee did not explore the fundamentals of nuclear weapons is that he decided to use U.S, aid to rebuild national infrastructure. However, the American security guarantee and general economic assistance played much more important roles in Rhee's nonproliferation decision. In addition, he probably had little confidence that South Korea could develop nuclear weapons while avoiding detection until the weapons were ready to be deployed, due to Korea's inadequate economic, industrial, and nuclear capabilities.

In February 1956, South Korea and the United States signed the first bilateral agreement for cooperation on the peaceful use of atomic energy. In 1958, the General Atomic exported a 100kWt research reactor (TRIGA MARK-II) under close supervision of the Atomic Energy Agreement between the United States and South Korea. The reactor first reached criticality in 1962. The Korean government requested the General Atomic to take the responsibility of financing it with specified constraints because the General Atomic had better negotiation experience and information. The United States would fund the building of research reactors in democratic countries. This helped South Korea's financial situation; half of the amount was financed by the United States. At that time, foreign currency in South Korea was so devalued that an approval was required from the office of President for foreign currency expenditures over $100.

The United States requested that South Korea agreed to return all spent nuclear fuels from the research reactor. Under the term of agreement that South Korea accepted, it could not process spent nuclear fuels for any purpose including separation of radioactive isotopes. South Korea joined the IAEA in 1957, one year before it agreed to import the research reactor. In 1961, the IAEA published a safeguards agreement INFCIRC/26 for research reactors with power less than 100MWt. Based on this agreement, South Korea's TRIGA MARK-II was placed under the supervision of the IAEA. In January 1968, with the IAEA's new authority, South Korea signed a safeguards transfer agreement relating to the bilateral agreement between South Korea, the United States, and the IAEA.

The long-term plan, including bidding for the first nuclear power plant, was approved by the South Korean government on May 16, 1969. Three vendors in the United States and one vendor in the United Kingdom participated in the bid competition. These companies were Westinghouse Electric International Co. (Pressurized Water Reactors), General Electric Company (Boiling Water Reactors), and Combustion Engineering, Inc.

(Pressurized Water Reactors), and the United Kingdom Atomic Energy Authority (Advanced Gas Cooled Reactors). After sending a bid specification, Korean specialists visited nuclear power plants that were constructed by the four companies. Because they observed little difference among the four designs in long-range economic efficiency and benefits, competitive lobby activities were expected. Through the review process with industries, research institutes, and foreign engineering firms, South Korea contracted with Westinghouse.

South Korea originally tried to construct two plant units, but it could only afford $45 million, which was $135 million short for one nuclear power plant. Westinghouse asked the Export-Import Bank of the United States (EIBUS) for a loan. EIBUS hesitated to approve a financial loan because of low confidence in Korea. Also, it could afford to provide a financial loan for only one unit because it had just approved a major loan for 4 plant units to other countries. Westinghouse found another loan supplier, Lazzarde Bank in the United Kingdom, which shared the risk with EIBUS. In return, U.K. industrial companies joined in Kori 1 construction for turbine generators. South Korea withdrew the original plan of constructing two plant units.

On December 31, 1973, the United States agreed to supply Korea with long-term nuclear fuel enrichment services for the first plant unit and the upcoming second unit from Westinghouse, covering the 30 years of design life. After this, for every nuclear power plant using enriched uranium, South Korea consistently signed 30-year enrichment contracts with various suppliers, including the United States and France in 1985 and the Soviet

Union in 1990. Because South Korea wanted to be independent from U.S. enrichment services, it sent a research group in July 1973 to Canada to evaluate the performance, safety and economy of the CANDU reactor using natural uranium fuels. The CANDU was a strong candidate for the third nuclear power plant in South Korea.

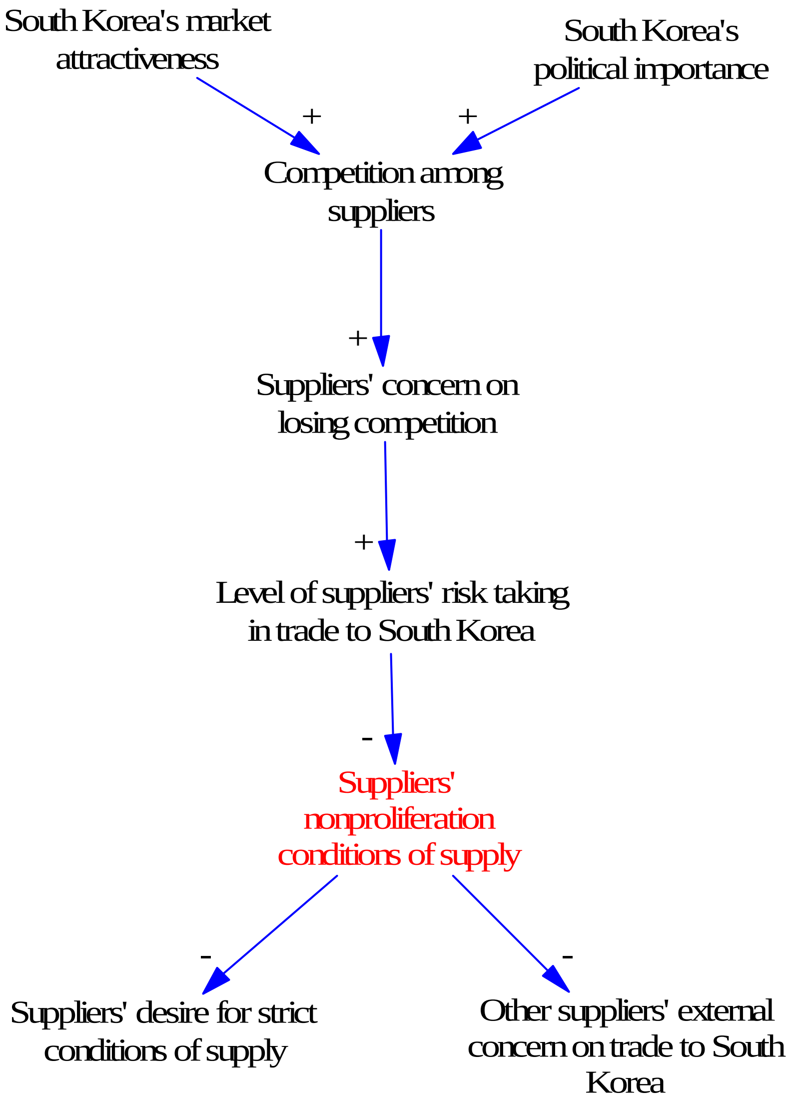


Figure 5.10 USA and Canada decision making logic on prerequisite safeguards for assistance to South Korea

Nuclear deals with France, Belgium, and Canada: 1970s

In 1971, President Park Chung-hee established and directed a Weapons Exploitation Committee to develop nuclear weapons. Security concerns were the strongest driving force for this. South Korea began to doubt American security guarantees after the defeat of American forces in Vietnam. On July 25, 1969, President Richard Nixon announced the Nixon doctrine. As a result, in 1971 one of the two U.S. military divisions in South Korea withdrew, with 24,000 U.S. troops leaving by 1973. Nixon's visit to the People's Republic of China in 1972 began to thaw Sino–U.S. relations. With the sixth-largest military force in the world, North Korea was clearly threatening South Korea. It seized a South Korean civilian ship in June 1970. It also sent commandos to assassinate President Park in 1968 and 1974. In June 1975, in an interview with the Washington Post, Park maintained that the withdrawal of the U.S. nuclear umbrella or troops from South Korea might trigger nuclear weapons development (Park 1998:109).

In addition to the security environment, discrimination in American policy encouraged South Korea to pursue a self-security mechanism. Park felt Japan and India were treated well by global powers because of their potential nuclear weapons capability. The United States, for example, withdrew its troops from South Korea while maintaining forces in Japan. During a trip to South Korea, U.S. Vice President Spiro Agnew argued that Japan's heavy and chemical industries impelled American military assistance, as these would add to an adversary's capability if Japan were occupied. Park had good reason to think that the United States felt Japanese nuclear capability was in fact the most important infrastructure that had to be protected (Kim 2009).

On October 31, 1975, the U.S. Embassy in Seoul provided the State Department with an analysis of South Korea’s nuclear motivations: (1) strong ethnic self-esteem and anger over discrimination between South Korea and Japan; (2) Korean scientists/engineers’ strong desire to develop a completely self-sustainable nuclear fuel cycle; (3) the confidence to import nuclear technology from nuclear suppliers other than the United States; (4) the expectation that the United States would provide NPPs with financial assistance in return for the relinquishment of a nuclear weapons program; (5) the desire to establish a self-reliant national defense capability against North Korea; and (6) the need for nuclear options when the United States withdrew its extended nuclear deterrence (Kim 2008).

For the Park administration, another driving factor was that scientists and engineers strongly advocated setting up an independent nuclear power program including reprocessing. Park Chung-hee and South Korean engineers may have had different goals within this complex decision, but they needed the same technology. Korean engineers wanted to develop complete nuclear fuel cycle capability, while Park wanted a self-reliant security mechanism. In the 1970s, the literature on nuclear bomb manufacturing was widely distributed and well understood. However, South Korea had to secure reprocessing or enrichment facilities to acquire fissionable material (Park 1998).

In order to secure foreign assistance for plutonium reprocessing, Hyung Sup Choi, Minister of Science and Technology, first negotiated with American companies and research institutes such as Nuclear Fuel Services, Argonne National Laboratory, and General Electric, but the United States refused the requests (KAERI 1990:418). In 1972, Choi visited France to meet Francois-Xavier Ortoli, Minister of Industrial and Scientific Development. Ortoli agreed to provide reprocessing technology. From October 1972, Korea Atomic Energy Research Institute (KAERI) and the French Atomic Energy Commission began to discuss details of technology transfer. Saint Gobain Techniques Nouvelles and Cerca agreed to assist in developing a reprocessing plant and a fuel fabrication plant with conversion from UF_6 to UO_2, respectively (Kim 2010).

In October 1974, South Korea and France signed a bilateral nuclear cooperation agreement. Four months later, the technology transfer agreement went into effect; South Korea paid for part of the cost of the reprocessing plant and the conversation facility. When the Nuclear Suppliers Group raised proliferation concerns, South Korea agreed to a new French constraint that was non-replication of reprocessing equipment for twenty years (Reiss 1988). On September 22, 1975, South Korea, France, and the IAEA reached a trilateral safeguards agreement. However, the United States opposed South Korea’s import of the French reprocessing plant which could process 50 to 100 metric tons of spent nuclear fuels.

In addition, South Korea tried to introduce a Canadian heavy water reactor that could produce weapons-grade plutonium. In April 1973, John L. Gray, the President of Atomic Energy of Canada Limited, visited Seoul to sell commercial CANada Deuterium Uranium (CANDU) plants. He agreed to provide a 30MWt NRX research reactor employing an online refueling option – the same reactor that was used to produce weapons-grade plutonium for the 1974 Indian nuclear test. The deal was almost reached in 1975, but made U.S. leaders suspicious.

In January 1974, South Korea and Belgium began to discuss the introduction of a Mixed Oxide Fuel (MOX) plant from Belgonucleaire. The MOX plant was intended to use commercial nuclear fuels in combination with French reprocessing. Solingen commented that South Korea's "efforts to acquire Belgian and French reprocessing facilities were justified as a means to ensure greater energy security and economic saving considerations that had also driven Japan toward reprocessing (Solingen 2007:85)."

Consensus-building and external constraint

South Korea's economic system has been a growth-oriented export-led development model that largely depends on foreign markets. High economic growth was crucial to developing a military capability superior to North Korea's. Unfortunately, as it was heavily dependent on foreign energy sources, South Korea faced serious challenges as a result of the 1973 oil shock, with only two weeks of oil reserves at that time (Solingen 2007:91). Consequently, South Korea reformed its energy policy to significantly accelerate its nuclear power program. With a scarcity of foreign currency, South Korea needed loans from the United States and Canada. Between 1972 and 1976, about eighty-five percent of all foreign direct investment to

South Korea was from Japan and the United States – countries opposed to the reprocessing program (Kim 2010). If the United States rescinded on its nuclear guarantee and pulled out its troops before South Korea acquired nuclear weapons, South Korea would be exposed to an extreme security risk from North Korea and its allies.

The U.S. and Canadian actions against the South Korean nuclear program became aggressive after the Indian nuclear test in May 1974. The United States suspected that South Korea might pursue nuclear weapons to overcome serious security challenges (Kim 2010). In December 1974, the United States expected that South Korea's nuclear weapons program could be accelerated by Park's fear on losing power, especially after his wife was assassinated by North Korea on August 15, 1974. A report of the U.S. Department of State assessed that South Korea could develop an independent nuclear deterrent within ten years if it imported a research reactor and a reprocessing plant from Canada and France (Suh 2009). Again, Washington finished an interdepartmental research project on South Korean nuclear capability at the end of February 1975, reaffirming that South Korea could develop nuclear weapons.

In January 1976, Park suspended contractual negotiations for the French reprocessing plant and the Canadian research reactor, even though key scientists such as Hyung Sup Choi were opposed. In return, the annual ROK–U.S.A. Joint Standing Committee on Nuclear Energy Cooperation was established to provide South Korea with continuous nuclear power assistance. The United States could also use this committee to secure internal information about the South Korean nuclear program. After the cancellation of the reprocessing plant, Canada agreed to export its commercial CANDU reactor to South Korea without a research reactor transfer (Oberdorfer 2001). France provided a uranium milling/conversion facility, radioactive waste treatment facility, and fuel fabrication facility.

On March 9, 1977, President Jimmy Carter announced the withdrawal of all remaining U.S. troops and nuclear weapons from South Korea over four to five years. This decision reignited the South Korean debate about nuclear weapons development (Reiss 1988). In 1978, Seoul and Paris resumed negotiations on a reprocessing facility. Carter persuaded French President Valery Giscard d'Estaing to suspend bilateral negotiations with Seoul. In 1979, Carter finally suspended the withdrawal of U.S. military personnel to prevent Park from developing nuclear weapons.

After 1978, when the first NPP began its commercial operation, South Korea relied on the United States for nuclear fuel and equipment. Regardless, according to Won-Chul Oh, Park might still want to secretly develop nuclear weapons (Kim 2010). There is no clear evidence that a nuclear weapons program was continued after this decision.

After the assassination of Park Chung-hee, Prime Minister Choi Kyu-hah temporarily assumed power. He became the country's fourth president after democratic elections were held in December 1979. However, General Chun Doo-hwan seized power in a military coup a few weeks later and became the fifth president. The Chun regime faced serious public opposition, such as the Gwangju Democratization Movement. To obtain U.S. political, military, and economic support for the regime, the new government renounced all activities related to nuclear weapons development and missile development (Kim 2010). The Reagan administration also promised to provide South Korea with nuclear fuel, electricity generation equipment, and power technology (Reiss 1988).

To avoid handling negotiation conflicts with South Korea alone, the United States urged other suppliers to establish consensus over conditions of supply. They were willing to use their leverage to pressure South Korea into nonproliferation compliance. The United States persuaded France and Canada not to export sensitive facilities. Instead, the U.S. government urged France to supply South Korea with a fuel fabrication plant. Hence, French fuel fabrication technology was transferred to South Korea. Construction of the facility began October 1978. France also provided a uranium milling/conversion facility, hot cells, and radioactive waste treatment facility.

Another reason for the French decision was that Ottawa requested South Korea to give up the French nuclear reprocessing deal before it supplied South Korea with nuclear power plants (Lee 2008). Canada argued that South Korea had no irradiated nuclear fuels for reprocessing because spent nuclear fuels from all Korean reactors were restricted. Thus, there was no commercial reason to develop the back end of the nuclear fuel cycle. The Canadian government signed the agreement on January 26, 1976 after South Korea cancelled the French reprocessing plant deal.

Because Korea had already invested much money to prepare for introducing the CANDU, breaches of negotiations obviously would have been costly. Canadian reactors were more attractive for South Korea because the technology did not require American uranium enrichment and because Canada offered generous financial loans. Canada agreed to export a commercial CANDU reactor to South Korea without a research reactor.

On August 23, 1975, Richard L. Sneider, the U.S. Ambassador to South Korea, visited Hyung Sup Choi to request the renunciation of nuclear weapons development. He argued that a South Korean military nuclear program could lead to a nuclear-armed North Korea and that the reprocessing technology was tricky. Washington also threatened that it would stop military and energy assistance including: 1) the complete withdrawal of U.S. troops from South Korea; 2) the suspension of commercial and financial loans for nuclear power plants; 3) the suspension of nuclear fuel supply; 4) the delay of approval for loans; and 5) a withdrawal of nuclear-capable missile units and, by implication, extended nuclear deterrence.

In February 1975, South Korea ratified the NPT. In January 1976, Park suspended the contract for French reprocessing plant and Canadian research reactor. However, U.S. President Jimmy Carter announced in 1977 the withdrawal of all remaining U.S. troops and nuclear weapons from South Korea over four to five years. This decision reignited the South Korean debate about nuclear weapons development (Reiss 1988). In 1978, Seoul and Paris resumed negotiations on a reprocessing facility. Carter persuaded French President Valery Giscard d'Estaing to suspend bilateral negotiations with Seoul. In 1979, Carter finally suspended the withdrawal of U.S. military personnel to prevent Park from developing nuclear weapons.

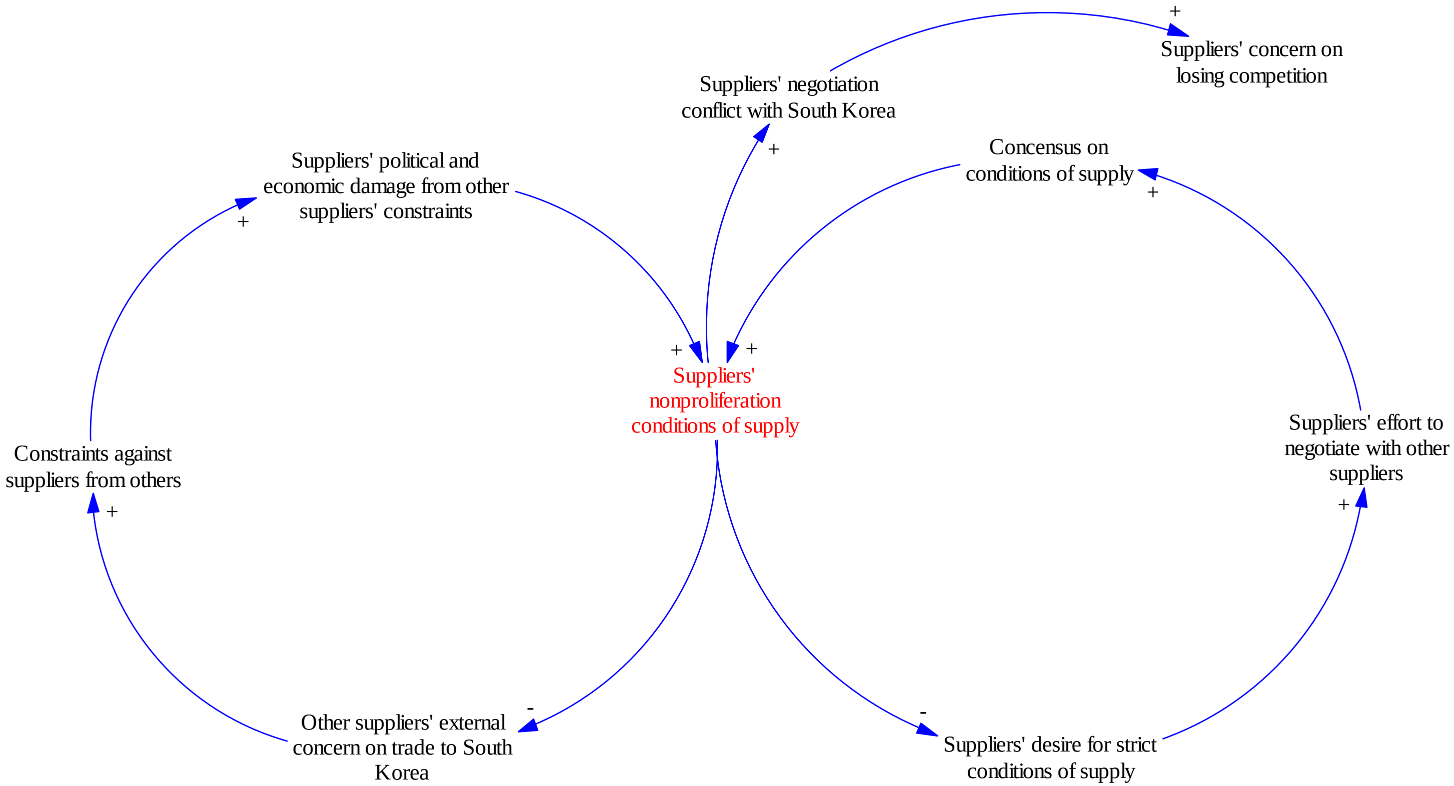


Figure 5.11 Two nonproliferation feedback in moderate supply-side competition

5.3.3 Assessments, summary and lessons

In the case of nuclear trade from the United States and Canada to South Korea, healthy export competition produced supply-side interaction that strengthened nonproliferation conditions of supply. Significant nuclear technology transfer was supplied after the United States and South Korea formed a reliable partnership based on American military and economic assistance. This partnership provided the United States with effective and powerful military and economic leverage on South Korea.

The United States tried to prevent other suppliers from loosening conditions of supply while pressuring South Korea to give up its reprocessing program. To preserve bilateral relationship with South Korea, the United States should block other alternative routes for South Korea to import nuclear technology with weak nonproliferation conditions of supply. Thus, the United States persuaded Canada to join its efforts to strengthen conditions of supply to South Korea. It also pressured France to export fuel fabrication technology and uranium handling technique instead of sensitive reprocessing technology.

Figure 5.12 shows the decision-making process regarding nuclear exports of the United States and Canada to South Korea. South Korea's economic attractiveness and political importance caused moderate competition among nuclear suppliers, i.e. the United States, Canada, France, and the United Kingdom. The United States and Canada were concerned about proliferation risks in South Korea, and required strict nonproliferation conditions of supply for nuclear power plants. They shared knowledge and information about South Korea and established consensus over conditions of supply. They convinced France that South Korea might use the French reprocessing technology to develop nuclear weapons against its communist adversaries. This would damage France’s nuclear export opportunities and bilateral relationship between France and the United States.

In U.S. calculations, the United States wanted to avoid negotiation conflicts with South Korea. It was concerned on jeopardizing bilateral relationship with South Korea because that could lead South Korea to develop nuclear weapons in the worst case. The United States was even more motivated to prevent South Korean proliferation after the 1974 Indian nuclear test. The United States began to reinforce denial of requests for technology transfer and offered bilateral arrangements to reduce proliferation motivations, such as security assurances and economic assistance.

In the Indian case, the United States and Canada took proliferation risk in nuclear trade, but they did not want to make the same failed approaches. Through active consensus-building among other suppliers, the United States wanted to share the costs of negotiation with South Korea. The United States urged other suppliers to establish consensus over conditions of supply and to pressure South Korea into nonproliferation compliance. Interdependence and collaboration between the suppliers increased their negotiating power in nuclear trade with South Korea. The supply-side consensus, built under moderate competition, allowed the United States, Canada, and France to share the South Korean market without compromising nonproliferation goals.

The consensus-building feedback balanced out the negotiation cost feedback. Efforts to build agreed-upon conditions of supply and offer security guarantees were successful because both the United States and Canada recognized the potential proliferation danger in South Korea and agreed to act. The lack of vigilance feedback was prevented by the external constraint feedback, as exemplified by the United States persuading France to modify its deal with South Korea.

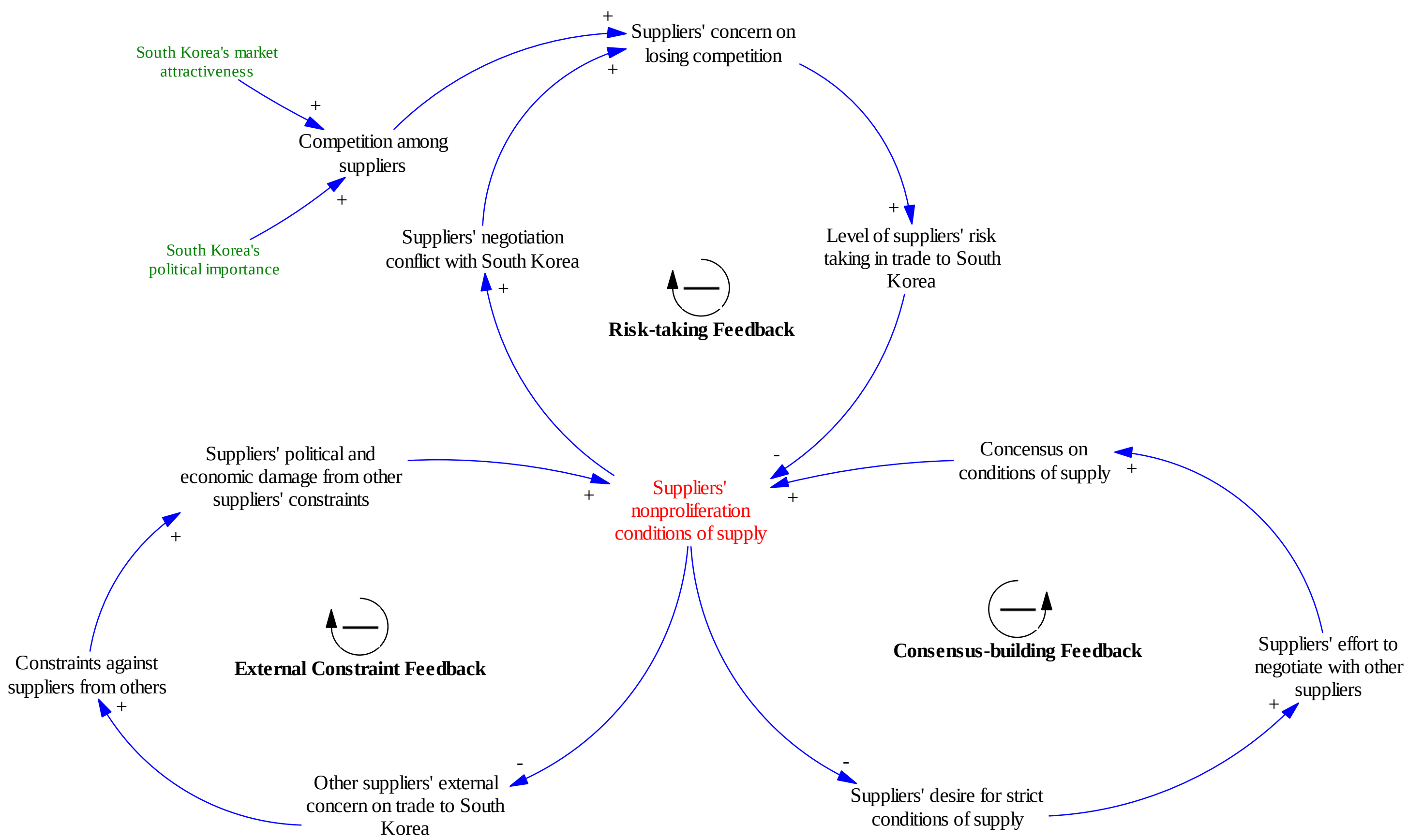


Figure 5.12 USA and Canada's export decision making logic on nonproliferation assurance

Chapter 6 Cross-case Comparison and Verification with Current Export Regime

The three export cases are observed to develop the nuclear supply dynamics feedback model that is consisted of the four types of feedback. The model is intended to describe how interaction among suppliers determines conditions of supply. The supply-side competition is the best variable that reflects the interaction among suppliers. The cross-case comparison in this chapter logically presents the key findings of three export cases to elucidate the relationship between supply-side competition and conditions of supply. The model is valid to explain the current nuclear export regime. The current regime is a product of compromise among suppliers that have different interests. The nuclear export regime is still changing toward either positive or negative directions. The U.S.-India nuclear cooperation agreement is selected to show how self-interests of suppliers change the nuclear export regime, and how the nuclear supply dynamics feedback model explains the recent case.

6.1 Cross-case comparison: export to India, North Korea, and South Korea

Figure 6.1 shows the relationship between supply-side competition and conditions of supply with examples of nuclear export cases: “Canada and the United States to India,” “the Soviet Union to North Korea,” and “the United

States and Canada to South Korea." High export competition causes weak conditions of supply; low export competition results in the same consequence. On the other hand, moderate level of export competition produces high-level of conditions of supply. Under the different levels of the competition, the four types of feedback in the nuclear supply dynamics model have made different impact to the conditions. The nuclear supply dynamics model is based on the process of the compromise between supply-side competition for political benefit and economic profit and international regulation for nonproliferation and security concern.

As shown in Figure 6.2, this trend is closely related to the relationship between competition among suppliers and recognition of proliferation risk. In order to win political and economic competition, high export competition leads to ignore proliferation risk recognized by internal and external sources. In other words, a nuclear supplier loosens nonproliferation conditions of supply. Political and economic interests triumph nonproliferation concern; the decision is dominated by the negotiation cost feedback. If this decision is applicable to other competition levels, low export competition might cause strict conditions of supply, but such uncompetitive environment actually results in weak conditions of supply. This is because suppliers overlook potential proliferation risk and underestimate nuclear capability of unattractive recipient while focusing on attractive market. No competition leads to lack of vigilance on proliferation risk in nuclear trade to unattractive recipient; this decision is dominated by the lack of vigilance feedback.

In contrast, a moderate level of export competition produces two types of feedback that balance out the previous feedback, so the interaction among suppliers reaches a compromise on conditions of supply. First, when a nuclear supplier wants to strengthen conditions of supply, it would request others to take a collective action toward consented standards in order to avoid political and economic disadvantages against its own political and business opportunity – the consensus-building feedback. Second, when a nuclear supplier tries to reduce nonproliferation conditions of supply, others would constraint it from affording a recipient state special favors in order to maintain their competitive political and economic advantages – the external constraint feedback. Thus, suppliers encourage or constrain other suppliers to maintain nuclear nonproliferation in nuclear technology transfer.

As shown in Figure 6.3, exports to India showed that the negotiation cost defeated the consensus-building feedback. Effort to build mutually agreed conditions and offer collective security assurance was failed. The lack of vigilance feedback was negligible because many suppliers paid much attention to the attractive market; the external constraint feedback was trivial due to a supplier had little leverage to influence other suppliers' decisions on conditions of supply.

In exports to North Korea, the lack of vigilance feedback dominated the low competitive export case. Once a supplier falls into lack of vigilance, it is extremely difficult to overcome it by itself. Unfortunately, the external constraint feedback was not strong enough to balance out the lack of vigilance. This is because other suppliers are also indifferent at the unattractive or uncompetitive market. With little attention, the negotiation cost feedback and the consensus-building feedback were trivial in this case.

In exports to South Korea, the consensus-building feedback balanced out the negotiation cost feedback. Effort to build consented conditions of supply and offer security guarantee was successful because both the United States and Canada recognized potential proliferation danger in South Korea. The lack of vigilance feedback was prevented by the external constraint feedback; an external constraint from the United States was effective to France's nuclear deal that included the reprocessing plant.

India conducted nuclear tests at Pokharan in 1974 and 1998. India called the first test as a peaceful nuclear explosion; the second test demonstrated India's capability on deployable nuclear weapons. The 1974 nuclear detonation was a bitter experience for Canada and the United States that assisted India in developing a nuclear program under high competition with the Soviet Union. Canada also competed with the United States and France for Indian nuclear market. The high competition among the suppliers was caused by economic attractiveness and political importance of India. The competition led suppliers to ignore India's proliferation risk, despite internal and external warnings. In the strong negotiation cost feedback, suppliers were concerned about negotiation conflict with India where competitors awaited an opportunity to join the market. In contrast, effort to build agreed conditions and offer collective security assurance was failed. The negotiation cost defeated the consensus-building feedback. The lack of vigilance feedback was negligible because many suppliers paid attention to the attractive market; the external constraint feedback was trivial due to a supplier had little leverage to influence others' decision on conditions of supply. The first section describes how nuclear assistance contributed to India's nuclear program. The following explains what types of supply-side feedback determine nonproliferation conditions of supply in nuclear export of Canada and the United States, and how supply-side competition influences conditions of supply.

In nuclear trade from Canada and the United States to India, economic and political benefit overwhelmed nonproliferation concern. Not only that nuclear export was not a product of credible alliance or strict bilateral relationship, but also it was exploited as a means, despite high failure risk, to establish political and economic partnership. Canada and the United States recognized proliferation risk in nuclear transfer to India beforehand, but promoted nuclear export. Selling nuclear materials, equipment, or services was imperative, preventing the establishment of relationship with enemies was critical, but countering potential nuclear proliferation was a less important and urgent agenda.

India's economic attractiveness and political importance caused the intense competition among suppliers. As competitors in India's market, nuclear suppliers included the United States, the Soviet Union, the United Kingdom, Canada, and France. The high supply-side competition threatened the competitive position of Canada and the United States. The high competition made beneficiaries of nuclear export anxious on losing India by other competitors that awaited an opportunity to join the market. They lobbied national decision-makers to ignore external and internal proliferation warnings and loosen level of safeguards as a condition of nuclear supply.

Once insufficient safeguards were imposed on nuclear export to India, internal proliferation concern became strong, resulting in desire for stringent nonproliferation assurances. With the consensus-building feedback, some diplomats and officials in Canada attempted to strengthen the required level of safeguards for nuclear reactors. However, such requests increased negotiation conflict with India. As described in the negotiation cost feedback, the cost of negotiation gave negative impact on Canada's competitive position. Canada chose to reduce conditions of supply to eliminate serious concern on losing India, an important customer and political partner, by other competitors.

Under the high competition and the weak nuclear export regime, it was difficult to expect that nuclear suppliers cooperate with competitors to set up consented conditions of supply. Their nonproliferation policies were not strong sufficient to resist political and economic temptation. The bilateral safeguards agreements of Canada and the United States with India were very weak to clarify Indian nuclear intention, detect internal activities, and respond to proliferation attempts. The nuclear suppliers were reluctant to establish diplomatic, security, economic, and technical leverages for India's nuclear program. After about 10 years later from initial nuclear cooperation, Ottawa and Washington found that they had little influence to prevent New Delhi from developing nuclear explosives.

In the nuclear export to India, high economic profit gave the suppliers a strong driving force to promote nuclear deals with India where market size and growth rate were huge. Thus, it avoided the cost of negotiation with India. Moreover, India's political importance in the Cold War environment led Ottawa and Washington to overlook proliferation risk in New Delhi in order to win political competition against communism. The political importance of India was another reason to avoid the cost of negotiation with India. In addition, the global nonproliferation norms were newly emerging; there was no consensus over the baseline of conditions of supply. Effort for consensus-building was ineffective in the face of contrasting interests under high competition, if suppliers had limited interdependence.

North Korea tested nuclear explosive devices in 2006 and 2010. Its nuclear development dates back right after the ceasefire that ended the Korean War, 1950-53. The nuclear trade between the Soviet Union and North Korea shows how lack of vigilance in nuclear assistance contributes to nuclear proliferation. The Soviet Union gave North Korea nuclear assistance for political benefit in the 1950s-1960s, but Soviet nuclear assistance was limited to basic research only. The lack of valiance feedback mainly influenced Soviet decisions on nonproliferation conditions of supply. For the Soviet Union, North Korea was less attractive and important than China and Eastern Europe where supply-side competition was strong. North Korea's technical capability might be underestimated because no supplier wanted to provide significant assistance to the unattractive market. On the other hand, the external constraint feedback balanced the lack of vigilance feedback. Competitors constrained the Soviet Union from exporting nuclear materials and technology with insufficient safeguards. Unfortunately, the feedback was weak in North Korea because the competitors more focused on the attractive partner as well. With little attention, the negotiation cost feedback and the consensus-building feedback were trivial in this case. In following, the first section discusses how foreign nuclear assistance contributed to improve North Korea's nuclear capability. The next section elaborates why the Soviet Union overlooked proliferation risk in nuclear export to North Korea.

In nuclear assistance from the Soviet Union to North Korea, Soviet lack of vigilance allowed North Korea to develop nuclear weapon capability without serious external constraints. Soviet Political confidence made it to overlook proliferation risk in nuclear technology transfer to North Korea. The confidence was intensified by underestimating long-term potential on technical capability development in North Korea. Soviet nuclear export to North Korea did not result from a long-term vision of bilateral partnership, but it was rather an instant reactive decision to compete with regional adversaries. In decision-making based on political and economic interests, protecting Soviet influence at Eastern Europe and China was urgent, and putting more effort into fully controlled country was useless.

Globally competitive environment between capitalism and communism was an initial driving force of Soviet nuclear export. However, North Korea's economic attractiveness was trivial, so there was low market competition among nuclear suppliers. With low supply-side competition, the Soviet Union was not threatened by other nuclear suppliers that were not interested in jumping into an unattractive market. For this reason, confident Soviet leaders produced national export controls with lack of vigilance on

North Korea’s nuclear program. Underestimation on North Korea’s nuclear capability intensified such lack of vigilance. Thus, the lack of vigilance feedback loop was dominant in this low competition case.

In that situation, a scenario that North Korea developed nuclear weapons was considered a low probabilistic event. While the Soviet Union required North Korea to sign low-level safeguards, it offered no solutions for North Korea to reduce proliferation motivation. Since the beginning, North Korea’s nuclear program was largely biased to a nuclear fuel cycle that was a money-consuming weapon-making activity rather than a commercial nuclear power plant that is a primary money-making business.

Nuclear export controls of the Soviet Union were questioned by other suppliers to improve the nonproliferation conditions of supply especially after it jumped into the global nuclear power market. With this external constraint feedback, the Soviet Union strengthened the conditions of supply and participated in the international nonproliferation regime. The Soviet Union denied its allies’ requests for nuclear assistance and urged them to sign the international safeguards. This feedback was strong in the attractive market where other suppliers closely watched Soviet nuclear export. For the Soviet Union, this attractive market had to be well managed to keep its competitive advantages.

In contrast, North Korea was an unattractive market where no supplier wanted to sell major industrial products. Nuclear assistance the Soviet Union provided was less significant than those other allies gained. The Soviet Union recognized no need to request stringent conditions of supply for rather minor nuclear items North Korea imported. Other suppliers also had no motivation to tackle Soviet nuclear export controls on North Korea because there were more controversy countries that had higher proliferation risk. Thus, the external constraint feedback in the nuclear export from the Soviet Union to North Korea was weak. Nuclear suppliers were rather indifferent in North Korea's nuclear program.

North Korean nuclear program remained outside of international monitoring system for over 20 years. The Soviet Union, a primary supplier, was less concerned about North Korea's indigenous programs and cooperation activities. Without appropriate Soviet attention, concern over North Korea's nuclear program did not fully emerge until 1985 (Cirincione et al. 2005:244). They only allowed the first comprehensive IAEA inspection in 1992 after 38 years of unsafeguarded nuclear development. Soviet lack of vigilance could not a direct cause of North Korea nuclear proliferation, but it certainly helped North Korea to develop nuclear capability without receiving serious questions about proliferation for a long time.

In the 1970s, South Korea attempted to import a French reprocessing plant and a Canadian heavy water research reactor to develop nuclear weapons. South Korea's nuclear weapon program was eventually suspended because of the security assurances and economic pressure from the United States. Moreover, South Korea's high expectations for nuclear power changed the cost-benefit matrix of nuclear weapons. Market competition among the United States, Canada, France, and the United Kingdom was moderate in South Korea − weaker than India and stronger than North

Korea. Healthy competition produced supply-side interaction that strengthened nonproliferation conditions of supply. To avoid the cost of negotiation with South Korea all alone, the United States urged other suppliers to establish consensus over conditions of supply. They were willing to use their leverage to pressure South Korea into nonproliferation compliance. Interdependence between the suppliers and the recipient as well as collective actions among the suppliers increased their negotiating power in the nuclear trade. In other words, the consensus-building feedback balanced at the negotiation cost feedback. The lack of vigilance feedback was prevented by the external constraint feedback. Under the U.S. pressure, France supplied a fuel fabrication plant instead of a reprocessing plant. The first section describes how assistance contributed to South Korea's nuclear program. The following explains how supply-side competition strengthened conditions of supply.

In nuclear trade from the United States and Canada to South Korea, healthy competition produced supply-side interaction that strengthened nonproliferation conditions of supply. Significant nuclear technology transfer was supplied after the United States formed reliable partnership based on American military and economic assistance; it tried to maintain long-term partnership. This partnership necessarily provided the United States with effective and powerful military and economic leverage on South Korea. Because of U.S. pressure on France and collective actions of U.S. and Canada, South Korea could not find other sources for nuclear technology inside the Capitalist World.

Economic attractiveness and political importance in South Korea caused moderate competition among nuclear suppliers that included the United States, Canada, France, and the United Kingdom. Among them, the United States and Canada were concerned about proliferation risk in South Korea, especially, when it attempted to import a French reprocessing plant and a Canadian research reactor. The United States and Canada required strict nonproliferation conditions of supply for nuclear power plants. They shared knowledge and information of South Korea as well as established consensus over conditions of supply. They constrained France from selling a reprocessing plant while recommending it to alternatively export a fuel fabrication plant.

Despite potential negotiation conflict with South Korea, they were not concerned about losing a customer or a political partner by other competitors. Because of active consensus-building of the United States with other Western suppliers, South Korea could not find a best alternative for nuclear imports. The supply-side consensus built under moderate competition allowed the United States, Canada, and France to share the South Korean market without compromising nonproliferation goals.

To avoid the cost of negotiation with South Korea all alone, the United States urged other suppliers to establish consensus over conditions of supply. They were willing to use their leverage to pressure South Korea into nonproliferation compliance. Interdependence between the suppliers and the recipient and collective actions among suppliers increased their negotiating power in nuclear trade. Canada soon agreed to join the U.S. nonproliferation effort in nuclear trade to South Korea. Under the U.S. pressure, France supplied a fuel fabrication plant instead of a reprocessing plant.

Internal nonproliferation advocators in the United States and Canada became strong after the 1974 India's nuclear test. The United States began to reinforce technology control that denied requests of technology transfer. In addition, it offered bilateral arrangements to reduce proliferation motivation such as security assurances and economic assistance. It was only possible because suppliers agreed to raise nonproliferation conditions of supply together up to sufficient level. Otherwise, the U.S. efforts might face difficulties while others gave what South Korea wanted. To avoid the difficulties, promoting consensus-building and using external constraints were important. That is, the United States requested other suppliers to adopt identical conditions of supply while preventing others from weakening the conditions. South Korea had no other choice, but it abandoned proliferation activities and accepted global standards.

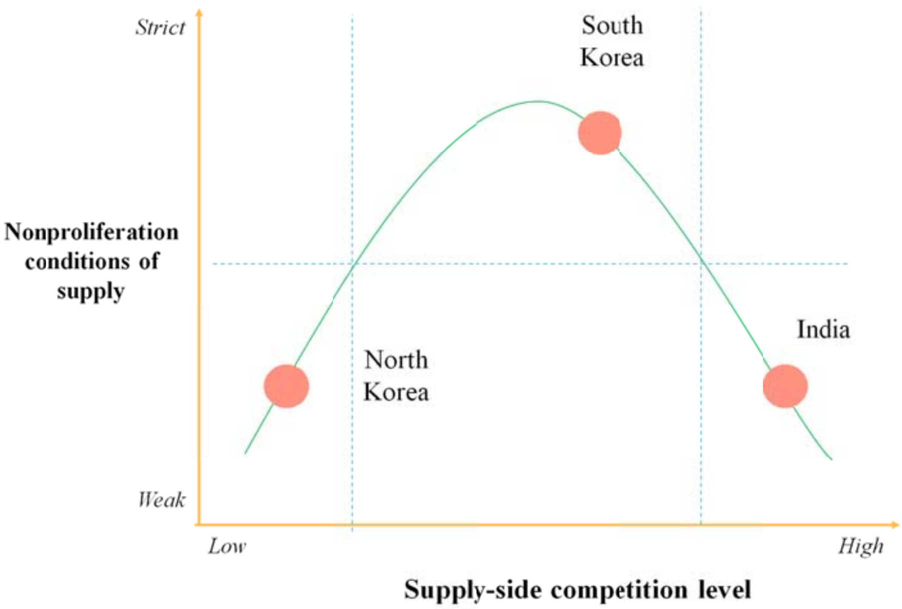


Figure 6.1 Relationship between export competition and nonproliferation conditions of supply

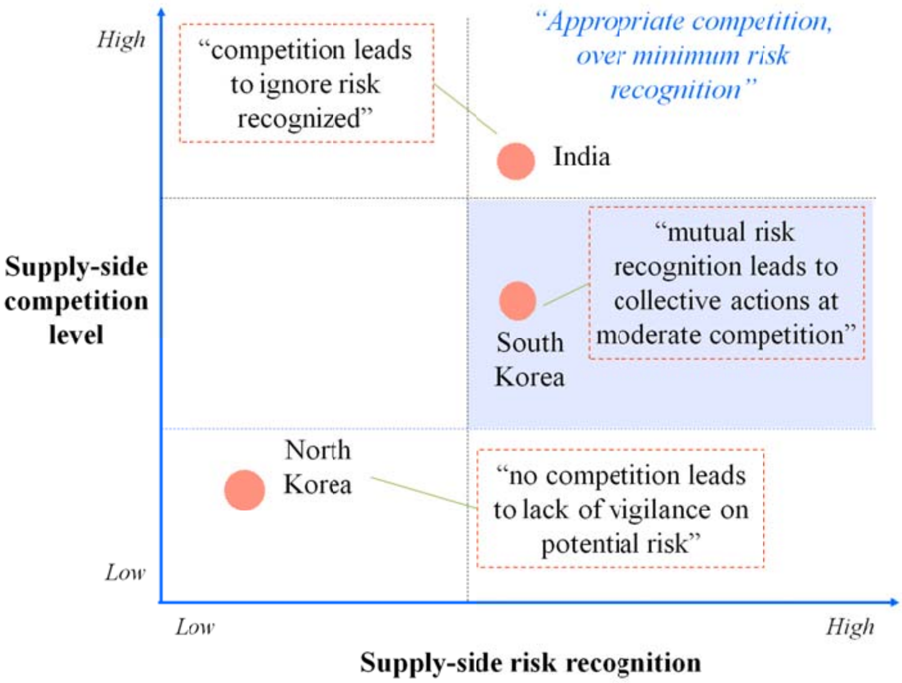


Figure 6.2 Mapping of three export cases with export competition and supply-side proliferation risk recognition

	India	North Korea	South Korea
Risk-taking	Strong	Weak	Moderate
Lack of vigilance	Weak	Strong	Moderate
Consensus building	Moderate	Weak	Strong
External constraint	Weak	Moderate	Strong
Supply competition	Strong	Weak	Moderate
Key suppliers	Canada, USA	The Soviet Union	USA, Canada, France
Conditions of supply	Weak	Weak	Strong
Consequences	Conduct nuclear tests	Conduct nuclear tests	Only use nuclear power
Global environment	Loose	From loose to strict	Strict
Causality	High competition leads to ignore proliferation risk	Low competition leads to lack of vigilance on risk	Healthy competition leads to mutual risk recognition

Figure 6.3 Cross-case comparison: nuclear export to India, North Korea, South Korea

6.2 Application to U.S.-India civil nuclear agreement

On July 18, 2005, U.S. President George W. Bush and Indian Prime Minister Manmohan Singh announced a new nuclear cooperation between the United States and India. The new agreement required major changes of many national laws and international norms that were consisted of the global nonproliferation regime. Many experts criticized it as erosion of the rule-based international nuclear order. Nevertheless, the NSG unanimously approved to exempt India from nonproliferation restrictions that were supposed to apply to all other states in 2008 (Perkovich 2010:20). Washington and New Delhi persuaded all 45 members of the NSG to agree with this India-specific decision – all NSG decisions have to be unanimous.

The rule-based nuclear order was too weak against the sole superpower in the post-Cold War environment. The United States once formalized Security Council Resolution 1172 of June 6, 1998 to "encouraged all states to prevent the export of equipment, materials or technology that could in any way assist progammes in India or Pakistan for nuclear weapons (Meier 2006:30)." Now, it relived the imposed sanctions against India by breaking the rule it made even though India did not agree nuclear disarmament. George Perkovich notes "the 1990s was a period when the United States, unbalanced in power by the fall of the Soviet Union, became nearly hegemonic." He also commented "in hegemonic systems, rule-making and enforcing tend to depend on the leader (Perkovich 2010:21)" The political will of the superpower is also largely influential to decide which countries are its allies and acceptable for the international systems.

This decision enables suppliers to supply India with nuclear materials, fuels, reactors, structural components, dual-use items, and technical services. In return, India accepted international safeguards on civilian facilities, signed the additional protocol, and agreed to improve internal export control systems. This agreement did not include the provision that restricted India's future nuclear test. India did not make any commitments to sign either Comprehensive Test Ban Treaty (CTBT) or Fissile Material Cutoff Treaty (FMCT).

However, the Indian government alone could decide which facilities shall be subject to civilian facilities. India only opened 16 reactors out of 22 to international inspection; the remaining 8 reactors are for both civil and military applications. India's reprocessing and enrichment plants remain at military purposes, so these will not be safeguarded even in the future. Hence, Perkovich said "the deal also has granted India the right to reprocess, for military purposes, the spent fuel from the eight reactors (Perkovich 2010:25)." Meier also pointed out that "the largest nuclear centers – the Babha Atomic Research Centre and the India Ghandi Centre for Atomic Research – are to remain completely inaccessible to international inspections (Meier 2006:32-33)."

Moreover, India accepted international safeguards, but not comprehensive safeguards as many facilities remain at outside the inspection. The United States and the NSG gave India a waiver that dropped comprehensive safeguards as a condition of supply. In 1978, the United

States adopted a law that prevented nuclear trade to states without full-scope safeguards. In 1992, the NSG agreed to make a guideline that required comprehensive safeguards as a condition of nuclear supply. Despite India separated civil and military programs, the delivered know-how and technology would improve nuclear weapons capability because there is no clear distinction between civil and military technology.

Furthermore, the additional protocol India signed on March 3, 2009 was another waiver from the 1997 original model of the additional protocol. This India-specific agreement allowed India to keep its nuclear weapons capability without international intervention to that perspective. Peter Crail assessed that "the agreement the agency approved omitted many of the key provisions of the Model Additional Protocol regarding the type of information India would provide to the agency and the access that would be granted to agency inspectors (Crail 2009)." India only agreed to provide the IAEA with the information about nuclear exports, whereas it was not requested to report the other information the original mode required. The missing information such as nuclear fuel cycle activities and nuclear imports is critical to boost the IAEA's ability to detect undeclared nuclear activities. Also, the India-specific protocol does not allow the IAEA to request complementary access to inspect undeclared facilities to clarify the persistent suspicions about the regular inspections.

Then, why did the United States give India a nonproliferation waiver for the U.S. Nuclear Nonproliferation Act and the NSG guideline? The political and strategic competition with China stimulated India to give India, China’s next-door neighbor, special exception in nuclear matters. Perkovich pointed out that “a top priority should be to dissuade China from attempting to rival the United States militarily, including by ensuring that China’s neighbors share U.S. interests in balancing Chinese power… The friendliness of India toward the United States was more important than its nuclear policy, period, especially insofar as it could help constrain China’s future power (Perkovich 2010:22-23).” He also added that “U.S. commercial interests were motivating the changes, making the deal a matter of self-aggrandizement (Perkovich 2010:27).” Selling nuclear reactors and nuclear fuels could be major economic benefit, although the deal did not specify any details or mandate provisions of commercial arrangements between the two countries. According to Thyagaraj and Thomas, “one potential benefit to the United States from the deal would be gaining access to India’s vast reserves of thorium (Thyagaraj and Thomas 2006:366).”

U.S. Under Secretary of State Nicholas Burns, a leading negotiator on the nuclear agreement said “we treat India, a democratic and peaceful friend differently from Iran and North Korea, and we are proud of it… India keeps to the rules, Iran does not. If that is a system of double standards then we are proud to adopt such double standards for a democratic friend (Meier 2006:37).” In the U.S. intention to confront China via India, it is too much to hope that the United States encouraged India to disarm nuclear weapons under the new nuclear agreement. In fact, Indian Prime Minster Singh publically spoke that “there will be no restrictions on our strategic program and the plan to separate civil and military nuclear facilities ensures that sufficient fissile materials and other basic materials will be available to satisfy the present and future requirements of our strategic program… The integrity of our nuclear doctrine and our ability to ensure a credible minimal deterrence have been adequately maintained (Meier 2006:35).”

In the early 1990s, the United States provided Pakistan with such a political benefit. After the United States discovered illicit nuclear trade for nuclear weapons capability in 1970s, it imposed sanctions on Pakistan. However, Washington relieved the imposed on Pakistan by presidential waiver once Pakistan became strategically important against the Soviet occupation of neighboring Afghanistan. The United States used Pakistan as a route to provide money and arms to the Mujahideen that then fought against the Soviet Union, but it ended such a waiver after the end of the military conflict (Thyagaraj and Thomas 2006:359). The United States also investigates or solves Israel’s ambiguity. Thyagaraj and Thomas commented that “U.S. technology-transfer restrictions have proven to be flexible and temporary in the service of national-security interests (Thyagaraj and Thomas 2006:361).”

Not only the United States, but other nuclear suppliers consented or closed their eyes to the U.S. intention. France and Russia were too happy about loosening or lifting restrictions on India’s nuclear market where they could sell nuclear materials, fuels, and reactors. Russia negotiated with India to export 2,000 metric tons of uranium for the existing Indian reactors and six additional power plants. France and Kazakhstan is also negotiating to sell uranium to India. India has long suffered from deficiency of domestic uranium reserves. German supported the India-specific deal in the NSG for not nuclear sales, but commercial interests in Indian market. Japanese Prime Minister Abe has strongly advocated enhancing Japan-India relations. Also, Japan’s industry found a strong economic incentive from the U.S.-India nuclear agreement (Koizumi 2006). Although each member of the NSG had a formal veto, the almost majority of the members might not block the deal because they wanted to maintain favorable relationship with the United States and India.

The U.S.-India nuclear agreement made three major global impacts on the nuclear nonproliferation regime. First, it intensified supply-side competition in nuclear market and regional power dynamics. In response to the U.S. approach to India, China announced that it would export nuclear power plants to Pakistan by citing the grandfather clause of the NSG. Although Pakistan has showed more critical proliferation behavior such as A. Q. Khan Network, this Chinese decision could be justified by the case that the United States exempted India from nonproliferation rules. Russia and France already began to negotiate with India in order to sell nuclear materials, equipment, and technology to India. France also might supply India with advanced enrichment and reprocessing technology; Russia has helped India not to be constrained by the NSG rules by establishing a joint nuclear company. Australia agreed to sell natural uranium to India. South Korea signed the nuclear cooperation agreement with India in 2011. After the Fukushima accident, Japan is also reforming its nuclear program for nuclear export-oriented strategy that likely includes the cooperation with

India. Under this strong competition, the nuclear suppliers might provide even further exceptions on the nonproliferation regime to India. Perkovich worried that “those suppliers would find significant self-interest in rejecting national or UN Security Council sanctions against India for resuming nuclear tests (Perkovich 2010:26).”

Second, the special treatment for India caused anger from a group of recipient countries. Until now, unlimited access to peaceful nuclear technology is only allowed to the NPT parties. Especially, the non-aligned group expressed its serious concerns on the special exception from the existing nonproliferation norms. In the 2010 NPT Review Conference, Ambassador Abelardo Moreno, Permanent Representative of Cuba to the United Nations, said on the behalf of the group of non-aligned states, “Nuclear Weapon States, in cooperation among themselves, and with Non-Nuclear Weapon States, as well as the States not Parties to the Treaty, must refrain from sharing of nuclear know-how for military purposes under any kind of security arrangements. Without exception, there should also be a complete prohibition of the transfer of all nuclear-related equipment, information, material and facilities, resources or devices… to States, which are not Parties to the Treaty. The recent developments in particular the nuclear cooperation agreement with a non-party to the NPT is a matter of great concern, since in accordance with that agreement nuclear materials can be transferred to unsafeguarded facilities in violation of Article III, paragraph 2 of the NPT (Moreno 2010).”

Third, the U.S.-India nuclear deal made other proliferators to hope that they received civil nuclear assistance without giving up nuclear weapons or joining the NPT. Perkovich gave two examples of this impact based on his personal communication with a North Korean and an Iranian. According to him, a North Korean diplomat said in July 2008 that it is a prerequisite to receive nuclear power plants under the 1994 Agreed Framework before North Korea completes nuclear disarmament. An U.S. official told him such nuclear cooperation before complete disarmament would be against the nonproliferation regime. He replied, "You did it for India." The U.S. official said there were many distinctions between North Korea and India. The North Korean said, "The point is not about North Korea. It is that when the U.S. decides that it wants to treat another state differently, it can do so. You decided India was your friend, so you did that it wanted. That's the issue (Perkovich 2010:28)." Perkovich also notes that "Some Iranians… note not only how the United States accommodated India, but also how other countries went along with it because India is a major country and a big economic market. They believe, or hope, that the international community will accept Iran's ongoing enrichment program and drop sanctions because Iran is important in the way that India is (Perkovich 2010:28)."

6.3 Evaluation of current global nuclear export regime

The NPT includes a provision in export control: "… not to provide (a) source or special fissionable material or (b) equipment or material especially designed or prepared for the processing, use, or production of special fissionable material, to any non-nuclear weapon State for peaceful purposes, unless the source or special fissionable material shall be subject to the safeguards required by this Article [III.2].” Some parties to the NPT formed the Zangger Committee in 1971 to clearly define (a) and (b) in the article. In 1974, the Zangger Committee confirmed the definition of source or special fissionable material and released a list (called the Trigger List) of material and equipment for the processing, use, or production of special fissionable material (Strulak 1993:2). The items in the control lists would “trigger” conditions of supply that the committee proposed – nuclear suppliers were obligated to (1) obtain a recipient’s assurance to use exported items for only peaceful purpose, (2) impose IAEA safeguards on Trigger List items, and (3) ensure re-transfer meets the previous two conditions. These requirements as well as the control lists were published by the IAEA as INFCIRC/209.

In response to the 1974 India’s nuclear test, the NSG was formed in 1978 after three years of discussion among seven nuclear suppliers: the United States, the Soviet Union, the United Kingdom, Canada, Germany, Japan, and France (Anthony et al. 2007:3). The suppliers were convinced that the NPT Article III.2 alone was insufficient to prevent nuclear items from being used for the development of nuclear weapons. The NSG adopted the three conditions the Zangger Committee proposed as well as the Trigger List. The major difference from the Zangger Committee included the addition of heavy water production items to control lists as well as the extended concern on non-nuclear weapon states that were not parties to the NPT. The NSG guidelines were published by the IAEA as INFCIRC/254. As a consensus-based and voluntary group, its main function was giving guidelines for export requirements or licensing processes that NSG members voluntarily incorporated into national-level rules. After the 1978 guidelines, the NSG was inactive until 1990 because some suppliers did not compromise their commercial interest (Strulak 1993:3).

Meanwhile, the Iraq's nuclear attempt in the early 1990s stimulated the NSG again to gather together in Hafue in March 1991, for the first time in thirteen years. In 1992, all parties to the NSG adopted new guidelines that requested to control nuclear-related dual-use items and CSA as conditions of supply for all non-nuclear weapons states. Beyond the control lists, the guidelines demanded nuclear suppliers to "govern transfers of items that are not on export control lists when such items are or may be intended for use in connection with a nuclear explosive activity" and to "consult with members of the group in the event a recipient state violates its nonproliferation commitments (McGoldrick 2011)."

Despite these achievements, the NSG allowed two exceptions in the guidelines that required comprehensive safeguards as a condition of supply. First, the requirement of comprehensive safeguards does not apply for the existing nuclear contracts at the time [1992] – so called grandfather clause. Second, the guidelines enabled a supplier to sell nuclear technology and materials in exceptional cases when they are deemed essential for the safe operation of existing facilities. Russia claimed that its nuclear power plant deal with India was grandfathered by the 1988 Russian-Indian agreement; full-scope safeguards were not implied for the reactor export transaction. In

2001, Russia exported low-enriched uranium fuels to India for the two power reactors located at Tarapur while citing the NSG guidelines that permits a supplier to supply nuclear items without comprehensive safeguards for the safe operation of existing facilities. In 2004, Russia suspended fuel supply to India, but it resumed fuel supply in 2006 by claiming the safety exception rule again. China now is citing the grandfather clause for nuclear power plant sale to Pakistan (McGoldrick 2011).”

In response to the 9/11 attacks, the NSG newly updated the guidelines to require greater efforts to prevent the Trigger List items from being delivered to terrorists. According to Mark Hibbs, the A. Q. Khan network, which was disclosed in 2004, used the United Arab Emirates, Malaysia, and other over thirty countries with weak national export controls as intermediate delivery points to avoid international detection. He also suspected that Malaysia and South Africa were manufacturing sites from about 1998 to 2006 for enrichment-related equipment transferred to Libya and Iran. As a follow-up measure, the NSG member states adopted in 2004 a catch-all mechanism “urging participating states to provide a national legal basis to control the export of nuclear related items which are not on the control lists, when such items are or may be intended to be used for nuclear weapons programs (Hibbs 2011:10).”

However, the NSG made a controversy exception for nuclear trade to India in 2008. With the U.S. initiative, the NSG member states relieved sanctions imposed on India, allowing it to import civil nuclear materials and technology in the Trigger List without abandoning nuclear weapons. So far, such exceptions have been permitted only for five nuclear weapon states recognized by the NPT. For India, the group dropped the 1992 guidelines that require CSA as conditions of supply; India was offered to only accept India-specific AP modified from original versions. Under the India-specific AP, India is not obligated to allow short-notice inspection to undeclared facilities and to report nuclear imports and exports. For other non-NPT member states like Israel, Pakistan, and North Korea, the United States, Russia, and France rejected to provide a similar exception.

In June 2011, the NSG members updated export guidelines on enrichment and reprocessing. Specifically, the new text says that "suppliers should authorize enrichment and reprocessing exports only if the recipient has brought into force a comprehensive safeguards agreement and an additional protocol or, pending this, [the recipient] is implementing appropriate safeguards agreements in cooperation with the IAEA, including a regional accounting and control arrangement for nuclear materials, as approved by the IAEA Board of Governors (Horner 2011)." Especially, enrichment-related transfers are only accepted under the black box conditions that prevent technology replication by recipient states. The guideline permits limited exception for the development of new enrichment technologies until the technology is commercialized.

The global nuclear export regime is not always changed toward the maximization of nuclear nonproliferation assurances. Its evolution process has been based on compromises between political, strategic, and economic self-interest and nuclear proliferation concern. Sometimes, the regime moves a step backward in terms of nonproliferation assurances in nuclear trade. That is, the regime, legally non-binding but politically binding, is still changing. The rules, guidelines, and recommendations in the nuclear export regime themselves are meaningless unless they are effectively delivered by effective and transparent interaction among suppliers to national-level laws.

There are two missing points for the effective and transparent interaction among suppliers. First, negotiation processes between a supplier and recipient are almost closed; a few interaction opportunities are allowed for other nuclear suppliers. Because most nuclear transactions still rely on bilateral arrangements between a supplier and a recipient, there is no way that other suppliers legally request to disclose nuclear negotiation processes. This trend might be intensified with the rapid evolution of the nuclear business practices from point-to-point transfers to a system of complex transactions (Hibbs 2011:54).

In the closed process, there is risk that some suppliers arbitrarily interpret the NSG guidelines. The NSG has no outreach programs to consult with enforcement agencies in member states as well as the peer reviews for national export controls. The current regime only requires post-reporting features without the rules for information sharing fast enough to give other nuclear suppliers time to respond in time. Transparent information sharing in time is critical to permit effective interaction among nuclear suppliers.

Moreover, there is no systematic approach for information sharing between the NSG and the IAEA. This would assist the IAEA and the NSG in improving the implementation of the AP and catch-all mechanism. In the

Carnegie workshop titled The Nuclear Suppliers Group and the Future of Nuclear Trade in 2011, some participants pointed out that "some participating governments may not support providing information to the IAEA, since they have little confidence that the IAEA would prevent such information from being leaked to any of its 150 member states… because of the IAEA's safeguards confidentiality provisions, information-sharing with the NSG could easily not be reciprocal (Hibbs 2011:48)."

Second, nuclear suppliers are sharing little political, strategic, and economic benefit. Interdependence among suppliers is important to maintain a power balance to prevent diversion from supply-side rules. Although there is export power transition from great powers to middle powers, the current regime is still experiencing significant power imbalance among suppliers. So far, only a few multinational approaches have been implemented; none of them was successful. Nonproliferation-based multinational consortiums (such as KEDO) are very rare and weak momentum, but some vendors have formed the consortiums for economic profit. This lack of shared benefit may result in slow consensus-building because of little incentive to do so among suppliers.

Chapter 7 Conclusion

In commercial trade of nuclear materials, equipment, and technology, buyer-dependent export practices might have facilitated the spread of nuclear weapons and weapons-grade fissile materials. Furthermore, the existing international nuclear export control regime is still too fragile to maintain consistent export policies. Despite the importance of supply-side aspects in nuclear proliferation, the majority of past studies have focused on the demand-side aspects. With the rise of new suppliers, it is necessary to investigate an evolving spectrum of business competition based on structured and focused case studies, as pointed out by this dissertation. This dissertation goes on to suggest a set of positive reform strategies for the global nuclear export regime.

Nuclear export controls have been considered a significant instrument that helps prevent the acquisition of nuclear weapons by countries without them. International nuclear export norms have been reinforced over time, but the complexity of nuclear market is also growing. The global export rules cannot include sufficient details of supply conditions because of the different interests of individual actors. The regime necessarily leaves the large details to weakly binding interactions among suppliers. Although more and more suppliers have adopted national export control laws based on intentional guidelines, nuclear export controls largely rely on each supplier’s bilateral arrangement with a recipient. The role of each supplier is crucial; this will remain changed until suppliers pursue their own benefits.

It is significant to understand how a nuclear supplier interacts with others on behalf of its political, strategic, and economic self-interests, and how the supply-side interaction contributes to shape the nuclear export control regime. The central control for every detail is impossible; all suppliers have to be rule-makers, controllers, managers, and compliers. Still, nonproliferation negotiations between a supplier and a recipient is closed and classified in many export cases. There is no room for other suppliers to interact with the supplier and the recipient. The nuclear export regime thus should be reformed to allow more opportunities to transparently interact with each nuclear supplier, and more political, strategic, and economic benefits shared by nuclear suppliers. This study could improve the process of law-making by reflecting the nature of the legitimate market mechanisms.

7.1 Policy recommendation on nuclear export controls

This dissertation has identified a nuclear supply feedback structure that determines nonproliferation conditions of supply. This study has also observed the causalities between nuclear supply feedback and the supply-side competition. Some level of competition is needed to achieve adequately strict conditions of supply, whereas high or low competition is vulnerable in nonproliferation perspectives. Unfortunately, we have no control over the level of the competition, because it naturally results from political importance and economic attractiveness of recipients. However, it is still possible to disconnect the causalities by enhancing nonproliferation conditions of supply so that they are high enough for all competition levels, as shown in Figure 7.1. To do that, the conditions of supply in both high and low competition contexts need to be enhanced via the nuclear export control regime or export policies.

As a dependent variable, "*nonproliferation conditions of supply*" is assumed to be derived from, but not necessarily be limited to, four indicators:

1) Safeguards on recycled fissile materials
2) Re-export requirements for nuclear technology and materials
3) Incentive to reduce proliferation benefit and increase cost (diplomatic, political, strategic, economic assistance)
4) Assistance for a recipient to set up national export control and physical protection systems

In the dissertation, as shown in Figure 7.2, the four types of supply-side feedback are identified and verified: the risk-taking feedback, the lack of vigilance feedback, the consensus-building feedback, and the external constraint feedback. The first two types of feedback loosen nonproliferation conditions of supply, whereas the last two strengthen the conditions. The nuclear export control regime has to promote the feedback that enhances nonproliferation, while balancing the feedback that accelerates proliferation. As such, this section identifies leverage variables that are influenced by export policies or global environments. The leverage variable in each type of feedback has to exert a large influence on the conditions. Because all feedback is closely related, changing one would impact others. Thus, controlling leverage variables in the feedback that strengthens the conditions would influence leverage variables in the feedback that weakens the conditions.

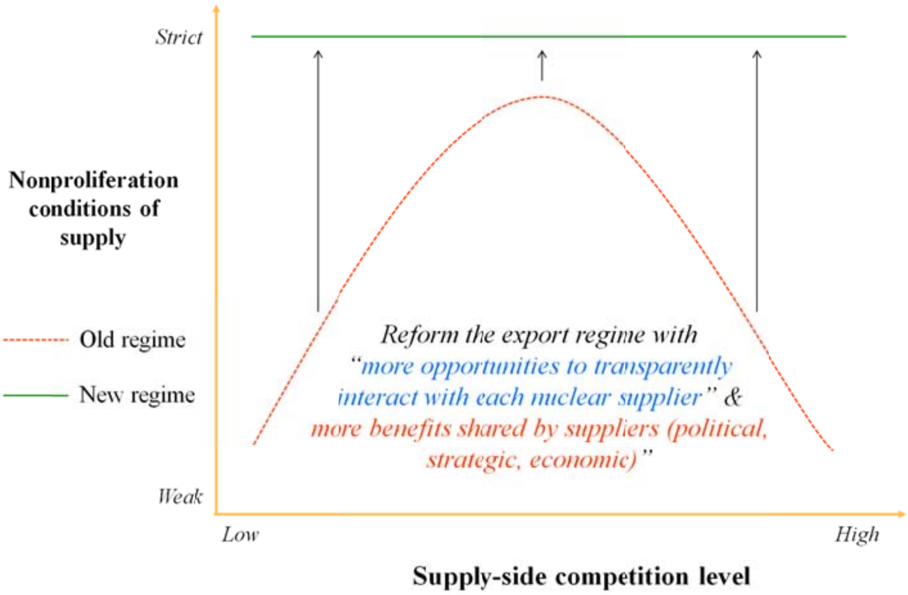
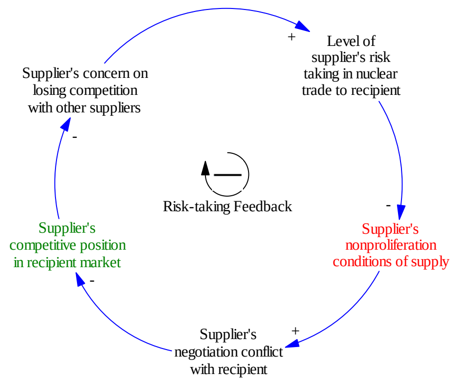
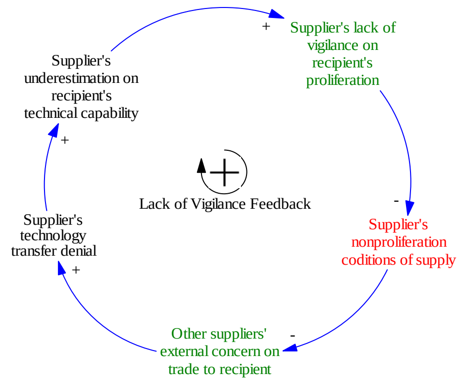


Figure 7.1 Reform strategies for global nuclear export regime



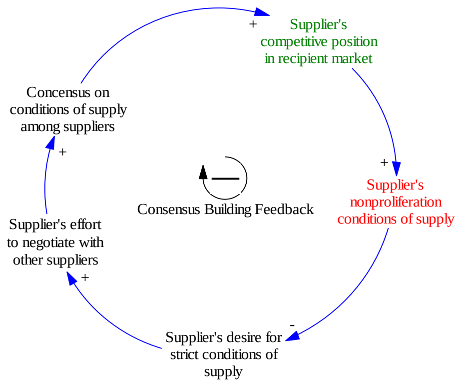
Risk-taking feedback

(a)



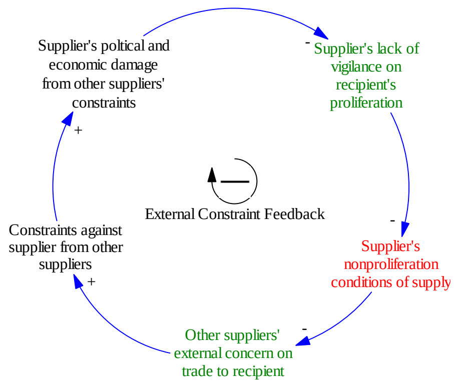
Lack of vigilance feedback

(b)



Consensus-building feedback

(c)



External constraint feedback

(d)

Figure 7.2 Four types of nuclear supply feedback determining nonproliferation conditions of supply

The risk-taking feedback reflects that nonproliferation conditions of supply could be damaged by the cost of negotiation with recipients when a supplier reinforces the conditions. The leverage variable for this feedback is "a *supplier's negotiation conflict with a recipient*." National export policies or global approaches that reduce the cost of negotiation would mitigate a supplier's concern on losing its competitive edge, maintaining conditions of supply at high level. The negotiation conflict is particularly high in the case where a supplier takes on the cost all alone through the unilateral approach — to reinforce the conditions with no consensus over conditions of supply. Thus, Figure 7.3 shows that the negotiation conflict is reduced by reinforcing the impact of the consensus-building feedback.

The lack of vigilance feedback reflects the case where a supplier is lacking in vigilance regarding proliferation risk results in weak conditions of supply. "Other suppliers' *external concern on trade to a recipient*" is the leverage variable in this feedback. Because other suppliers are also indifferent to the proliferation risk of an uncompetitive or unattractive market, the external concern produces only a limited impact on increasing conditions of supply. Breaking the lack of vigilance is effective only if a supplier has significant interdependence with others, giving them sufficient constraining power. The interdependence would be established by mutual cooperation and shared benefits. Thus, Figure 7.4 shows that reinforcing the impact of the external constraints feedback increases attention of a supplier to proliferation risk in trade.

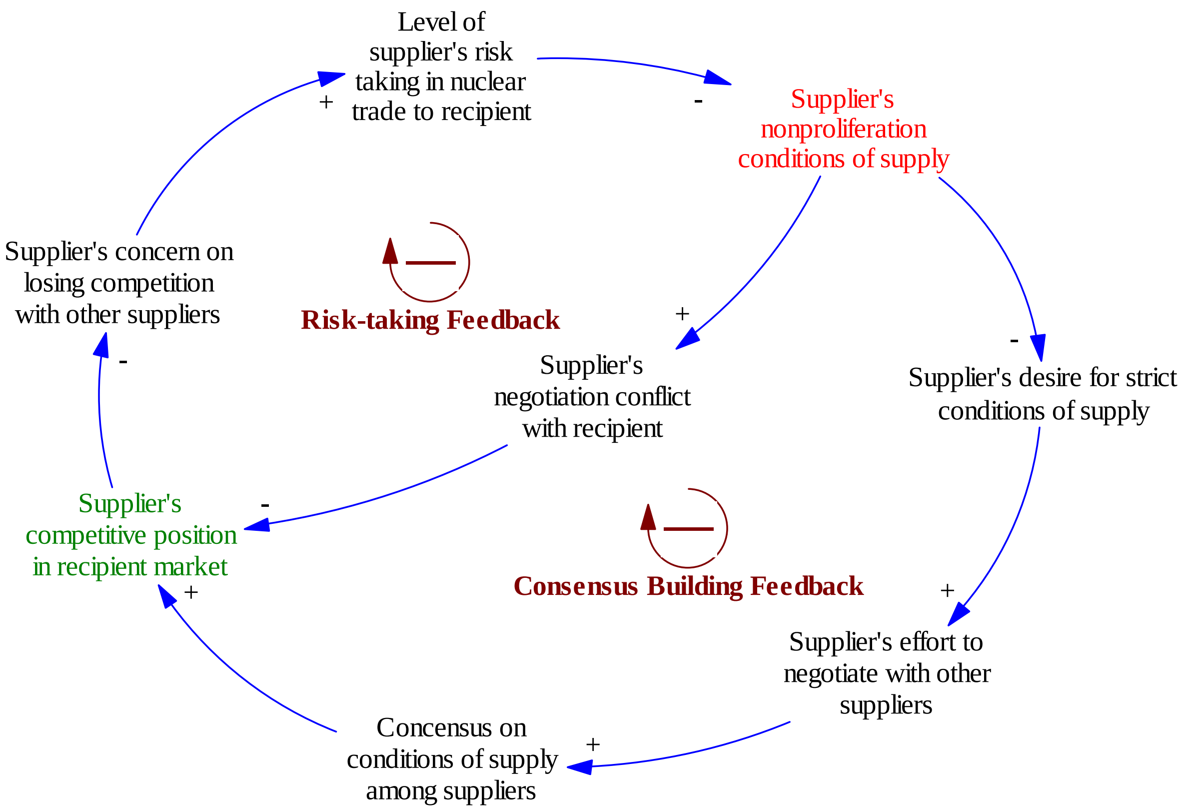


Figure 7.3 Competing link between the negotiation cost feedback and the consensus-building feedback

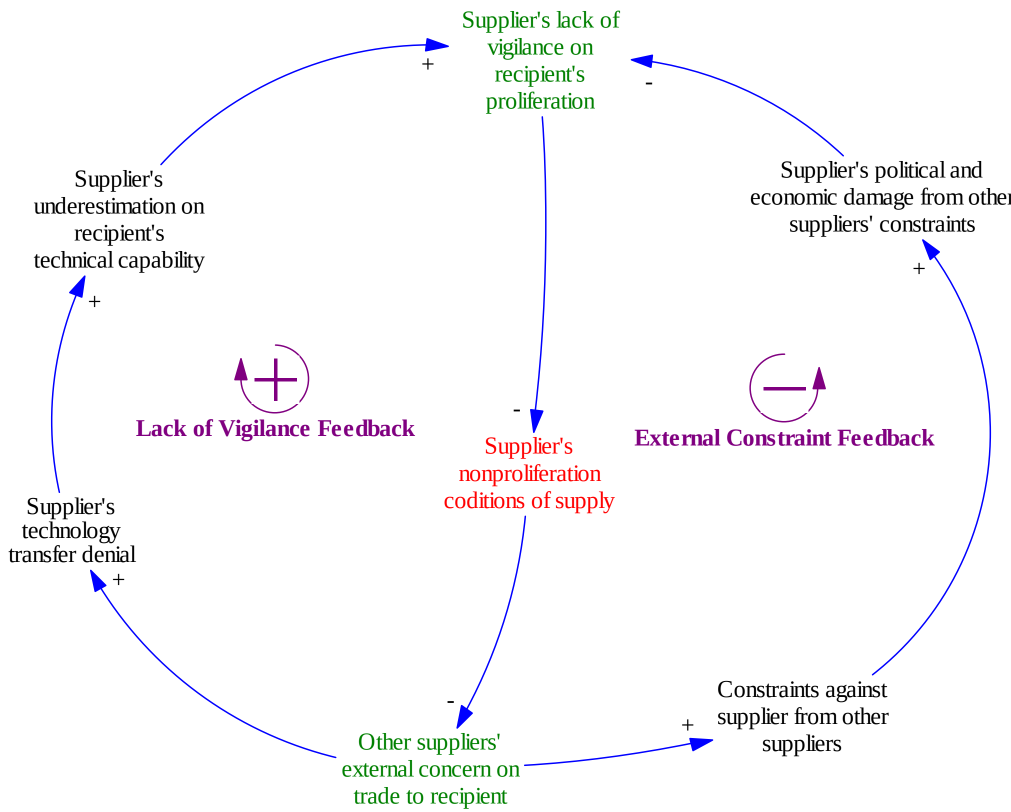


Figure 7.4 Competing link between the lack of vigilance feedback and the external constraint feedback

As discussed above, managing the previous two types of feedback is achievable by controlling leverage variables of the following two types of feedback. In *the consensus-building feedback*, a supplier persuades other suppliers to build consensus on nonproliferation conditions of supply so as to avoid having to handle unilateral negotiation conflict with a recipient all by itself. In the feedback, "*a supplier's effort to negotiate with other suppliers*" is the leverage variable. Unfortunately, the current nuclear export regime has only limited incentives to bring as many suppliers as possible to the negotiation table and to agree to the consented export standards.

In *the external constraint feedback*, a group of nuclear suppliers constrain another supplier from loosening nonproliferation conditions of supply to prevent it from gaining a competitive edge. "*Constraints against a supplier from other suppliers*" is the leverage variable for this feedback. This feedback is significantly weak in the current regime, which has a power imbalance between rule-makers and rule-compliers. However, the current power transitions within nuclear export could provide the nuclear export regime with driving forces to resolve the imbalance. This feedback is also closely related to consensus-building feedback that establishes legitimate grounds for constraints or regulations.

Therefore, this dissertation suggests reform strategies that improve the two types of nonproliferation feedback –consensus-building and external constraint. First, the international nuclear export regime shall increase opportunities for transparent interaction among suppliers. In the current regime, many negotiation processes in nuclear trade are classified, so there is little chance that other suppliers can observe, review, and react to the processes. Instant information-sharing about nuclear exports is critical, since supply-side interaction is required for effective and meaningful impact on conditions of supply. While business information is still classified, information related to nonproliferation should be shared with and tackled by other nuclear suppliers. Second, the international nuclear export regime shall establish more political, strategic and economic benefits shared by many nuclear suppliers, to establish interdependence among suppliers. The interdependence provides effective external constraints against violations of global export rules, and acts as a driving force to promote mutual cooperation and build consensus on conditions of supply. To do that, each supplier has to have equal rights and obligations in the specific multinational approaches as well as in the overall global nuclear export regime. Otherwise, any decision would result in significant damages or one-sided benefit to a few suppliers.

As practical approaches, more opportunities to transparently interact with each supplier are accommodated by specific policies:

1) Building a transparent negotiation framework for nonproliferation conditions of supply under the IAEA and the NSG, while other business conditions are still classified
2) Running more interactive programs on making international rules, procedures, or guidelines, e.g. Carnegie Nuclear Power Plant Exporters' Principles of Conduct, or peer review of national laws

3) Sharing more information among suppliers through the IAEA, the NSG, the Zangger Committee, and the UNSCR 1540
4) Supporting the international network of national licensing officers and vendors

Moreover, more political, strategic and economic benefits can be shared by nuclear suppliers by establishing multinational approaches:

1) Encouraging a multinational consortium for reactors, fuels, components, enrichment, reprocessing, storages, other services
2) Conducting a joint secret threat response study within an export consortium with help from the IAEA before technology transfer
3) Forming interdependence among nuclear suppliers by means of diplomatic, economic and technical cooperation
4) Reforming the NSG decision-making regarding anonymity, equal rights and obligations

7.2 Summary, findings, and future work of dissertation

This dissertation explored two research questions to suggest reform strategies for nuclear export systems. First, what types of supply-side feedback influence nuclear suppliers to decide nonproliferation conditions of supply? It is assumed that nuclear suppliers want to win the political and economic competition within the nuclear market. The nuclear supply dynamics model shows that suppliers' pursuit of economical, strategic, and political benefits produces the four types of feedback among suppliers. Under high supply-side competition, a supplier can compromise conditions of supply in order to avoid negotiation deadlock with a recipient; otherwise, the supplier must risks losing its competitive position – this is *the risk-taking feedback*. Under low competition, a supplier can be distracted to attract markets while it deals with no vigilance with unattractive recipients – this is *the lack of vigilance feedback*. In contrast, a supplier can build consensus with other suppliers on conditions of supply to avoid being the only party in negotiation conflict with a recipient, and thus to seek its competitive position – this is *the consensus-building feedback*. In addition, if a supplier tries to loosen conditions of supply, other suppliers constrain it from doing so to keep their competitive positions – this is *the external constraints feedback*. The first two types of feedback can loosen conditions of supply, while the latter two can strengthen the conditions.

Second, how political and business competition among suppliers, in turn, affects the feedback structures? The four types of feedback in nuclear supply dynamics could explain the relationship. Both the special concessions made in order to win a high-level competition and the lack of vigilance in a monopolistic trade scenario increase the likelihood of proliferation. Under a high level of competition, the negotiation conflict with a recipient is fatal for a supplier's market share goal, because the recipient can easily make deals with other suppliers that loosen the conditions of supply. If no trust-based consensus regarding the conditions has been established among suppliers, the supplier will choose the safe option. Otherwise, other competitors, sometimes even adversaries, may steal away the important partner and attractive market. Under a low level of competition, a supplier recognizes a negligible proliferation risk in an unattractive recipient, and focuses on more competitive markets with attractive recipients. The supplier believes that the unattractive recipient has no technical capability to manufacture nuclear weapons, unless someone helps it. There are no suppliers that want to sell products to the recipient that offers no political benefit, strategic advantage, and economic profit.

The proposed reform strategies strengthen feedback that intensifies conditions of supply, while weakening feedback that loosens the conditions. Three export cases of 1960-70's representing different competition levels were studied: 1) a strong export competition between Canada and the United States to India; 2) a monopolistic case of the Soviet Union to North Korea; and 3) a moderate competition between the United States and Canada in export to South Korea. As a result, a new supply dynamics model for nuclear export decision-making has been developed; it was tested via the three cases and a new cooperation case between the United States and India

Under high competition, Canada and the United States compromised safeguards conditions of supply to India that was the largest democracy and business economic market – the risk-taking feedback was dominant. Under low competition, the Soviet Union as well as other suppliers was indifferent to proliferation risks in North Korea where market attractiveness was trivial and Soviet political influence seemed credible – the lack of vigilance feedback was superior. Under moderate competition, the United States persuaded Canada to build consensus on stringent conditions of supply while constraining France from supplying South Korea with sensitive reprocessing technology – the consensus-building and external constraint feedback were prominent. In summary, the nuclear supply dynamics model predicts that a high competition renders suppliers to discount recognized proliferation risk, whereas a low competition may also increase potential proliferation risk due to lack of vigilance of suppliers. It is expected that a moderate competition results in healthy feedback among suppliers, allowing them to pay due attention to strict nonproliferation conditions of supply.

Case-specific supplier behaviors have been preserved up to date with continuing pursuit for gaining strategic advantages and economic profits. Even today, the existing international nuclear export control regime such as Nuclear Suppliers Group is still too weak to maintain consistent export policies for nuclear nonproliferation and nuclear security. Moreover, the export control regime is traditionally governed by nuclear weapons states encountering a transition, as new nuclear power plants are mostly supplied by emerging nuclear suppliers. The United States lifted a ban on India permitting the unaccepted nuclear weapon state legitimate access to civil nuclear technology and materials without requiring her ratification of NPT. This recent example highlights that strong strategic and economic stake of the supplier led to pursue the market at the expense of negative impact on the international nonproliferation regime while most nuclear transactions still rely on specific bilateral arrangements.

Such a bilateral negotiation process between a supplier and a recipient is usually exclusive; few interaction opportunities are allowed for other nuclear suppliers. There is no way that other suppliers can legally require a disclosure of nuclear negotiation processes. In addition, nuclear suppliers are sharing scant political, strategic, and economic benefits, although interdependence among suppliers is important to maintain a power balance and prevent a supplier from violating the global nuclear export guidelines. Soon, this trend would be a significant problem because nuclear transactions would evolve from point-to-point transfers to a system of complex trade networks, and the non-binding global regime has no control over every detail of nuclear export.

Therefore, today’s nuclear export systems need to be upgraded so as to facilitate transparent interactions with each supplier, and to create more political, strategic, and economic benefits shared by nuclear suppliers. The upgraded strategy can assure the consensus-building process and reinforce the external constraint mechanism, while preventing both special concessions to win intense competition and lack of vigilance in a monopolistic trade. Practicable approaches for more supply-side interaction and more benefit-sharing include: building a global negotiation framework based on nonproliferation conditions of supply while classifying other business conditions; running more interaction programs for a global code of conduct; establishing a multinational consortium for reactors, fuels, components, enrichment, reprocessing, and storages; and forming higher diplomatic, economic, and technical interdependence among suppliers.

Related incentives are lacking in the current approach. Practicable mechanisms to incentivize the actions include establishing an international joint plant vendor, forming a multinational fuel supply consortium, conducting an independent threat response study, agreeing to a global code of conduct, and eliminating loopholes in NSG guidelines. Each supplier’s role inside the regime is significant to monitor, detect, delay, respond, and prevent nuclear proliferation and potential nuclear terrorism. All nuclear suppliers require equal rights and obligations under the global nuclear export regime in order to create healthy competition.

Much more study is required to fully discover and understand the fundamentals of nuclear supply dynamics. This dissertation describes how interaction among nuclear suppliers influences nuclear nonproliferation. The interaction is specified and represented by supply-side competition. More specifically, this study looks at the relationship between supply-side competition and nonproliferation conditions of supply. It is necessary to verify, update, and refine the nuclear supply dynamic feedback model by studying more export cases. The remaining questions include: how are conditions of supply important to the proliferation decision of recipients and how does supply-side competition in nuclear trade change nuclear import strategies of recipients? In addition, findings in this dissertation may be not limited to nuclear export controls; they should be applied to the nuclear supply dynamic model regarding missile technology controls or other dual-use technologies.

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Abbreviation

AECL	Atomic Energy of Canada Limited
AP	Additional Protocol
BWR	Boiling Water Reactor
CANDU	Canada Deuterium Uranium Reactor
CIRUS	Canada-India-Reactor-United States
CSA	Comprehensive Safeguards Agreement
CTBT	Comprehensive Nuclear Test Ban Treaty
HEU	Highly Enriched Uranium
IAEA	International Atomic Energy Agency
INFCE	International Nuclear Fuel Cycle Evaluation
INPRO	International Project on Innovative Nuclear Reactors and Fuel Cycles
KEDO	Korean Peninsula Energy Development Organization
MTCR	Missile Technology Control Regime
NASAP	Nonproliferation Alternatives System Assessment Program
NPT	Nuclear Non-Proliferation Treaty
NSA	Negative Security Assurances
NSG	Nuclear Suppliers Group
PRPPWG	Proliferation Resistance and Physical Protection Working Group
PSA	Positive Security Assurances

PTBT	Partial Test Ban Treaty
PUREX	Plutonium-Uranium Extraction Process
PWR	Pressurized Water Reactor
RAPP	Rajasthan Atomic Power Project
RgPu	Reactor-grade Plutonium
SPNFZ	South Pacific Nuclear Free Zone
SQ	Significant Quantity
TOPS	Technical Opportunities for Increasing the Proliferation Resistance of Global Civilian Nuclear Power Systems
TTBT	Threshold Test Ban Treaty
UNSCR	United Nations Security Council resolution
WgPu	Weapons-grade Plutonium

초 록

지난 60년간 평화적 목적으로 전달된 핵물질·장비·기술은 때때로 핵무기, 핵테러 등의 부작용을 양산해왔다. 특히, 일부 공급국들이 자국의 이익을 위해 특정 수요국에만 특혜를 주는 차별적 공급정책은 핵비확산에 악영향을 미쳐왔다. 하지만 이를 규제하는 원자력공급국그룹과 같은 국제수출통제체제의 권한은 매우 제한적이고, 아직도 원자력수출은 양자 간의 복잡한 이해관계에 크게 의존하고 있어, 핵확산의 위험성은 원자력거래에 계속 내재하고 있다. 이런 위험은 최근 수출체제가 급격한 변화를 겪으면서 더 도드라지고 있다. 체르노빌사고 이전까지 설치용량의 90%를 담당하던 미국, 러시아, 프랑스, 영국, 캐나다, 독일의 영향력이 사고 이후에는 30%로 감소하면서, 이제는 신규 공급국들이 시장을 주도하고 있다. 또한, 새로운 기술들이 산업화되고 있으며, 핵확산에 취약한 불법거래네트워크가 일부 국가 혹은 테러리스트들을 통해 확산되고 있다.

이런 공급 측면의 핵확산 문제에도, 현재까지 핵확산과 관련된 수요측면의 연구가 주를 이루고 있으며, 공급 측면의 연구는 미비한 상황이다. 지금까지 공급자측 연구의 주요논지는 과도한 경제·정치·전략적 이익추구가 극심한 공급경쟁을 유발하여, 수요자에게 충분한 핵비확산 선행조건을 요구하지 않은 채 수출이 진행되었다는 것이다. 기존연구의 단점을 방법론 측면에서 살펴보면, 통계연구는 검증된 데이터가 매우 적고 상세한 인과관계 파악마저도 불가능하며, 사례연구는 오직 소수의 과열경쟁에만 초점을 맞추고 있다. 그러므로 사례연구를 통해 여러 공급경쟁 수준에 따라 핵확산위험이 어떻게 달라지는지 분석하고, 상세한 인과관계를 파악하여 의미 있는 정책제언을 할 필요가 있다.

따라서 본 논문의 연구질문은 ① “원자력수출에서 핵비확산·핵안보 공급조건에 영향을 미치는 공급국 사이의 상호작용은 무엇인가?” ② “공급경쟁이 이 공급국 상호작용에 미치는 영향은 무엇인가?”이다. 이에 대한 답을 찾기 위해, 여기서는 시스템 사고로 실제 수출 사례를 분석하고, 공급조건을 결정하는 변수들 사이의 인과관계를 밝혀냈다. 이를 바탕으로 핵확산을 방지하는 피드백을 강화하고, 반대로 촉진시키는 피드백을 규제하는 방향으로 정책제언을 도출했다. 사례분석의 독립변수로 *수요국의 정치적 중요성*, *수요국의 시장매력도*, 종속변수로 *수요국에 대한 공급국의 핵비확산 요구조건*을 설정했다. 자료 확보가 용이한 1950-70년대 사례를 중심으로, 공급경쟁의 정도에 따라 과열경쟁은 캐나다와 미국의 인도수출, 독점체제는 소련의 북한수출, 중간사례는 미국과 캐나다의 한국수출을 선택했다. 이 사례분석에서 드러난 문제의식을 최근 미국과 인도 원자력협정 사례에 적용하여 현 제도의 문제점과 개선점을 제시하였다.

캐나다와 미국은 인도로의 원자력수출이 핵확산으로 이어질 가능성을 인지했음에도, 충분한 핵비확산 공급조건을 요구하지 않았다. 미·소·영·캐·프는 지정학적으로 중요하고, 매력적인 시장을 지닌 인도를 차지하기 위해서 치열한 공급경쟁을 벌였고, 그 중 후발주자에 국내시장도 작은 캐나다가 특히 경쟁에서 승리하기 위해 적극 핵확산위험을 감수하였다. 소련은 대북한 원자력거래에서 핵확산위험을 인지하지 못하고, 무관심 때문에 북한을 핵비확산 의무로부터 자유롭게 내버려뒀다. 특히 북한의 경제불황은 공급국들의 원자력수출에 대한 유인을 약화해, 북한의 핵기술 개발 속도를 둔화시켰다. 이는 북한 핵기술에 대한 공급국들의 저평가로, 나아가서 핵확산 위험에 대한 무관심으로 이어졌다. 1970년대 초, 한국은 프랑스로부터 재처리시설 도입을 시도하였다. 이에 미국은 캐나다에게 상업원전을 협상카드로 한국을 함께 설득할 것을 요청했고, 프랑스에는 민감한 재

처리시설 대신 핵연료제조 및 우라늄처리기술을 수출할 것을 권고했다. 미국은 다른 공급국들과 상호협력 및 상호규제를 통해 엄격한 핵비확산 공급조건을 요구하면서도, 다른 공급국들이 느슨한 공급조건을 무기로 시장을 빼앗는 것을 방지하였다. 최근까지도 핵확산에 취약한 차별적 공급정책은 현재까지도 계속되고 있다. 미국은 2005년에 인도가 핵비확산 조약에 가입하거나 핵무기를 포기하지 않아도 원자력 발전기술을 수입할 수 있도록 특혜를 주었다.

공급경쟁 정도와 관계없이 공급자의 핵비확산·핵안보 공급조건 결정에 경제·정치·전략적 이익은 중요한 요인이다. 과도한 공급경쟁 때문인 특혜 또는 독점으로 말미암은 무관심은 핵확산을 일으키기도 했다. 중간 정도 공급경쟁에서는 공급자간의 상호협력 및 상호규제가 지나친 경쟁이나 독점의 무관심을 방지하는 중요한 피드백으로 작용했다. 따라서 원자력거래에 동반되는 핵확산위험을 낮추려면, 국제 핵비확산 체제도 공급국 사이의 상호협력 및 상호규제를 강화하는 방향으로 개선되어야 한다.

이를 위해, 첫째로 투명성이 보장되는 공급국과 수요국 사이의 핵비확산 공급조건에 특화된 국제협상절차가 수립되어야 하며, 다른 공급국들에 이 협상과정을 지켜보고 상호작용할 기회를 줘야 한다. 둘째로 공급국들이 같은 권리와 의무 아래에서 상호이익 및 의존도를 키워서 수립된 국제협상절차가 제 기능을 발휘하도록 상호협력과 상호규제를 강화해야 한다.

주요어:
핵비확산, 핵안보, 원자력공급국, 수출통제, 공급경쟁, 핵공급조건
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