A STUDY ON OPTIMAL INVESTMENT IN NEW ENERGY INDUSTRY OF MYANMAR

（ミャンマーの新エネルギー産業への最適投資に関する研究）

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Abstract（Doctor）

Title of Thesis	A STUDY ON OPTIMAL INVESTMENT IN NEW ENERGY INDUSTRY OF MYANMAR（ミャンマーの新エネルギー産業への最適投資に関する研究）

Approx. 800 words

Energy is necessary for socio-economic development. Growth in energy demand increasingly comes from developing economies, including Myanmar. On the other hand, the energy mix is seriously getting shift towards lower carbon fuels for supporting ecosystem, the climate adaptation and technological advances. Currently, 57% of total population in Myanmar is still deprived of access to electricity although endowed with renewable and non-renewable energy resources. As Myanmar is a developing country, it needs innovative modern technology with huge capitalization in energy sector to be a developed nation.

The research questions are that what kinds of irreversible investment decision make financially optimal under uncertainty, how it is possible for Myanmar to invite foreign technology and investment from a perspective of win-win relationship and finally how Bayesian method would be a useful framework to estimate the parameters and clarify the signaling of investment in new energy industry.

In this thesis, a combination of option-games and Bayesian analysis will be utilized to analyze the optimal investment strategies for high-tech energy industry which needs huge irreversible capitalization and involve a great deal of uncertainty with asymmetric information among competitors. Particularly, managerial flexibility is connected with the Real Options Analysis. In Game Theory, the final realization of competition and cooperation tends to achieve "win-win" relationship with partners. Then, Bayesian MCMC Analysis is useful to the parameter estimation of the risk factors even when using incomplete information. Bayesian method has its advantage of signaling effect over the options-games theory of asymmetric information among competitors. Using options-games and Bayesian method to analyze the condition of two firms in clustering cooperation solves the problems between open innovation for advanced energy technology and cluster formation of the firms rationally.

In dissertation, one-stage strategic investment model is the introduction to the option-games between two players. In this model, option without competition, propriety option, has the implication of incentive to delay investment under uncertainty. But, option with competitive reactions has the timing trade-off between early commitment and flexibility value.

In two-stage option-games models, market structure is assumed to be oligopoly, duopoly in this case, where firm A is the pioneer and firm B is the follower. Firm A and B take actions in R&D commercialization period. The results show that a joint research venture enabling the firms to cooperate in R&D based on reciprocity during the second stage can be the successful strategy for future growth in aspects of their market size. Then, it can save the

R&D cost at favorable condition and can stay flexibility by waiting under unfavorable condition. By other words, firms of cooperation can get the win-win survival by the sharing strategy for uncertain condition. However, it needs to remove opportunism and improve the incentive for pioneer's entrepreneurial initiative.

Then, the Bayesian MCMC analyses are made as the parameter estimation in order to find the optimal energy mix for safe and secure electricity supply and, to examine the R&D investment continuity of new energy start-ups at the 'Valley of Death'. The flood disaster analysis is made for the risk management from the building of dams for hydroelectricity and also to figure out the best energy mix in electricity supply. In order for the stable supply of electricity all the seasons, solar electricity is an interesting renewable energy source in a dry zone like Myanmar as a backup to hydroelectricity. The revenue analysis from Bayesian perspective pointed out how much amount of investment should be made in new energy industry and how to continue the investments in negative financial period. At that time, firm's revenue as the sort of real options can be guideline to facilitate the risky but promising investments.

Since it has to invite the outside investors to invest in new energy project, two-players' game is extended for perfect competition between the competing firms under incomplete information. With information asymmetry in attracting to invest in a project, firm of better information tries to signal the project quality to the competing firm by acquiring patent as signaling game of perfect Bayesian equilibrium.

As the next challenge for my research, Bayesian inferences on stock returns and a Bayesian Regression Analysis for the potentiality to make the R&D investment in new project will be tried by referring to a study on opportunity for the sustainability of energy industry from a viewpoint of jump valuation.

The thesis concludes that there are ample opportunities for regional cooperation and technological innovation for new energy industry between advanced foreign countries including Japan and Myanmar in the development of renewable sources of energy. One of the conclusions of this thesis is that strategic cooperation with Japan would help Myanmar in strengthening energy related infrastructures and sourcing modern technology. I propose the result to appear sufficient generation and stable supply of electricity and then, a vision for the new energy project as the regional development in Myanmar.

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ABBREBIATIONS

ADB	:	Asian Development Bank
CNG	:	Compressed Natural Gas
CSR	:	Corporate Social Responsibility
DEPP	:	Department of Electric Power Planning
DHPI	:	Department of Hydropower Implementation
DPTSC	:	Department of Power Transmission and System Control
EMP	:	Energy Master Plan
ENPV	:	Expanded Net Present Value
EPGE	:	Electric Power Generation Enterprise
ERIA	:	Economic Research Institute for ASEAN and East Asia
ESE	:	Electricity Supply Enterprise
FCF	:	Free Cash Flow
FDI	:	Foreign Direct Investment
FEPC	:	Federation of Electric Power Companies
FY	:	Fiscal Year
GW	:	Gigawatt
GWh	:	Gigawatt hour
HSE	:	Health, Safety and Environment
IEA	:	International Energy Agency
IES	:	Intelligent Energy Systems
IMF	:	International Monetary Fund
IPP	:	Independent Power Producer
IPPs	:	Independent Power Producers
JICA	:	Japan International Cooperation Agency
JV	:	Joint Venture

Kcal	:	Kilocalorie
km	:	Kilometer
km^2	:	Kilometer Square
KTOE	:	Kilo Tons of Equivalent
kV	:	Kilovolt
kW	:	Kilowatt
kWh	:	Kilowatt Hour
LPG	:	Liquefied Petroleum Gas
LRMC	:	Long Run Marginal Cost
MCMC	:	Markov Chain Monte Carlo
MESC	:	Mandalay Electricity Supply Cooperation
MIMU	:	Myanmar Information Management Unit
MMbbl	:	Million Barrels (double M means square of Roman numerical thousand)
MMCF	:	Million Cubic Feet
MMIC	:	Myanmar International Consultants
MOEE	:	Ministry of Electricity and Energy
MOGE	:	Myanmar Oil and Gas Enterprise
MOUs	:	Memorandums of Understanding
MPE	:	Myanmar Petrochemical Enterprise
MPPE	:	Myanmar Petroleum Products Enterprise
MTOE	:	Million Tons of Oil Equivalent
MW	:	Megawatt
MWh	:	Megawatt Hour
NEP	:	National Electrification Plan
NEP	:	National Energy Policies
NPV	:	Net Present Value
OGPD	:	Oil and Gas Planning Department

OJT	:	On-the-Job Training
OT	:	Options Theory
PBE	:	Perfect Bayesian Equilibrium
PPPs	:	public-private partnerships
QOL	:	Quality of Life
ROA	:	Real Options Analysis
SEA	:	Strategic Environmental Assessment
SPE	:	Subgame Perfect Equilibrium
TA	:	Technical Assistance
TCF	:	Trillion Cubic Feet
TVM	:	Time Value of Money
TWh	:	Terawatt Hour
UN	:	United Nations
YESC	:	Yangon Electricity Supply Cooperation

CHAPTER 1[1]

INTRODUCTION TO THE STUDY

1.1 Study Background

Growth in energy demand increasingly comes from developing economies, especially within Asia including Myanmar. Myanmar is naturally endowed with energy resources and has considerable potential in non-renewable and renewable energy resources, which can meet demand from community in the long term if it is properly managed. But they are far away to fulfill the energy requirement of the domestic people. And it much remains to be done in terms of research, cost-benefit observations and experimentation together with taking priority to the awareness of environmental affects like pollution, deforestation, and so on. Thus, it has immense potential for the cooperation in energy sector with foreign countries including Japan.

Energy is necessary for socio-economic development to meet basic needs of human beings and support the industrial development. However, the energy sector of the country has been underdeveloped due to the lack of financial power and technical capacity and, global isolation in the past. Moreover, insufficient power supply has emerged as one of the most essential infrastructure constraints for the sustainable economic growth of the country. After the country had opened everything to the world in 2011, the energy demand from industry, residential sectors and commerce is on the rise, placing pressure on energy infrastructure which has still some limitations.

Just as the cooperation in energy is a major concentration of future initiative for all nations nowadays, sustainable energy has also turned into a promising way to tackle the challenges of energy demand problems for numerous worldwide consumers. Of course, the energy mix is seriously getting shift towards lower and cleaner carbon fuels, driven by environmental needs to respond the changing nature of supporting ecosystem services, the climate adaptation and technological advances.

[1] The contents of these chapter are partially drawn from published papers namely Nyein Nyein Aye & T. Fujiwara, 2014, Nyein Nyein Aye & T. Fujiwara, 2017, Nyein Nyein Aye & T. Fujiwara, 2019.

At the same time, the industrial development mainly depends on the technological advances to be resulted in economic progress of Myanmar. It should not be for the people to live in the poor mire of energy-poverty in such a favorable condition of numerous energy potential in Myanmar. In our opinion, Japan is one of the most developed nations in management concerning with the commercialization technique. As Myanmar is a developing country, it needs innovative modern technology to promote the energy sector and construction of the country to be a developed nation. The thesis includes that there are ample opportunities for regional cooperation and technological innovation between Japan and Myanmar, not only in efficiently production and utilization of natural gas, coal and oil but also in hydroelectricity; and especially in the development of new and renewable sources of energy as solar, wind, biomass, etc. Strategic cooperation with Japan and other advanced foreign countries would help Myanmar in strengthening energy related infrastructures and sourcing modern technology for energy generation and supply.

1.2 Problem Statement of the Study

In this study, the first problem is to find the optimal solution for the energy generation and supply to be able to meet the energy demand by the people. In that case, another problem is that it is needed R&D investment in the new energy generation project and in infrastructure development of the electricity sector.

Energy demand for electricity is increasing nowadays in Myanmar. Due to a heavy reliance on hydropower, which accounts for about 70% of electricity production, the country's power generation is extremely seasonal (World Bank, 2013). Delays in hydropower investment program and a rapid increase in electricity demand result in large shortages which are estimated at about 30% of power demand during the dry season every year. To satisfy such problem, the best energy mix from the available energy sources has been formulated by JICA (JICA, NEWJEC Inc., 2015). In the aspect of long-term viewpoint, the new energy generation projects form clean and renewable energy sources as solar, wind, biomass, etc. will have to be implemented for the stable supply of energy demand during the peak season, also for sustainability and eco-system protection. At that time, it is important to promote the international collaboration in electric power and energy sector for financing and technical support. In order to mobilize urgently needed investments and improve efficiency in the power sector, the government plans to attract Independent Power Producers (IPPs) and promote public-private partnerships (PPPs) both from foreign and domestic partners to accelerate construction of modem power generation projects and reduce losses in the power distribution sector. In such partnership, it is crucial to have the optimal cooperation between existing firm and new comer of foreign investor so as to minimize the gap of the sharing benefits.

1.3 Research Questions

Based on the above study problems, this thesis centralizes the following research questions.

1) What kinds of investment decision make optimal for the financial performance of the electricity firms in the competitive market under uncertainty?

2) How is it possible for Myanmar to invite and promote foreign technology and investment for energy sector from a perspective of win-win relationship and mutual benefits?

3) How would Bayesian Method be a useful framework to estimate the parameters and clarify the signaling of influenced factors on investment in new power plant?

1.4 Research Objectives

The first objective of this thesis is to evaluate the potential of technological new energy industry and support them in eco-system from entrepreneurial perspective.

The second one tends to search the implications for invitation of foreign technology and capital investment from a perspective of win-win relationship and mutual benefits for regional development in Myanmar.

Then it tends to develop an appropriate model for robust R&D investment in innovative and initiative production technology for the implementation of the reliable future plan of energy efficiency, conservation and sustainability.

1.5 Overall Research Methodology

Here, a new energy industry can be defined as the portfolio of real options by considering that the renewable energy resources are ample and investment opportunities that will result in eco-system and commercialization in the future. In order to cover the above concepts, questions and objectives, a combination of real options, game theory and Bayesian Analysis will be utilized to analyze the optimal investment strategies for high-tech energy industry which needs huge irreversible capitalization and involve a great deal of uncertainty with asymmetric information among competitors.

Technical management is a critical factor influencing global competitiveness particularly when competition is becoming increasingly technology intensive. At such time, Real Options Analysis (ROA), which is a decision method to irreversible investment in real assets under uncertainty, should be employed in decision-making for such kind of high risky investment projects (Dixit, A. K. and Pindyck, R. S., 1994). Particularly, managerial flexibility is connected with the Real Options Analysis (ROA) (Copeland, T. & Antikarov, V., 2003).

Moreover, game theory is also needed to analyze the cluster formation and behavior of players in new industry. In addition, the final realization of competitive results and cooperation tends to achieve "win-win" relationship with partners, not to kill the rivals (Fujiwara, T., 2008). Using option-games theory to analyze the condition of competitive firms in clustering cooperation solves the problems between open innovation for advanced energy technology and cluster formation of the firms rationally.

Bayesian MCMC analysis is useful to the assessment of firm's performance and value for overcoming the 'Valley of Death' and consequently, to the parameter estimation of the risk factors even when using incomplete information. Then, Bayesian method has its advantage of signaling effect over the options-games theory of asymmetric information among competitors (David, B. D., 2001). In a dynamic game of asymmetric information, ill-informed players have the ability to learn something about the playing game by observing the moves of better-informed opponents (Bierman, H. Scott & Luis Fernandez, 1998). These Bayesian games require the players to rationally update their beliefs about the game by using the procedure of Bayesian updating that results in Perfect Bayesian Equilibria.

1.6 Scope and Opportunities of Research Approaches

The scope of the study is confined to identifying strategic investment plans of an innovative electric power project and thus suggests the framework for investment model in competitive landscape by evaluating the self-firm's performance. Especially, this thesis will help to provide background information of the energy sector for R&D investment in new energy generation project in Myanmar. In addition, the research models in this thesis can be applied to any project of huge capitalization under uncertainty and global competition with high level of risk.

1.7 Research Outline

Energy has been a key in the progress of human society not only in Myanmar but also all over the world. In order to meet the increase in domestic energy demand in the 21st century, efficient and effective management of energy resources and technology for producing it is inevitable and has become very crucial. And electricity consumption is comprising an increasing share of global energy demand at the present time and it will continue to be happened during next two decades. In recent years, the increasing prices of fossil fuels and concerns about the environmental impact of greenhouse gas emissions have renewed the interest in the development of alternative energy resources around the world. As the consequence, the focus has been on renewable energy sources and many countries have started to install facilities that use renewable energy sources for power generation. Among the renewable energy sources, the solar energy use in the world is increasing dramatically nowadays, providing both heat energy and generation of electricity. This trend is expected to continue due to solar technologies becoming cheaper and more readily available. I believe this research will help us in making decision how to commercialize the technology and how to manage the technology commercialization in the competitive global market to overcome the challenges of energy demand growth.

For my research, I am really interested in management of intangible information like technical proficiency, perception, concept, ideas, analytical and tracing abilities, knack, etc., in addition to objective information that is already built-in within a machine or machinery in the industry by dividing the technology into technical skill and technical knowledge. Technology commercialization, a technical process by which how to use an input and convert it into an output in an effective and efficient technique, is especially interested. I also have a plan to build and apply real options models for the investment in promising but high risky energy generation projects from the renewable energy source, especially solar, as technology innovation and research development in Myanmar. And then, it is intended to integrate them with game theoretical aspects for the strategy to be able to compete and cooperate with the global large energy companies. Finally, Bayesian games analysis under the incomplete information will be applied as the extension of option-games models for the perfect Bayesian equilibrium and to optimize the cluster growth of new energy industry among competitive players.

1.8 Structure of the Thesis

The thesis is organized into eight chapters as follows.

Chapter 1 is introduction. It provides the background of the research and describes problem statement of the study. Moreover, research questions and research objectives are also detailed in this chapter. Then, it lays down overall research methodology and, scope and opportunities of research approaches as well as outlines of research observation and the whole organization of the thesis in broad term.

In Chapter 2, the review of literature for ROA method, Option-Games models for competitive analysis and strategies and Bayesian Games for perfect competition among players are described. It covers the all the relevant literature about Myanmar and Myanmar Energy status as well as literature review for all research approaches and methods in very detail.

The content of the Chapter 3 is about industrial cluster formation for regional development in Myanmar. First it explains why the cluster formation is important for the regional development and also the benefits of cluster formation. Then, it gives the information about clustering of the organizations and development partners for Myanmar energy and electricity sector.

Chapter 4 demonstrates the application of Option-Games as methodology and the first model of it as the one-stage game. It is the introduction to the application of real options and game theory. Since then, it compares the difference between the games without managerial flexibility and with managerial flexibility. After that, it continues as the game of real options and its analysis are made.

In Chapter 5, the one-stage game from Chapter 4 is extended to two-stage strategic investment game as the second model of the research. It includes the endogenous competition of the players during the second stage and discusses the payoffs results under the various kinds of strategic competitiveness.

The modeling of the two-stage strategic investment under the different market structures by the option-games for optimizing between flexibility and commitment values is studied in Chapter 6. Although the model is two-stage game, it is more complicated than the previous model that is used in Chapter 5. In that model, it is explained about not only concept and the framework of the model, but also the types of competitive strategies and the actions of players are mentioned. Then, the valuations of the different cases based on the competitive strategies are made and the optimization between flexibility and commitment values are determined by sensitivity analyses.

Chapter 7 deals with Bayesian MCMC analysis and application of the Bayesian games. In the first part, searching for optimal switch and mix of energy sources for electric power generation is analyzed by Bayesian MCMC method. In addition, expected income analysis to invest in new energy project as well as search for the way of enduring and surviving of the industry during the period of negative profits has been presented. Then, the two-stage game is continued as the Bayesian game with perfect competition under the condition of incomplete information in the real state of the world. Finally, it finishes with Bayesian analysis to trace and estimate the relationship among the sensitive parameters of firm's sustainability and success.

Chapter 8 summarizes all research observations together with the findings from the studies and analyses as the conclusion of the thesis. It also guides to possible future research of the study.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Introduction

Urbanization is an enormous global issue at the moment. Agricultural land is being converted into urbanized areas at the same pace as the rapid growth of developing nations, including Myanmar. Energy is also a necessity for socioeconomic development to meet basic human needs and support industrial development. At the same time, the existing social infrastructures in most of the countries are ageing in such a way that they no longer meet the requirements of modern-day lifestyles. On the other hand, reducing the burden on the environment through such activities as cutting back on CO_2 emissions which is a global issue is an extremely important prerequisite at the current time. Together with these situations, the energy sector of Myanmar has been underdeveloped due to a lack of financial and technical capacity and global isolation. Furthermore, inadequate power supply has emerged as one of the most serious infrastructure constraints for the country's sustainable economic growth. Actually, the country has ample scope to rely on renewables in the electrification strategy. Until now however, renewable energy other than hydroelectricity projects has not been widely adopted in a significant way in Myanmar. To launch such new generation project, it has to invite technical and financial aids form private companies and international organizations.

In the uncertain and fiercely competitive high-tech industry, some of the most important decisions relate to investments in capital intensive equipment. The Energy industry for such kind of new electric power generation project is characterized by intense technological and market competitions. Companies must make huge capital investments with a corresponding high degree of risk because falling behind competitors means dropping out of the game. Rapid responses to competition and technology improvements are critical to success in this industry. This rush to get the latest-generation production facilities in high-tech energy industry is akin to an arms race, and therefore, capital investment for such kind of start-up company is critical to the continuously success of firms.

The responsibilities as developing investment decision, resource allocation, innovation and switching a new option require a broad view by making analytical investigations. At this point, by applying the Real Options Analysis for promoting this technology management process, ideas and human resources are developed; technology is rapidly advanced and as a final result, the productivity of energy will increase to a level. And for the sound proposal to new industry of business development as high-tech cluster, game theory is also necessary to analyze the win-win relationships even among competitors as a perspective of Pareto optimization. Furthermore, the application of Bayesian games with the perfect competition under asymmetric information will help to guide the players for making decision of optimal R&D investment in new project by the estimation of some important parameter values with Bayesian updating.

2.2 Country's Context

Myanmar is the largest country in mainland Southeast Asia with an area of 676,578 Km^2 (Worldometer, Myanmar Populaltion, 2020). As of 2019, the population is about 54 million with the population density of 83 per Km^2 (Worldometer, 2020). Currently, the population in urban area is 31% and the others live in rural area (Worldometer, 2020). The capital city is Naypyidaw, and the largest city is Yangon.

Myanmar is divided into seven states and seven regions. Regions are predominantly Bamar that is, mainly inhabited by the dominant ethnic group. States, in essence, are regions that are home to particular ethnic minorities. The administrative divisions are further subdivided into districts, which are further subdivided into townships, wards, and villages. According to the Myanmar Information Management Unit (MIMU), as of December 2015, there are 73 districts, 330 townships, 84 sub-townships, 413 towns, 3,133 wards, 13,620 village tracts and 63,698 villages in total.

Myanmar is bordered with in the northwest, north and northeast by Bangladesh, India and China. It is bounded by Laos and Thailand to the southeast. Myanmar has 1,930 km of contiguous coastline along the Bay of Bengal and Andaman Sea to the southwest and the south, which forms one quarter of its total perimeter (World Factbook, 2020). Three mountain ranges run north-to-south from Himalayas and divide Myanmar's three river systems, which are the Ayeyawaddy, the Thanlwin and the Sittaung rivers. Fertile plains exist in the valleys between the mountain chains. The majority of Burma's population lives in the Irrawaddy valley, which is situated between the Rakhine Yoema and the Shan Plateau.

The climate of the country is generally tropical, with a rainy season from mid-May to October due to the southwest monsoon, a cool and dry season from November to mid-February, and a hot pre-monsoon season from mid-February to the beginning or the middle of May (World Climate Guide, 2020). In addition, there are mountainous areas, with a mild or cool climate, but also a portion of the Himalayan range in the far north, which is very cold, at least at high altitude. Annual rainfall in coastal regions is over 5,000 mm and in the delta region is approximately 2,500mm; while average annual rainfall in the Dry Zone is less than 1,000mm. Northern regions of the country are the coolest, with average temperatures of 21 °C. Coastal and delta regions have an average maximum temperature of 32 °C (Thein, M., 2005).

Agriculture, industries, energy and tourism are the main sectors of the Myanmar’s economy. Agriculture, however, is the dominant sector and accounts for almost 60% of the GDP (Encyclopedia of the Nations, 2020). Agriculture, with rice as the major product, is a backbone of the economy by employing the majority of the country’s workforce. Industrial manufacturing is still developing and most of the foreign direct investments go to manufacturing industries. Myanmar, although classified as a less developed country, has a wealth in natural resources such as timber, hydropower, natural gas, precious gems, rare earth and minerals.

Myanmar has rich solar power and hydropower potential. Country's technical solar power potential is the highest among the nations of the Greater Mekong Sub-region (Myanmar Times, 2019). Wind energy, biogas and biomass have limited potential and weakly developed. The energy sector grew considerably during the late 1990s. The exploration and discovery of petroleum and natural gas deposits continued during this period. Myanmar produces precious stones such as rubies, sapphires, pearls, and jade. Rubies are the biggest earner; 90% of the world's rubies come from the country, whose red stones are prized for their purity and hue (uvvm.edu, 2015). Since 1992, the government has encouraged tourism in the country and the government receives a significant percentage of the income of private sector tourism services (Mon, H. K., 2020).

Table 2.1 General Configuration Data for Country Profile

General Facts & Figures	
Capital (Administrative)	Nay Pyi Taw
Largest City (Commercial)	Yangon (about 5 million people)
Population	About 54 million (Worldometer, 2019)
Ethnic Groups (world population prospects 2019 Revision)	Burmese (68%), Shan (10%), Kayin (7%), Rakhine (4%), Mon (2.6%), Chin (2%), Kachin (1.4%), others incl. Chinese & Indians (5%)
Official Language	Myanmar
Currency	Kyat (MMK)
Climate (Seasons)	Summer, Rainy and Winter
Total Land Area	676, 578 km^2
Population Density per km^2	83
Population Growth Rate (Annual)	0.9%
Forest Area	49% of the Country
Literacy Rate	92%
Standard Time	Six hours and thirty minutes ahead of Greenwich Mean Time
Neighboring Countries	China, Laos, Bangladesh, India and Thailand
Coastal Strip	1,930km facing to the bay of Bengal and Andaman Sea
GDP	USD71.4 billion (IMF) USD65.7 billion (UN)
GDP Per Capita	USD1,312.32 (2017)
GDP Growth Rate (Average)	7.28% (2010 to 2017)

Source: Industrial Energy Efficiency – Current Status of Oil and Gas Sector for Myanmar (July, 2019)

Nowadays, Myanmar is set to benefit from strengthening foreign direct investment inflows. According to the Myanmar Investment Commission, foreign direct investment inflows rose sharply with the bulk of investments channeled into transportation, communication, and manufacturing (Myanmar Times, 2020).

2.3 Overview of Myanmar Energy Status

Myanmar has been reconnected with the world economy since its major reforms in 2011. Gross domestic product growth increased from 5.6% in fiscal year (FY) 2011 to an average of over 8% from FY2013 to FY2015, reflecting strong expansion in construction, manufacturing, and services. Growth is expected to further accelerate to 8.3% in FY2015 and remain close to this pace in FY2016 (ADB, 2016). This optimistic projection is based on the country's abundant natural resources; strategic location at the crossroads of Asia; and a large, youthful population. To realize it, however, the country needs to successfully implement extensive reforms and integrated policies, build basic infrastructure, and tackle many bottlenecks. The development of energy sector is key to the country's future.

The energy sector accounted for 55% of export earnings and 86% of foreign direct investment in 2013 (ADB, 2016). However, the country's energy sector has been underdeveloped due to a lack of financial and technical capacity and global isolation in the past. Only 34% of the total population had access to electricity in 2014. In terms of per capita electricity consumption, Myanmar is ranked one of the lowest countries in the world, with 110 kilowatt-hours (kWh) per capita in 2011, which is much lower than the world average per capita of 3,000 kWh and even lower than a least developed country average per capita of 174 kWh. In terms of energy intensity, Myanmar was ranked 191 in 2011, making it one of the least energy consuming countries in the world. Traditional biomass (mainly firewood and agricultural wastes) is widely used by most rural people, particularly for cooking and lighting, and access to conventional energy resources is very limited, which impacts the welfare of these people. After the country's opening in 2011, the demand for energy from industry, commerce, and residential sectors is on the rise, placing pressure on the limited energy infrastructure.

Compared to the population and economy, the availability and accessibility of modern energy resources are significantly low and hence a bottleneck to improve the living standards and support industrial activities. To tackle such constraints, the government shifted its policy toward increasing domestic energy supply and improving policy frameworks to encourage greater investment in the energy sector. This opens the opportunities for extensive international assistance including public–private partnerships.

2.3.1 Primary Energy Data

The strong economic growth during the last 6 years was also accompanied by an increase in energy consumption in all sectors. Myanmar is endowed with abundant, rich natural resources that, if fully developed, would be sufficient to meet most of the country's daily energy needs. Myanmar's energy policy is generally aimed at ensuring energy independence by increasing national production of available primary energy resources through intensive exploration and development activities.

Coal: Coal data is maintained by the Ministry of Natural Resources and Environmental Conservation (MONREC) in Myanmar. In 2015-16, the production of coal is 419.87 kilotons (MOEE, 2017). Among coal production, 57.14% (239.92 kilotons) was used for cement, 17.14% (71.97 kilotons) for steel companies, 0.95% (3.99 kilotons) for briquette and 4.76% (19.99 kilotons) for electric power generation, and 15.24% (63.98 kilotons) for others. 4.76% (20 kilotons) of total production is accounted for export. Since 2010, all coal production has been made by the private sector and coal price is set by the market.

Crude Oil and Petroleum Products: Crude oil production consists of oil from the oil wells owned by Myanmar Oil and Gas Enterprise (MOGE) and some small wells. There is total production of 4,765.19 kilo barrels in 2015-16 (MOEE, 2017). Among them, 68% (3,255 kilo barrels) are domestic consumption and others are exported to neighboring countries. Myanmar, however, has to import 55,120 thousand barrels due to its insufficient production for its domestic consumption, especially for vehicles.

Natural Gas: Myanmar produces 696, 231 Million Cubic Feet (MMCF) of natural gas per year as of 2015-16 ranking 37th in the world (MOEE, 2017). Domestic gas consumption has percentage of only 17.12% (119, 206 MMCF) Myanmar exports 80.14% (557, 956 MMCF) of its natural gas production in 2015-16. The stock data has been inconsistent between the production and total usage due to its losses in distribution. Natural gas is a major export resource, which generated USD2.1 billion export revenue in the first half of FY2014 (world Bank, 2016).

Hydropower: Myanmar has abundant renewable energy resources such as hydro, solar, wind, biomass and other types of renewable energy. Among these resources, hydropower is the only renewable energy resource that is being exploited and utilized on a commercial scale for electricity generation, while other resources remain under research and development or pilot stage. Hydropower has the rich potential that drains the four main basins of the Ayeyarwady, Chindwin, Thanlwin, and Sittaung rivers. It is estimated that there is more than 100,000 Megawatts (MW) of installed capacity potential. Myanmar has identified 92 large hydropower potential projects with a total installed capacity of 46,000 MW, while the current installed capacity of hydropower plants is 3,033 MW as the commercial use.

Furthermore, A total of 26 micro-hydro and 9 mini-hydro projects have been implemented with installed capacity ranging from 24 kilowatts (kW) to 5,000 kW to reach remote border areas. The regional government is permitted to approve small-scale hydro plants up to 30 MW according to the new Electricity Law [2014]. Through this strategy, small scale hydropower plants of approximately 40 MW will be developed until 2030 (ADB, 2016).

Solar: Myanmar has a strong solar radiation level, especially in the central parts of the country and extensive dry zones, reaching more than 6.5 kilowatt-hours (kWh)/ square meter and collecting up to 1.9 megawatt-hours (MWh) annually on a square meter, and 60% of the land area appears suitable for photovoltaics (ADB, 2016). Due to its mountainous terrain and protected areas, Myanmar's maximum solar power potential is estimated at about 40 terawatt-hours per year. However, the development of solar energy is still in the beginning stages. Solar energy has been introduced in some rural areas in the last decade through photovoltaic cells for charging batteries and pumping water for irrigation. The MOEE is conducting a preliminary investigation to construct solar power plants with foreign direct investment in Minbu, Magway Region, Myingyan, and Mandalay Region. According to MOEE, there is also a plan to build two solar power plants in Myingyan and Wundwin in the Mandalay region and these are expected to have the capacity to generate 150MW of electricity each.

Solar power in Myanmar has an estimated levelized cost of electricity between USD0.16/kWh and USD0.19/kWh.

Wind: As for wind energy, an average wind speed required for modern wind turbines is at least 6 meters/second, most of Myanmar is considered unattractive as average wind speeds are below 4 meters/second, except for coastline and mountain ranges such as Shan and Chin states. The theoretical wind resource potential in Myanmar is shown as about 80 terawatt-hours per year but site‒specific wind data is limited to a few; therefore, an in-depth assessment is needed. ADB said that foreign investment proposals for a total of 4,032 MW have been received but none of them has yet to begin any activities (ADB, 2016).

In addition, there are small-scale experimental projects. As a very first project for wind power in Myanmar, MOEE signed an agreement with China's Three Gorges Corporation to develop a 30MW wind power project in Chaung Thar, Ayeyarwady Region (Lwin, K.W., 2019). Myanmar is an agriculturally based economy with plenty of land which provides huge potential for wind-powered projects.

Bioenergy: For biogas, the potential annual yield of wood fuel is up to 21.75 Million Cubic Meters (m^3 in million), and 18.56 million acres of land could generate residues, by-products, or direct feedstock for biomass energy. Agricultural by-products, such as sugarcane bagasse, rice straw, rice husks, sesame stalks, and palm leaves, offer limited sources of energy. In addition, there is approximately 103 million heads of livestock generating animal waste that could be used for biogas. Around 190 biogas digesters of varying capacities as 5, 15, and 25 kW have been installed all over the country for lighting and cooking purposes (ADB, 2016).

Biofuels: Five biofuel (biodiesel and bioethanol) plants have been constructed by various agencies between 2003 and 2010, with a total annual production of 19.5 million gallons (ADB, 2016). However, these five facilities are not currently in operation due to lack of support such as subsidies for production, presence of pest and diseases in Jatropha-type cultivation, as well as outstanding legal issues. Bioethanol is a convenient fuel acceptable in remote locations and could provide self-sufficiency supply on a community level. In 2009, the government issued a notification permitting the production, transport, storage, and sale of biofuel in Myanmar to encourage the use of biofuel in place of gasoline.

Geothermal, Tidal, and Waste Energy: For geothermal energy, there are a total of 93 potential locations for commercial geothermal-generated electricity throughout the country (ADB, 2016). Around 43 of these sites are being assessed and tested. For tidal energy, there are no studies to assess its potential in Myanmar despite a coastal line of 2,832 km. The first tidal power plant (3 kW) was installed in 2007 in Kanbalar village, providing electricity to about 220 households, approximately 1,200 persons (ADB, 2016). A similar project was being implemented at a salt production site. For waste-to-energy, there is a significant opportunity to develop waste-to-energy projects in urban areas as there is a potential for at least 20 MW of waste-to-energy installed capacity (ADB, 2016).

Table 2.2 summarizes the potential energy resources of Myanmar as of 2017. Then, the identified and installed energy resources are shown in Table 2.3 and sectoral energy production by yearly can be checked in Table 2.4 respectively.

Table 2.2 Potential Resources of Myanmar Energy

Resource		Reserve
Hydropower		>100 GW (Estimate)
Wind		365 TWh/year
Solar		52,000 TWh/year
Coal		540 million tons (Estimate)
Crude Oil	Onshore	102 MMbbl (Proven)
	Offshore	43 MMbbl (Proven)
Natural Gas	Onshore	5.6 TCF (Proven)
	Offshore	11 TCF (Proven)
Biomass (Biogas, Rick Husk, Forest Residue, Biofuel etc.)		9242 KTOE (62%)

Source: Energy Planning Department, MOEE , 2018

Table 2.3 Identified and Installed Energy Resources in Myanmar as of 2016

Description	Hydropower	Coal-fired	Gas-fired
Number of Installed Plants	62	1	20
Installed Capacity in MW	3,033	120	1,823
Number of Proposed Plants	51	10	1
Proposed Capacity in MW	46, 000	7, 994	270
Number of Ongoing Plants	7 (out of planned 51)	1	2
Capacity of Ongoing Plants in MW	1,656	405	625

Source: ADB, Myanmar Energy Assessment, Strategy and Road Map, 2016

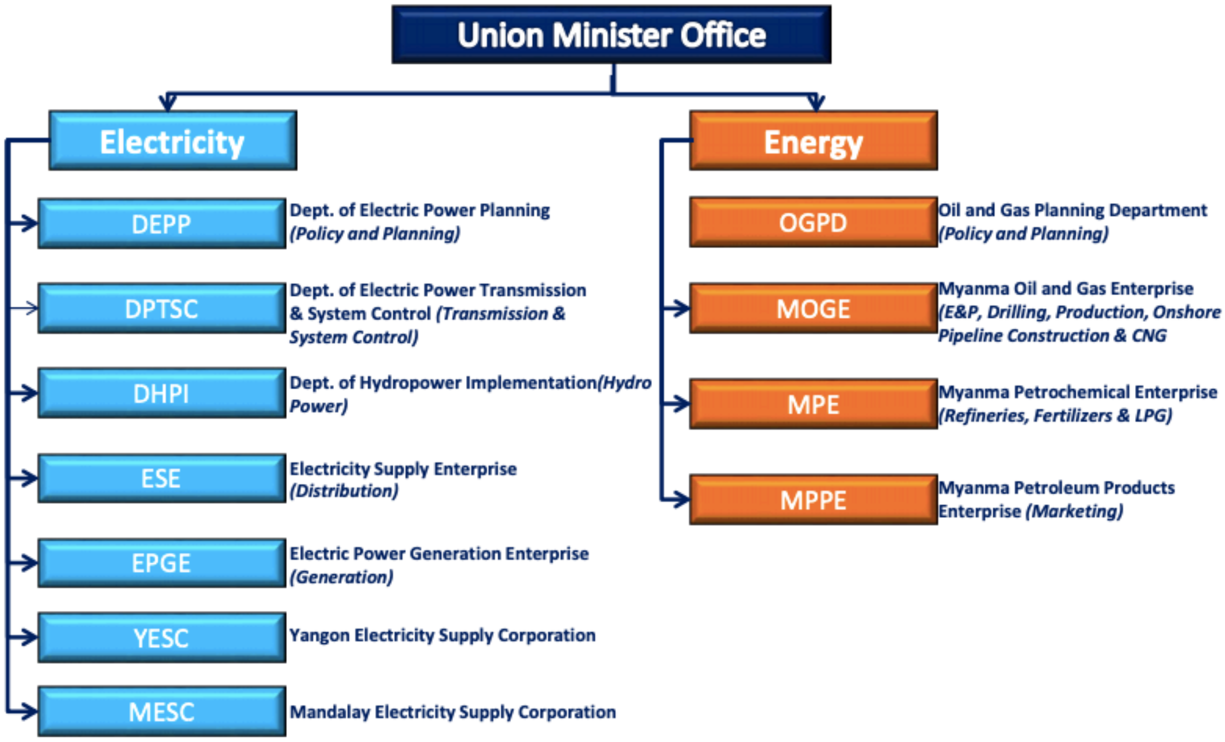
Table 2.4 Yearly Renewable Energy Production by Sector

Year	Fuelwood	Charcoal	Biomass	Biogas	Wood-waste (Gasifier)	Photovoltaic (Electricity)	Wind Turbine	Micro-Hydro
	Cubic Ton	Cubic Ton	1000t	10^{10}KCal	1000t	GWh	GWh	GWh
2011-12	224.659	200.959	22040	0.5216	0.558	4.32	0.0016	0.002
2012-13	227.471	217.001	22302	0.5479	0.558	4.32	0.0016	0.002
2013-14	263.379	228.584	21410	0.5216	0.558	4.32	0.0016	0.002
2014-15	276.052	231.168	23043	0.5200	0.558	13.91	0.0016	5.753
2015-16	289.056	233.73	20622	0.5200	0.558	10.94	0.0016	1.253

Source: Ministry of Electricity and Energy (MOEE), Republic of the Union of Myanmar

2.3.2 Organizational Structure and Institutional Framework of Energy Sector

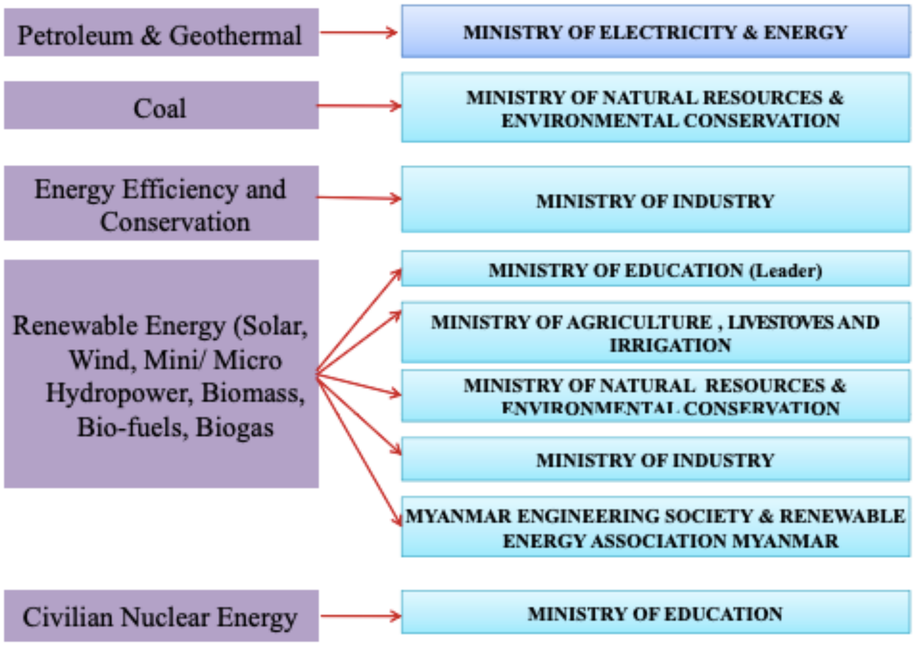
In April 2016, the organization of the Myanmar government was restructured and the number of ministries was reduced from 36 to 21. In the new organization, Ministry of Electric Power and Ministry of Energy were merged into the new Ministry of Electricity and Energy (MOEE), which is responsible for oil, gas and electricity operations. The current organizational chart of MOEE and the respective responsibilities are shown in Figure 2.1.



Source: Ministry of Electricity and Energy (MOEE), 2016

Figure 2.1 Organizational Structure of MOEE

Other ministries related to the energy sector include (i) Ministry of Agriculture, Livestock, and Irrigation with responsibility for off-grid rural electrification, (ii) Ministry of Natural Resources and Environmental Conservation with responsibility for coal mining, and (iii) Ministry of Industry with responsibility for energy efficiency. Ministry of Education is taking responsibility not only for the research and development of the civilian nuclear energy but also for renewable energies with other related government ministries and private organizations as seen in Figure 2.2 below.



Source: Ministry of Electricity and Energy

Figure 2.2 Institutional Framework of Myanmar Energy Sector

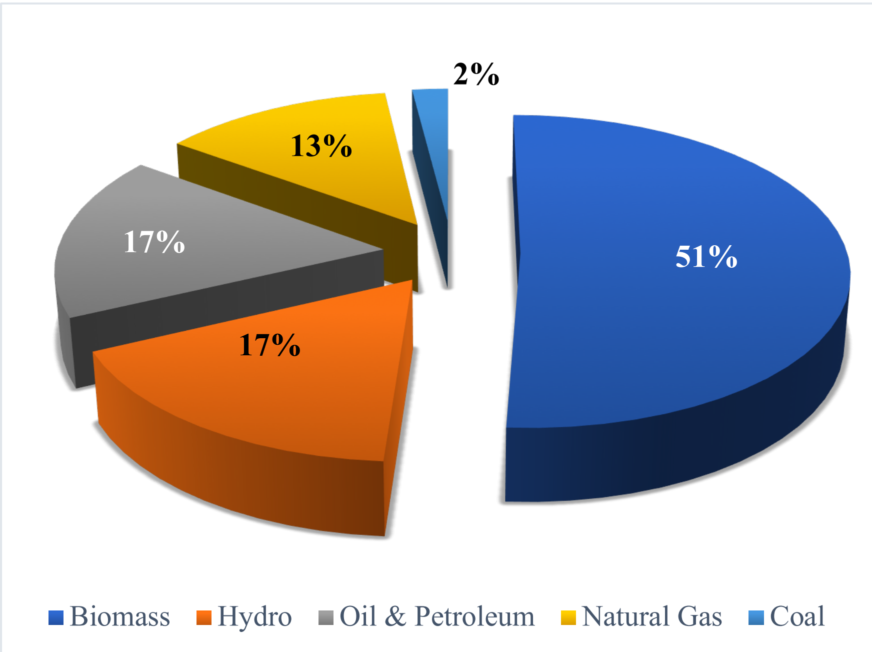
2.3.3 Total Energy Supply and Consumption

Although Myanmar is sitting on huge energy resources, current national electrification ratio for households is less than half of the total households. In 2019, electrified households are only 43% all over the country, thus 57% has not yet accessed to electricity (Zaw, H., 2019). 69.81% of total population had a connection to electricity power in 2019 (Energypedia, 2020). Although access to electricity ratio of the population is 89.48% in urban area, only 39.79% of rural households can use electricity as of 2016 (Trading Economics, 2020). It reveals that disparities of electricity access between urban and rural areas are seriously striking.

According to World Bank, Myanmar has one of the lowest rates of electrification in Southeast Asia, and its electricity consumption per capita is among the lowest in the world - twenty times less than the world average. The per capita electricity consumption is 333kWh in 2017-18, it became increased from the per capita electricity consumption of 150-160kWh in 2016 (Zaw, H., 2019). The total electricity consumption in 2017-18 is 17036.6 million kWh.

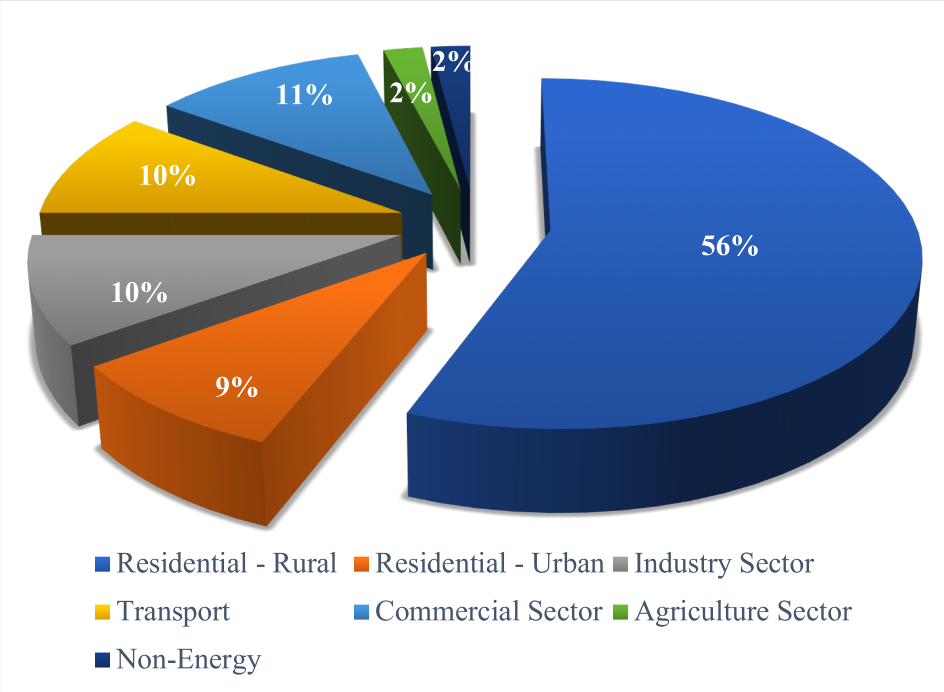
Rural areas remain mostly unelectrified, with only 16% of rural households with access to grid-based electricity (World Bank, 2016). Also, access to modem fuels for cooking, such as Liquefied Petroleum Gas (LPG), is limited to urban areas where only one third of population lives. Consequently, traditional biomass, fuelwood and animal dung, is widely utilized and accounts for about two-thirds of Myanmar's primary energy consumption. The country's primary energy supply mix consists of coal, oil, gas, hydro and biomass.

The major energy sources for the total primary energy supply in Myanmar are coal, oil and petroleum products, gas, hydro, and biomass. Most of the total energy supply came from biomass, with about 10 Million Tons of Oil Equivalent (MTOE) in 2012–2013 (Tun, M. M. and Juchelkova, D. 2019). In 2014-15, the traditional biomass (51%) has the largest share in primary energy supply, followed by hydro and oil & petroleum (17%) each, natural gas (13%) and coal (2%) as seen in Figure 2.3. According to this, it can be known that biomass and traditional fuel woods are main energy sources for residential energy consumption. Meanwhile, the total final energy consumption in Myanmar had a gradual increase by around 2% annually during 2000–2013. The final energy consumption by sector in 2014-15 can be seen in Figure 2.4.



Source: Current status of oil and gas sector, MOEE, Myanmar

Figure 2.3 Primary Energy Supply in 2014-15



Source: Myanmar Energy Master Plan, ADB, 2015

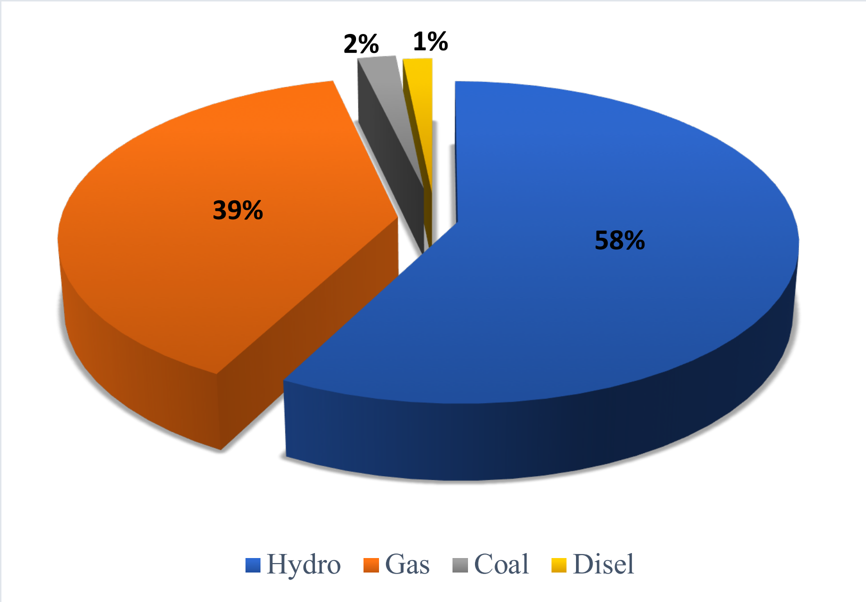
Figure 2.4 Final Energy Consumption by Sector (KTOE) in 2014-15

2.3.4 Power Sector, Electricity Network and Grid System of Myanmar

The local energy demand is increasing nowadays. The ongoing enhancement and expansion of Myanmar's energy (electricity) industry is thus an important part of enabling economic growth to occur. Increase in electricity production capacity is urgently needed for Myanmar in order to accommodate rising power demands from foreign and local commercial projects and, to meet ambitious economic development targets of the country.

Electricity Consumption: Total electricity consumption was 11,252 gigawatt-hours in 2015, of which Yangon accounted for 44%. Electricity consumption has grown by 9.8% per year during 2000–2012. The peak load reached 2,500 MW in February 2016 (ADB, 2016).

Electricity Generation and Supply: The total installed capacity at mid-2016 is 4,764 MW, with 2,820 MW (59.2%) from hydropower, 1,824 MW (38.3%) from gas, and 120 MW (2.5%) from coal. The MOEE owns about 75% of total installed capacity and the rest owned by private sector (ADB, 2016). The available capacity is approximately 50% of the installed capacity. Energy mix in the commercial electricity supply in 2019 can be seen in Figure 2.5.



Source: Current Status of Myanmar's Electricity Sector, MOEE

Figure 2.5 Existing Power Supply of Commercial Electricity as of 2019

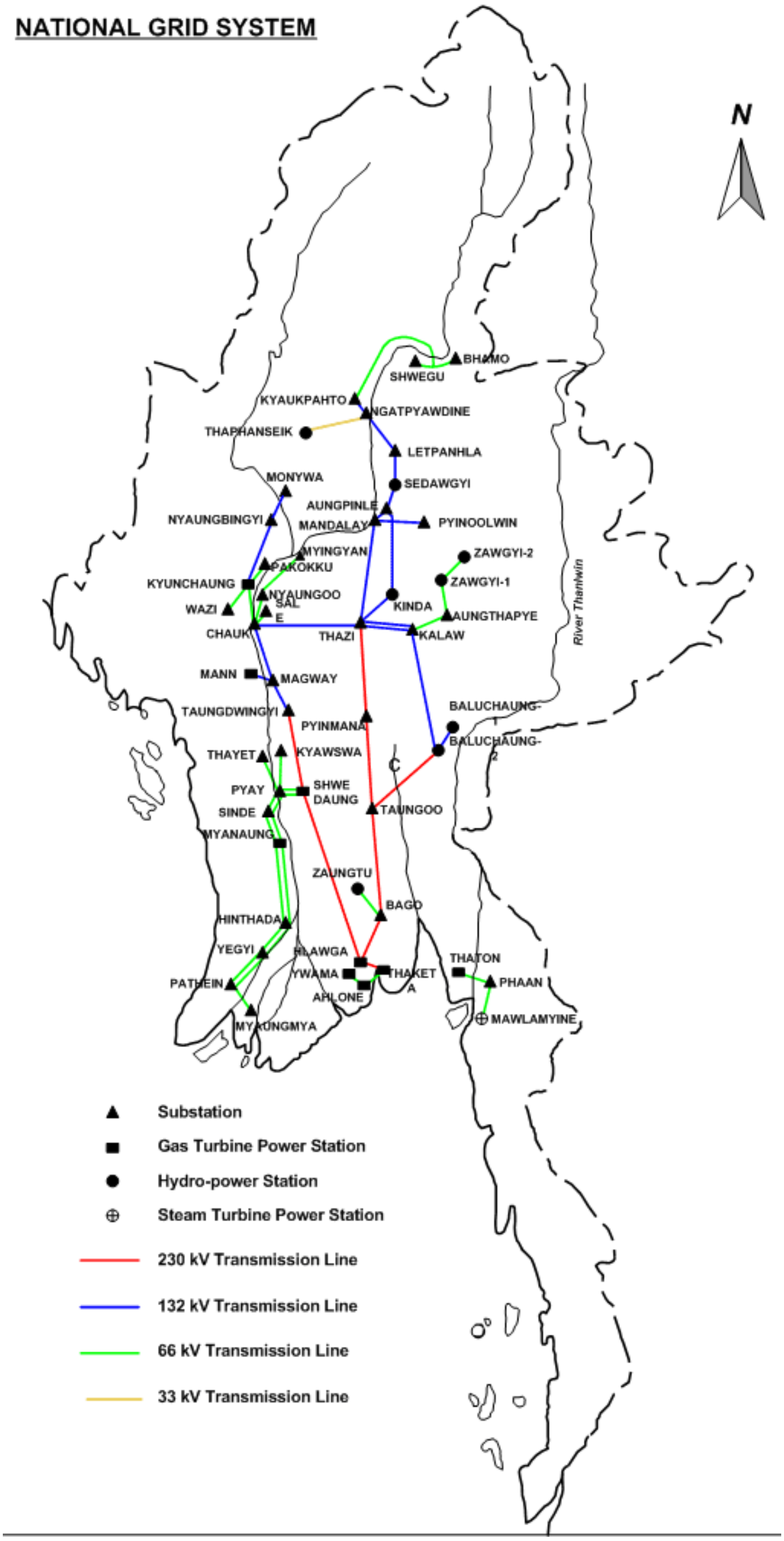
Transmission and Distribution: The country's transmission system comprises a network of 230-kilovolt (kV), 132-kV, and 66-kV transmission lines and substations. Most of these lines lead from the northern part of the country, where most hydropower plants are, to the southern load centers, particularly the Yangon area. A 454-km long 500-kV transmission line is under implementation from north to south through bilateral assistance (ADB, 2016). The first section of 146 km from Meiktila (in Mandalay) to Taungoo (Phase I), which is financed by the Government of Serbia, is almost complete. The middle section of 188 km from Taungoo to Karmarnat (near Bago) (Phase II) was confirmed for financing by the Government of the Republic of Korea (USD100 million) in 2014. The Government of Japan will finance the last section of 120 km from Karmarnat (near Bago) to Hlaingtharyar in Yangon (Phase III). The current transmission lines are mostly single circuit, with relatively few double-circuit connections. Structure designs are mostly lattice steel towers, with a variety of portal and conventional freestanding towers, some with overhead lightning protection earth wires. Lines are generally in good condition.

The distribution system comprises a network of 33-kV, 11-kV and 6.6-kV lines and substations. Technical and nontechnical losses of the combined transmission and distribution system were as high as 30% in 2003 and fell to 20% in 2013. To improve efficiency, it is planned to phase out the 6.6-kV systems in favor of an 11-kV network, and to expand the 33-kV systems.

Electricity Network and National Grid System: The available capacity of the gas power plants is low because of maintenance and lack of compression of the gas pipeline. During the dry season, the hydropower plants cannot generate the full capacity due to lack of water. Hence, Myanmar's power grid is experiencing significant load shedding during the dry season.

Myanmar has a unified interconnected transmission and distribution network covering some parts of the country. Figure 2.6 shows the national grid system (Global Energy Network Institute, 2020). Some off-grid distribution systems are also used in some remote regions from national grid system. Transmission network is under the responsibility of the Myanmar Electric Power Enterprise (MEPE). As power is transmitted over long distances, the transmission system of 220 kV suffers from high voltage drop, in some case exceeding 10%. The system has to lose the power between the power station and the customer due to aging or unsatisfactory equipment. Although the installed capacity has increased significantly nowadays, shortage of electricity, unstable voltage, and frequent blackouts are still a common occurrence, indicating that demand by far still outstripped supply.

Under the national target of universal access by 2030, the government approved the National Electrification Plan (NEP) in September 2014, which proposes an aggressive grid electrification rollout program and an ambitious off-grid program. For this, the state and regional governments are permitted to approve small-scale hydropower plants up to 30 MW according to the new Electricity Law of 2014. An expansion plan of the national grid should be coordinated with the NEP on Rural Electrification supported by World Bank.



Source: Map of Myanmar Electricity Grid, Global Energy Network Institute

Figure 2.6 The National Grid System in 2019

2.3.5 Core Issues and Causes and Effect of the Electricity Sector

Core sector-wide issues are summarized as follows.

(i) uncertainty over sector planning and introduction of new policy frameworks impeding private sector investment and mobilization of finance;

(ii) outmoded sector structure with state-owned enterprises being under the direct control of the MOEE and with the transmission function being a department within the MOEE while the MOEE has conflicting responsibilities for investment, policy, regulation, and commercial performance;

(iii) outdated or absent legal rules and regulations and

(iv) concerns about sector sustainability with below-cost tariffs

(v) and cross-subsidization, and weak capacity of government and institutions.

Then, the main issues and constraints of the oil and gas sub-sector and, power sub-sector (i) persistent power supply shortage; (ii) high technical and non-technical losses due to poor maintenance of existing power transmission and distribution systems, and gas pipeline networks; (iii) lack of technical capacity of staff; (iv) lack of planning function, e.g., there are no long-term supply and demand projections and no analysis of alternative supply options; (v) government controlled-pricing policy; (vi) absence of energy efficiency and climate change-related policies; (vii) absence of legal safeguard requirements; and (viii) the needs to consolidate responsibilities within the energy sector, with respective ministries being responsible for energy matters and limited overall planning.

Although progress is being made on all these issues, ongoing and expedited progress is needed to ensure the required scale of investments is met and sector performance is improved such that government targets are met of an efficient and sustainable sector providing energy to the entire population**.**

2.3.6 Electricity Tariffs and Myanmar Energy Reform

Electricity rates in Myanmar have been the lowest in the ASEAN region. The average price of electricity is USD0.044 per kWh for households and USD0.119 for businesses which includes all components of the electricity bill such as the cost of power, distribution and taxes. For comparison, the average price of electricity in the world for that period is USD0.14 per kWh for households and USD0.12 for businesses (Global Petrol Prices, 2020).

The state subsidy on power supply is a key obstacle to attract investors to scale up the much-needed power generation. The government has been distributing electricity to the public at a loss of MMK507 billion (USD333 million) in 2017-18 fiscal year (French Myanmar Chamber of Commerce and Industry, 2019). That amount has climbed to MMK630 billion (USD414 million) in 2018-2019, according to data from the Ministry of Planning and Finance. Blackouts in Yangon have also severely affected manufacturers and businesses.

The government increased electricity rates for both residential and business users starting from July, 2019. This is the first change in power tariffs since 2014. Under the new rates, residential households and religious buildings have to pay at the previous rate at MMK35 (USD0.023), but only for up to 30 units. But beyond this level of consumption different rates are applied, depending on the number of units used. Similarly, a new rate regime is specified for non-domestic consumers.

For business consumers including companies, factories, government buildings, embassies, and international organizations, they have to pay MMK125 per unit up to 500 units, increasing by MMK10 until 50,001-100,000 units. MMK180 per unit are charged for over 100,000 units. The government losses are expected to be reduced with the new incoming tariff structure.

The previous per-unit prices of electricity for households are MMK35 from 1 unit to 100 units, MMK40 from 101 to 200 units, MMK50 above 201 units and street lights. For businesses the charges are MMK75 from 1 unit to 500 units, MMK100 from 501 units to 10,000 units, MMK125 from 10,001 units to 50,000 units, MMK150 from 50,001 units to 200,000 units, MMK125 from 200,001 units to 300,000 units and MMK100 from 300,001 units and above. The electricity tariffs in 2014 and 2019 are compared in Table 2.5.

According to the new rates, domestic consumers who used to pay MMK3,500 for 100 units (USD2.3) now have to shell out MMK6,050 (USD3.97), not including the service fee. This represents a 72.9% increase, based on previous rates. Currently, the government incurs costs of MMK89 per unit to generate and distribute electricity from hydropower, and MMK178 per unit for electricity from natural gas, according to the MOEE.

Table 2.5 Comparison of Current and Previous Rates of Electricity Prices

No.	Types of Electricity Consumers	Current		Previous	
		Rate for Consumption		Rate for Consumption	
		Unit	Kyat	Unit	Kyat
1	**Domestic**	1 - 30	35	1 - 100	35
	Domestic Consumption	31 - 50	50	101 - 200	40
	Power Meter at Home	51 - 75	70	201 and above	50
	Religious Building	76 - 100	90		
		101 - 150	110		
		151 - 200	120		
		Over 200	125		
2	**Non- Domestic Consumption**	1 - 500	125	1 - 500	75
	Industries	501 - 5,000	135	501 - 10,000	100
	Businesses	5,001 - 10,000	145	10,001 - 50,000	125
	Temporary	10,001 - 20,000	155	50,001 - 200,000	150
	Lamp Posts	20,001- 50,000	165	200,001 - 300,000	125
	Governmental Buildings	50,001 - 100,000	175	300,001 and above	100
	State-owned Businesses	Over 100,001	180		
	River Pumping Stations				
	Municipal Departments, Works				
	Non-Governmental Organizations				
	Embassies				
	International Organizations				

Source: Global New Light of Myanmar and Myanmar Times – Business

Exchange rate is 1MMK (Myanmar Kyat) = 0.0007USD (April, 2020)

The new tariff structure will reduce the electricity subsidy and will stimulate the off-grid sector, which has been hamstrung by the low price of grid electricity. Projects related to solar panels are expected to become more commercially viable as a result. The country is in such situation that rolling blackouts throughout the summer with power delivery lag behind rising demand. To cater to the increasing demand, investment in the power sector is needed.

With the revised rates now coming into effect, more electricity projects will become financially sustainable and developers will be more competitive. With greater investment in the nation's energy infrastructure potentially in the pipeline, the expectation is that Myanmar will begin to bridge its electricity gap.

2.4 Net Present Value (NPV)

2.4.1 Definition of NPV

For the simply definition, Net Present Value (NPV) can be defined the difference between the present value of cash inflows and the present value of cash outflows over a period of time (Kenton, W., 2019). In more detail, NPV is the total sum value of all future cash flows, positive and also negative, over the entire life of an investment discounted to the present (Cooperate Finance Institute, 2018). In other words, the standard NPV analysis of capital budgeting values a project by discounting its expected cash flows at a risk-adjusted discount rate (Benninga, S., 2000). The cash flows in net present value analysis are discounted for two main reasons: to adjust for the risk of an investment opportunity and to account for the time value of money (TVM).

NPV can be calculated as follows:

$$NPV = -I + \sum_{t=1}^{N} \frac{E(FCF_t)}{(1+k)^t} \quad (2-1)$$

where, $E\ (FCF)$ = expected free cash inflow

k = risk-adjusted rate

t = time point

I = Investment

2.4.2 Scope and Usefulness of NPV

NPV analysis is a form of intrinsic valuation and is used extensively across finance and accounting for determining the value of a business, investment security, capital project, new venture, cost reduction program, and anything that involves cash flow. This technique was the most widely used technique for evaluating capital projects in acquisitions of companies or purchases of machines over the two decades between 1959 and 1978. (Benninga, S., 2000; Copeland, T. & Antikarov, V., 2003).

NPV analysis is used to help determine how much an investment, project, or any series of cash flows is worth. It is an all-encompassing metric, as it takes into account all revenues, expenses, and capital costs associated with an investment in its Free Cash Flow (FCF). In addition to factoring all revenues and costs, it also takes into account the timing of each cash flow that can result in a large impact on the present value of an investment. In other words, it is better to see cash inflows sooner and cash outflows later, compared to the opposite.

Thus, it is useful for managers to make the decision making since NPV is an indicator of how much value an investment or project adds to the firm. According to the NPV rule, an investment should be accepted if the NPV is positive and rejected if it is negative. How to make the decision in regard with NPV rule on the project is described in Table 2.6.

Table 2.6 Criteria of Decision Making on NPV Analysis

If…	It means…	Then…
NPV > 0	The investment would add value to the firm	The project may be accepted
NPV < 0	The investment would subtract value from the firm	The project may be rejected
NPV = 0	The investment would neither gain nor lose value for the firm	The managers should be indifferent in the decision whether to accept or reject the project. This project adds no monetary value. Decision should be based on other criteria, e.g., strategic positioning or other factors not explicitly included in the calculation.

2.4.3 Weakness of NPV

Managerial operating flexibility and strategic adaptability typically are ignored or underestimated by conventional Net Present Value (NPV) (Dixit A. K. and Pindyck, R. S., 1994). Furthermore, the NPV method assumes that the company has to accept all the possible outcomes of a project as a whole once the investment has been decided. Part of the complexity of the capital budgeting processes is that decisions can be changed dynamically, depending on the circumstances (Benninga, S., 2000).

It can be seen in the above NPV formula that the uncertainty of the cash flows is not explicitly modeled in the approach, merely discounts expected cash flows (Copeland, T. & Antikarov, V., 2003). In reality, there are many paths of possible free cash flows that might be realized between of the project and its finish. It happens because the NPV approach is constrained to pre-committing today to a go- or no-go decision and it uses only information that is available today. This rule is equivalent in mathematically:

$$NPV\ rule:\ MAX\ (at\ t = 0)\ [0, E_0\ V_T - X] \qquad (2-2)$$

where, E_0 is the expected value at time = 0, V_T is the value of underlying asset at $t = T$, T is the maturity date of the option and X is investment expenses. Thus, it is to compare all possible mutually exclusive routes to determine their value, $E_0\ (V_T - X)$ and then, choose the positive best among them.

Therefore, the traditional NPV rule is a static concept that fails to capture the need for managerial flexibility, which is especially important when investments are irreversible and involve a great deal of uncertainty. Moreover, the competition that characterizes the High-tech Energy industry with huge capital investment requires a more comprehensive analysis of players' market strategies. But it is the foundation of Real Options Analysis (ROA).

2.5 Real Options Theory

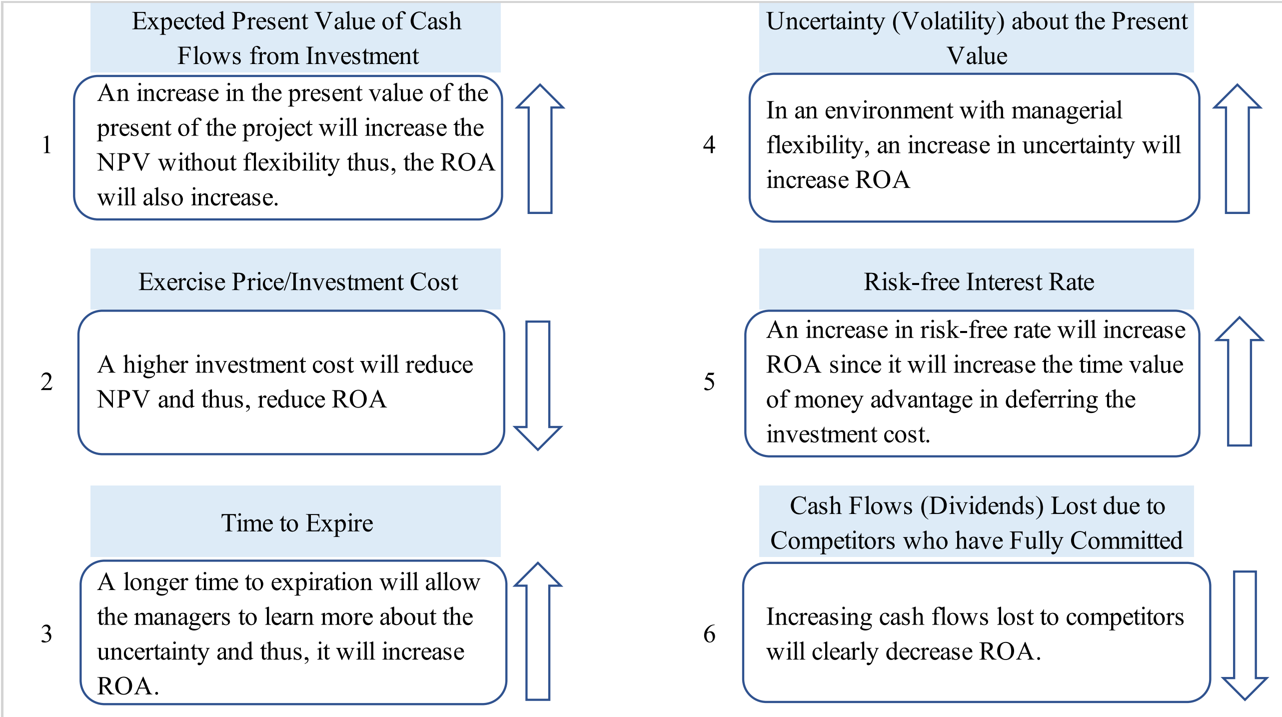
2.5.1 Definition and Theory of Real Options

A real option is the right, but not the obligation, to take an action for the project scaling, timing and/or terminating at the predetermined cost called the exercise price, for a predetermined period of time – the life of the option (Copeland, T. & Antikarov, V., 2003).

ROA is an approach to evaluate investment opportunities to acquire real assets that are called as real options (Dixit, A. K. and Pindyck, R. S., 1994). ROA is the most acceptable dynamic solution for investment, which is derived from a conceptual extension of financial option theory (Black, F. & Scholes, M., 1973, Merton, 1973 and; Dixit, A. K. and Pindyck, R. S., 1994).

Today, at least in academia, real options theory has been widely accepted as an innovative tool for capital planning and asset valuation. Fundamentally, options theory (OT) offers a new and more realistic means of evaluating strategic opportunities and risks by hedging the downside risks and utilizing the upside chances that traditional valuation methods, such as the NPV approach, do not consider. Moreover, in real options theory, the investor may wait for some time until additional favorable information validates the investment commitment; while the NPV method views any investment as a "now-or-never" opportunity (Trigeorgis, L., 2000). To date, most studies of the technology management field have applied real options methods to consider the investment decisions of monopolists, i.e., single player options, and have not considered the interaction between two firms.

The value of the real options depends on six variables and these six are illustrated in Figure 2.7.



Source: Copeland, T., T. Koller, and J. Murrin, 2000

Figure 2.7 Six Driving Variables for valuing ROA

2.5.2 Two Kinds of Real Options: Call and Put

A description for two kinds of real options can be seen here. Copeland and Antikarov states that a call option is the right to buy the underlying asset by paying the exercise price (Copeland, T. & Antikarov, V., 2003). At the time of exercise, the profit on the option is the difference between the value of the underlying asset and the exercise price.

But a put option is said as the opposite of the call option, thus it is the right to sell the underlying asset to receive the exercise price. Usually, one who has options is called as holder instead of either buyer or seller. And one who receive obligation when option is exercised is acceptor.

Options that can be exercised only on their maturity date are called European options and exercise frequency is only one time. On the other hand, American Options are those that can be exercised at any time during the life of options and can be exercised at only time. The exercise price is the price that seller and holder have agreed to be exercised on the option. Next, the exercise date is the date on which the seller and buyer have agreed to be exercised on the option. Summary information of the call and put options are shown in Table 2.7.

Table 2.7 Summary Information of the Call Options and Put Options

Options	Kinds of Options	Exercise Timing	Holder	Acceptor	Exercise Frequency
Call Option	European	Only on maturity date	Right to BUY asset	Obligation to SELL asset if the option is exercised	Just one time
	American	On or before the maturity			
Put Option	European	Only on maturity date	Right to SELL asset	Obligation to BUY asset if the option is exercised	
	American	On or before the maturity			

Source: Author

2.5.3 Common Types of Real Options

Real options are classified primarily by the type of flexibility that they offer. The brief description of basic options, their effectiveness and option type are illustrated in Table 2.8.

2.5.4 Real Options Analysis (ROA) Rule and Formula

ROA takes the different perspective from NPV rule. Mathematically, ROA for call option is an expectation of maximums, not a maximum of expectations (Copeland, T. & Antikarov, V., 2003):

$$\textit{ROA rule for call option: } E_0 \ MAX\ (at\ t{=}\ T)\ [0,\ V_T - X] \qquad (2-3)$$

From a call option aspect, a project is undertaken, at a future time, if and only if $V_T > X$. Conversely, ROA for put option is an expectation of maximum, not a maximum of expectations, if and only if $V_T < X$:

$$\textit{ROA rule for put option: } E_0 \ MAX\ (at\ t{=}\ T)\ [0,\ X - V_T] \qquad (2-4)$$

Table 2.8 Basic Options, Effectiveness and Option Type

Options	Effectiveness	Kind of Option
The option to abandon (Abandonment option)	Dispose or terminate of an unprofitable project	American Put
The option to shrink (option to contract)	Reduce the size or capacity by selling a fraction of the project depending on market conditions	American Put
The option to wait (Deferral option)	Wait until further information reduces uncertainties.	American Call
The option to scale up (Expanding option)	Expand the project capacity or scaling up the project operations depending on the market situations	American Call
The option to switch (Switching options)	Allows the owners to switch at a fixed cost between two modes of operation: switch on/open or switch off/shut down the project.	American Call and Put
Growth option (Learning option)	Create and acquire the related future opportunities of the project.	American Call
Compound options including rainbow and compound rainbow options	Option on another option to take the project to next level of the project phases based on multiple sources of uncertainties.	American Call

Source: Copeland, T. & Antikarov, V., 2003

For the real options method, the binomial model is formulated as follows:

$$C_0 = \frac{[pC_u + (1-p)C_d]}{1+r_f} \qquad (2-5)$$

where, C_0 = current option value

p = risk-neutral probabilities

C_u = call value in up state

C_d = call value in down state

r_f = risk-free interest rate

Risk-neutral probabilities can be calculated as:

$$p = \frac{(1 + r_f) - d}{u - d} \qquad (2-6)$$

where, u = up movement

d = down movement

Strategic initiatives can no longer be looked at as stand-alone investments, but rather as links in a chain of interrelated, staged investment decisions. Moreover, if a firm's investment decisions are contingent upon and sensitive to competitor's moves, a more involved game-theoretic treatment might be necessary. Appropriate competitive strategies can still be analyzed using an integration of game theory with real options analysis.

2.6 Game Theory

2.6.1 Definition of Game Theory and Its Usefulness

Game theory is a tool used to analyze strategic behavior by taking into account how participants expect others to behave. Game theory is used to find the optimal outcome from a set of choices by analyzing the costs and benefits to each independent party as they compete with each other. Game theory is a bag of analytical tools designed to understand the phenomena that we observe when decision-makers interact (Osborne, M. J. and Rubinstein, A., 1994). The basic assumptions that underlie the theory are that decision-makers pursue well-defined exogenous objectives that are rational and take into account their knowledge or expectations of another decision-makers' behavior that are reasonably strategic.

Game theory was developed extensively in the 1950s by many scholars. It was explicitly applied to biology in the 1970s. Game theory has been widely recognized as an important tool in many fields.

Real-world investments are characterized by strategic competition between rival firms, where each firm assesses its own strategic competitiveness. Several studies have investigated how a firm's investment decisions are affected by the behavior of rival firms because an investment option can usually be shared by several firms in the same industry (Wu, Li, Ong and Pan, 2012). Therefore, the analysis of strategic investment decisions under the joint real options and game theoretic framework has been the subject of intense study in recent years. It is important to use the analytical capabilities provided by game theory to support real options theory in researching the decision-making of technology investment.

Thus, Game Theory is an important management decision tool for studying strategies involving multiple players whose decisions are designed to maximize their own payoff or utility. In game theory, decisions made by each player impact the other players' utility gains. Therefore, game theory models can yield further insights into the investment process. The merging of real options theory and game theory has raised the awareness of researchers. Table 2.9 compares the NPV, options and the game approach.

Table 2.9 Comparison among NPV, Option & Game

	NPV	**Option**	**Game**
Uncertainty type	Trivial	High	Interactive uncertainty
Minimal players	1	1	≥2
Strength	Intuitional	Consider uncertainty	Dynamic representation of uncertainty
Weakness	Fail to consider uncertainty	Complexity	Complexity

Source: Nyein. N. A., 2013

To sum up, the options method incorporates uncertainty when future volatility is contextually important. When the number of market players is more than 1, the interplay must be represented by the game approach, in which the payoff matrices are calculated by the options approach. The final monetary form of the payoff metric is represented by a discounted risk-adjusted NPV form. In most parts of this research, the hybrid model named option-games, the integration between real options and game theory, will be utilized.

2.6.2 Strategic Form Games with Managerial Flexibility

A strategic form game is a model of interactive decision-making in which each decision-maker chooses his plan of action once and for all, and these choices are made simultaneously (Osborne, M. J., 2002). The simplest form of strategic interdependence prevails in contexts in which the actions are either taken simultaneously or without the knowledge of action choices of the other players. The model consists of a finite set N of players and, for each player i, a set A_i of actions and a payoff function on the set of action profiles. The high level of abstraction of this model allows it to be applied to a wide variety of situations.

A strategic game consists of:

1) a set of players (N)
2) A set of actions (A_i) for each player $i \in N$
3) A payoff function ($u_i: A \rightarrow R$) for each player $i \in N$

The Figure 2.8 represents a strategic form game of two plyers in which each payer has two actions.

		Player A	
		Left	Right
Player B	Top	(w_1, w_2)	(x_1, x_2)
	Bottom	(y_1, y_2)	(z_1, z_2)

Figure 2.8 A Representation of Strategic Form Game

Game theory can help determine what a competitor's reaction might be and what kinds of actions might trigger positive or negative competitive responses (Smit, Han T. J. & Trigeorgis, L., 2004). Thus, it studies interactive decision-making, where the outcome for each participant or player depends on the actions of all.

2.6.3 Four Dimensions of the Game

Game theory is concerned with the strategic impact of investment decision where firms are aware that their strategy affects the value of the investment opportunities of the other firms. It is also a helpful valuation tool for strategic decisions because it encompasses a solution concept that can help in understanding or predicting how competitors will behave, and it also provides equilibrium strategy and values for strategic decisions. The basic dimensions and rules for structuring and solving the games are described below.

A simple analytical structure of the game consists of four dimensions. These four dimensions are: (i) identification of the players, (ii) the timing or order in which the players make their decisions, (iii) the available actions and information set, and (iv) the payoff structure attached to each possible outcome. To apply the game theory in strategic decision making, management needs to know the timing available and the possible action to each rival, e.g., invest in the new technology or not, and the payoff from choosing each action.

The Players: Decision makers are like players in a game. In games under uncertainty, the actions of the players not only depend on their belief about the competitors' strategies, but also exogeneous events or states of the world. Nature chooses the state of the world at random without regard to the plyers' action.

The Timing or Order of the Play: Understanding how decisions are interdependent is essential in a game of strategy. The players in a game can choose among the set of actions at certain points in time, called decision nodes. The real-life games involve a combination of simultaneous and sequential games. The pioneer enters a new market first. After that, the firm is likely to face competition from entrants who will install additional capacity. The investment decisions in capacity would form a sequential game. However, once capacity is installed, competition might shift to prices. The plyers would then face a simultaneous price-setting game.

In a simultaneous game, it is not sufficient to merely take notice of the opponent's position. The strategist must also consider that the opponent's strategic thinking process simultaneously has an impact on its own position (Dixit, A. K. and Nalebuff, B. J., 1991).

Available Actions and Information Set: Players face different choices or actions, and have different information sets on which these decisions or actions are based. The information set consists of all information available to a player at a given time on which it bases its actions. At each decision node, the information set may be different. Relying on the information known at each decision point, a player chooses that action which provides the highest value or utility.

Payoff Structure: Each sequence of possible actions by the players results in an outcome for each player. By choosing the right action, each firm purses a strategy that maximizes its value. Next, a player chooses the optimal set of actions at each decision node to maximize his/her payoff (Smit, Han T. J. & Trigeorgis, L., 2004).

2.6.4 Dominant Strategy

For simultaneous-move games, it should be first considered whether a player has a strategy or course of action that outperforms all others regardless of what the other player does. In that case, the problem of a player in a strategic game is to decide upon an action to take without knowing which actions will be taken by her opponents (Osborne, M. J., 2002). However, the firm should pursue its dominant strategy without taking consideration of the rival moves when a dominant strategy exists (Smit, Han T. J. & Trigeorgis, L., 2004).

To reiterate, a dominant strategy for a player is an action that is optimal for this player no matter what his opponents do. Put differently, a player with a dominant action does not have to worry about how his opponents will play the game; for any belief that he might have about the plans of actions by others, playing a dominant action is optimal. Consequently, there is good reason to believe that rational players would play their dominant actions in a given game.

2.6.5 Nash Equilibrium

The most commonly used solution concept in game theory is that of Nash equilibrium. It is complex chain of thinking about convergence. Then, the strategies of all players would be mutually consistent in the sense that each would be choosing his or her best response to the choices of the other. Consequently, it is a set of strategies such that no player can do better by unilaterally changing her position or strategy. In a Nash equilibrium, each player follows his/her best response to the other plyers' strategy.

2.6.6 Strategies and Competitive Reactions in Extensive Form Games

Here, simply assume to have a two-player game (Player A and B) and it consists of two stages. At first stage, strategic investment is made only by Player A as the pioneer. During the second (production) stage, the two players will make endogenous competition between them. Their relative competitive position and market value (V_A, V_B) at time 1 will vary depending on the following two main factors:

A) **The Type of Investment (*Propriety vs. Sh*ared)**: If the strategic R&D investment generates a competitive advantage with proprietary benefits (making the pioneer firm tough), the pioneer captures most of the total market value in the second stage. On the other hand, if the strategic investment is diffused to the industry and become shared with competitor (an accommodating stance), each firm captures an equal part of the total value. Let say that a pioneer firm may develop a new technology, but fail to become the market leader when it lacks complementary assets needed to commercialize the product. At that time, an early mover may affect the pace of technology development and it may establish a product standard with network externalities (with a rival firm in the market) that may increase the market share of the firm.

B) **The Nature of Competitive Reaction (*Contrarian or Reciprocating*)**: The follower Firm B will react to the strategic competitiveness with the two behaviors of whether the competitor's reactions are similar or whether they are opposite to the (tough or accommodating) stance of the first firm. In the case of contrarian competition, firm has an incentive to make in R&D strategic investment to improve its competitive position and ability to appropriate future benefits for itself. When a larger quantity produced by the firm (e.g. capturing a larger market share via economies of scale or a learning cost advantage) results in a lower equilibrium quantity for its competitor, this quantity competition is regarded as contrarian.

		COMPETITITOR (Firm B)	
		Contrarian/ Strategic Substitutes	***Reciprocating/ Strategic Complements***
PIONEER (Firm A)	***Proprietary*** (Tough)	V^+ (Invest, Invest) V^- (Wait, Wait)	V^+ (Invest, Invest) V^- (Wait, Wait)
	Share (Accommodating)	V^+ (Invest, Invest) V^- (Wait, Wait)	V^+ (Invest, Invest) V^- (Wait, Wait)

Figure 2.9 Four Kinds of Competitive Strategic Analysis

Above Figure 2.9 distinguishes four different competitive investment strategies, depending on whether the resulting benefits of the strategic R&D investment are proprietary or shared and whether competitive reactions are contrarian or reciprocating.

2.6.7 Decision Tree in Option-Games

As it is stated above, strategic form of a game has three ingredients: (1) the set of players, (2) the set of actions, and (3) the payoff functions. The extensive form provides a richer specification of a strategic interaction by specifying who moves when while doing what and with what information. The easiest way to represent an extensive form game is to use a game tree, which is a multi-person generalization of a decision tree. Game trees are made up of nodes, branches, information sets, player labels, action labels and payoffs. The following Figure 2.10 illustrates the simultaneous game tree for the R&D investment and its components.

The game is formed by two plyers, A and B. It can be seen that there are two types of nodes in the game: circle node and square one. Circle nodes are regarded as decision nodes which represent the points in the game at which players make a decision whether to take the action of committing R&D investment or not. The other square node in the game which are called as the initial node represents the state of nature up and down moves. To each decision node, including the initial node, one, and only one, player label is attached, to indicate who moves at that particular decision node.

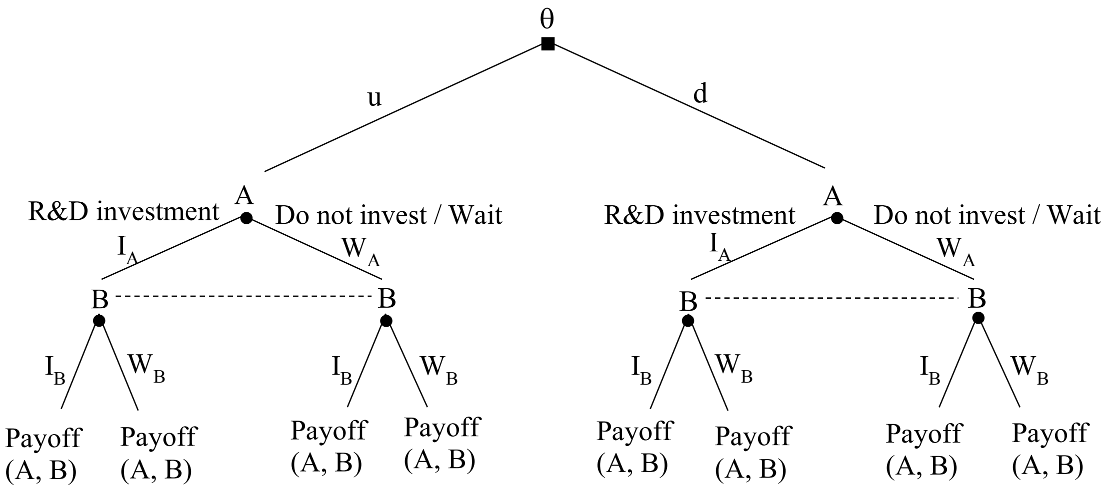


Figure 2.10 R&D Investment Game Tree

And the game is over at terminal nodes and nobody takes any action anymore. To each terminal node a payoff vector is appended. From each decision node, one or more branches emanate, each branch representing an action that can be taken by the player who is to move at that node. Each such branch is labelled with the action that it represents. A branch either leads to another decision node or to a terminal node. The last component is the information sets. Information sets tell us what the players know when they are making a decision. They are collections of decision nodes of a player that cannot be distinguished from the perspective of that player (Osborne, M. J., 2002).

2.7 Bayesian Games

All of the above games are assumed that all players had perfect information regarding the elements of a game. These are called games with complete information. A game with incomplete information, on the other hand, is modeled as the game in which some players have private information before the game begins (Osborne, M. J., 2002). The initial private information is called the type of the player. Private information could be the privately observed costs or payoff prospect of the project in an oligopoly game, or privately known valuations of an object in an auction, etc.

2.7.1 Definition of Bayesian Games

A Bayesian game is a strategic form game with incomplete information (Osborne, M. J. and Rubinstein, A., 1994). In a Bayesian game, a player knows neither the other players' private information nor the actions that they take. It consists of:

1) A set of players, $N = \{1, ..., n\}$, and for each $i \in N$
2) A set of actions, A_i, for each player $i \in N$
3) A set of type, ϕ_i, for each player $i \in N$
4) A set of signals, T_i (that may be observed by player i) and a signal function, T_i: $\phi_i \rightarrow T_i$
5) A probability function, p_i: $\phi_i \rightarrow \Delta$ (ϕ_{-i}) (the prior belief of player i on ϕ)
6) A payoff function, u_i: $A \times \phi \rightarrow R_i$

The function p_i summarizes what player i believes about the types of the other players given her type. So, p_i (θ_{-i}| θ_i) is the conditional probability assigned to the type profile $\theta_{-i} \in \phi_{-i}$. Similarly, u_i (a|θ) is the payoff of player i when the action profile is a and the type profile is θ.

2.7.2 Bayesian Equilibrium

Nash equilibrium for a game is the strategy profile in which every plyer's strategy is optimal given that the other players use their equilibrium strategies (Bierman, H. Scot & Luis Fernandez, 1988). In brief, each player chooses the best action available to him given the signal that he receives and his belief about the state and the other players' actions that he deduces from this signal in a Nash equilibrium of a Bayesian game. Type, in general, can be any private information that is relevant to the player's decision making, such as the payoff function, player's beliefs about other players' payoff functions, her beliefs about what other players believe her beliefs are, and so on. It is also needed to specify strategies for each type of a player, even if in the actual game that is played all but one of these types are non-existent. This is because, given a player's incomplete information, analysis of that player's decision problem requires the decision maker to consider what each type of the other players would do, if they were to play the game.

2.7.3 Backward Induction Equilibrium

The equilibrium concept in extensive form games is based upon the idea that each player plays a best response to the play of the other players. The difference is that strategies are required to be optimal at every step in the game. The backward induction equilibrium is an algorithm that results in a recommendation of an action choice at every decision node with a property (Osborne, M. J., 2002). The property is that their strategies would be optimal at every decision node they may be called upon to move if every player follows those recommendations. This will also result in a path of play, a sequence of branches, which will be called the backward induction outcome.

According to this algorithm, the game theorist determines the best action available to the players who are to move at final decision nodes. Since there are no more moves after players make their moves at these decision nodes, the action chosen lead to the highest payoff for the player who is moving. Next, is going to the penultimate decision nodes to determine the optimal action at those nodes. By continuing this manner, it will reach to the initial node and can determine the optimal action there.

2.7.4 Subgames and Subgame Perfect Equilibrium

Subgame perfect equilibrium (SPE) is a generalization of the backward induction equilibrium to extensive form games with imperfect information. To define subgame perfect equilibrium, first is to define a subgame. A subgame is a part of the game tree such that

1) it starts at a single decision node,
2) it contains every successor to this node,
3) if it contains a node in an information set, then it contains all the nodes in that information set.

The notion of equilibrium requires that the action prescribed by each player's strategy must be optimal, given the other players' strategies, after every history. Then, the notion of subgame perfect equilibrium eliminates Nash equilibria in which the players' threats are not credible. In contrast, a strategy profile is a subgame perfect equilibrium of a game, *G*, if this strategy profile is also a Nash equilibrium for every proper subgame of *G* (Bierman, H. Scot & Luis Fernandez, 1988). In other words, Nash equilibrium demands rationality in only those subgames that can be reached in equilibrium, whereas SPE demands rationality in every subgame, and this latter form of rationality is called sequential rationality.

2.7.5 Perfect Bayesian Equilibrium

The analysis of extensive form games with incomplete information will show the necessity to provide further refinements of the Nash equilibrium concept (Osborne, M. J., 2002). In particular, subgame perfect equilibrium (SPE) concept in extensive form games with complete information is not adequate for the games with incomplete information. Thus, this is the extension of the concept from Nash equilibrium and subgame perfection to reach out the perfect Bayesian equilibrium (PBE). The solution approach is that it requires the players to rationally update their beliefs about the game using the procedure of Bayesian updating.

A perfect Bayesian equilibrium consists of a strategy profile with optimization on the part of the players and a belief profile that respects the laws of probability, especially Bayes' Theorem by obeying the following requirements (Bierman, H. Scot & Luis Fernandez, 1988).

Requirement 1: The strategy profile that means the collections of strategies along the game constitute a Nash equilibrium, given the players' belief.

Requirement 2: At each player's information set, the move required by the player's strategy maximizes that the player's utility, given the player's beliefs about the state of game up to that move and other players' strategies.

Requirement 3: Whenever possible, every player's belief must be formed by the both of equilibrium strategy profile and common prior beliefs using Bayesian updating.

2.7.6 Signaling Games

One of the most common applications in economics of extensive form games with incomplete information is signaling games (Osborne, M. J., 2002). Since there can be frequently a very large number of possible strategies and beliefs, the signaling game is very useful in that situation (Bierman, H. Scot & Luis Fernandez, 1988). In its simplest form, in a signaling game there are two players, a sender *S*, and a receiver, *R*. Nature draws the type of the sender from a type set ϕ, whose typical element will be denoted by θ. The probability of type θ being drawn is $p(\theta)$. Sender observes his type and chooses a message $m \in M$. The receiver observes m (but not θ) and chooses an action $a \in A$. The payoffs are given by u_S (m, a, θ) and u_R (m, a, θ).

Let $\mu(\theta|m)$ denote the receiver's belief that the sender's type is θ if message m is observed. Also let $\beta_S(m|\theta)$ denote the probability that type θ sender sends message m, and $\beta_R(a|m)$ denote the probability that the receiver chooses action a after observing message m. Given an assessment (μ, β), the expected payoff of a sender of type θ is then;

$$U_S(\mu, \beta, \theta) = \sum_m \sum_a \beta_S\,(m|\theta)\beta_R(a|m)u_S(m, a, \theta) \qquad (2-7)$$

whereas the expected payoff of the receiver conditional upon receiving message m is:

$$U_R(\mu, \beta|m) = \sum_\theta \sum_a \mu\,(\theta|m)\beta_R(a|m)u_R(m, a, \theta) \qquad (2-8)$$

Also, Bayes' rule implies,

$$\mu(\theta'|m') = \frac{\beta_S(m'|\theta')p(\theta')}{\sum_\theta \beta_S(m'|\theta)p(\theta)} \qquad (2-9)$$

whenever $\sum_\theta \beta_S(m'|\theta)p(\theta) \neq 0$. That means at least one type of sender sends the message m'.

2.7.7 Bayesian Data Analysis and Bayesian Inferences

The contributions of the Bayesian Data Analysis are to provide another set of risk management practice, which offers rational and logical information for decision making process on capitalized project. Moreover, it can recommend key points in making the decision among environmental data noisiness. The followings are the steps of Bayesian Data Analysis.

1) Identify the data relevant to the research questions.
2) Define a descriptive model for the relevant data.
3) Specify the prior distribution on the parameters.
4) Use Bayesian inference to re-allocate probability across parameter values.
5) Conduct a posterior predictive check whether the model is good fit or not. If not, consider a different descriptive model.

Bayes Theorem and the way to make Bayesian inference is as in the following method.

$$\text{Bayes' Theorem: } P(\mathrm{A}|\mathrm{X}) = \frac{\mathrm{P}(X|A)\mathrm{P}(\mathrm{A})}{\mathrm{P}(\mathrm{X})} \qquad (2-10)$$

1) It infers the prior distribution by considering the unknown parameters as random variables.
2) It uses the information that has flowed in additionally or is gained through data sampling along with the prior distribution.
3) It draws the posterior distribution.

Figure 2.11 shows the methodology on how to draw the Bayesian inference.

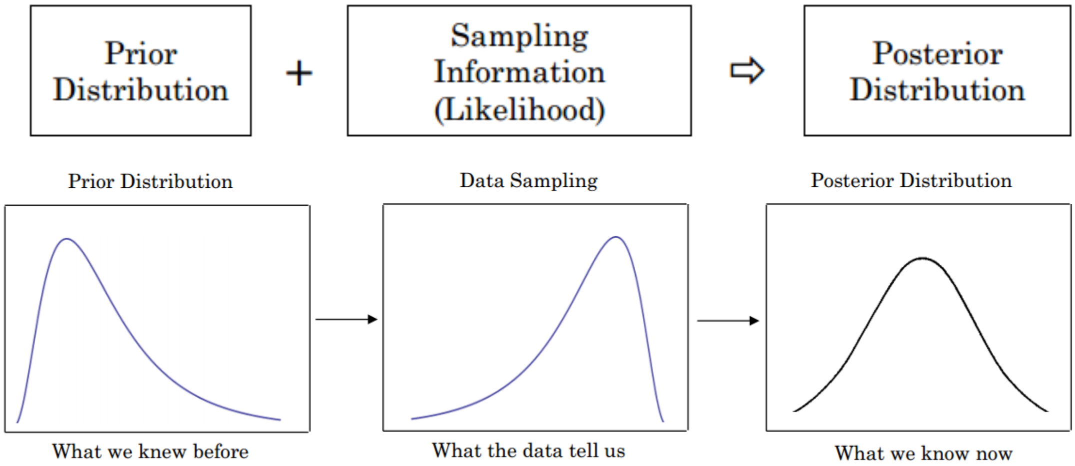


Figure 2.11 The Method for Bayesian Inference

2.8 Summary

The chapter provides a review of current energy situation of Myanmar and some studies pertaining to research methods to solve for research problems and achieve research goals. The main goal of this study is to explore how to invite the foreign investment for new energy generation project and then, when the investors enter the market, how to make the market competition optimal between the existing firms of power generation and new comers of investors. Then, it intends to investigate the firm's potential of survival analyzing on the important parameters for firm's growth. Thus, it is emphasized on the advantage of the study that consists of developing the learning and adaptive skills of option-games and Bayesian perspectives. Finally, this research contributes to providing the radical information and tactics for the investors who enters Myanmar energy market and invest in power generation project.

CHAPTER 3[2]

INDUSTRIAL CLUSTER FORMATION FOR REGIONAL DEVELOPMENT

3.1 Introduction

21st Century is the ICT age of knowledge economy. Rapid development of high-tech industries has become the core of economic growth for many countries and, energy industry is one of them. With the increase in energy demand in this century, efficient and effective management of energy resources and technology for producing it is inevitable and has come to a pervade aspect of human life. At the same time, cooperating among local governments and companies in creating smart communities for the development of new energy industrial technology has become very crucial. While the industrial/organizational clustering is being a global economic development and technological evolution, innovation-initiative has a lot of advantage, which can be converted into regional industrial competitiveness (Hu, Yuhua, 2010).

3.2 Industrial Cluster Formation

3.2.1 Concept of Industrial Cluster Formation

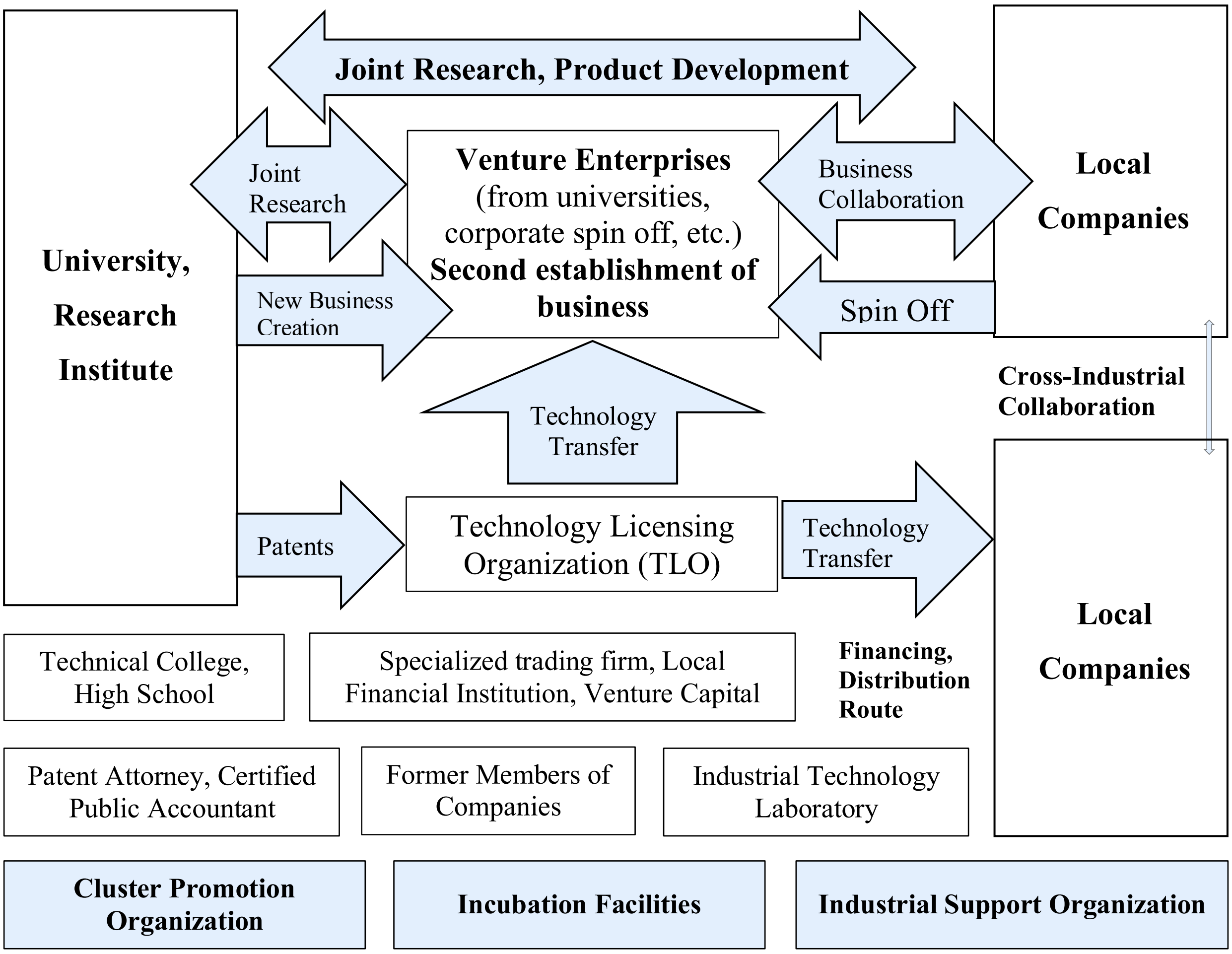
1) **Basic Structure:** An industrial cluster a gathering of action entities in a certain interconnected industrial group such as geographically-close companies and research institutes, industry support organizations, network organizations, technology licensing organizations, industry-academia collaboration intermediary organizations, and specialist groups, all of which are attracted by the charm of region.

[2] Some parts of this chapter are used from master thesis by Nyein Nyein Aye, 2013

In an industrial cluster formation, intellectual values accumulated in the cluster such as technology, know-how, knowledge and information circulate quickly through the flexible horizontal web of network linkage between constituents. And active innovation is induced through competition and collaboration mechanism by fusion and emergent of constituents, both of which enable quick and agile response to the changes in business environment.

2) **Innovation Chain:** An industrial cluster is not a mere agglomeration of large-volume producers, but includes companies, universities, research institutes, industry support organizations and local governments, in which strategy and scenario on local industry are shared and led by core persons and core groups. It also realizes innovations such as R&D, design, adjustments, launching of business, and exploitation of new business and management innovation. In addition, innovation chain is expected to occur in various ways by synergy effects of cross-industrial chains.

Furthermore, it is also necessary to build cooperative relation based on the geographical and psychological closeness. Unique R&D such as invention, discovery and the development of products and services requires face-to-face human interaction. Such geographical closeness is a factor for innovation chains. As a result, agglomeration is incessantly evolved and then, industrial of the region and the securing of competitive superiority can be realized in an industrial cluster formation.



Source: Industrial Cluster Study Report by Industrial Cluster Study Group, 2005

Figure 3.1 System of Industrial Cluster Formation

3.2.2 Characteristics of Industrial Cluster Formation

1) External Economies: The industrial location theory states that the cost savings that occur as a result of spatial concentration are a major cause for creating industry clusters. The cost savings usually result from increased market power, availability and use of specialized facilities, shared physical and human infrastructure, reduced risk for budding entrepreneurs and knowledge transfer. More important than the static external economics like cost savings are the dynamic external economy associated with knowledge transfer, innovation and specialization. The focus on knowledge related externality is predominant in advanced technology industries.

2) **Generalized Reciprocity**: Generalized reciprocity is a feature of industry cluster formation. It is the social dimension where transactions occur not by discrete exchanges or administrative fiat but through relations based on trust and reputation between the constituents.

3) **Flexible Specialization**: The concept of flexible specialization is a key feature of the constituents of the industry cluster formation. 'Flexible' here refers to the nature of production systems where general-purpose machinery is used to produce a variety of products and 'specialization' refers to the fragmented nature of product markets requiring more variety and innovation. This leads organizations to vertically disintegrate since economies of scale makes it difficult to remain flexible and usually results in an industry cluster characterized by a number of specialized organizations with a complex web of relationships among them.

3.3 The Benefits of Industrial Cluster Formation

3.3.1 Enhancing the Global Competitiveness of Industry

Industrial cluster can generally increase competition of the whole area through all kinds of ways, such as cutting cost, stimulating innovation and efficiency, cause to form a cluster of competitiveness. In a word, under the same conditions, the cluster is more competitive than non-cluster.

Competitiveness exists not only just in the market competition, but also it is in cooperation. In the industrial cluster, large enterprises come together each other, spread the intense market competition and carry out various forms of cooperation. They can combine together to develop new product, exploit new market and set up supply chain, then to form a mixture of mechanism between competition and cooperation. Through such ways, SMEs of cluster in training, financial and technical development, design, marketing, export and distribution, to achieve network interaction and cooperation efficiently, to overcome the disadvantage of scale economy and then able to fight with strong competition. Lots of SMEs which have not capacity to live in the market, but finally they can be alive in the cluster formation and become stronger.

3.3.2 Creating a Power for Effective Cooperation

In most of market economy of various countries, enterprise is the main innovation system. Technical cooperation between enterprises and other informal interacted relationship become the most direct and significant form of knowledge transfer. Cooperation between enterprises is the basis of trust, not a contract. These enterprises of cluster establish a close collaborative relationship to reduce the opportunist tendency towards cooperation and reduce the risk and cost.

Therefore, the opportunity of co-operation and chance of success will undoubtedly greatly increase. Namely, cooperation can create power larger than single enterprise power in sum. However, not all businesses are able to carry out effective cooperation, because some of them don't enable to discover partners.

3.3.3 Boosting the Innovative Ability

Cluster conducts to raise productivity as well as it helps to promote innovation of enterprises. The innovation shows in the following aspects: a sense of organization, management, technical institutions, environment and so on. Generally, clustering could provide a good innovation environment to enterprises, which is to cultivate enterprises learning and innovation ability of the nest.

In industry cluster, it is easy to spread new ideas, new concept, new technology and fresh knowledge with proximity location, close cooperation and face-to-face contact and thus, form knowledge spillover effect, enhance the ability of research and innovation.

Cluster plays an important role for new business entrances and growth. On one hand, it has competitive advantage for attracting more business into cluster with good creative environment and perfect system for innovation. On the other hand, the geographical concentration and a favorable external environment are good for growth and expansion of enterprises.

3.3.4 Sharing Effect

Industrial cluster has a kind of characteristic of geographical concentration. Therefore, the relative enterprises and supportive enterprises, such as local government, industry associations, financial and educational training institutes, join together in the same location, corresponding to form flexible production integration, formed the core competitiveness. In addition, government would like to invest in the related education, training, inspection and verification and other public facilities because of the formation of cluster. Moreover, these facilities established shall be to improve the development of enterprises within cluster. Sharing public facilities will be to make enterprises more efficiently.

Individual companies to establish its own brand need a large capital investment, however, enterprises increase the dynamics of advertising by organization's overall strength. Grouping makes able to form 'regional brand' easily. If it is compared the regional brand with individual organization brand, regional brand has more widespread, direct and persistent brand effect and then, it is also precious intangible assets.

3.4 Clustering of the Organizations for Regional Development of Myanmar

In this section, the author will introduce with government strategy, policy and plans for sectoral transforming of Myanmar's power.

Development Plan and Reform Program: Myanmar acknowledges electricity as the main power source driving economic development and addresses the need to generate and distribute more power in terms of greater volume, density, and reliability.

According to ADB, the government, in 2014, prepared a set of reform programs aiming to transform the country to a modern, democratic, and developed nation by 2030. The framework for these reforms was laid down in the 2011–2031 "National Comprehensive Development Plan." The 2012 "Framework for Economic and Social Reforms" aimed to achieve poverty alleviation, improved infrastructure, and capacity building through many plans, such as (i) rural development and poverty alleviation; (ii) human resources development, investment, and trade sector development; (iii) industrial development; (iv) finance sector development; and (v) regional and sector-wise development.

National Energy Policy: The national energy policies (NEP) are summarized as follows:

- To promote international collaboration in energy matters.
- To invite the local and foreign investments for the extraction and utilization of natural resources in order to fulfill the nation's energy needs by minimizing the environmental impacts and practicing the Health, Safety and Environment (HSE) assessment and; Corporate Social Responsibility (CSR) activities measures.
- To establish the regional cooperation for energy by expanding the power grid and pipeline network to neighboring countries.
- To adopt prioritized plans on Energy Efficiency and Conservation
- To define the energy pricing by observing the ASEAN and international energy pricing policy for the affordable and reliable energy prices for end users & customers.
- To formulate the energy standards and specifications which are appropriate for the nation and which are also in compliance with ASEAN and international practices.
- To promote private sector participation or privatization according to the State's economic policy.
- To lay down the short-term and long-term plans not only for increasing the power generation of hydropower, renewable energy sources, thermal power plants but also the feasible alternative energy sources.
- To implement full-fledged power generation as short-term and long-term plans in order to get stability of power generation.

- ❖ To establish Energy Database System and to draw and execute the energy supply plans by surveying the nation's energy demand annually.
- ❖ To plan energy stockpiling for energy security.
- ❖ To formulate the short-term and long-term plans for fulfilling petrochemical products requirements of the country by constructing the innovative refineries and plants.

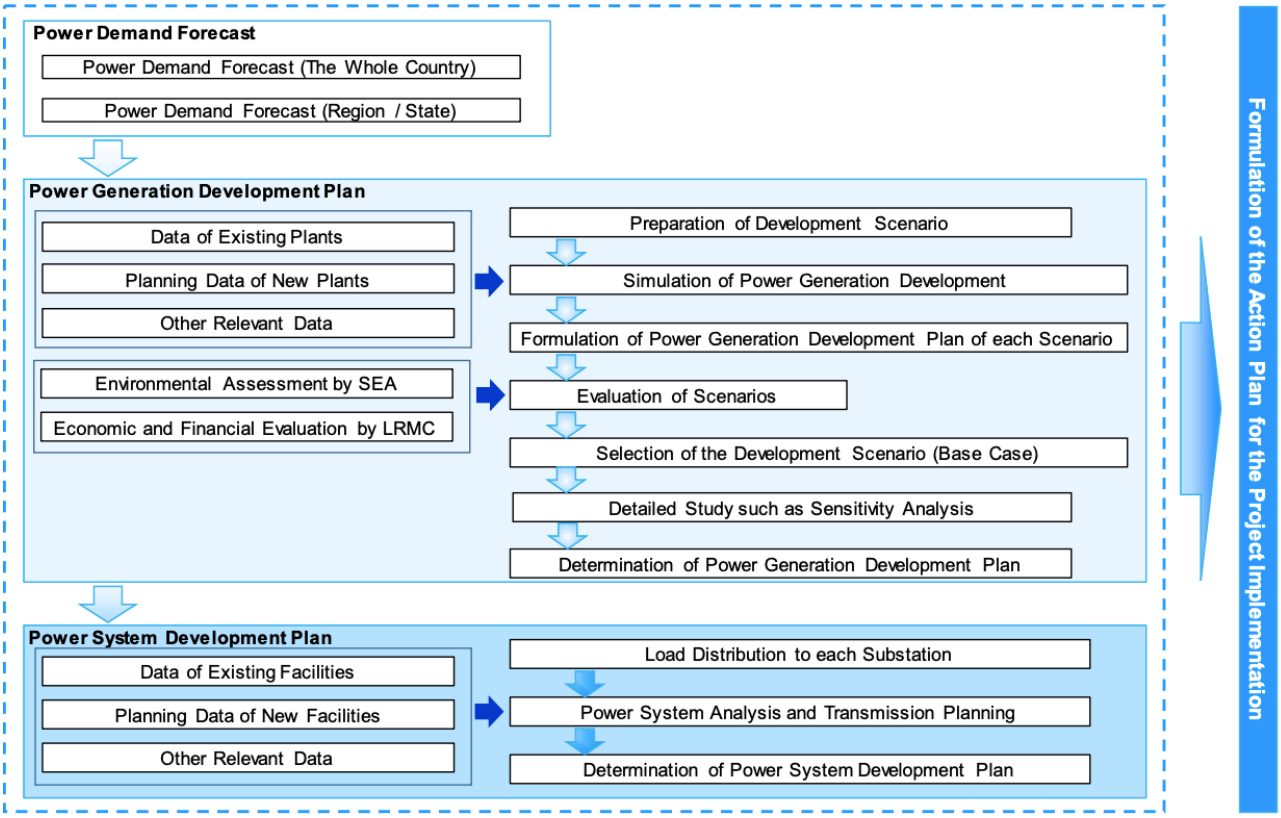
In accordance with above NEP, government 's plans include sector restructuring, investment planning, pricing and fuel subsidy review, renewable energy and energy efficiency development, promotion of private sector, increased international trade, and a national electrification program to achieve 100% electrification by 2030. ADB has expressed that these plans are at various stages of development and implementation with (i) a new electricity law approved in 2014 allowing for corporatization, private sector participation, and establishment of an independent electricity regulatory commission; (ii) energy sector and power subsector plans to be completed identifying required investments; and (iii) commencement of a national electrification program.

Myanmar Energy Master Plan: The Myanmar government shifted the policy toward increasing domestic energy supply and improving policy frameworks to encourage greater investment in the energy sector. This opens the opportunities for extensive international assistance including public-private partnerships.

The 2015 Myanmar Energy Master Plan is put forward by the Asian Development Bank and Myanmar Ministry of Energy in order to analyze energy demand development from 2014 to 2035 along five supply expansion scenarios. These feed into a national investment strategy in energy sector infrastructure and form the basis for recommendation on institution building for Myanmar's future national energy planning.

The plan envisions a 15% - 20% share of renewable energy in 2020 in the total installed capacity, most of which will be used to advance rural renewable energy purposes. The preferred energy scenario shows energy generation mix of 57% hydropower, 30% coal, 8% natural gas and 5% solar and wind by 2030 (IEA, 2017).

Explanation and provision of the data and analysis related to the Master Plan had been implemented by JICA Survey Team as the technical transfer for MOEE staffs concerned. The components of the analysis of the Master Plan are of power demand forecast, power generation development plan, power system plan, and economic and financial analysis. Study Flow of the Myanmar Energy Master Plan is shown in Fig. 3.2. In this Survey, the training program on the analysis and simulation of the Master Plan will be executed for MOEE staffs concerned to assess and develop their technical capacity.



Source: Final Report Summary for Power Sector Development, JICA

Figure 3.2 Study Flow of Myanmar Energy Master Plan

3.4.1 Asian Development Bank as Main Partner

Since 2012, ADB has been a lead development partner in the energy sector. ADB's initial assessment of Myanmar's energy sector, 2012 outlined the need for (i) preparation of a detailed energy sector assessment including demand projections, supply options, and investment plan; (ii) an advisory technical assistance (TA) for institutional strengthening and coordination in the energy sector and capacity building; (iii) rehabilitation of power generation, transmission, and distribution facilities; and (iv) capacity building. Separate from project preparatory TA projects, a summary of capacity development and policy and advisory TA projects is described in Table 3.1.

In addition to technical assistance, there are also the financial assistances. ADB, in 2013, provided a USD60 million loan to rehabilitate the distribution network in five townships in Yangon, four districts in Mandalay, five districts in Sagaing, and two townships in Magway. ADB also approved an USD80 million loan focusing on strengthening the 230-kV transmission lines and substations in the Yangon area. ADB also approved a loan and political risk guarantee of USD260 million to the project company of the Myingyan gas power plant (ADB, 2016).

Table 3.1 ADB's Capacity Development, Policy and Advisory TA Projects to Myanmar

	Description	Type of TA	Status
1	Capacity development and institution support	TA	Completed
2	Policy, strategy, and energy master plan development	CDTA	Ongoing
3	Legal and regulatory framework development	PATA	Completed
4	Off-grid renewable energy demonstration	CDTA	Ongoing
5	Investment project identification and feasibility study	TA	Completed
6	Financial management assessment of energy sector	RETA	Completed
7	Country safeguard system strengthening		Completed
8	Public–private partnership framework development	CDTA	Ongoing

TA= technical assistance

CDTA = capacity development technical assistance

PATA = policy advisory technical assistance

RETA = regional technical assistance

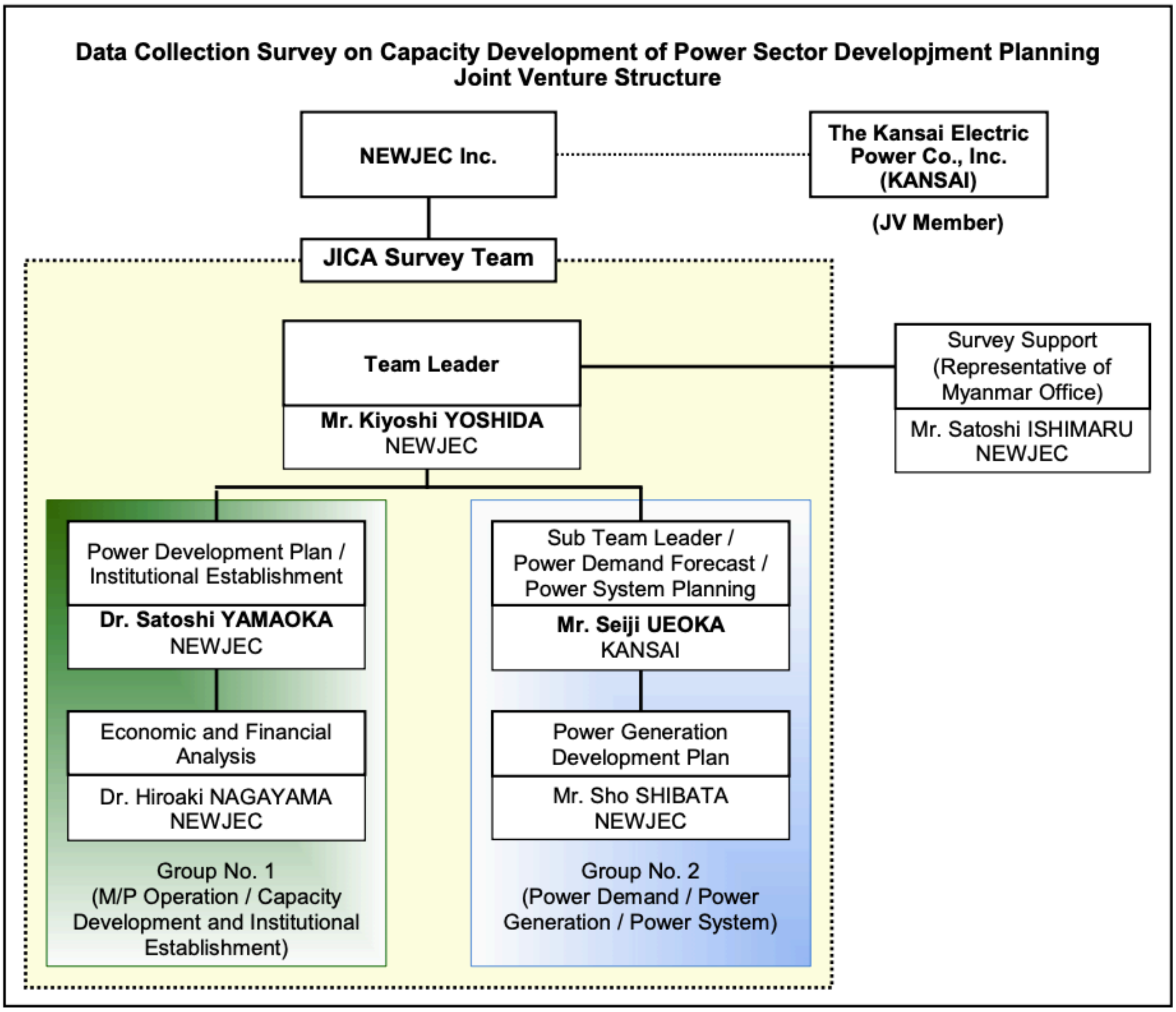
Source: Asian Development Bank

3.4.2 JICA's Financial Aids and Technical Supports

Since June 2013, JICA has been assisting the MOEE in preparing the National Electricity Master Plan focusing on power sector generation and transmission sector planning. The report was submitted in September 2014 and JICA is now assisting in its update and revision. Ongoing and planned JICA loans and grants, totaling more than USD1 billion, cover all power subsectors. These include the following:

- Power Generation: (i) Urgent Rehabilitation and Upgrade in Yangon (USD40 million), (ii) Infrastructure Development in Thilawa (USD100 million), (iii) Rehabilitation of Baluchaung No. 2 Hydropower (USD70 million);
- Power Transmission: (i) National Power Network Development 500 kV Phase I (USD250 million) and (ii) National Power Network Development 500 kV Phase II (USD400 million); and
- Power Distribution and Electrification: (i) Power Distribution Improvement in Yangon (USD60 million), (ii) Power Distribution Improvement in Major Cities (study completed), (iii) Rural Power Infrastructure Development Phase I (USD40 million loan), (iv) Rural Power Infrastructure Development Phase II (USD40 million loan under study).

In implementing the Master Plan, JICA supports its technical assistance in power system & development planning, economic & financial analysis, environmental & social consideration and investment efficiency of Joint Venture (JV)/ Independent Power Producer (IPP), especially intending to have technical skill, technical knowledge, experiences, and analytical perspectives by the concerned staffs. The implementation of the training had been planned by JICA Survey Team for few Myanmar staffs from MOEE based on the OJT (On-the-Job Training) style in order to have effective support on its technical assistance. Additionally, it also shares and transfers the advanced technologies for the power generation development. The Figure 3.3 represents joint venture structure of data collection survey team for implementing capacity development of power sector development planning by JICA.



Source: Final Report Summary by JICA

Figure 3.3 Implementation Structure of the Survey Team on Myanmar Power Sector Development

3.4.3 Partnership from World Bank Organization

World Bank Group. Since May 2013, the World Bank Group has been assisting MOEE and the Ministry of Agriculture, Livestock and Irrigation in preparing the NEP focusing on power distribution extension and off-grid applications. In line with the NEP, the World Bank Group has approved a USD400 million International Development Association credit to support the first phase of its implementation in parallel with an International Finance Corporation Lighting Myanmar Program. In 2013, the World Bank approved the USD140 million International Development Association credit to support replacement of the existing gas turbine station in Thaton with a new combined cycle gas turbine power plant. This credit also provides TA for the energy sector, including transaction advisory services provided by the International Finance Corporation for the corporatization of Yangon Electricity Corporation and procurement of Myingyan Independent Power Producer (IPP).

3.4.4 Assist from German Development Bank

The German development bank on behalf of the German government supports rural electrification in off-grid areas and by grid expansion under the NEP. A grant fund of €7 million (€2 million for TA and €5 million for investment) for a solar home system program in southern Shan State has been allocated. In addition, a program for extending the grid to rural areas in Shan State, which amounts to a €30 million (€24 loan and €6 million grant) under the MOEE, is under preparation. The federal agency for international cooperation for development on behalf of the German government is providing €2 million for TA in rural electrification policy.

3.4.5 Assist from Department for International Development

It has provided financial support to the International Finance Corporation for the Myingyan 250 MW IPP Transaction Advisory Services and ADB for public–private partnership framework development with the MOEE. It has also established Infraco Asia in Myanmar, a not-for-profit infrastructure project development institution, which is looking to develop off-grid power projects, as well as other rural infrastructures. It has plans for a new private sector development program in Myanmar.

3.4.6 The Government of Thailand as Developing Partner

The Government of Thailand will provide grant funding for two 120-MW gas-fired power plants in Yangon, and a grant of USD20 million to rehabilitate distribution networks in three townships in Yangon (North Dagon, Okkalarpa, and Shwe Pauk Kan), since 2013.

3.4.7 The Government of Norway as a Partner

The Government of Norway provided assistance, through ADB, for revising the electricity law. In 2015, Norway approved USD10 million of TA to MOEE for planning and implementation of hydropower plants, electricity law and regulations, and capacity building and for resident advisory group in MOEE.

There are other development partners and most of the partners assist Myanmar in financially for the implementation of Master Plan and energy sector development. As described in transmission and distribution section, the Government of Serbia, the Government of the Republic of Korea and the Government of Japan have financed in developing and implementing some power transmission lines across the country.

3.4.8 Private Sector Participation

The private sector has demonstrated strong interest in developing commercially operated power plants. The government signed memorandums of understanding (MOUs) with developers promoting 44 hydro-plants, 11 gas-fired power plants, and various solar power plants. These projects are at various stages of development. Since 2013, 620 MW of gas-fired IPP projects have been added, representing 40% of the total gas fleet. The Myingyan 225 MW gas IPP is at an advanced stage of development.

It is estimated to require a total of USD650 billion by 2030 to satisfy its growing demand for energy. Among them, USD170 billion is from foreign investors and the remainder from domestic sources. Investment is needed in both the petroleum and renewable energy sectors. Due to lack of capital, technology and knowhow in Myanmar, much of the necessary investment will have to come from abroad (Vakulchuk, R., Hlaing, K. .K., Naing, E. D., Overland, I., Suryadi. B. and Velautham, S., 2017). It is also the private sector participation under the new arrangements of the government for such information that foreign direct investment (FDI) is expected to increase which will see more private entities enter the electricity market.

3.5 Summary Result of Cluster Formation

Above overall, industrial cluster formation is a win-win choice for power sector development and generation projects in a concern with Energy Industry Park that depend on the advantages of cluster formation.

On the one hand, it can gather a lot of the relevant enterprises into cluster to improve and explore industry chain effectively with good policies of the cluster. On the other hand, enterprises and organizations with cluster network contacted closely, all of the competitive advantages can be copied to the park, that no longer simply depend on preferential policies for development, but to lasting development with industrial superiority, that is an effective way for promoting the regional competitiveness.

It can be seen in practice from domestic cases that industrial cluster formation in theory is in line with the development of energy industry characteristics, which is the core of energy industry pattern in a world power. Industrial cluster formation is a common trend to the development of energy in this world of developed and developing countries including Japan and Myanmar. My country, Myanmar, is a developing country, and needs modern technology in construction of our country to be developed nation, especially in energy sector for social development of the community. Thus, technologies of power industry in Japan can be exported to Myanmar in term of technology outsourcing pattern. By cooperating between Japan innovators/foreign investors and domestic government/Myanmar's potential industrial players of the energy sector, it is sure that this will have the mutual benefit as a golden future result for both parties.

CHAPTER 4

APPLICATION OF OPTION-GAMES AND THE ONE-STAGE STRATEGIC GAME

4.1 Introduction

Energy industry is one of the most capital intensive among high-tech industries. Moreover, strategic investment decisions involve a great deal of uncertainty in this dynamic and competitive environment. To capture the need for managerial flexibility is especially important when investments are in such an irreversible situation and under uncertainty (Schwartz, E. S. and Trigeorgis, L., 2001). Technology investments have unique characteristics and thus, investing in technology for the start-up of new energy industry is a high-risky process that requires significant capital investment, and uncertainty plays a key role in decision-making. In this chapter, I use a combination of real options and game theory to analyze the investment strategies for the start-up of high-risky energy industry.

4.2 Analyzing the One-Stage Strategic Investment under Uncertainty

This section introduces different aspects into the analysis with simple one-stage investment decisions under uncertainty, first when proprietary and then under competition. Here, the following formulas will be used. NPV formula is:

$$NPV = -I + \sum_{t=1}^{N} \frac{E(FCF_t)}{(1+k)^t} \qquad (4-1)$$

If the NPV is positive, the project should be accepted and if not, it is to be rejected. Then, the option value will be calculated from:

$$C_0 = \frac{[pC_u + (1-p)C_d]}{1+r_f} \qquad (4-2)$$

And the risk-neutral probability calculation is:

$$p = \frac{(1+r_f)-d}{u-d} \qquad (4-3)$$

4.3 Game against Nature: Under Simple Proprietary Options

The problem of the management is to optimize in the face of random fluctuations in demand or prices and hence in project value, most typical in markets with a large number of small rivals.

4.3.1 Game Model without Managerial Flexibility

Here is the model assumption and its valuation. A start-up of high-tech company of energy industry has an exclusive opportunity to decide whether to invest in new attractive power generation project this year as the project extension that involves the investment I = USD300M (in million), volatility parameter $\sigma = 0.19$, up or down movement with binomial parameter $u = 1.21$ and $d = 0.83$, risk-adjusted discounted rate $k = 0.15$, risk-free interest rate $r_f = 0.075$, actual probability for up-side and down side risks $q = 0.5$ and original project value V = USD300M. Next, risk neutral probability is:

$$p = \frac{(1 + 0.075) - 0.83}{1.21 - 0.83} = 0.65, and\ 1 - p = 0.35$$

Then, the project tree can be seen as in Figure 4.1.

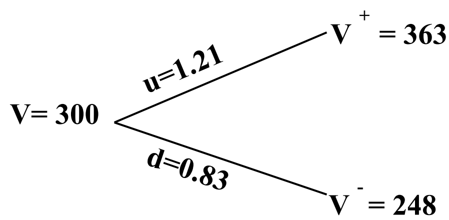


Figure 4.1 One-Stage Game Tree without Managerial Flexibility

At $t = 1$, $E(FCF_1) = (0.5 \times 363) + (0.5 \times 248) = 305$

Then, the gross present value of the project is to be discounted at the opportunity cost of capital:

$$V_0 = \frac{305}{1 + 0.15} = 266$$

Invest now commitment value: $NPV = (-300) + 266 = (-34) < 0$

Since the project NPV is negative, it should not be accepted according to its original plan of now or never commitment without managerial flexibility.

4.3.2 Game with Managerial Flexibility

The real options analysis can tackle the decision problems of this type. In the case of simple proprietary options, when commercial prospects are uncertain, firms may have an incentive to wait to invest until market develops sufficiently, rather than investing immediately and killing option to ‘‘wait and see’’. To introduce the value of operating flexibility into the deferral investment (a call option), it will be analyzed the capital investment opportunity described as in Figure 4.2.

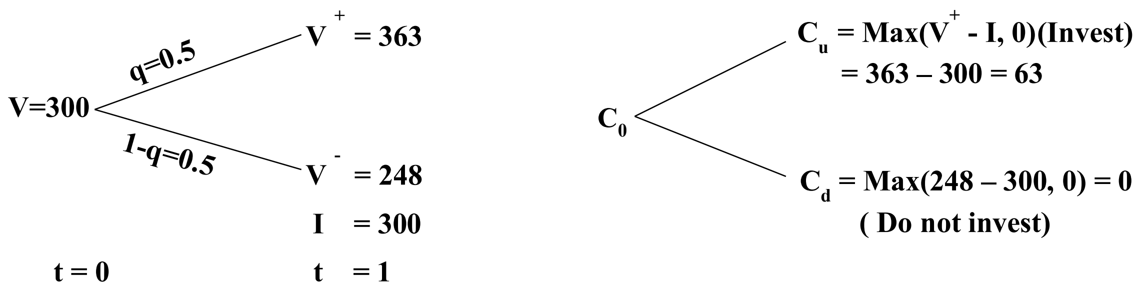


Figure 4.2: Option Value of Proprietary Opportunity: Wait to Invest under Uncertainty

Current call option value (or) Proprietary opportunity for the commitment:

$$C_0 = \frac{(0.65 \times 63) + (0.35 \times 0)}{1 + 0.075} = \mathbf{38}\ (ENPV) > -34$$

Above Figure 4.2 shows the managerial flexibility to defer investment for a year and invest if developments (e.g. demand or prices) are favorable (upward movement) or back out with limited loss (0) under unfavorable developments. In fact, such an investment opportunity will have a positive value, even if immediate investment commitment would generate a negative NPV because investment can be made only if the value of cash inflows, *V*, actually exceeds the required outlay *I* by a positive premium. Many investment opportunities with high barriers of entry for competitors are such kinds of proprietary real options. And the option to wait is valuable in the industries of high uncertainties, long investment horizons and limited competitive erosion.

However, in high-tech industries including energy industry, competitors can substantially influence a firm’s investment opportunity. Increased competition may have an erosion effect on a growth option’s value.

And when the type of investment invites a rival's response that in turn affects everyone's investment decisions and industry equilibrium production or pricing choices, a more involved game theoretic treatment is required. These will be discussed in next sections.

Shared real options can be used for the opportunity to introduce a new technology of energy productivity impacted by introduction of close substitutes or to penetrate a new geographic market without barriers to competitive entry.

4.3.3 Impact of Exogenous Competitive Entry

Figure 4.3 presents an example of such an investment opportunity that is shared with the competition. Suppose for simplicity that the incumbent and its competitor participate equally in the collective opportunities of the industry, sharing both the necessary investment commitment for developing the technology of *I* = USD300M, as well as the total market value of cash inflows (''size of the pie''), *V* = USD300M.

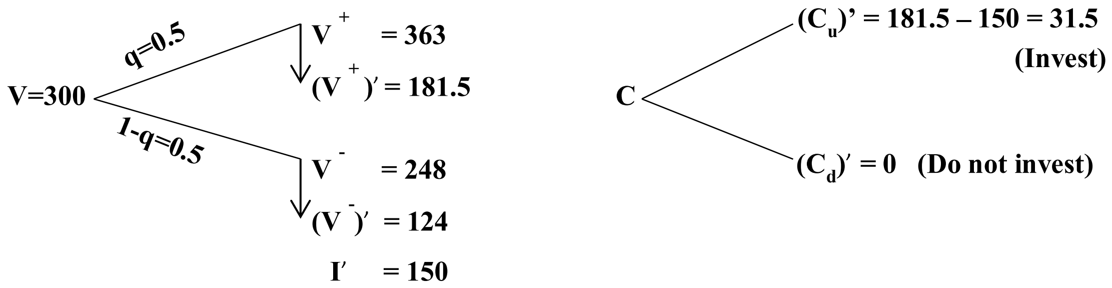


Figure 4.3 Shared Opportunity

Then, calculation for wait (call option with dividends) is:

$$C_0' = \frac{(0.65 \times 31.5) + (0.35 \times 0)}{1 + 0.075} = 19.01 \cong 19 > -34$$

Here, the option value of the incumbent would be eroded by exogeneous competitive entry, analogous to paying a dividend yield (50%), that tends to reduce the value of this option. However, it is found that incumbent firm in such kind of negative profit project for new power generation is possible to continue and extend the project by R&D commitment by exercising the shared right when the investment outlay is very huge. The incumbent doesn't have an incentive to commit to invest early and receive the immediate negative

NPV under the market uncertainty of high risks. It can be clearly seen that the firm might prefer to wait until future price or demand uncertainty is solved.

There will be advantage in cases that the benefits of the strategic option are shared, later-mover may free-ride on the pioneering firm's early investment. However, if the up-front strategic investment is high as in R&D, there is an increased incentive not to pioneer but to follow a coordinated R&D strategy with rivals as joint research venture project in such situation of energy generation of technology and capital intensive cases.

The movers' position may provide differing advantages depending upon the quality and market power of the mover, the proprietary nature of the incumbent's position, the time lag of the follower, learning, buyers' switching costs and network externalities. If the technology or position of the firm is more difficult to protect, the erosion effect could be higher and it will be opposite condition. Time-to-market may be an important source of advantage that may establish a sustainable strategic position for the organization.

4.3.4 The Effects on Games against Nature

In one-stage investment options against nature, the following effects can be distinguished:

The flexibility effect: arising from management's ability for waiting to invest until demand or price develops sufficiently.

A competitive value erosion effect: presenting when exogenous competitive entry can take part of total market value away from the incumbent firm; viewed analogous to the impact of dividends on a call option.

Switching effect in changing markets: arising while there are rapid technological changes and switching costs to new launch may favor in terms of its benefits. This appears when the incumbent can be challenged by superior projects that yield switching benefits in the market environments that experience technological change.

4.4 Strategic Games Against Competition: Under Shared Options

When investment decisions require an explicit recognition by the firm that they may invite competitive reaction that would in turn impact the value of its own investment opportunity, this game can be generally found in oligopolistic markets with a small number of rivals.

4.4.1 Investment-timing Scenarios and Competitive Interactions

If each competitor's decisions depend on the other's moves, then a more involved game-theoretic treatment is necessary. Investing earlier than one otherwise to pre-empt anticipated competitive entry is a simple case of such strategic game against competition. Under the following four investment-timing scenarios, the resulting values either at the end of each tree branch or in the payoff table for firms A and B appear as:

(i) When both firms invest immediately and simultaneously {I, I}, they share equally the total NPV (½ × -34), resulting in a (-17, -17) value payoff for each firm;

(ii)/(iii) When one firm (A or B) invests first while the other waits {I, W} or {W, I} and it pre-empts its competitor, appropriating the full negative NPV (-34) for itself and resulting in a payoff of (-34, 0) or (0, -34), respectively; and

(vi) When both firms decide to wait {W, W}, they share equally the value of the defer option (½ × 38), resulting in a (19, 19) payoff.

4.4.2 Payoff Structure of the Game and Analyzed Result

The payoffs of above scenarios are shown in the Table 4.1 and Figure 4.4 below.

Table 4.1 Simultaneous Investment Timing Game Payoff

		Firm B	
		Wait	**Invest**
Firm A	**Wait**	**(19, 19)***	(0, -34)
	Invest	(-34, 0)	(-17, -17)

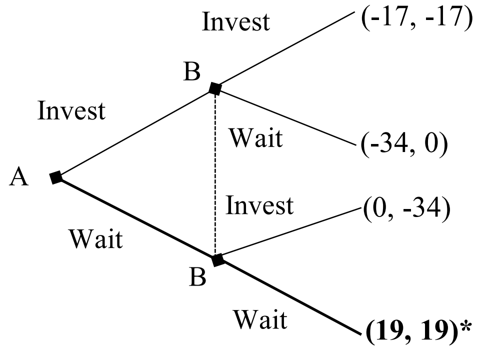


Figure 4.4 Decision Tree of Premature Competition and Investment

In the above value payoff structure, a Nash- equilibrium outcome is reached. It can be clearly seen firm A has a dominant strategy to wait, regardless of the timing decision of its competitor. Firm B also has a dominant strategy to wait, resulting in a Nash equilibrium (*) in the upper right cell, where both firms receive their maximum payoff of (19, 19), the Pareto Optimum (Gibbons, R., 1992). According to this result, they could share the flexibility benefits of the wait-and-see option.

4.5 Lessons from the Applications of Games in Real Option Analysis

Table 4.2 summarizes the key lessons to managers in terms of sense-making and decision making in a dynamic competitive context under uncertainty. For one-stage investment decisions, uncertainty provides an incentive to delay until investing is clearly profitable.

Table 4.2 Summary of Lessons from One-stage Game in ROA (with and without competition)

Situation	Problem Description	Lessons/Implications
One-stage options with no competition (proprietary option)	Investment opportunities viewed as proprietary options to invest in high-tech company of energy industry giving it an option to decide to extend the new project this year or wait until next year when demand uncertainty will be clarified.	Incentive to delay investment under uncertainty (as found in extraction industries).
One-stage options with competitive reactions/game (shared options)	Shared opportunities facing competitive loss. Firms also have no incentive to invest earlier to pre-empt anticipated competitive entry (strategic games against competition) under uncertainties.	Timing tradeoff between early commitment and flexibility value. Competitors face a timing game to overcome the negative profit from exercising their shared rights when investment outlay is huge.

4.6 Sensitivity Analysis for the Strategic Game Investment

4.6.1 Analyzing the NPV Behavior Based on Investment Amount Changes

Following Figure 4.5 shows how to effect on the NPV whenever the investment amount changes. In the figure, NPVs are the Nash-equilibrium values for both rival companies according to both well-known Prisoners' Dilemma and Pareto Optimum under the four investment-timing scenarios of Section 4.4.1. Under the well-known Prisoners' Dilemma (Gibbons, R., 1992), both firms first receive their second-worst payoff with some small amount of investment outlays as seen in figure. In high-tech industries, a firm may pre-empt competition and capture a significant share of the market by setting the product standard early on.

According to the analyzed result, it can be clearly seen that both players' invest-now strategy has more favorable condition compared to both players' wait strategy (deferral investment) at Nash-equilibrium except Pareto optimal strategies. And, finding result with the specified parameter values suggests that the companies should invest now until they reach the amount of USD215M. Moreover, the smaller the investment is, the more NPV they will get. The slope of NPV gradually becomes steeper and steeper upwards with the small amount of investments as seen in figure.

On the other hand, the companies should defer their immediate investment over the amount of USD215M. It means the companies must wait to invest if the commitment amount is large. But for the Pareto Optimum, deferral investment is unique strategy. And then, we can find that the NPV declines little by little together with the greater investments for both strategies. Together with the specified parameters' setting in the analysis, it is found that the investment amount is limited to USD362M for both firms. Once that amount is reached, both firms will abandon the new project extension at that time and may wait for the next time point again. In summary, it proves that it is not so good to invest too much under uncertainty according to both Prisoners' Dilemma and Pareto Optimum.

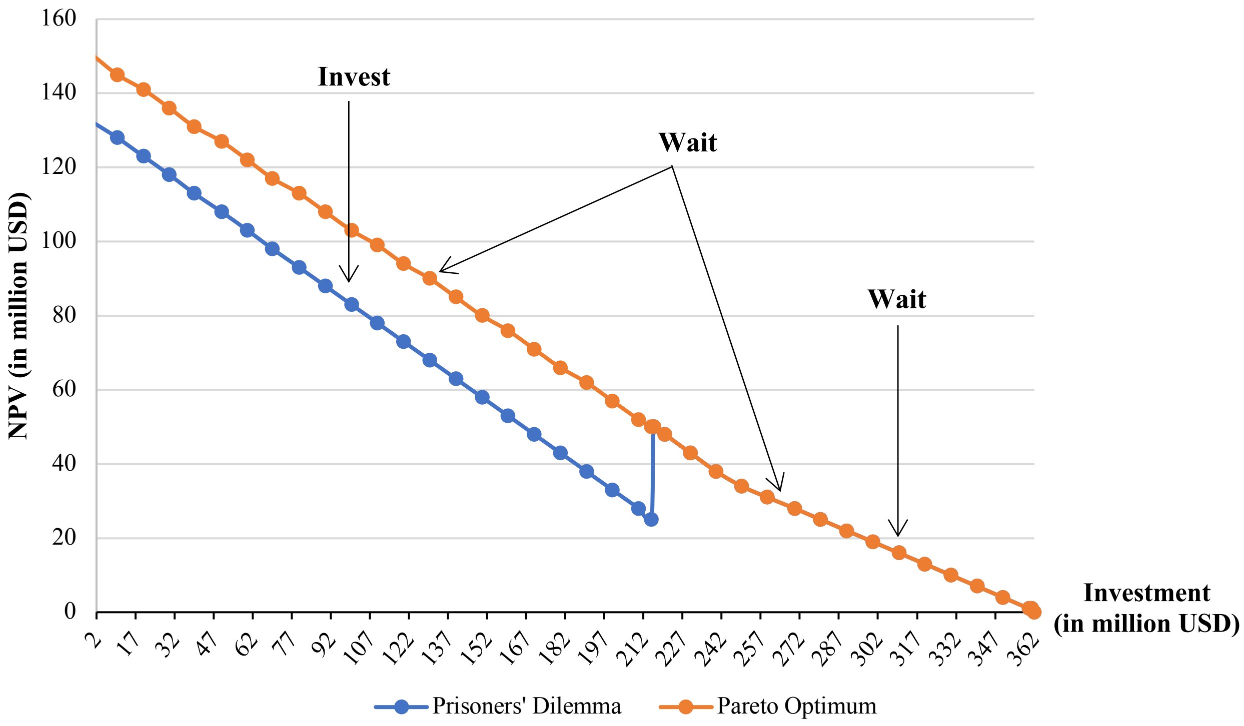


Figure 4.5 Impact on the NPV Depending on the Investment Movements

4.6.2 Impact on NPV due to Simultaneously Changes of Investment and Volatility

Figure 4.6 and 4.7 bring out the result of NPV changes for both companies due to the dramatic movements of investment scale and volatility parameter. This analysis is also made under the well-known Prisoners' Dilemma and Pareto Optimum. Thus, NPV results are Nash-equilibrium points for both sides.

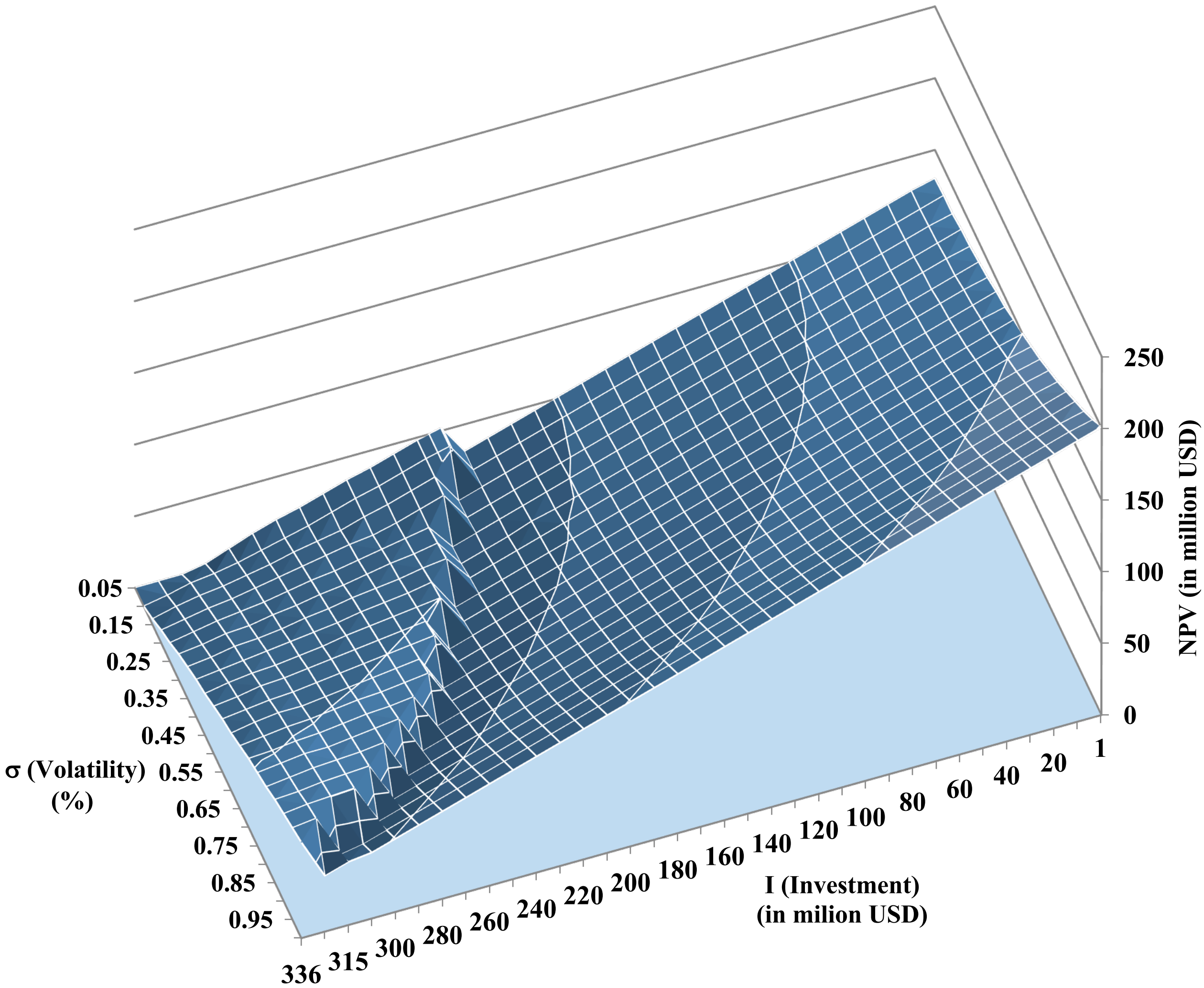


Figure 4.6 The Behavior of NPV Change with the Shifts of Investment Amounts and Volatility according to Prisoners' Dilemma

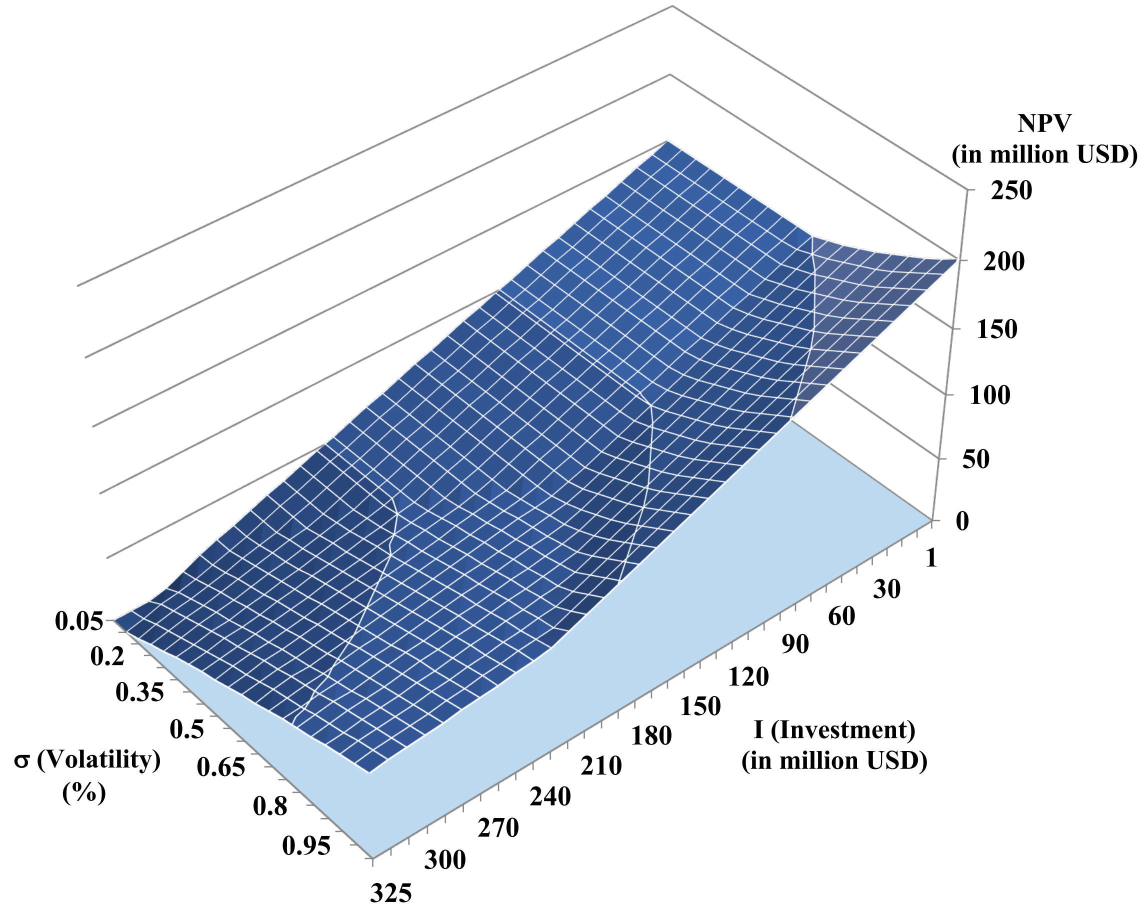


Figure 4.7 NPV Changes on the shifts of two parameter values, *I* and *σ* Under the Pareto Optimum

Prisoners' Dilemma vs. Pareto Optimum

Based on the result of analysis, the contrast points between the two will be discussed as follows.

In Figure 4.6, the boundary diagonal line can be used as the index for strategic shift between {Wait, Wait} and {Invest, Invest}. This line expresses the evident relationship of Nash-equilibrium between risk and investment amount. However, NPV gaps are not distinct for strategic shifts as seen in Figure 4.7.

Another contract point is that the two firms are more desirable to make the early investments many more frequencies with the high volatility than waiting under Prisoners' Dilemma. For the Pareto Optimum, more preferable strategy is to practice {Wait, Wait} for all amounts of investments at most of the risk levels under market uncertainty. It is found that they will make the early commitment with low amount of investment under high degree of risks.

The common results over the two strategies are summarized as follows.

Under the range of σ 0.05 to 1, the investment scales are limited from the smallest amount of USD1M to the largest one of USD336M to protect against negative Nash-equilibrium NPV for any of the both companies. This means that if the investment outlay is over the largest amount of the analysis, both firms will defer the project again waiting for the more favorable market condition.

According to the analysis result of NPV figures, it also reveals that the early investment is better than deferral one. Depending on the various amount of investment, they can get more NPV under the invest-now shared strategy if it is compared with waiting result. As the same with previous analysis, too much investment is not a favorable situation for both sides at all.

In addition, it is obviously pointed out the increase in NPVs depends upon the increase in the volatility with the riskiness. It shows that there is high return if there is high risk. Finally, we can see the highest NPV with the lowest investment of USD1M and uppermost range of σ, 1 in the analysis result representing highest risk, highest return, but with adverse effect of investment.

In Table 4.3 and Table 4.4, the numerical result of NPV and the strategic shift of investment behavior between {Invest, Invest} and {Wait, Wait} for both Prisoners' Dilemma and Pareto Optimum strategies can be checked respectively.

4.6.3 NPV Gaps between Pareto Optimum and Prisoners' Dilemma

The Figure 4.8 shows opportunity loss for the firm to shift Pareto Optimum to Prisoners' Dilemma. There are no NPV gaps in the flat areas of the figure.

Table 4.3 The Numerical Result of NPV and Investment Tree Types Under Prisoners' Dilemma

Prisoners' Dilemma

I / σ	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95	1
1	130	131	131	133	134	136	138	141	143	147	150	154	158	163	168	174	180	186	193	201
10	126	126	127	128	130	131	134	136	139	142	146	150	154	159	164	169	175	182	189	196
20	121	121	122	123	125	126	129	131	134	137	141	145	149	154	159	164	170	177	184	191
30	116	116	117	118	120	121	124	126	129	132	136	140	144	149	154	159	165	172	179	186
40	111	111	112	113	115	116	119	121	124	127	131	135	139	144	149	154	160	167	174	181
50	106	106	107	108	110	111	114	116	119	122	126	130	134	139	144	149	155	162	169	176
60	101	101	102	103	105	106	109	111	114	117	121	125	129	134	139	144	150	157	164	171
70	96	96	97	98	100	101	104	106	109	112	116	120	124	129	134	139	145	152	159	166
80	91	91	92	93	95	96	99	101	104	107	111	115	119	124	129	134	140	147	154	161
90	86	86	87	88	90	91	94	96	99	102	106	110	114	119	124	129	135	142	149	156
100	81	81	82	83	85	86	89	91	94	97	101	105	109	114	119	124	130	137	144	151
110	76	76	77	78	80	81	84	86	89	92	96	100	104	109	114	119	125	132	139	146
120	71	71	72	73	75	76	79	81	84	87	91	95	99	104	109	114	120	127	134	141
130	66	66	67	68	70	71	74	76	79	82	86	90	94	99	104	109	115	122	129	136
140	61	61	62	63	65	66	69	71	74	77	81	85	89	94	99	104	110	117	124	131
150	56	56	57	58	60	61	64	66	69	72	76	80	84	89	94	99	105	112	119	126
160	51	51	52	53	55	56	59	61	64	67	71	75	79	84	89	94	100	107	114	121
170	46	46	47	48	50	51	54	56	59	62	66	70	74	79	84	89	95	102	109	116
180	41	41	42	43	45	46	49	51	54	57	61	65	69	74	79	84	90	97	104	111
190	36	36	37	38	40	42	44	46	49	52	56	60	64	69	74	79	85	92	99	106
200	31	31	32	33	35	36	39	41	44	47	51	55	59	64	69	74	80	87	94	101
210	52	52	27	28	30	31	34	36	39	42	46	50	54	59	64	69	75	82	89	96
220	48	48	48	48	25	26	29	31	34	37	41	45	49	54	59	64	70	77	84	91
230	43	43	43	43	43	45	47	26	29	32	36	40	44	49	54	59	65	72	79	86
240	38	38	38	38	40	42	45	48	50	27	31	35	39	44	49	54	60	67	74	81
250	34	34	34	34	37	40	42	45	48	51	54	30	34	39	44	49	55	62	69	76
260	29	29	29	32	34	37	40	43	46	49	52	55	58	34	39	44	50	57	64	71
270	24	24	26	29	31	34	38	41	44	47	50	53	56	59	34	39	45	52	59	66
280	20	20	23	26	29	32	35	38	42	45	48	51	54	57	61	34	40	47	54	61
290	15	16	19	23	26	29	33	36	39	43	46	49	53	56	59	62	35	42	49	56
300	9	12	16	20	23	27	30	34	37	41	44	47	51	54	57	60	63	37	44	51
310	3	9	13	17	21	24	28	32	35	39	42	45	49	52	55	59	62	65	39	46
315	0	7	11	15	19	23	27	30	34	38	41	45	48	51	55	58	61	64	36	44
325	0	3	8	12	16	20	24	28	32	35	39	43	46	49	53	56	59	63	66	39
336	0	0	4	9	13	18	22	26	29	33	37	40	44	48	51	54	58	61	64	67

Wait Invest

Table 4.4 Tree Table of NPV Values and Investment Strategy Combination for Pareto Optimum

Pareto Optimum Solution

I / σ	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95	1
1	150	150	150	150	150	150	150	150	150	150	150	154	158	163	168	174	180	186	193	201
10	145	145	145	145	145	145	145	145	145	145	146	150	154	159	164	169	175	182	189	196
20	141	141	141	141	141	141	141	141	141	141	141	145	149	154	159	164	170	177	184	191
30	136	136	136	136	136	136	136	136	136	136	136	140	144	149	154	159	165	172	179	186
40	131	131	131	131	131	131	131	131	131	131	131	135	139	144	149	154	160	167	174	181
50	127	127	127	127	127	127	127	127	127	127	127	130	134	139	144	149	155	162	169	176
60	122	122	122	122	122	122	122	122	122	122	122	125	129	134	139	144	150	157	164	171
70	117	117	117	117	117	117	117	117	117	117	117	120	124	129	134	139	145	152	159	166
80	113	113	113	113	113	113	113	113	113	113	113	115	119	124	129	134	140	147	154	161
90	108	108	108	108	108	108	108	108	108	108	108	110	114	119	124	129	135	142	149	156
100	103	103	103	103	103	103	103	103	103	103	103	105	109	114	119	124	130	137	144	151
110	99	99	99	99	99	99	99	99	99	99	99	100	104	109	114	119	125	132	139	146
120	94	94	94	94	94	94	94	94	94	94	94	95	99	104	109	114	120	127	134	141
130	90	90	90	90	90	90	90	90	90	90	90	90	94	99	104	109	115	122	129	136
140	85	85	85	85	85	85	85	85	85	85	85	85	89	94	99	104	110	117	124	131
150	80	80	80	80	80	80	80	80	80	80	80	80	84	89	94	99	105	112	119	126
160	76	76	76	76	76	76	76	76	76	76	76	76	79	84	89	94	100	107	114	121
170	71	71	71	71	71	71	71	71	71	71	71	72	75	79	84	89	95	102	109	116
180	66	66	66	66	66	66	66	66	66	66	68	70	73	75	79	84	90	97	104	111
190	62	62	62	62	62	62	62	62	62	64	66	69	71	73	76	79	85	92	99	106
200	57	57	57	57	57	57	57	57	59	62	64	67	69	72	74	77	80	87	94	101
210	52	52	52	52	52	52	52	54	57	60	62	65	67	70	72	75	77	82	89	96
220	48	48	48	48	48	48	50	52	55	57	60	63	65	68	71	73	76	78	84	91
230	43	43	43	43	43	45	47	50	53	55	58	61	64	66	69	72	74	77	79	86
240	38	38	38	38	40	42	45	48	50	53	56	59	62	65	67	70	73	75	78	81
250	34	34	34	34	37	40	42	45	48	51	54	57	60	63	66	68	71	74	77	79
260	29	29	29	32	34	37	40	43	46	49	52	55	58	61	64	67	70	72	75	78
270	24	24	26	29	31	34	38	41	44	47	50	53	56	59	62	65	68	71	74	76
280	20	20	23	26	29	32	35	38	42	45	48	51	54	57	61	64	66	69	72	75
290	15	16	19	23	26	29	33	36	39	43	46	49	53	56	59	62	65	68	71	74
300	9	12	16	20	23	27	30	34	37	41	44	47	51	54	57	60	63	66	69	72
310	3	9	13	17	21	24	28	32	35	39	42	45	49	52	55	59	62	65	68	71
315	0	7	11	15	19	23	27	30	34	38	41	45	48	51	55	58	61	64	67	70
325	0	3	8	12	16	20	24	28	32	35	39	43	46	49	53	56	59	63	66	69
336	0	0	4	9	13	18	22	26	29	33	37	40	44	48	51	54	58	61	64	67

Wait Invest

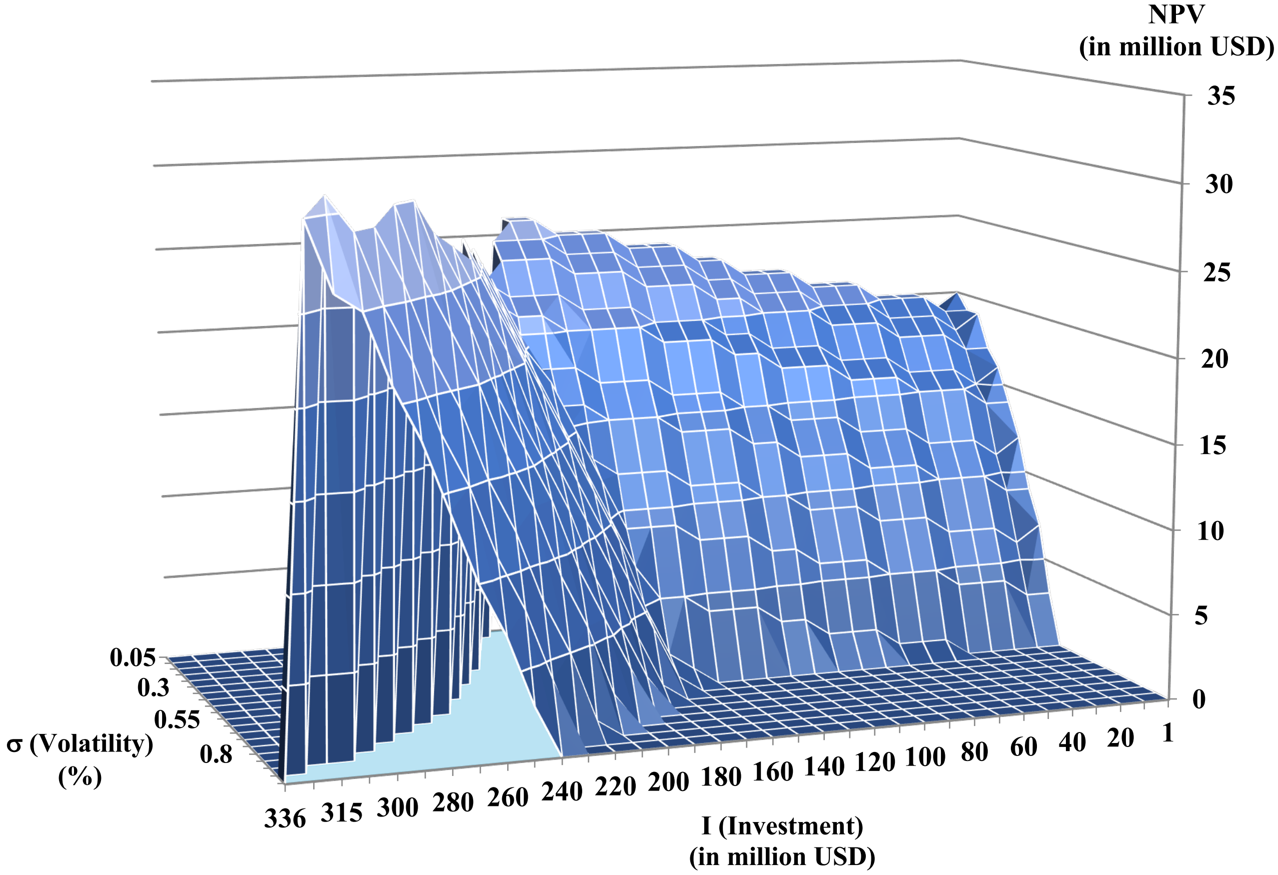


Figure 4.8 NPV Differences between Pareto and Prisoners' Dilemma

4.6.4 Exceptional Points for the Pareto Optimum Solution

In some points of the area of $\sigma \geq 0.55$ and $I \leq$ USD240M, there are some exceptional points for strategy combination of {Invest, Invest} and {Wait, Wait} for Pareto Optimum Solution. This means the payoffs of both strategies have same value.

The critical points that are found in the analysis are at:

$\sigma = 0.55$, $I = 1$, NPV = 150

$\sigma = 0.55$, $I = 20$, NPV = 141

$\sigma = 0.55$, $I = 30$, NPV = 136

$\sigma = 0.6$, $I = 40$, NPV = 1131

$\sigma = 0.6$, I = 130, NPV = 90

$\sigma = 0.6$, I = 140, NPV = 85

$\sigma = 0.6$, I = 150, NPV = 80

$\sigma = 0.95$, I = 230, NPV = 79

$\sigma = 1$, I = 240, NPV = 81

4.7 Summary

General summary: It can be generally drawn a conclusion that for a start-up company, the best way of investment decision is to practice the strategy of investing a little under market uncertainty, but high riskiness with the rival firm to avoid the threat of entry within the dynamic technological and competitive environment.

Weakness: however, it should be noted that this analysis has neglected the changing of other parameter values such as risk-free rate and time to maturity and has no consideration of certain key inputs like the level of technical skill, market demand and the response manner of rival firm.

Next frontier: the analyses will be made a progress to the two-stage or multi-stage investment model. It includes the opportunity to abandon, to stay flexibility, to defer the investment (wait), to expend, to contract, etc.

Connection between Analyses and Power Project: nevertheless, above two quantitative analyses provide a treatment of important analytical considerations for huge investment decisions which are directly related to the case of pioneering a high-tech power generation project's executives.

Application: the intention is to apply them compatibly with the practical condition of electricity-shortage in Myanmar, intending to reliable, adequate and affordable energy supplies throughout the country based on these project model technologies. Thus, it is possible to analyze the cooperative investment in R&D at energy industrial clusters for developing new and attractive generation project.

CHAPTER 5

TWO-STAGE OPTION-GAMES FOR THE STRATEGIC INVESTMENT

5.1 Introduction

In an increasingly uncertain and dynamic global marketplace, strategic adaptability has become essential if firms are to take advantage of favorable future investment opportunities, respond appropriately to threatening competitive moves, and limit losses from adverse market developments. In addition, precisely the strategic investment decisions determine the firm's competitive success, market value and sometimes its survival.

Investment decisions that have a major strategic impact on the firm's future path have been more difficult to analyze than standard NPV techniques would suggest. Rapid technological changes and intensified competition necessitate an analysis for the project's strategic growth potential that is more dynamic than just a forecast of expected cash flows. Thinking of growth in future investment opportunities in terms of real options has provided powerful new insights and has already enabled substantial progress in modern corporate decisions on allocation of resources.

Real options stress the importance of wait-and-see flexibility, suggesting that managers should wait until major uncertainties are resolved and the project is more clearly beneficial, requiring a positive premium over the zero-NPV threshold. Of course, it may not always be advisable to follow a flexible wait-and-see strategy from a competitive perspective (Smit, Han T. J. & Trigeorgis, L., 2004). When a competitor's investment decisions are contingent upon others' moves, a more comprehensive game-theoretic treatment becomes necessary.

Proper strategy valuation and design of irreversible investments require careful consideration of the capabilities for growth of project values, of the effect of competitive moves and the type of competitive reactions, of the value of commitment and deterrent strategies, as well as of the development of successful commercial investment opportunities.

The distinction between one-stage and two-stage option-games is important because most strategic opportunities involve path-dependent sequential investments. Many multi-stage strategic investments appear to have a negative NPV when considered in isolation, although they may have substantial growth option values. Two-stage games additionally include exploratory options involving firm-specific uncertainties that may or may not be reduced by investment. These include technical, strategic, and organizational uncertainties. The uncertainty of technical success relates to the outcome of the R&D effort.

In this chapter, option-games will be used to analyze profit of enterprises under different strategic profiles. The content will be examined how to take action to gain more profits for firms in cluster formation or joint research venture.

5.2 Assumption of the Model and Evaluation under Exogenous Uncertainties

An existing domestic company of power project has an exclusive opportunity to decide whether to invest in commercial production as an R&D venture with a rival foreign company who will enter Myanmar energy market. Figure 5.1 illustrates a two-stage R&D project with the first stage basic research investment, I_0 = USD50M. Its follow-on commercialization (second) stage development investment, I_1 is USD250M. Its risk-adjusted discount rate, k is 0.15, risk-free rate, r_f is 0.075, natural probability for up-state, q is 0.5, original project value, V_0 is USD300M, volatility parameter, σ is 0.65, so, binomial parameter up-ratio, u = 1.65 and its down state value, d is 0.61.

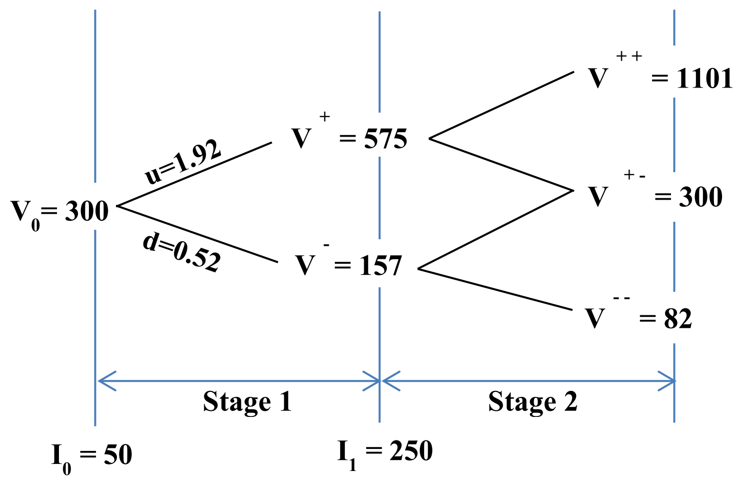


Figure 5.1 Two-Stage Investment Project Value Tree

Calculation for risk-neutral probability of the project is:

$$p = \frac{(1 + r_f) - d}{u - d} = \frac{(1 + 0.075) - 0.52}{1.92 - 0.52} = 0.4, \qquad 1 - p = 0.6$$

Despite high costs and no expected cash inflows during the first stage, management intuitively feels the necessity of the investment to prove the new technology and enhance the company's market position. Investing now in the pioneer R&D venture derives strategic value from generating growth opportunities to invest in future commercial projects. Based on naïve Discounted Cash Flow (DCF) technique, the standard total NPV of the pioneer R&D venture is:

$$NPV = NPV^1 + NPV^2 = -50 + \left(\frac{-250}{1.075} + \frac{(0.5 \times 575) + (0.5 \times 157)}{1.15}\right) = -112.5$$

Standard NPV values R&D as if the firm is to pre-commit to both stages and thus, it has negative profit for the project. Real option theory recognizes that management has an opportunity to invest in the follow-on commercial project (stage II) only if project value at that time turns out to exceed the required investment outlay of I_I = USD250M, otherwise it has no obligation to proceed by truncating downside value to 0, rather than receiving 157 – 250 = –93.

Thus, by using options valuation, the total strategic value (expended NPV) of the entire pioneer R&D venture is:

$$NPV^* = NPV^1 + Option^2 = -50 + \left(\frac{0.4 \times (575 - 250) + 0.6 \times 0}{1.075}\right) = 70$$

The framework of the company in one-stage games is based on the market uncertainty over cash flows that result primarily from uncertainties in demand or prices of factors of production. These uncertainties are largely exogenous to the firm. This creates an incentive in simple options to delay until more information is revealed that the project is clearly profitable.

5.3 Two-Stage Investment Game with Endogenous Competition

With an early strategic investment, the company may enhance its relative competitive position in a later stage of the market by deterring entry or otherwise influencing the behavior of its competitors.

5.3.1 Competition in Commercial Production Stage

It assumes to be a two-player game (Player A and B) for simplicity. Player A will make the strategic initial investment at the first stage as the pioneer power company in Myanmar. Then, the two players will make endogenous competition between them during the second (commercial production) stage. Their relative competitive position and market value (V_A, V_B) at time 1 will be different depending on the types of investment (propriety and shared investment) and nature of competitive reactions (contrarian or reciprocating) explained in section 2.6.6. All kinds of competitive results will be finally generated as the extensive form games with their payoff matrices and binomial game tree under the scenarios of respective type of investment strategies and reactions.

5.3.2 Calculation Results from the Analysis of Strategic Competitiveness

(1) The payoffs of proprietary investment when competitor's reaction is contrarian

Proprietary (first-stage) strategic investment of firm A influences the equilibrium outcome on the second stage game when competitive reactions are contrarian, i.e. the competitor's response is opposite to the action of the incumbent. In this way, assume that proprietary benefits 2/3 of strategic investment to Pioneer A, resulting in 1/3 share acceptance by the follower B.

At V^+ (favorable condition), preempting each other and capturing entire benefit: $NPV^+ = 575 – 250 = 325$.

So, {W, I} or {I, W} outcome of the leader A and follower B: (0, 325) or (325, 0).

When both Firms (A and B) invest by sharing the cost of I_1, ($I^2_{A(or)B} = \frac{1}{2} \times 250 = USUSD125M$ each):

$$NPV_A^+ = \left(\frac{2}{3} \times 575\right) - 125 = 258 \qquad NPV_B^+ = \left(\frac{1}{3} \times 575\right) - 125 = 67$$

If both firms wait, the competitive dynamics of the next period sub-games are as follows:

Leader A will get a larger share ($S_A = 2/3$) at very high demand ($V^{++} = 1101$).

And it will preempt the full value at $V^{+-} = 300$. But they both will defer the investment at $V^{--} = 82$.

Hence, the deferral option value at $V^{+} = 575$ are:

$$Option_A^+ = \frac{0.4 \times \left(\frac{2}{3} \times 1101 - 125\right) + 0.6 \times (300 - 250)}{1.075} = 255$$

$$Option_B^+ = \frac{0.4 \times \left(\frac{1}{3} \times 1101 - 125\right) + 0.6 \times 0}{1.075} = 90$$

And the value of option at $V^{-} = 157$ are:

$$Option_A^- = \frac{0.4 \times (300 - 250) + 0.6 \times 0}{1.075} = 19$$

$$Option_B^- = \frac{0.4 \times 0 + 0.6 \times 0}{1.075} = 0$$

At $V^{+-} = 300$, $\left(\frac{1}{3} \times 300\right) - 125 = -25$. So, B decided not to make investment at that point.

Even if they both invest, firm A can have positive value because $\left(\frac{2}{3} \times 300\right) - 125 = 75$. Hence, A chose to invest alone to get its profit 50(= 300 – 250).

At $V^{--} = 82$, the investment cost is larger than their NPVs, so they chose not to invest.

At V^{-} (unfavorable condition), even if they each invest alone, this will result in negative value.

$NPV^{-} = 157 - 250 = -93$. So, the outcome of {W, I} or {I, W} is (0, –93) or (–93, 0).

If they both wait, Firm A will get full option value that results in the value of (19, 0).

When both A and B make shared investment,

$$NPV_A^- = \left(\frac{2}{3} \times 157\right) - 125 = -20 \qquad NPV_B^- = \left(\frac{1}{3} \times 157\right) - 125 = -73$$

The final outcomes of this strategy are as follows:

Table 5.1 Payoffs of Proprietary Investment with contrarian reaction

		Firm B Wait	Firm B Invest
Firm A	Wait	V^+ (255, 90) **V^- (19, 0)**	V^+ (0, 325) V^- (0, -93)
	Invest	V^+ (325, 0) V^- (-93, 0)	**V^+ (258, 67)** V^- (-20, -73)

As we have seen, both firms' Nash Equilibrium values appear when the pioneer firm chooses the sharing type of investment, following by the B with adaptable response at favorable market condition. On the other hand of unfavorable condition, their equilibrium result is at the {W, W} deferral investment type that makes the pioneer firm tough and hurts its competition; while the competitor's response is opposite under the Prisoners' Dilemma. Here, it is noted that most of the numerical calculation results are the nearest values of decimal places although some are taken from their exact values.

Calculation for NPVs at initial stage is:

$$NPV_A^* = -50 + \left(\frac{0.4 \times 258 + 0.6 \times 19}{1.075}\right) = 57$$

$$NPV_B^* = 0 + \left(\frac{0.4 \times 67 + 0.6 \times 0}{1.075}\right) = 25$$

(2) Proprietary benefits when the competitor's reaction is reciprocating

Proprietary strategic investment of firm A influences the equilibrium outcome on the second-stage game when competitive reactions are reciprocating, i.e. the competitor's reaction is similar to the action of the incumbent. By thus, proprietary benefits firm A 2/3 of stage-2 total value through its proprietary strategic investment, but because of competitor's reciprocating reaction, the total market value will be reduced by ¼. So, firm A's share is 2/3 × (3/4V) = 1/2V resulting in B's receiving: 1/3 × (3/4V) = 1/4V.

At a strategic profile {Invest, Invest}:

$$NPV_A^+ = \left(\frac{1}{2} \times 575\right) - 125 = 162.5 \qquad NPV_B^+ = \left(\frac{1}{4} \times 575\right) - 125 = 18.75$$

$$NPV_A^- = \left(\frac{1}{2} \times 157\right) - 125 = -46.5 \qquad NPV_B^- = \left(\frac{1}{4} \times 157\right) - 125 = -85.75$$

At strategic profile {Wait, Wait}:

$$Option_A^+ = \frac{0.4 \times \left(\frac{1}{2} \times 1101 - 125\right) + 0.6 \times (300 - 250)}{1.075} = 186$$

$$Option_B^+ = \frac{0.4 \times \left(\frac{1}{4} \times 1101 - 125\right) + 0.6 \times 0}{1.075} = 56$$

Finally, this strategy gives the following outcomes:

Table 5.2 Proprietary Benefits for reciprocating reaction

		Firm B: Wait	Firm B: Invest
Firm A	Wait	V^+ (186, 56) **V^- (19, 0)**	V^+ (0, 325) V^- (0, -93)
	Invest	V^+ (325, 0) V^- (-93, 0)	**V^+ (162.5, 18.75)** V^- (-46.5, -85.75)

Then, NPVs at initial stage are:

$$NPV_A^* = -50 + \left(\frac{0.4 \times 162.5 + 0.6 \times 19}{1.075}\right) = 21$$

$$NPV_B^* = 0 + \left(\frac{0.4 \times 18.75 + 0.6 \times 0}{1.075}\right) = 7$$

(3) The payoffs of shared strategic investment when competitor's reaction is contrarian

In this case, competitor B will take advantage over the pioneer A's accommodating position and so captures ½ of total market value.

Then, at a strategic profile {Invest, Invest}:

$$NPV_A^+ = NPV_B^+ = \left(\frac{1}{2} \times 575\right) - 125 = 162.5 \qquad NPV_A^- = NPV_B^- = \left(\frac{1}{2} \times 157\right) - 125 = -46.5$$

At a strategic profile {Wait, Wait}:

$$Option_A^+ = Option_B^+ = \frac{0.4 \times \left(\frac{1}{2} \times 1101 - 125\right) + 0.6 \times \left(\frac{1}{2} \times 300 - 125\right)}{1.075} = 172$$

$$Option_A^- = Option_B^- = \frac{0.4 \times \left(\frac{1}{2} \times 300 - 125\right) + 0.6 \times 0}{1.075} = 9$$

The outcomes are:

Table 5.3 Payoffs of Shared Strategic Investment with contrarian reaction

		Firm B: Wait	Firm B: Invest
Firm A	Wait	V^+ (172, 172) **V^- (9, 9)**	V^+ (0, 325) V^- (0, -93)
	Invest	V^+ (325, 0) V^- (-93, 0)	**V^+ (162.5, 162.5)** V^- (-46.5, -46.5)

Calculation for NPVs at time point zero is as follows:

$$NPV_A^* = -50 + \left(\frac{0.4 \times 162.5 + 0.6 \times 9}{1.075}\right) = 15$$

$$NPV_B^* = 0 + \left(\frac{0.4 \times 162.5 + 0.6 \times 9}{1.075}\right) = 65$$

(4) When the reaction is reciprocating, the payoffs of shared strategic investment

Because of competitor's reciprocating reaction, total market value increases by ¼ and they equally share this value. So, each firm owns a share of ½ × 5/4V = 5/8V.

Then at a strategic profile {Invest, Invest}:

$$NPV_A^+ = NPV_B^+ = \left(\frac{5}{8} \times 575\right) - 125 = 234$$

$$NPV_A^- = NPV_B^- = \left(\frac{5}{8} \times 157\right) - 125 = -27$$

At a strategic profile {W, W}:

$$Option_A^+ = Option_B^+ = \frac{0.4 \times \left(\frac{5}{8} \times 1101 - 125\right) + 0.6 \times \left(\frac{5}{8} \times 300 - 125\right)}{1.075} = 244$$

$$Option_A^- = Option_B^- = \frac{0.4 \times \left(\frac{5}{8} \times 300 - 125\right) + 0.6 \times 0}{1.075} = 23$$

The following outcomes of this strategy are resulted as:

Table 5.4 Sharing Benefits for reciprocation reaction type

		Firm B: Wait	Firm B: Invest
Firm A	Wait	V^+ (244, 244) **V^- (23, 23)**	V^+ (0, 325) V^- (0, -93)
	Invest	V^+ (325, 0) V^- (-93, 0)	**V^+ (234, 234)** V^- (-27, -27)

The initial NPVs' results are:

$$NPV_A^* = -50 + \left(\frac{0.4 \times 234 + 0.6 \times 23}{1.075}\right) = 50$$

$$NPV_B^* = 0 + \left(\frac{0.4 \times 234 + 0.6 \times 23}{1.075}\right) = 100$$

The followings are the calculation results of Second-Stage NPVs:

NPV_A (S, R) = 107 NPV_B (S, R) = 107

NPV_A (S, C) = 70 NPV_B (S, C) = 70

NPV_A (P, R) = 76 NPV_B (P, R) = 7.5

NPV_A (P, C) = 115 NPV_B (P, C) = 27

5.3.3 Simultaneous R&D Investment during the Production Stage

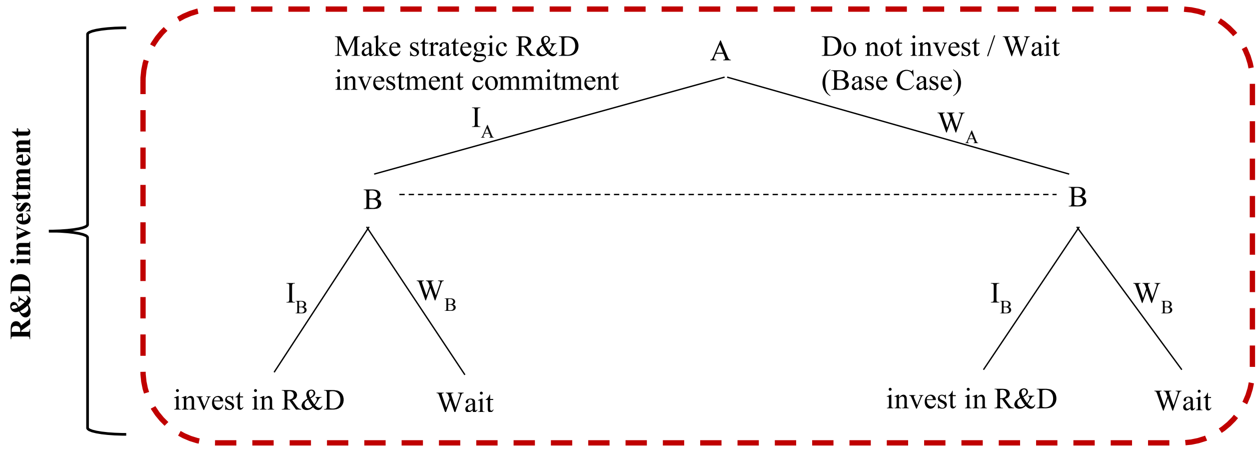
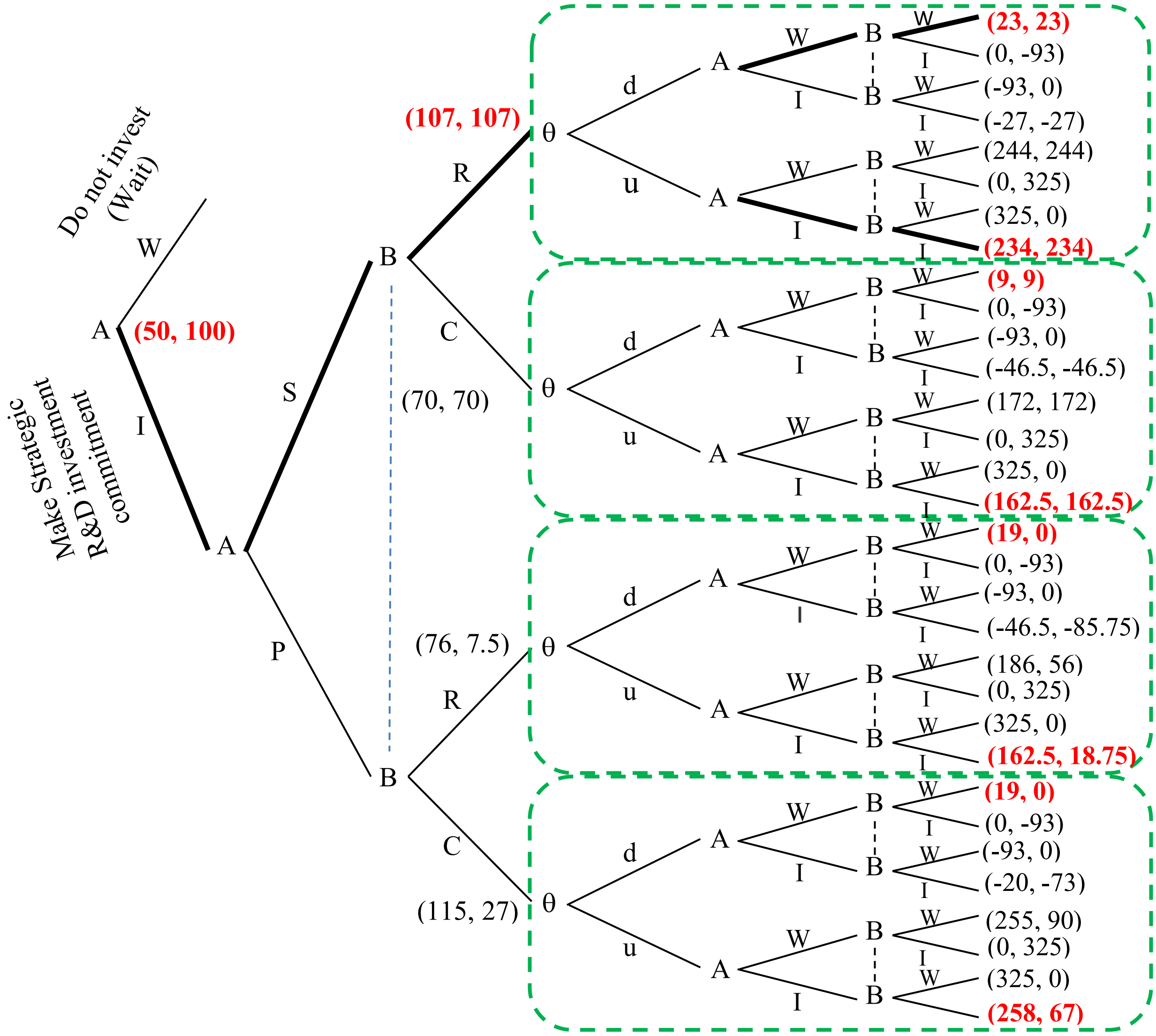


Figure 5.2 The Commercialization R&D Period Investment Game Tree

The above Figure 5.2 shows the commercialization R&D investment for both firms at the same time. After leader A had made the first stage investment as the pioneer, it will invite a competitor for the extension of new attractive project at the second stage, and firm B will invest in R&D investment as the follower.

In order to examine the results under different market structures, firm A will decide to practice one of the invest types – proprietary or shared according to the competitor's reactions – contrarian or reciprocating. In fact, a possibility which the strategies are practiced simultaneously also includes in this model. And there are different payoffs under different situations of high and low demands as described in Figure 5.3. Based on the final payoffs, the best choice for the optimum strategy is shown in bold type. And then, NPVs along this strategy can be calculated by backward discounting method.



Notes:

- A decides to invest first as the pioneer
- After period 1, A and B make simultaneous strategic investment.
- θ represents state of market demand or nature's up (u) and down (d) moves.

I = Invest, W = Wait, S = Shared, P = Proprietary, C = Contrarian, R = Reciprocating

$u = 1.92$, $d = 0.52$, $p = 0.4$, $k = 0.15$, $r_f = 0.075$, $V_0 = 300$, $I_0 = 50$, $I_1 = 250$

Figure 5.3 The Second Stage Development Payoffs under Different Market Structures

5.3.4 Explanation of Final Results

Figure 5.4 shows the first stage and the second stage development commercialization under different market structures. As shown in figure, at all final sub-games, if $\theta = u$, both firms should make immediate investment. But, $\theta = d$, they both should defer the investment to effectively apply the option value of waiting benefits as the flexible opportunity.

Moreover, if both firms invest simultaneously and B's reaction is contrarian, proprietary is better strategy for A. If A invest and B waits, no matter which reaction B choose because of preemption rights. Identically, if B invests and A waits, the result is totally opposite and thus, A's payoff is zero. It can be recognized that an early strategic investment commitment may not only result in future commercialization or growth opportunities but also may influence the competitor's future behavior in desirable of potentially damaging ways (Smit, Han T. J. & Trigeorgis, L., 2004).

Moreover, as an industrial cluster, they can mostly unite and cooperate to pursue a shared objective. When they wait and get the flexible option value, it is the best to practice shared strategy for A if B reacts with reciprocating. From the last payoffs in figure 5.4, the best choice among four strategies is expressed along bold line. So, the optimum R&D competitive strategy is to practice {Shared, Reciprocating} one. Their sub-game prefect Nash-equilibrium payoff is (107, 107) by mean of {I, I} at favorable and {W, W} at unfavorable market demand under the Prisoners' Dilemma. It is a proper way for expending their market share and save cost at high demand and; for retaining the flexibility at low demand to the firms of cooperation in extending the new attractive power generation project for energy industry.

For the Pareto Optimum solution, they can coordinate each other to get the largest market value of wait and see {W, W} under favorable condition. In order for the cooperation in power project and for industrial cluster formation, they can observe the situation of the market first, and then make decision to invest or wait. Finally, we can clearly see that Shared and Reciprocating R&D can bring a strategic advantage to capture a larger total market value in that case.

5.4 Summary

Experimental research shows that a joint research venture enabling the firms to cooperate in R&D based on reciprocity during the second stage can be the successful strategy for the future growth opportunity in the market. It can achieve the same research benefits with low costs by each firm that includes in the project. And it is possible for the cooperating firms to get the option value through wait and see under uncertain technology or demand to avoid or reduce competitive pressures from market innovation of new power project.

But in order to obtain these benefits, the firms may have to give up the possibility to gain a first-mover advantage on the other members of the alliance, especially at unfavorable condition. Furthermore, joint R&D ventures may have a more positive strategic effect in high-tech industry including new technological power generation project of energy industry. And a pioneer may have the chance to get shared profits from spill-over effects via the initial basic research investment.

CHAPTER 6

TWO-STAGE INVESTMENT MODEL FOR OPTIMIZING BETWEEN FLEXIBILITY AND COMMITMENT VALUES

6.1 Introduction

In this chapter, two-stage option-games model of strategic investment will be applied to analyze profits of enterprises in energy industrial cluster formation of new technological power generation project under different strategic profiles. On value creation of the firms, an innovation and high risky technology development such as energy industry of power project involves uncertainty. But to deal with it, a concept of real option is very effective for a measurement of the flexibility value as the expanded NPV created by a flexible decision-making and for a model design of flexibility built-in decision-making. Meanwhile, game theory is a useful method to measure and ensure the strategic value. Thus, this chapter develops option-games, a further integrated framework between real-options and game theory for analyzing investments in a more rigorous fashion.

The content examined in this chapter is that how to take the right action to gain more profits for firms in joint research venture cooperation in the cluster formation under the uncertain market environment. It will make the investment decision of "invest right now or wait / never invest" and, "share or propriety", which estimate the feasibility of project and minimize the loss.

Moreover, this chapter searches for a possibility of option-games as an experimental methodology to optimize a trade-off between flexibility and commitment concepts. Here flexibility is deal with uncertainty and; commitment is for a start-up of pioneering new technological power company with respect to energy generation and efficiency to compete with the existing power companies in Myanmar. In other words, ROA, the improvement of NPV with flexibility in investment development, examines the expanded the NPV to overcome the death-valley of start-up company successfully.

And on the other hand, Game Theory deals with the strategic NPV by relaxation of competition with existing rivals. The flexibility to wait until the decrease of uncertainty and the commitment to proactively pre-empt rivals have trade-off relationship each other. Then, it is necessary to decide the optimization between both functions. Specifically, in this chapter, the decision situations on each propriety or sharing strategy of developed results are examined at both quantitative and pricing competitions at duopoly. From these findings, clear conditions are searched for the strategic partnerships of cooperative development among various energy, especially electricity power companies, the concerned government and research institutes. Furthermore, it will seek the open innovation. The description for the trade-off between commitment and flexibility can be checked in Figure 6.1.

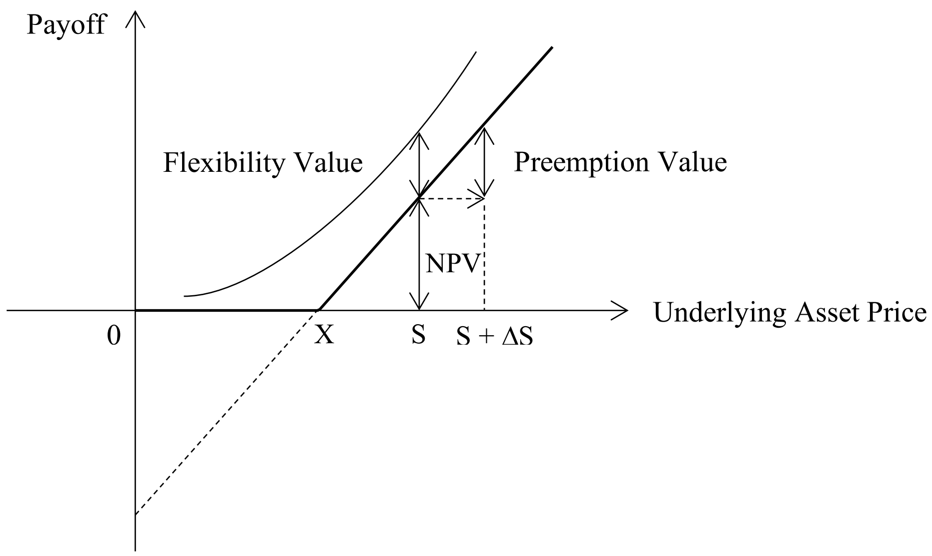


Figure 6.1 Trade-off between Commitment and Flexibility

6.2 Nature of Industry and Power Generation Project Model

The energy industry is characterized and followed by intense technological innovation and market competition. Many investment projects for power generation have multiple decision stages. It means that management can decide to abort, delay, reduce or expand the project after obtaining new information to resolve uncertainties of the project (Kodukula, P. and Papudesu, C., 2006). Regarding with the life cycle of energy generation projects specifically, a general business process with huge capital investment would include three phases: planning, construction and operation. Each of the phases has a go/no-go decision making with managerial flexibility and commitment to invest in the project. In the 25 years of operation, it is quite common for power plant to increase their plant capacity as expansion phase as in Figure 6.2.

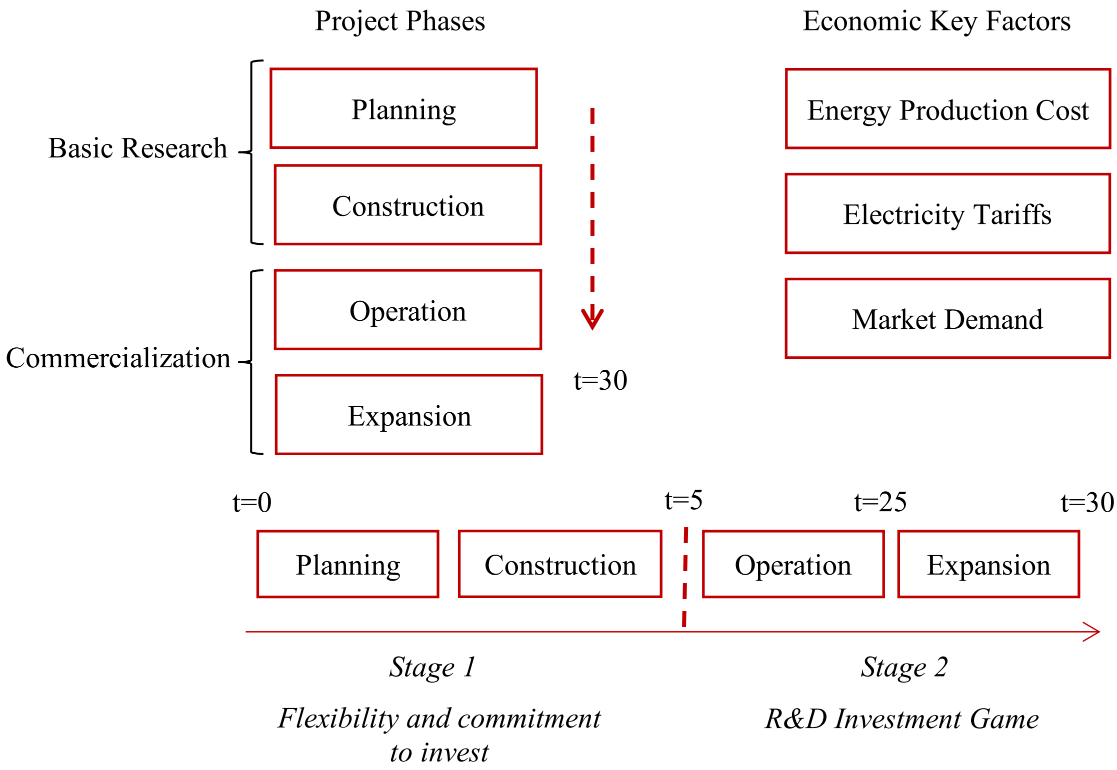


Figure 6.2 Power Generation Investment Model

6.3 Main Concepts and Framework of the Model

In an environment of high uncertainty, firms have an incentive to defer irreversible investment. However, early investment can be used to gain strategic advantages (Smit, Han T. J. & Trigeorgis, L., 2004). Pioneering strategies often involve a sequence of interdependent strategic investment decisions in early stage and subsequent commercial stages. If it decides to invest in commercialization, an early investment in R&D or a pilot plant in a new market may entail strategic value by improving the firm's competitive position.

In each strategy, the incremental flexibility value from postponing irreversible investments from the base case is traded off against the incremental commitment value from pre-committing investments to gain the strategic advantages. The value of the strategy is based on the expanded or strategic NPV criterion that incorporates both the early commitment effect on value from a firm's ability to influence its future competitive position, and the flexibility effect from strategic investment.

Expanded Net Present Value (NPV*) = [direct NPV + strategic value] + flexibility value

The basic setup is two-stage game which has two players, Player A, the existing power generation company in Myanmar market, and Player B, a new entrant into Myanmar energy market. At first stage (basic research), initial investment is made only by Player A as the pioneer or he will choose not to invest (called Base Case). During the second stage, the two players will make endogenous competition between them for the commercialization R&D investment. As the methodology for such game, the procedure is consisted of basically comparing both the value of flexibility by real options and the commitment value by game theory in a game tree and then, of utilizing both of them for the optimal strategic decision through the backward induction.

In other words, to evaluate flexibility and commitment value during second stage game, it can be divided into two cases in such game tree as:

(A) A base case of no R&D investment (i.e. continuing to use the existing technology in the first stage)

(B) The case of making R&D investment for the development of a new and upgrade of energy technological process to focus on more efficient generation

And then, to accommodate various market structures possibilities, the second stage itself is assumed to have two periods (1 & 2). At period 1, the market opens and the market structure is assumed to result in duopoly. At that time, either of two competing firms (A or B) can make subsequent commercial investments (period 2).

6.4 Model Building and Its Competitive Forms

Depending upon the market demand up or down moves, $\theta\{u, d\}$, each competitor's actions to invest (I) or defer(D) in the tree branch are $A\{I, D\}$ and $B\{I, D\}$. If both firms decide to invest simultaneously {I, I}, the game ends in a Cournot Nash equilibrium (C). The nature θ moves again and the game is repeated if they both choose to defer {D, D} the investment under the down moves. And if one firm invests first, he acts as a Stackelberg Leader (S_L) or Monopolist (M). The competitor is Stackelberg Follower (S_F) if he decides to invest later or he can decide to abandon (A). This comparison style is applied to both quantitative and pricing competition modes.

At a quantitative competition for the base case (no R&D investment), each NPV is compared in the Cournot Nash equilibrium, Stackelberg Leader/Follower equilibrium and Monopoly. In pricing competition for the base case, comparisons of NPVs are made among the Bertrand Nash equilibrium, Stackelberg Leader/Follower equilibrium and monopoly. After that, a comparison of NPVs between two players is made by a proprietary or sharing strategy of this R&D development investor at quantitative and pricing competition.

The different sets of actions of the two firms result in project value payoffs at the end of each branch (node) in the binomial valuation tree, representing the equilibrium outcomes of different competitive market structure games. If the first stage strategic investment is made, the end nodes of market outcomes are influenced by this investment of proprietary or shared relative to the base case.

Quantity vs. Price Competition Concept

Quantity Competition

Its concept is down-sloping (contrarian) reaction or strategic substitutes. In contrarian quantity competition, an aggressive firm that invests early, acting as a Stackelberg Leader can acquire a larger share of the market.

Price Competition

Up-sloping (reciprocating) reaction or strategic complements is price competition concept. Under the reciprocating pricing competition, a Stackelberg price leader would choose a price on the competitor's reaction function that maximizes its profit value. In the case of the accommodating price leader, it needs not a first-mover advantage, as both firms can be better off setting higher prices than when they invest at the same time.

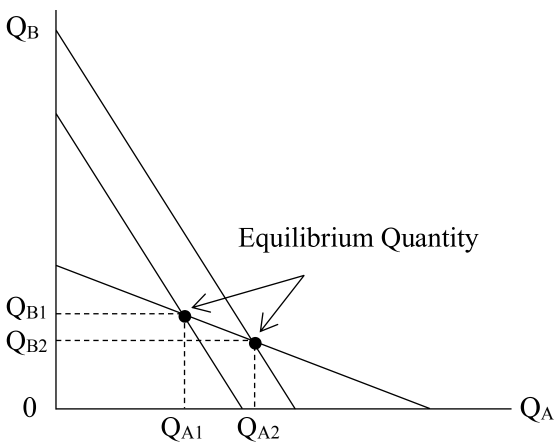


Figure 6.3 Strategic Substitute Type of Type of Quantity Competition

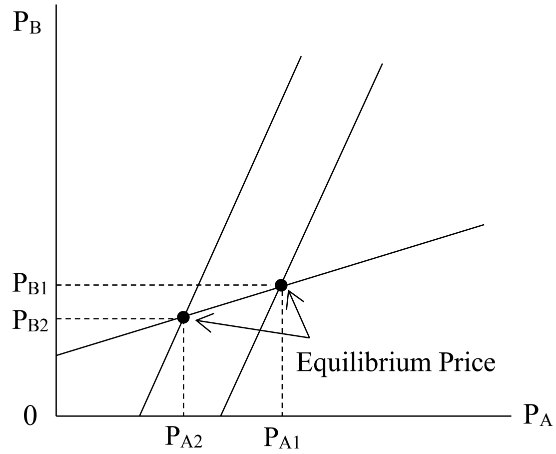
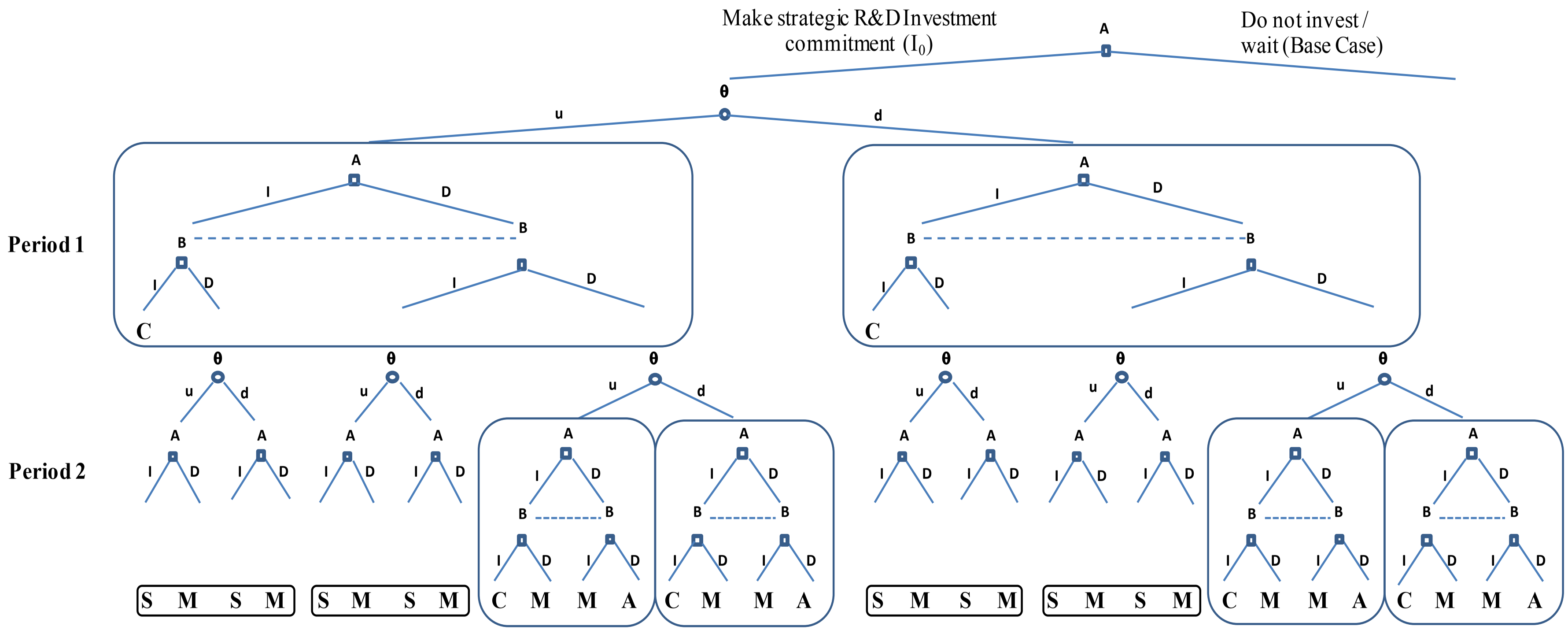


Figure 6.4 Strategic Complement Price Competition



Notes: A or B (□) represents a decision to invest (I) or defer (D) by firm A or B. θ (○) represents the state of market demand or nature᾿s up (u) and down (d) moves.

The combination of competitive decisions (A or B) and market demand moves (θ) may result in one of the following market structure game outcomes:

C : Cournot Nash quantity / price competition equilibrium outcome

S : Stackelberg Leader (S_L) /Follower (S_F) outcome

M : Monopolist outcome

A : Abandon (0 value)

D : Defer / stay flexible (option value)

Figure 6.5 Two-Stage Investment Game in Extensive Form

6.5 Model Analysis and Valuation of Competitive Strategies

Under this section, numerical results are calculated for the base case, proprietary strategy and sharing strategy of development findings. In each case, the competitive strategy of each firm consists of mapping the information set about its competitor's actions and the development of market demand (u or d moves in θ) to an optimal investment action by the firm.

6.5.1 Valuation for Model of Quantity Competition

In order to observe more possibilities under different strategic profiles, all kinds of market structures under quantity competition model will be analyzed first as in the successive procedures. Calculations for this model is done by the following formulas.

General equation for Cournot-Nash equilibrium (C) is:

$$NPV_i(C) = \frac{\left(\theta_t - 2c_i + c_j\right)^2}{9\text{k}} - I_1 \qquad (6-1)$$

In 2nd period, general equation of monopoly (M) is:

$$NPV_i(M) = \frac{(\theta_t - c_i)^2}{4\text{k}} - I_1 \qquad (6-2)$$

General equation of the Stackelberg Leader equilibrium is:

$$NPV_i(S_L) = \frac{(\theta_t - 2c_i + c_j)^2}{8\text{k}} - I_1 \qquad (6-3)$$

General equation of the Stackelberg Follower equilibrium is:

$$NPV_i(S_F) = \frac{\left(\theta_t - 3c_j + 2c_i\right)^2}{16\text{k}} - I_1 \qquad (6-4)$$

At 1st period, the general equation of the monopoly (M) is:

$$NPV_i(M) = \frac{pV_u + (1-p)V_d}{1 + r_f} - I_1 + \frac{\pi M}{1 + K} \qquad (6-5)$$

Meanwhile monopolist profit limited only for 1st period is defined by:

$$\pi M = \frac{(\theta_t - c_A)^2}{4} \quad (6-6)$$

As for the general equation of deferment (D) is:

$$NPV_i(D) = \frac{pNPV_u + (1-p)NPV_d}{1+r_f} \quad (6-7)$$

By the backward binomial risk-neutral valuation, the valuation for expected equilibrium at the first stage (t = 0) can be done by:

$$PV_i * = \frac{pPV_u + (1-p)PV_d}{1+r_f} \quad (6-8)$$

(A) Base Case Illustration

To illustrate the valuation process of this case, consider the game where the pioneer firm A can make the decision to invest its first stage initial R&D investment that results in a deterministic operating cost advantage in the second stage. Its commercialization (second) stage investment, I_1 is USD300M. When they make endogenous competition during this stage, either firm A or B can invest in this commercialization projects, depending on subsequent random demand moves with its initial demand θ_0 = 30 (in ten thousand units) and with its binomial parameters up and down moves of u = 1.21 and d = 1/u = 0.83. The risk-adjusted discount rate, k is 0.15 while risk-free rate, r_f is 0.075. As firm A choose not to make its basic R&D investment, the two firms would have the symmetric second stage operating costs based on first stage old technology, c_A = c_B = 10.

The constant asset (dividend-like) payout yield is:

$$\delta = \frac{k}{1+k} = \frac{0.15}{1.15} = 0.13$$

Then, its risk-neutral probabilities can be calculated as:

$$p = \frac{(1+r-\delta)-d}{u-d} = \frac{(1+0.075-0.13)-0.83}{1.21-0.83} = 0.3$$

where, $u = \exp(\sigma\sqrt{\Delta t}\,)\, and\, d = \exp(-\sigma\sqrt{\Delta t}\,)$ with volatility parameter, σ=0.19 and Δt = 1.

1) In the base case at the second period, when demand is up and both A and B select D (Defer) first and I (Invest) next, and C is attained.

So, *NPV* of A at $\theta = u$ is: $NPV_A\ (C) = NPV_A$ (uDuI, uDuI) is:

$$NPV_A(C) = \frac{(\theta_0 \times u^2 - 2 \times C_A + C_B)^2}{9k} - I_1 = \frac{(30 \times 1.21^2 - 2 \times 10 + 10)^2}{9 \times 0.15} - 300 = 552.422 \ldots \cong 552$$

2) Calculation for $NPV_A\ (M) = NPV_A$ (uDuI, uDuD) is:

$$NPV_A(M) = \frac{(\theta_0 \times u^2 - C_A)^2}{4k} - I_1 = 1617.949 \ldots \cong 1618$$

3) Calculation for $NPV_A\ (S_L) = NPV_A$ (uIuI, uDuI) is:

$$NPV_A(S_L) = \frac{(\theta_0 \times u^2 - C_A)^2}{8k} - I_1 = 658.975 \ldots \cong 659$$

4) Calculation for $NPV_A\ (S_F) = NPV_A$ (uDuI, uIdI) is:

$$NPV_A(S_F) = \frac{(\theta_0 \times u^2 - 3C_B + 2C_A)^2}{16k} - I_1 = 179.487 \ldots \cong 179$$

5) Calculation for Abandonment (*A*) is: $NPV_A\ (A) = 0$

So, $NPV_A\ (A) = NPV_A$ (uDuD, uDuD) = 0

And then, for the alternate demand of up and down($\theta = u$ or d) and for the downside demand ($\theta = d$), we can find all equilibrium results under all market structures of Cournot Nash equilibrium (C), Stackelberg Leader (S_L) and Stackelberg Follower (S_F), Monopoly (M) and Abandon (A) by using above same fashion formulas.

After that, we can solve for the first period outcome during the second stage by sharing the same equation with the second period for Cournot Nash equilibrium (C) for $\theta = u$,

1) Case calculation for $NPV_A\ (C) = NPV_A$ (uI, uI) is:

$$NPV_A(C) = \frac{(\theta_0 \times u - 2 \times C_A + C_B)^2}{9k} - I_1 = \frac{(30 \times 1.21 - 2 \times 10 + 10)^2}{9 \times 0.15} - 300 = 212.362 \ldots \cong 212$$

2) At first period, monopolized profit (πM) and NPV_A (M) = NPV_A (uI, uD) are calculated as:

$$\pi M = \frac{(\theta_0 \times u - C_A)^2}{4} = 172.922 \ldots \cong 173$$

$$NPV_A(M) = \frac{0.3 \times 959 + (1 - 0.3) \times 667}{1 + 0.075} - 300 + \frac{173}{1 + 0.15} = 554.261 \ldots \cong 554$$

3) The calculation for NPV_A (D) = NPV_A (uD, uI) is:

$$NPV_A(D) = \frac{0.3 \times 179 + (1 - 0.3) \times 0}{1 + 0.075} = 51.418 \ldots \cong 51$$

Then, for NPV_A (D) = NPV_A (uD, uD) is:

$$NPV_A(D) = \frac{0.3 \times 552 + (1 - 0.3) \times 0}{1 + 0.075} = 158.254 \ldots \cong 158$$

Finally, from the backward binomial risk-neutral valuation, the expected equilibrium value at the first stage (t = 0) is:

$$PV_A^* = \frac{0.3 \times 212 + (1 - 0.3) \times 0}{1 + 0.075} = 60.836 \ldots \cong 61$$

The base case value of no R&D investment is symmetric for both firms. So, (61, 61) is for both firms (pioneer firm, A and new entrant, B) and the results of game tree is exhibited in Figure 6.6.

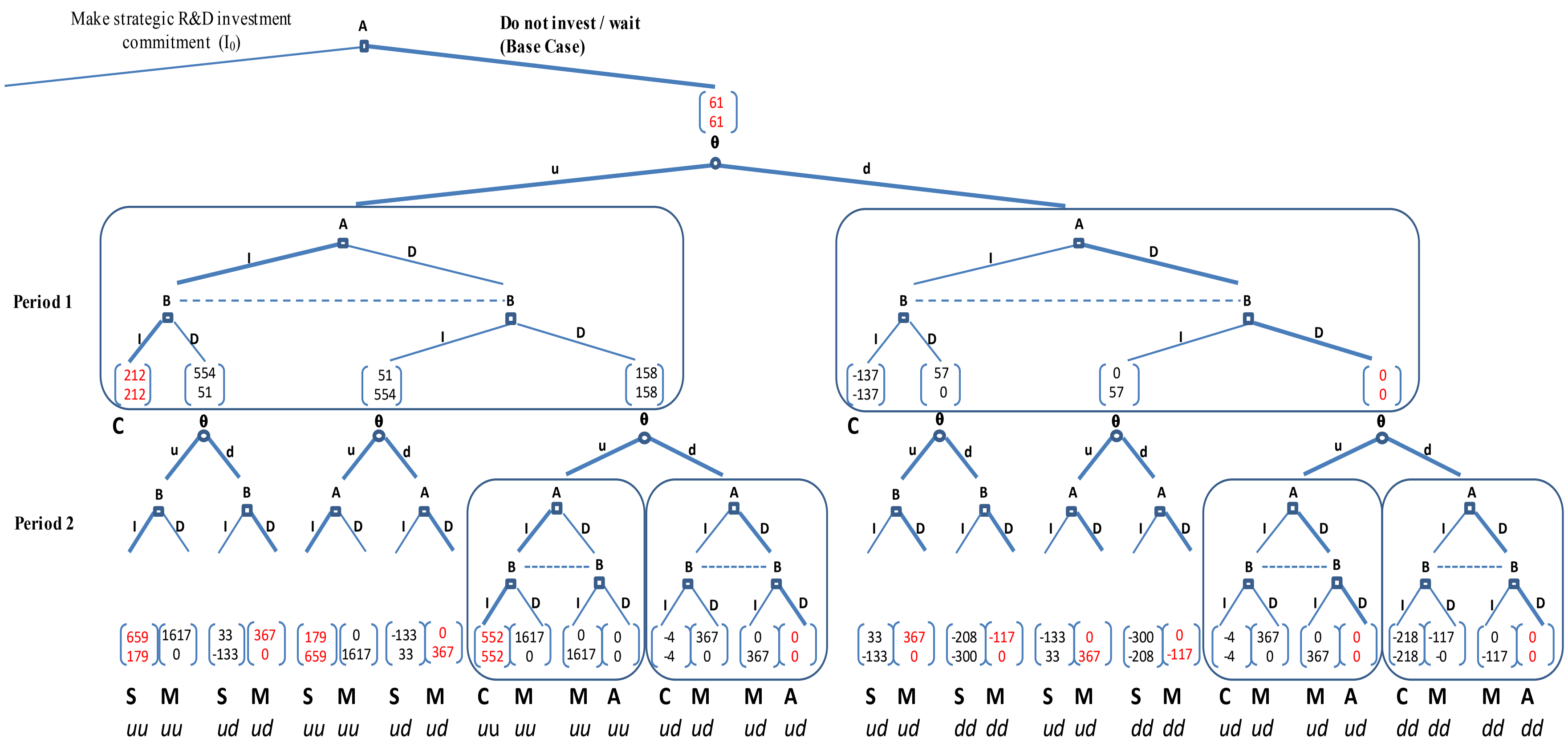


Figure 6.6 Game Tree of Base Case Model

(B) The Case of Making R&D Investment under Quantity Competition

When firm A decides to make a strategic R&D investment, two different strategies can result depending on whether the resulting cost benefits of the second stage commercialization project are propriety (asymmetric costs) or shared (symmetric).

(i) Proprietary Investment Strategy

Assume that the pioneer firm A can enhance its relative competitive position by making a basic research investment of I_0 = USD125M in a more cost-efficient technological process. As a consequence, pioneer A will achieve a degree of propriety operating cost reduction that is 0.5 times during the second stage (t = 1). And thus, there are asymmetric costs between pioneer firm A and follower B. Specifically, the operating cost of firm A is reduced from 10 to 5 (c_A =5). But it remains at 10 for firm B (c_B = 10). And the other values also remain the same as the base case. All valuation results can be solved by the similar fashion as in the base case. The calculated numerical equilibrium values can be checked in the tree diagram below.

As the result of this strategy, the rival firm without initial investment (B) tends to decrease the NPV with the expansion of the cost effect of the pioneering firm (A) as an initial investor. In this way, the bigger the cost reduction effect, the more advantage for the pioneer firm against its rival company is possible.

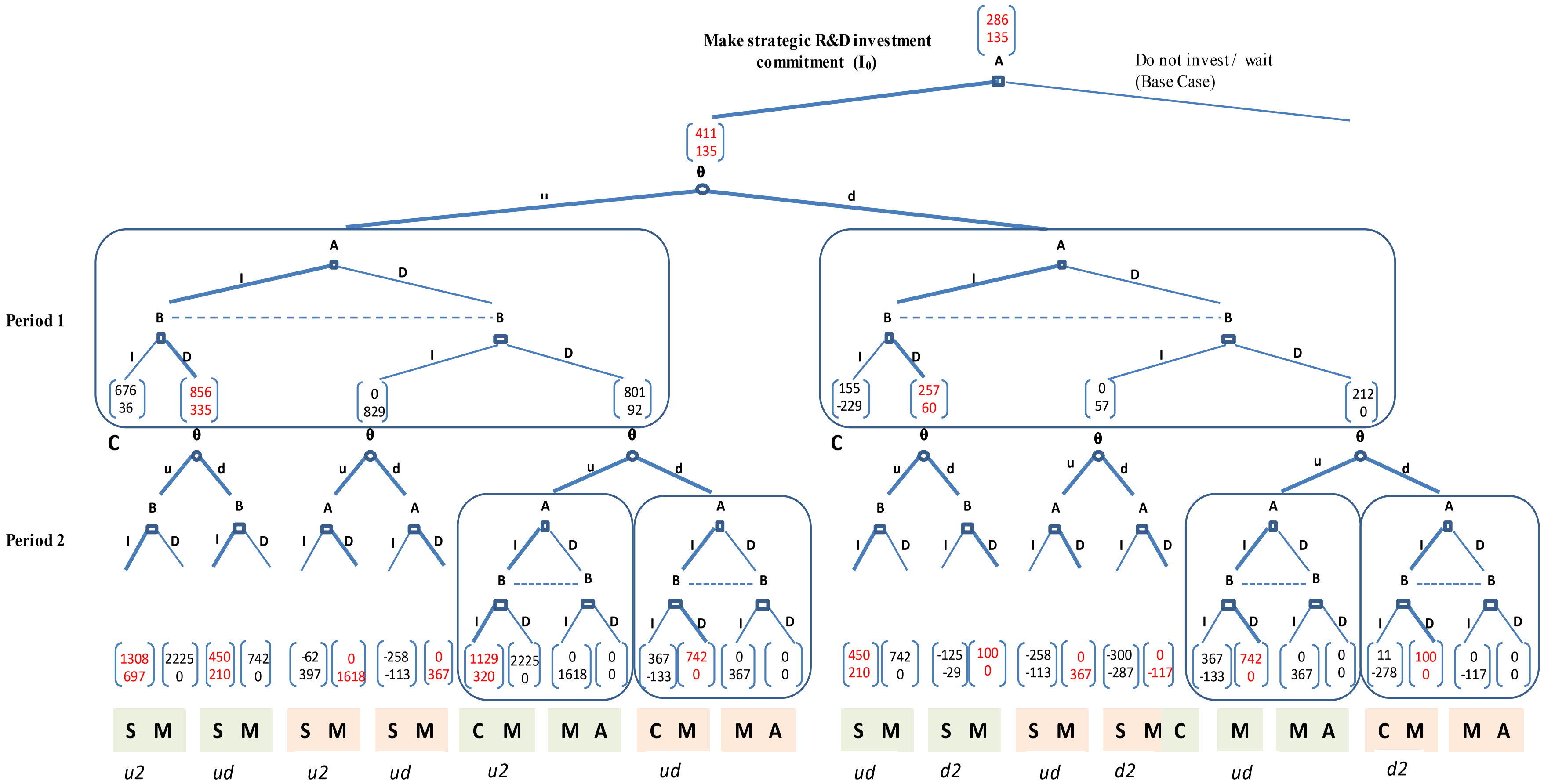


Figure 6.7 Propriety Investment Model in Two-Stage Game

(ii) Shared Strategy in the Case of Making R&D Investment

Under this strategy, the operating costs are symmetric for both firms. There is no mean to benefit from initial investment and pioneering firm (A) shares development findings with the rival firm (B). Because of more cost-effective technology by firm A, they can exploit the reduction in their costs ($c_A = c_B = 5$). All other values do not change. And the valuation method for all results is same as the base case. Figure 6.8 illustrates the symmetric shared case and all valuation equilibrium results can be seen in it.

The open market R&D expenditure strengthens the competitor's strategic position and enhances its incentive to respond aggressively in the future. As a consequence of this strategy, the pioneer firm A becomes disadvantageous compared with its base case of no investment.

The result comparison of above three strategies are shown in Figure 6.9 and Table 6.1 in the purpose of checking them easily.

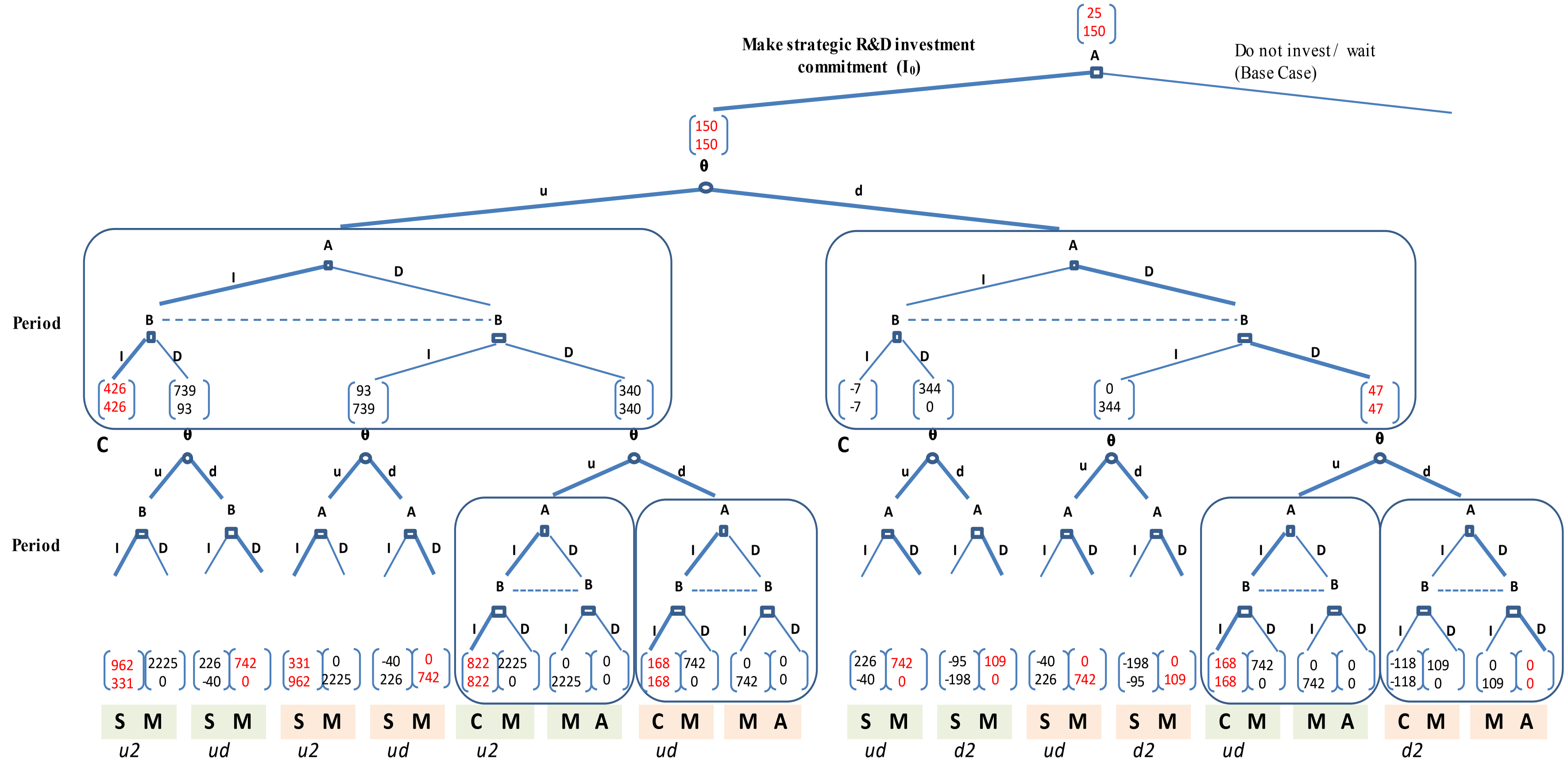
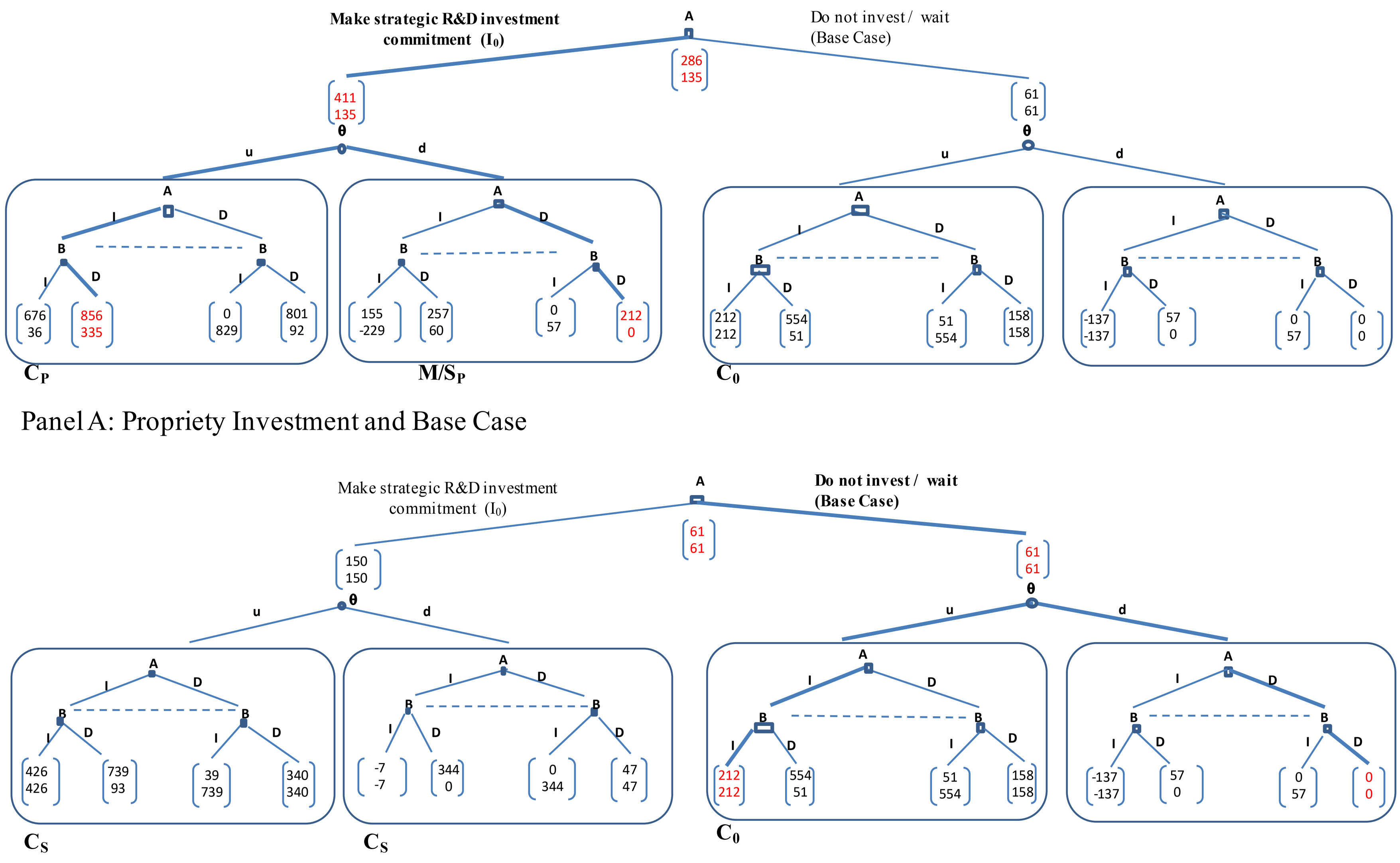


Figure 6.8 Shared Strategic Investment Game in Extensive Form



Panel A: Propriety Investment and Base Case

Panel B: Shared investment and Base case

Figure 6.9 Optimal Actions between Base Case and R&D Investment under Quantity Competition

Table 6.1 Comparison among the Results of Three Competitive Strategies

	Base Case	Propriety	Shared
Pioneer A	61	**286**	25
Follower B	61	**135**	150

Proprietary Investment vs. Base Case (no investment)

Panel A of Figure 6.9 summarizes the valuation results for the first period of R&D development phase (stage 2) and basic research phase (stage 1) of proprietary R&D case and base case. The tree branch values are solved by usual backward induction method. The highlighted bold lines along each tree indicate the optimal actions among the equilibrium paths. In this case, firm A may use the up-front R&D investment to strengthen its strategic position in second stage. Pioneer firm A should make the basic research investment in first stage. It should then make a follow-on commercialization investment in second stage for high demand and it should retain a flexible wait-and-see position for the lower level of demand.

The asymmetry (propriety) investment clearly influences each firm's reaction function and end-node equilibrium payoffs values. So, the propriety R&D investment causes the changing of base case Cournot equilibrium outcome from C_0 to C_p and increasing firm A's relative market share.

Share Investment vs. Base Case

As seen in Panel B of Figure 6.9, firm A should not invest in R&D, but should rather defer investment while retaining its flexibility and; attaining the base case equilibrium values of (61, 61). In summary, investing in R&D may create a strategic disadvantage for firm A by paying the cost of creating valuable investment opportunities for competition or by enhancing the competitor's ability and incentive to respond aggressively in the future.

6.5.2 Valuation for Model of Pricing Competition

Now we move to pricing competition model. Consider now a large expenditure on strategic goodwill investment on the purpose of pursuing the larger market demand in an environment of reciprocating competition. In this competition, price settings by competition firms are strategic complements. Firm A can make no investment in stage 1 or it can make the pioneering investment. During second stage, it can achieve a proprietary or a shared advantage via the strategic goodwill investment.

General Equations for Equilibrium Prices and Equilibrium NPVs

(A) Equations for the 2nd period during the 2nd stage

(1) Nash Equilibrium Price and NPV

$$PN_i = \frac{\{2b(\theta_{it} + b \times c_i) + dd(\theta_{jt} + b \times c_j)\}}{4b^2 - dd^2} \qquad (6-9)$$

$$NPV_i(N) = \frac{(PN_i - c_i)(\theta_{it} - b \times PN_i + dd \times PN_j)}{k} - I_1 \qquad (6-10)$$

(2) Monopoly Equilibrium Price and NPV

$$PM_i = \frac{\theta_{it} + c_i(b - dd)}{2(b - dd)} \qquad (6-11)$$

$$NPV_i(M) = \frac{(PM_i - c_i)\theta_{it}}{k} - I_1 \qquad (6-12)$$

(3) Stackelberg Leader and Follower Equilibrium Prices and NPVs

$$PSL_i = \frac{\{2b(\theta_{it} + b \times c_i) + dd(\theta_{jt} + b \times c_j - dd \times c_i)\}}{4b^2 - 2dd^2} \qquad (6-13)$$

$$NPV_i(SL) = \frac{(PSL_i - c_i)(\theta_{it} - b \times PSL_i + dd \times PSF_j)}{k} - I_1 \qquad (6-14)$$

$$PSF_i = \frac{\{2b \times \theta_{it} + dd(2b - dd^2)c_i + (2b + dd)(2b - dd)(\theta_{jt} + b \times c_j)\}}{4b(2b^2 - 2dd^2)} \qquad (6-15)$$

$$NPV_i(SF) = \frac{(PSF_i - c_i)(\theta_{it} - b \times PSF_i + dd \times PSL_j)}{k} - I_1 \qquad (6-16)$$

(4) The Abandonment Equation

$$NPV_i\,(A) = 0 \qquad (6-17)$$

(B) General Equations for the 1st period during the 2nd stage

(1) Nash Equilibrium *NPV*

$$NPV_i(N) = \frac{(PN_i - c_i)(\theta_{it} - b \times PN_i + dd \times PN_j)}{k} - I_1 \qquad (6-18)$$

(2) Monopoly Equilibrium *NPV*

$$NPV_i(M) = \frac{p \times V_u + (1-p) \times V_d}{1+r_f} - I_1 + \frac{\pi M}{1+k} \qquad (6-19)$$

$$\pi M = (PM_{it} - c_i)\theta_{it} \quad \text{(Monopolist profit limited only for the first period)} \qquad (6-20)$$

(3) General Equation for the Deferment

$$NPV_i(D) = \frac{p \times NPV_u + (1-p) \times NPV_d}{1+r_f} \qquad (6-21)$$

Finally, from the backward binomial risk-neutral valuation, the expected equilibrium value at the 1st stage ($t = 0$) can be calculated as follow:

$$PV_i{*} = \frac{p \times PV_u + (1-p) \times PV_d}{1+r_f} \qquad (6-22)$$

(A) Valuation for the Base Case

To evaluate this case, the following numerical and parameter values are specified first. There is commercialization (second) stage development investment, I_1 = USD300M (in million). Risk-adjusted discount rate, $k = 0.15$ and risk-free rate, $r_f = 0.075$. Initial demand, $\theta_{0A} = \theta_{0B} = 45$ (in ten thousand units). The binomial parameter up-ratio, $u = 1.21$ and down state value, $d = 0.83$ with their volatility parameter, $\sigma =$ 19%. Price sensitivity coefficients, $b = 6$, $dd = 3$, second stage operating costs, $c_A = c_B = 10$. Risk neutral probability as the same condition with quantitative competition, $p = 0.3$.

1) Bertrand Nash Equilibrium price and *NPV* of A

$$PN_A = \frac{2 \times 6(45 + 6 \times 10) + 3(45 + 6 \times 10)}{4 \times b^2 - 3^2} = 11.666 \ldots \cong 12$$

NPV at $\theta = u$ for the 2nd Period during the 2nd stage:

NPV_A (N) = NPV_A (uDuI, uDuI)

$$NPV_A(N) = \frac{(1.21^2 \times 12 - 10)(45 \times 1.21^2 - 6 \times 1.21^2 \times 12 + 3 \times 1.21^2 \times 12)}{0.15} - 300$$

$$= 391.167 \ldots \cong 391$$

2) Monopoly Equilibrium Price and *NPV* of A

$$PM_A = \frac{45 + 10(6 - 3)}{2(6 - 3)} = 12.5$$

NPV_A (M) = NPV_A (uIuI, uDuD)

$$NPV_A(M) = \frac{(1.21^2 \times 12.5 - 10)45 \times 1.21^2}{0.15} - 300 = 3346.149 \ldots \cong 3346$$

3) Stackelberg Leader and Follower Equilibrium Prices and *NPV*s of A

$$PSL_A = \frac{2 \times 6(45 + 6 \times 10) + 3(45 + 6 \times 10 - 3 \times 10)}{4 \times 6^2 - 2 \times 3^2} = 11.785 \cong 12$$

$$PSF_A = \frac{2 \times 6 \times 3 \times 45 + 3(2 \times 6 - 3^2)10 + (2 \times 6 + 3)(2 \times 6 - 3)(45 + 6 \times 10)}{4 \times 6(2 \times 6^2 - 3^2)}$$

$$= 10.505 \ldots \cong 11$$

NPV_A (SL) = NPV_A (uIuI, uDuI)

$$NPV_A(SL) = \frac{(1.21^2 \times 12 - 10)(45 \times 1.21^2 - 6 \times 1.21^2 \times 12 + 3 \times 1.21^2 \times 11)}{0.15} - 300$$

$$= 110.997 \cong 111$$

NPV_A (SF) = NPV_A (uDuI, uIuI)

$$NPV_A(SF) = \frac{(1.21^2 \times 11 - 10)(45 \times 1.21^2 - 6 \times 1.21^2 \times 11 + 3 \times 1.21^2 \times 12)}{0.15} - 300$$

$$= 609.885 \cong 610$$

4) The Abandonment *NPV* of A

NPV_A (A) = NPV_A (uDuD, uDuD) = 0

And then, for the alternate demand of up and down($\theta = u$ or d) and for the downside demand ($\theta = d$) during the 2nd period, we can find all equilibrium results under all market structures of Bertrand Nash equilibrium (N), Stackelberg Leader (S_L) and Stackelberg Follower (S_F), Monopoly (M) and Abandon (A) by using same formulas above.

After that, we can solve for the 1st period outcome during the 2nd stage as follows at $\theta = u$:

1) NPV_A (N) = NPV_A (uI, uI)

$$NPV_A(N) = \frac{(1.21 \times 12 - 10)(45 \times 1.21 - 6 \times 1.21 \times 12 + 3 \times 1.21 \times 12)}{0.15} - 300$$

$$= 32.077 \cong 32$$

2) NPV_A (M) = NPV_A (uI, uD)

$$NPV_A(M) = \left(\frac{0.3 \times 411 + (1 - 0.3) \times 750}{1 + 0.075}\right) - 300 + \left(\frac{(1.21 \times 12.5 - 10)45 \times 1.21}{1 + 0.15}\right)$$

$$= 542.572 \cong 543$$

3) NPV_A (D) = NPV_A (uD, uI)

$$NPV_A(D) = \left(\frac{0.3 \times 610 + (1 - 0.3) \times 0}{1 + 0.075}\right) = 175.873 \cong 176$$

4) NPV_A (D) = NPV_A (uD, uD)

$$NPV_A(D) = \left(\frac{0.3 \times 610 + (1 - 0.3) \times 0}{1 + 0.075}\right) = 112.801 \cong 113$$

Similarly, we can calculate for $\theta = d$ state equilibrium values. Finally, the expected equilibrium value at the 1st stage ($t = 0$):

$$PV_A^* = \left(\frac{0.3 \times 113 + (1 - 0.3) \times 0}{1 + 0.075}\right) = 32.528 \cong 33$$

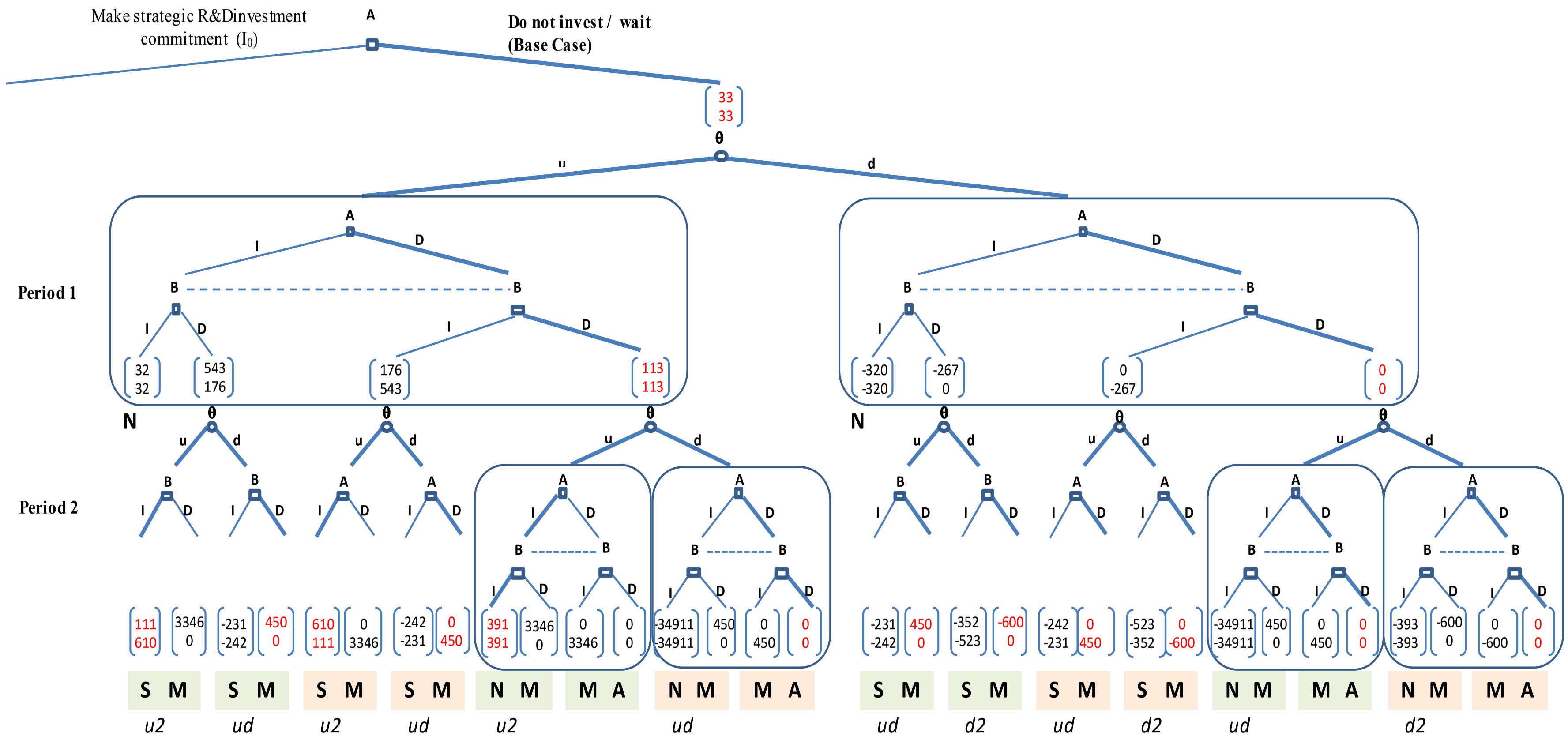


Figure 6.10 Base Case of Two-Stage Game under Different Market Structures

The calculated results and binomial tree diagram of the base case can be seen in the figure above. The base case value of no R&D investment is symmetric for both firms. So, (33, 33) is for firm (A, B).

(B) The Case of Making R&D Investment under Complementary Pricing Competition

(i) Proprietary Strategy

During the 2nd stage (t = 1), pioneer A will advantage the propriety benefits of a strategic goodwill investment for a larger market share of pricing competition because of its first stage investment (I_0 = USD125M). So, there are asymmetric demand between pioneer firm A and follower B. Specifically, the market demand of firm A will develop to 48 ($\theta_A = 48$) (in ten thousand units). But it reduces to 42 for firm B (θ_B = 42) (in ten thousand units). And the other values remain the same as the base case. All valuation results can be solved by the similar fashion as in the base case. The calculation result for all numerical equilibrium values can be checked in tree diagram of Figure 6.11.

As the result of this strategy, the rival firm without initial investment (B) tends to decrease the NPV with the expansion of the market demand share of the pioneering firm (A) as an initial investor.

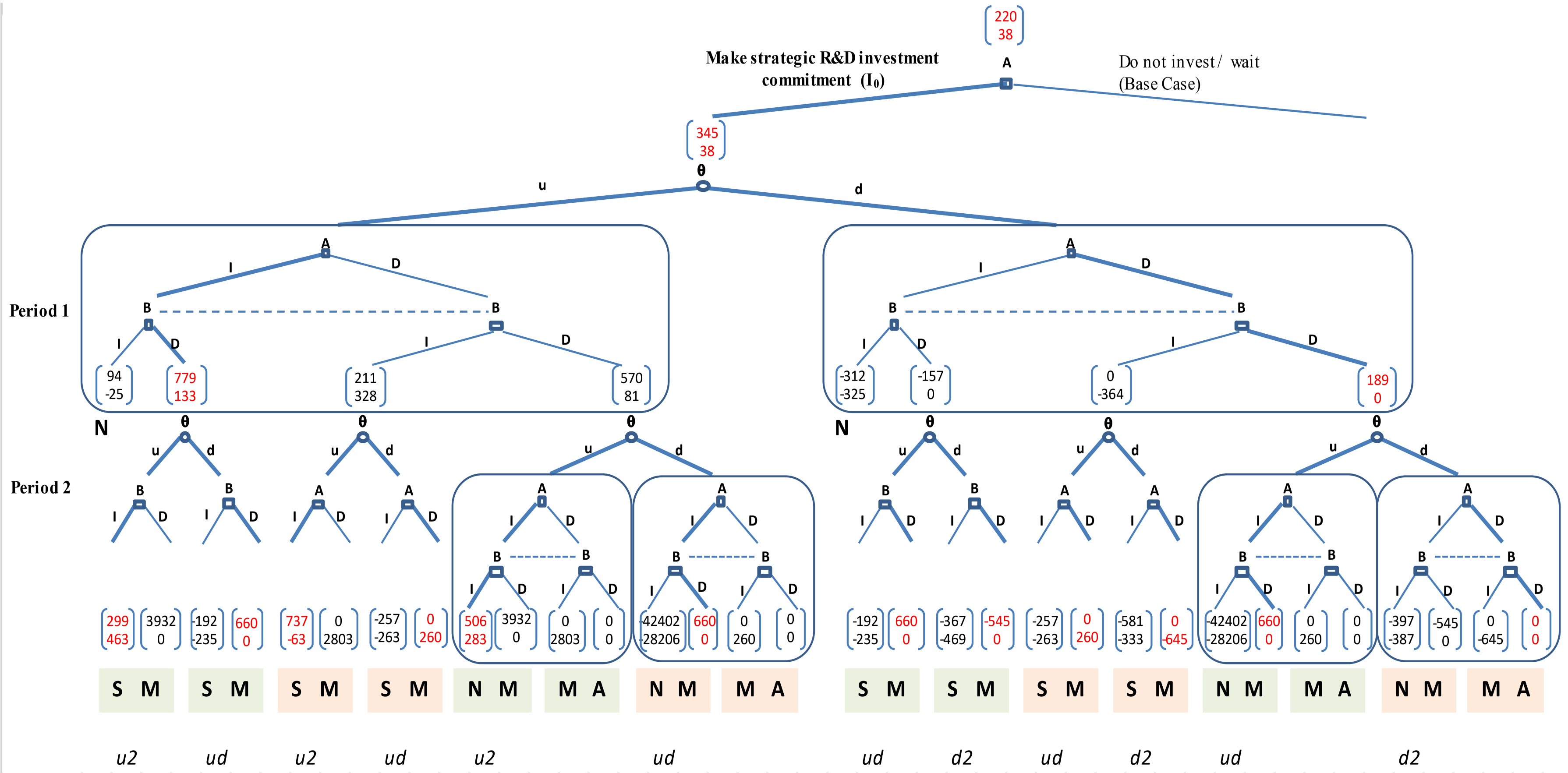


Figure 6.11 Propriety Investment of Two-Stage Strategic Game for Complementary Competition

(ii) Shared Strategy under the Case of Making R&D Investment in Pricing Competition

In this case, the market demands are symmetric for both firms. There is no mean to benefit from initial investment and thus, pioneering firm (A) has the ability to share development findings with the rival firm (B). So, they can generate the larger demand for both (θ_A = θ_B = 48) (in ten thousand untis). All other values do not change. And the valuation method for all results is same as the base case. All numerical results are illustrated in tree diagram of this strategy below.

As a consequence of this strategy, both of the pioneer firm A and follower B become advantageous compared with its base case of no investment.

The comparison of the equilibrium results between Base Case and Propriety or Shared strategy under pricing competition can be checked in the following Figure 6.13 and Table 6.2.

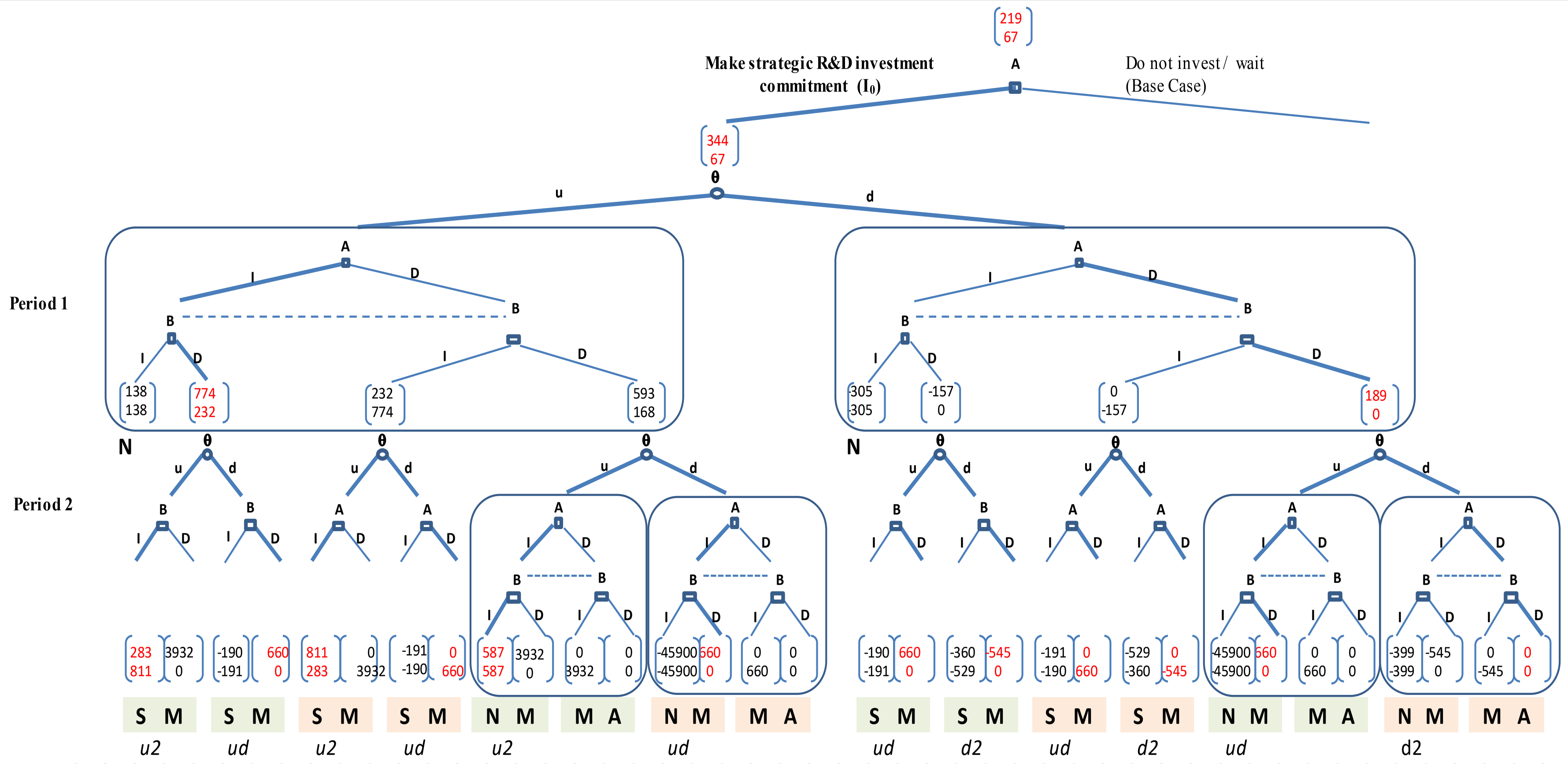
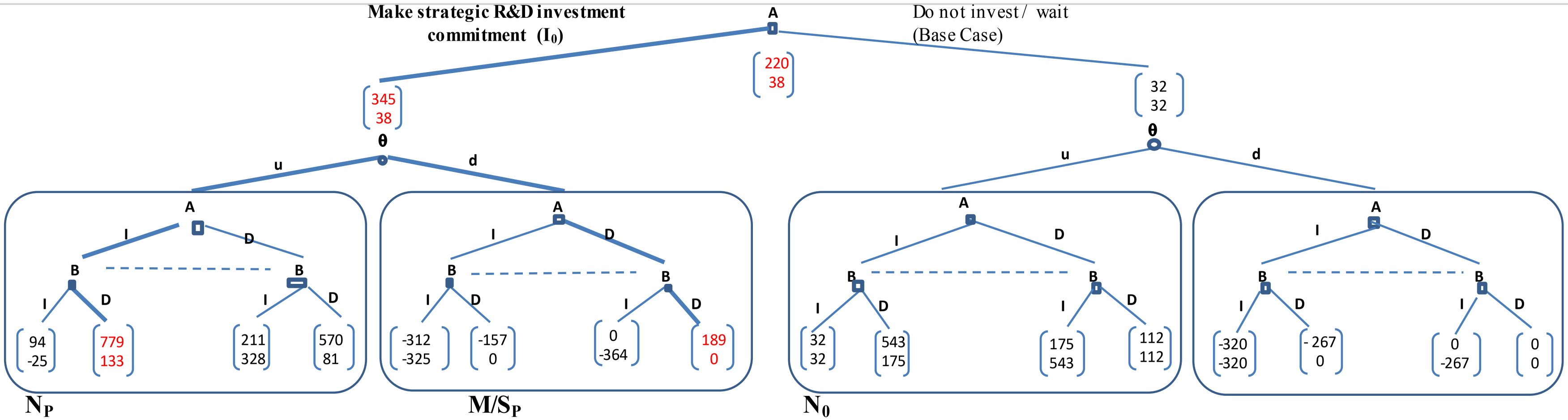
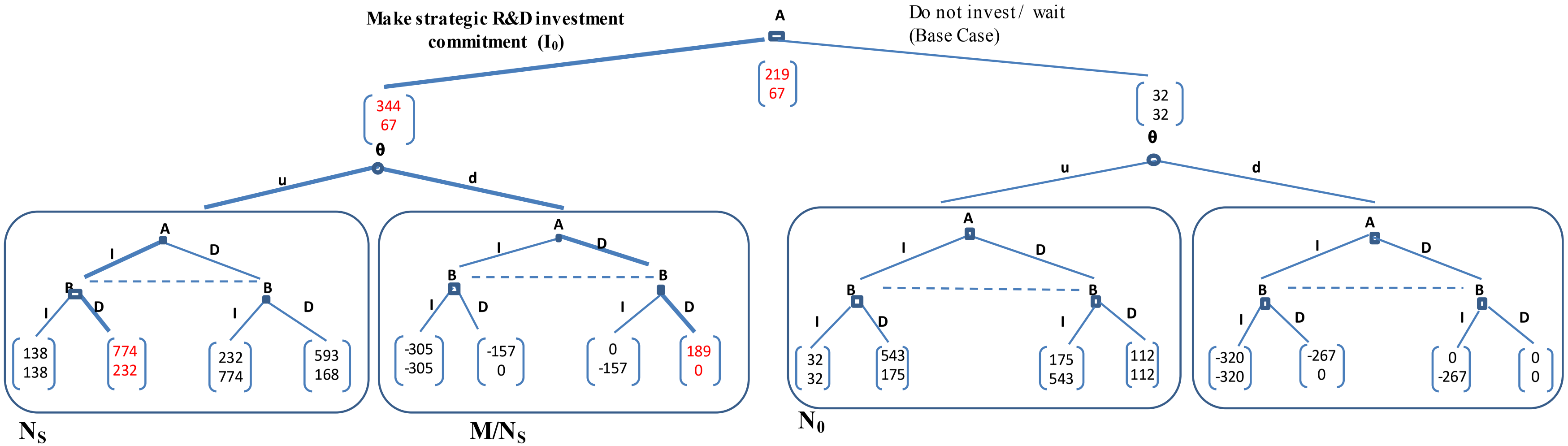


Figure 6.12 Shared Investment in Two-Stage Strategic Game Model



Panel A: Propriety Investment and Base Case



Panel B: Shared investment and Base case

Figure 6.13 Optimal Choices between Base Case and R&D Investment under Pricing Competition

Table 6.2 Result Comparison among Three Cases

	Base Case	Propriety	Shared
Pioneer A	32	220	**219**
Follower B	32	38	**67**

Proprietary Investment vs. Base Case of no R&D investment

The proprietary benefits of a strategic goodwill investment would help develop a larger market share, placing competition at an advantage compared to the base case alternative for A. To get total larger market share for both firms, firm A will pursue the proprietary strategy. This example is illustrated in Panel A of Figure 6.13. From a similar backward valuation process as applied earlier, the expected value of the investment opportunities for the two firms (220, 38) as in proprietary strategy.

If future market demand is favorable ($\theta = u$), firm A will have a dominant strategy to invest as Stackelberg leader with Stackelberg leader and follower price equilibrium values of (779, 133). If market demand is unfavorable, however, both firms may be better off to wait, resulting in expected values of (189, 0). To sum up, the asymmetry (proprietary) investment clearly influences each firm's reaction function and end-node equilibrium payoffs values. So, the propriety R&D investment causes the changing of base case Bertrand Nash equilibrium outcome from N_0 to N_p and increasing firm A's relative market share.

Shared Investment vs. Base Case (no investment)

In this case, pioneer firm A has the ability to use a strategic investment to create a shared advantage and larger demand for both. As illustrated in lower Panel B of figure 6.13, the committing but inoffensive strategy results in (344, 67) expected values for the growth opportunities. The expanded NPV for the shared strategic investment of firm A at initial time ($t = 0$) is 344 – I_0 (125) = 219. A high level of demand results in an asymmetric Stackelberg leader for firm A and Stackelberg follower for firm B price equilibrium, whereas for the low level of demand, both firms will retain a flexible wait-and-see situation. As the result of this strategy, firm A should rather pursue the flexible "invest-now" position at stage 1, attaining the shared investment case equilibrium value and total larger market value.

6.6 Sensitivity Analysis for Optimizing between Flexibility and Commitment Values

6.6.1 Analyzing the Results under Quantity Competition

Under this subsection, the competition based on the changes of investment values and demand under the base case and propriety strategy will be analyzed. First, the analysis for the base case of no initial basic research investment at first stage by A will be made as the following procedure.

1. Analysis for the changing behavior of NPV by shifting the two parameter values, I and θ, with 3-dimension graph.
2. Analysis for the Impact of Investment, I, on NPV only with 2-dimension graph
3. Analysis for the Impact of Demand, θ, on NPV only with 2-dimension graph

After that, the analysis for the proprietary investment case at the initial stage by A will be made. The procedure is:

1. Analyzing the Impact on NPV by changing simultaneously I and θ, with 3-D graph for firm A
2. Analyzing the Firm B's NPV result when the I and θ change at the same time with 3-D graph
3. Study on NPV gaps between firms A and B with 3-D graph

(A) Analysis under the Base Case

1) Analyzing the Impact on NPV Due to Simultaneous Changes of Investment Scale and Market Demand

At first, the optimal strategy for maximizing the own NPV with the rival company can be fixed as seen in the table of area-map below.

Table 6.3 Tree types in Base Case of Quantity Competition at the Start of Game

I / θ	10	30	50	100	500	1500	2500	4500	6000	8000
100	D for u & d	I for u&d	I	I	I	I	I	I	I	I
300	D	I for u & D for d	I	I	I	I	I	I	I	I
500	D	I & D	I	I	I	I	I	I	I	I
1000	D	D	I & D	I	I	I	I	I	I	I
2000	D	D	D	I	I	I	I	I	I	I
3500	D	D	D	I	I	I	I	I	I	I
5500	D	D	D	I & D	I	I	I	I	I	I
7000	D	D	D	I & D	I	I	I	I	I	I
8500	D	D	D	I & D	I	I	I	I	I	I
10000	D	D	D	D	I	I	I	I	I	I
12000	D	D	D	D	I	I	I	I	I	I

(I = Investment, D = Defer, u = up move, d = down move)

According to this table, they will prefer to defer if investment is large because it is a sunk cost. Generally, they need some time to decide to invest a lot, so they will wait the uncertainty to be sure in the market. But, if demand is high, they will prefer to invest now. Also, in some regions, both competitors will make strategic decision for the combination of investing and deferment as seen in the Table 6.3.

When a 3-dimension graph is used, it is possible to find the optimal NPV level by both sides of investment and volatility. As it is the base case of no initial basic research investment, the two players A and B have the equal rights over the game to choose their equilibrium NPVs. So, there is no difference between A's NPV and B's NPV along the projected period.

In Figure 6.14 and 6.15, NPVs are the equilibrium values for both rival companies according to the Prisoners' Dilemma. Figure 6.14 shows the analysis under the wide range of demand until 8,000 (in ten thousand units) and in Figure 6.15, demand level is limited to 100 (in then thousand units). It can be simply found, especially in Figure 6.15 of low ranged demand, that the optimal NPV level by both sides of I and θ is at minimum investment level and at the maximum amount of demand level. Generally speaking, from this 3D map, NPV gradually declines with the greater investments at all demand levels.

Under the wide range of demand level in Figure 6.14, the changes of NPV amount cannot be seen distinctly for their strategic shifts of their investment strategy {I, W}. But we can see that NPV rises sharply when the demand level reaches 4,500 (in ten thousand units). This obviously shows that the strong desire for the investment in the project deeply depends on demand in the market.

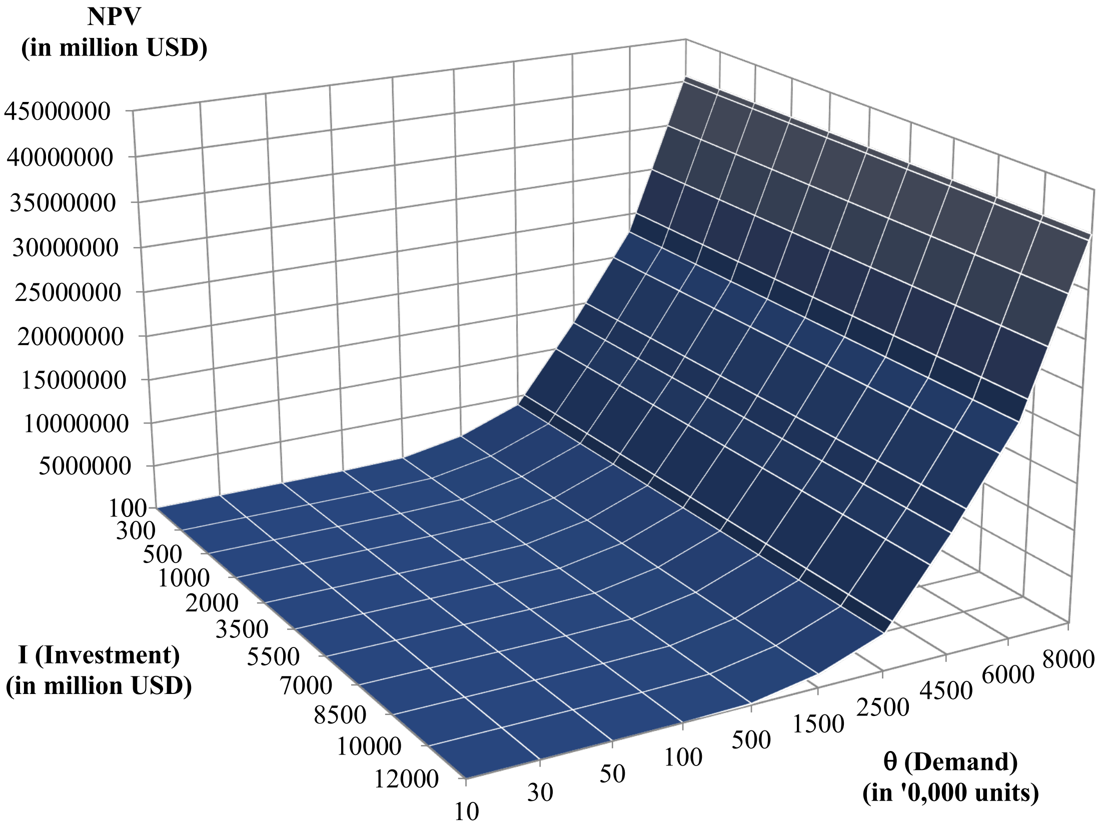


Figure 6.14 Changing Behavior of NPV depending on the Shifts of two parameter values, *I* and *θ*

In Figure 6.15 of narrow ranged demand, differences in NPV amount can be seen clearly whenever the competitors make the changes in their strategic decisions of selecting between the invest now and defer under demand range until 100 (in ten thousand units). Moreover, it pointed out that their NPVs' changing level was not same, at some points of I and θ, their NPV reduced down immediately due to their decision for equilibrium strategy to invest or defer. In summary, it can be said that the bigger the investment amount, the faster the speed of NPV's decrease according to the result as in the figure.

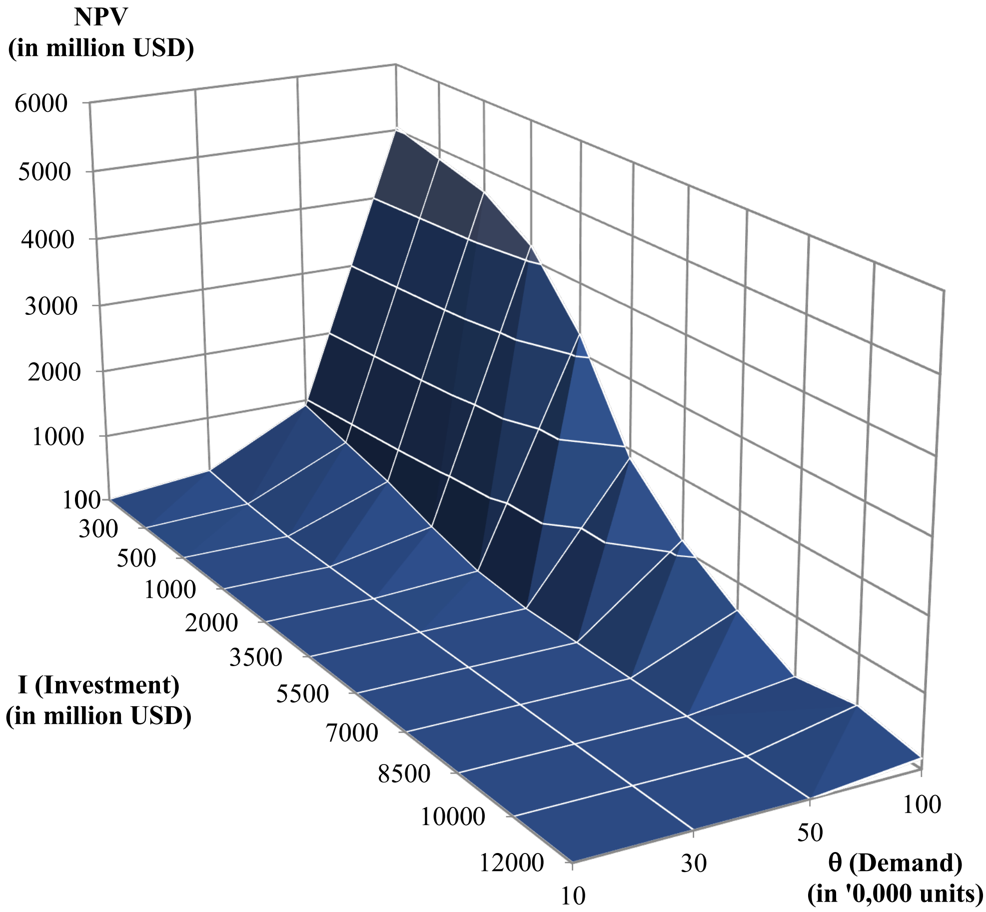


Figure 6.15 NPV Changes on the shifts of *I* and *θ* under low ranged Demand

Analyzing the Behavior of NPV Changes Separately with the Movements of *I* and *θ*

In each 2-dimension graph below, we can study the NPV changes due to the impact of investment and the impact of demand.

2) Impact of Investment on NPV

The results of the analysis can be checked in Figure 6.16 and Figure 6.17 with high demand levels and few demands respectively. In Figure 6.16 of going up to higher demand levels, we can see that NPV gradually declines with the growth of investment amount. And all NPV levels obviously decrease together with the contraction of demand. Thus, the demand is also important and has the influenced power on their will to invest in the project.

The Figure 6.17 with some few demand levels limited to 100 (in ten thousand units) suggests that the smaller the investment is, the more NPV they will get at all demand levels. It is found that they will defer their investment if the demand is very few. Moreover, the more NPV advantage can be acquired with the dramatically increase of demand at all investment levels. In brief, it proves that it is not so good to invest too much under the market uncertainties.

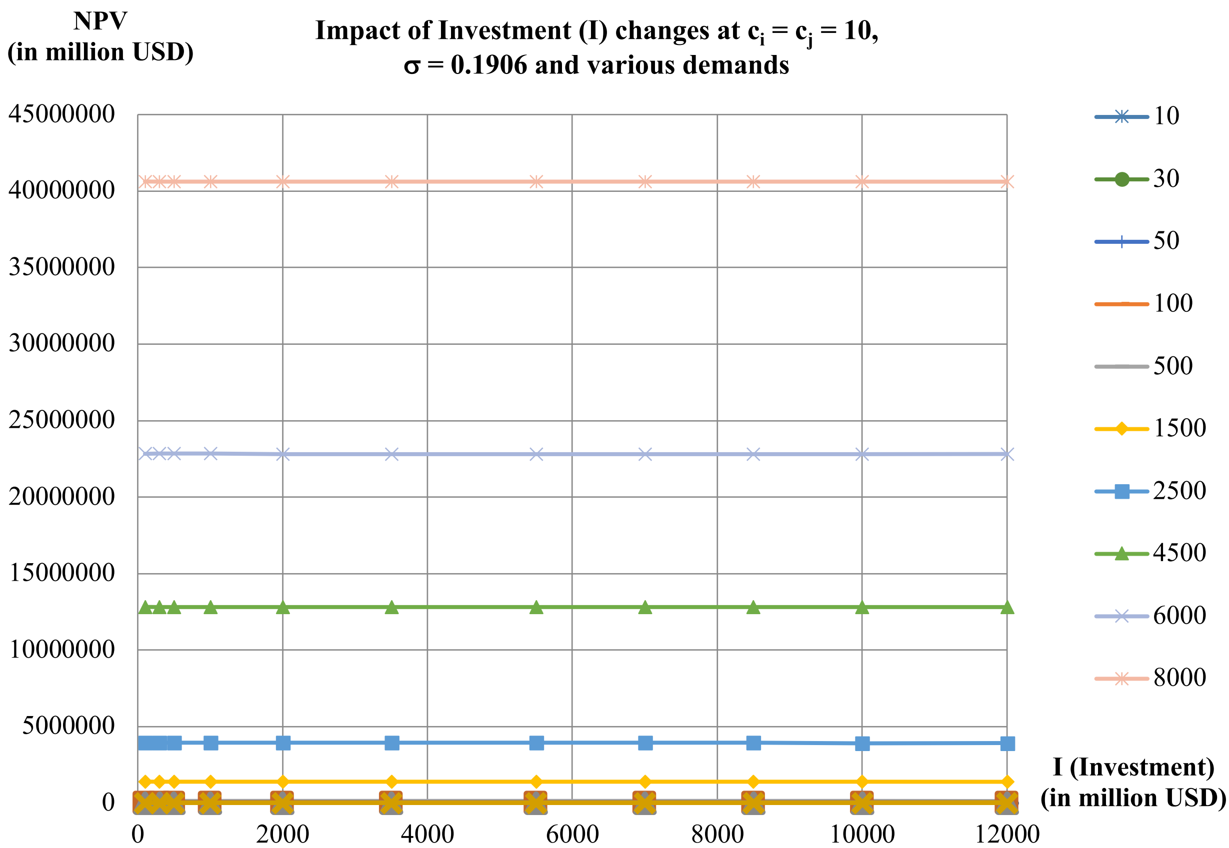


Figure 6.16 Impact of Investment on NPV until high Demands

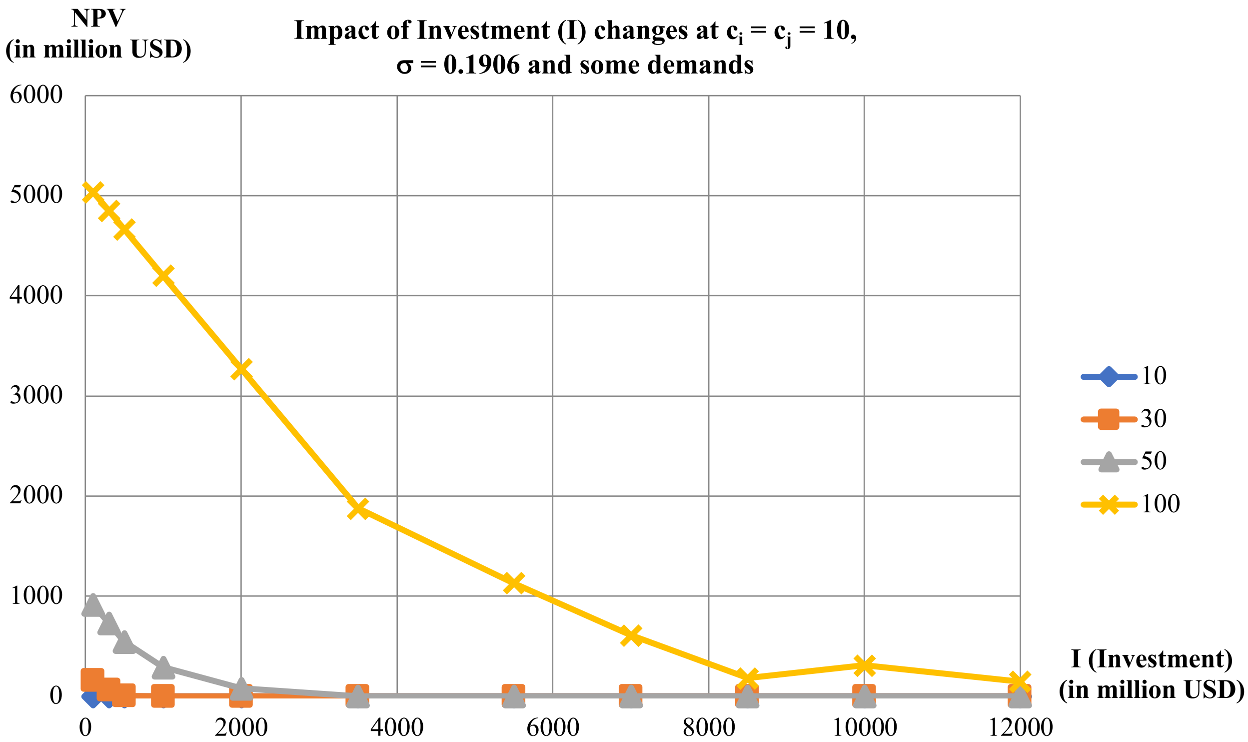


Figure 6.17 NPV Changes with the shift of Investment with few Demands

4) Impact of Demand on NPV

Under this analysis, it is also separated as the two graphs as the one for various high demands, Figure 6.18, and another one limited under some low levels, Figure 6.19. As seen in Figure 6.18, we can clearly see dramatically rise of NPV together with the increase in all demand levels. Under the wide range of demand level, NPV lines for all amounts of investment in graph are almost hidden behind the highest invested NPV line for all demand levels. This is due to the fact that the results of NPV trends are same at any demand level, no matter how much investment is made.

In the area of lower demand until 30 (in ten thousand units) according to the result of Figure 6.19 together with parameter settings of the analysis, there is no NPV at all or just very few at any amount of investments. But for the higher demand just level after $\theta = 30$ (in ten thousand units), the slope of NPV gradually becomes steeper and steeper upwards. But, we can find that the NPV declines distinctly along with the larger investments.

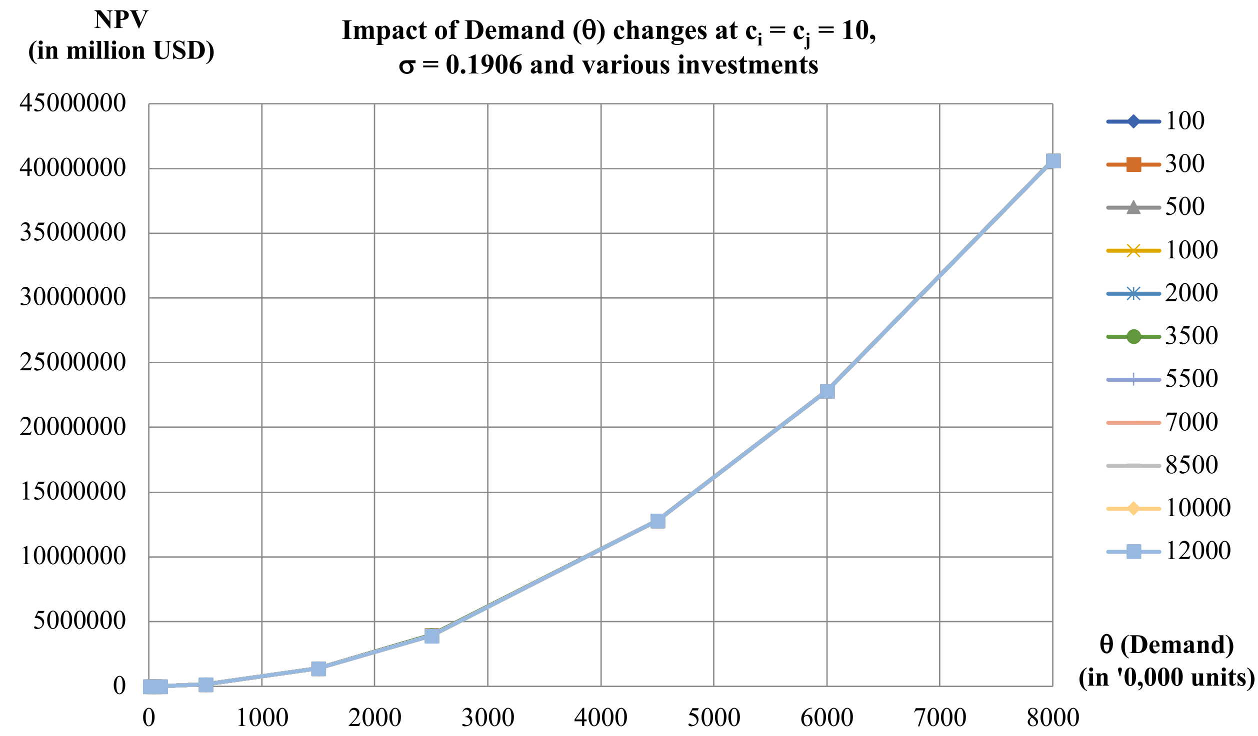


Figure 6.18 Impact on the NPV due to the Demand shifts

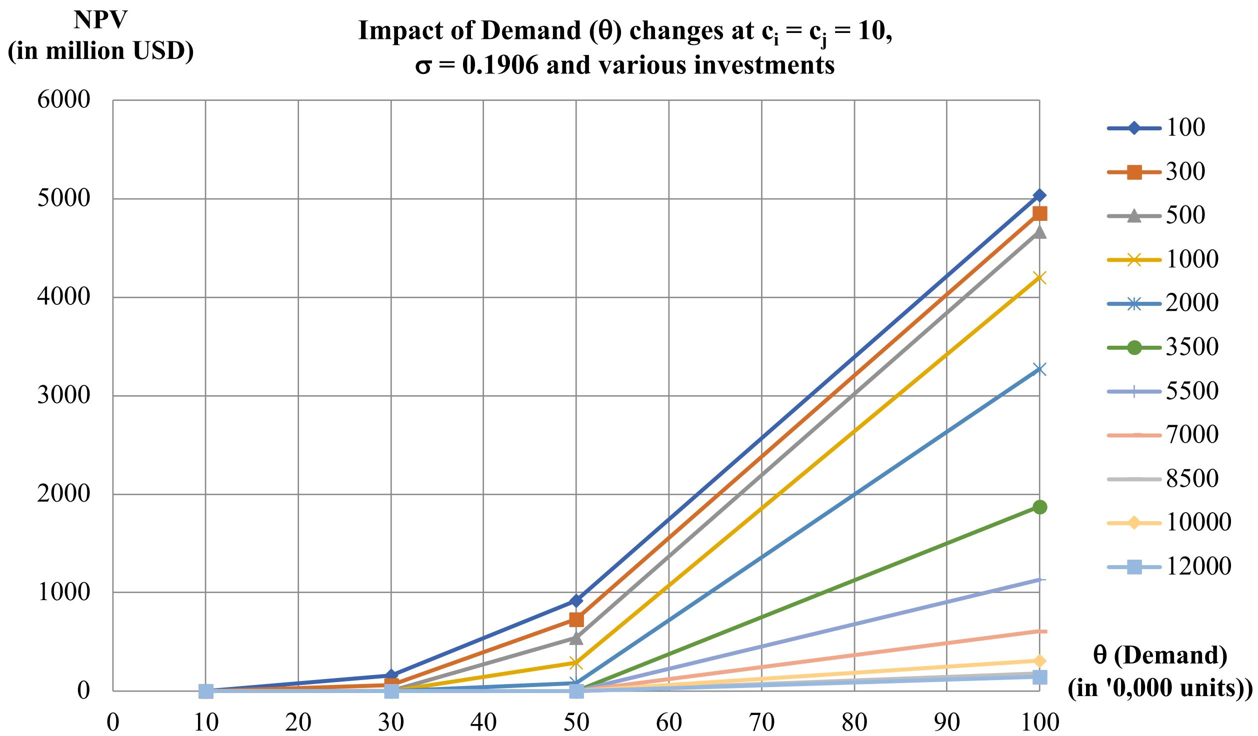


Figure 6.19 NPV Changes on the movements under low Demand levels

(B) Analysis under the Proprietary Strategy of Investment

Analyzing the Impact on NPV due to the Simultaneously Changes of Various Investment Amounts and Demand

The numerical results of this analysis can be seen in the following graphs and a trade-off relationship for NPV of each firm is understandable from these graphs by the investment and demand shifts. During the 2nd stage (t = 1), pioneer A will advantage a proprietary operating cost reduction effect because of its first stage strategic investment (I_0). So, there are asymmetric costs between pioneer firm A and follower B. And as a result, their respective NPVs will also be different from one to one. Let's check these results first for Firm A, and then for B.

1) Analyzing the Firm A's NPV Result when the I and θ change at the Same Time

First, the mixing of optimal strategy for maximizing the own NPV for A with the rival company is mapped as in the table 6.4 below.

Table 6.4 Tree Types in Propriety Case of Quantity Competition for Firm A during the Game

I / θ	10	30	50	100	500	1500	2500	4500	6000	8000
100	D for u & d	I for u&d	I	I	I	I	I	I	I	I
300	D	I	I	I	I	I	I	I	I	I
500	D	I for u & D for d	I & D	I	I	I	I	I	I	I
1000	D	I & D	I & D	I	I	I	I	I	I	I
2000	D	D	I & D	I	I	I	I	I	I	I
3500	D	D	I & D	I	I	I	I	I	I	I
5500	D	D	D	I	I	I	I	I	I	I
7000	D	D	D	I	I	I	I	I	I	I
8500	D	D	D	I for u & D for d	I	I	I	I	I	I
10000	D	D	D	I & D	I	I	I	I	I	I
12000	D	D	D	I & D	I	I	I	I	I	I

For 3-D graphs, it is divided into two types as the base case, one is under wide range of demand and another one for narrow range. This analysis is also made under the well-known Prisoners' Dilemma and thus, NPVs are equilibrium points for A. According to the analysis result of NPV Figure 6.20 and 6.21, it reveals that the optimum NPV can be acquired at the lowest investment and uppermost demand level as in the base case. As the same with previous analysis, too much investment is not a favorable condition.

In Figure 6.20, the blue region in lowest edge parts of the demand is expressing the negative NPV values. The firm has the loss due to its initial investment, I_0 = USD125M and thus, maximum loss is also 125. But in the area of high demand with the various amounts of investment, there is a situation to take the advantage for the profits by the pioneering company. Starting from demand level – 4,500 (in ten thousand units), it is found that NPV goes upwards sharply.

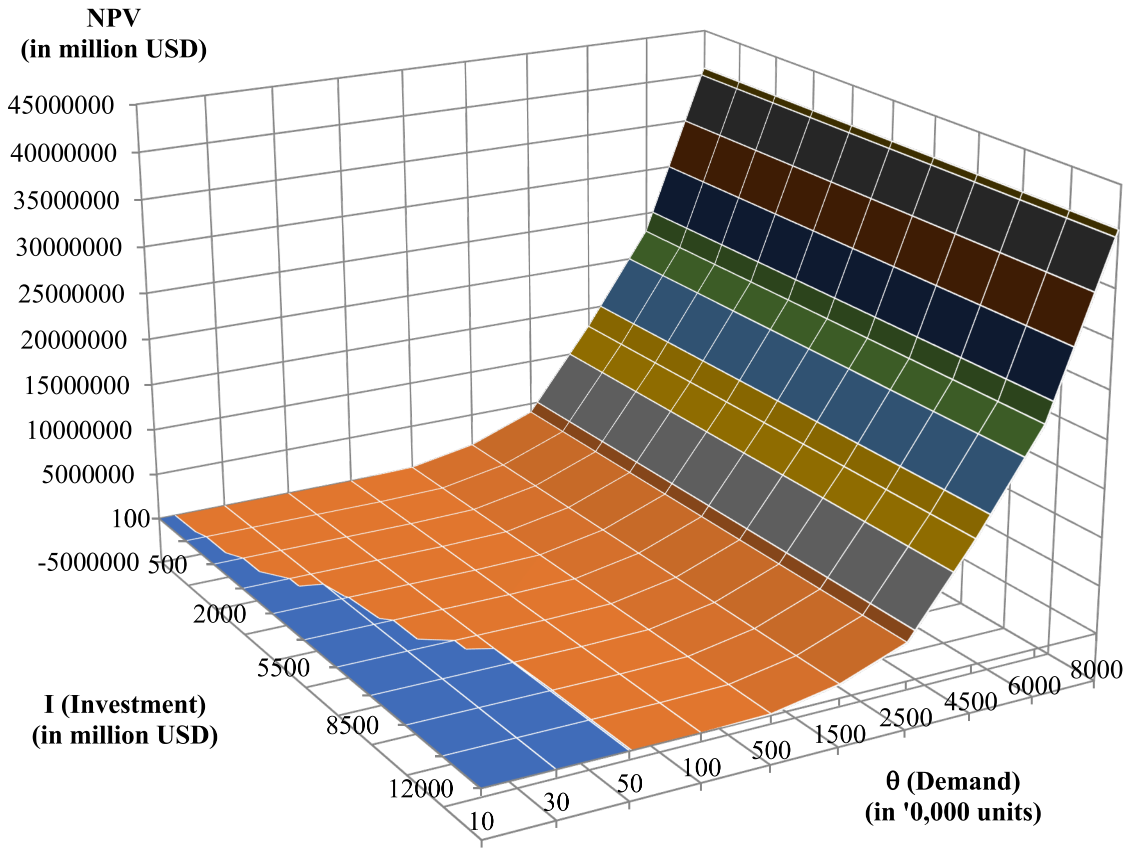


Figure 6.20 Changing Behavior of A's NPV under Propriety Strategy with wide ranged Demand

If we see the Figure 6.21, it is obviously pointed out that the payoffs of NPV depend upon the increase in the demand level. If it is compared with the base case, the NPV rage is much more sensitive because of the proprietary. Due to the cost reduction effect, the graph surface of the NPV level cannot be plane and this effect can be clearly seen in the graph of low ranged demand. Above overall, the influence of the pioneering company on NPV with the rival company can be traced out by cost reduction effect in this case.

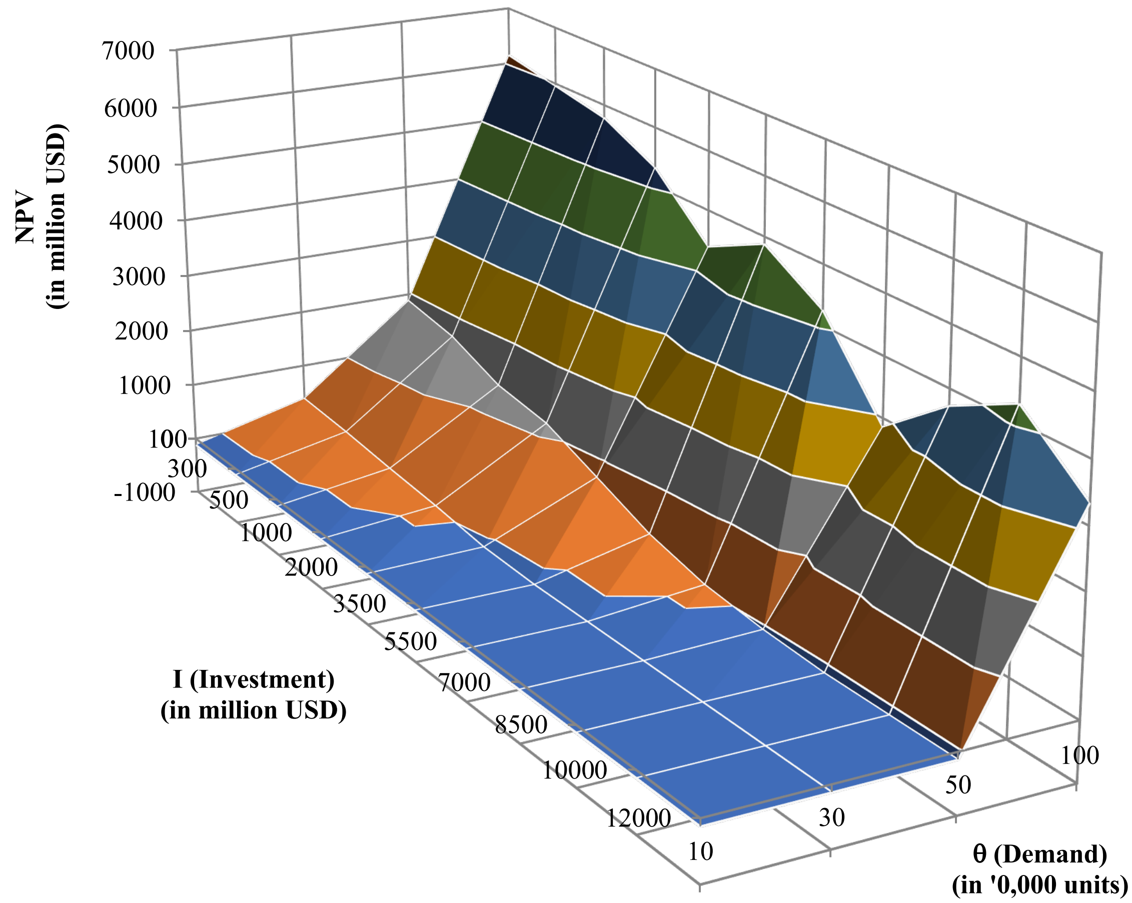


Figure 6.21 Behavior of A's NPV changes under low ranged Demand movements

2) Analyzing the Firm B's NPV Result when the I and θ change at the Same Time

After analyzing for Firm A, next is moving to analysis of firm B. The Table 6.5 presents the mapping out of the optimal strategy selection by Firm B to maximize its NPV. And then, the 3-D graphs of analysis are classified as two kinds of figures below and the results are shown in these graphs.

Table 6.5 Tree Types of Firm B at the Start of Game (1st period), 2nd stage

I / θ	10	30	50	100	500	1500	2500	4500	6000	8000
100	D for u & d	D	D	I for u&d	I	I	I	I	I	I
300	D	D	D	I	I	I	I	I	I	I
500	D	D	D	I	I	I	I	I	I	I
1000	D	D	D	I	I	I	I	I	I	I
2000	D	D	D	I	I	I	I	I	I	I
3500	D	D	D	I for u & D for d	I	I	I	I	I	I
5500	D	D	D	I & D	I	I	I	I	I	I
7000	D	D	D	I & D	I	I	I	I	I	I
8500	D	D	D	D for u & I for d	I	I	I	I	I	I
10000	D	D	D	D	I	I	I	I	I	I
12000	D	D	D	D	I	I	I	I	I	I

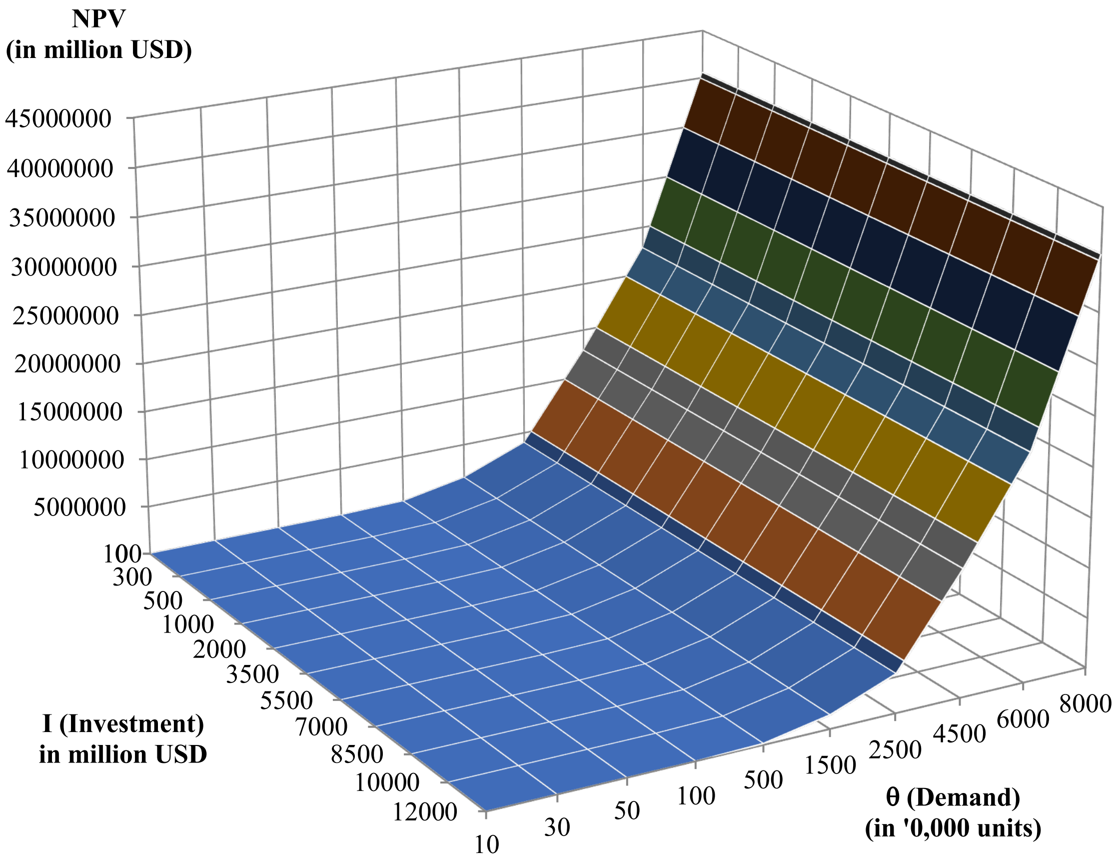


Figure 6.22 Changing Behavior of B's NPV with the shifts of *I* and *θ*

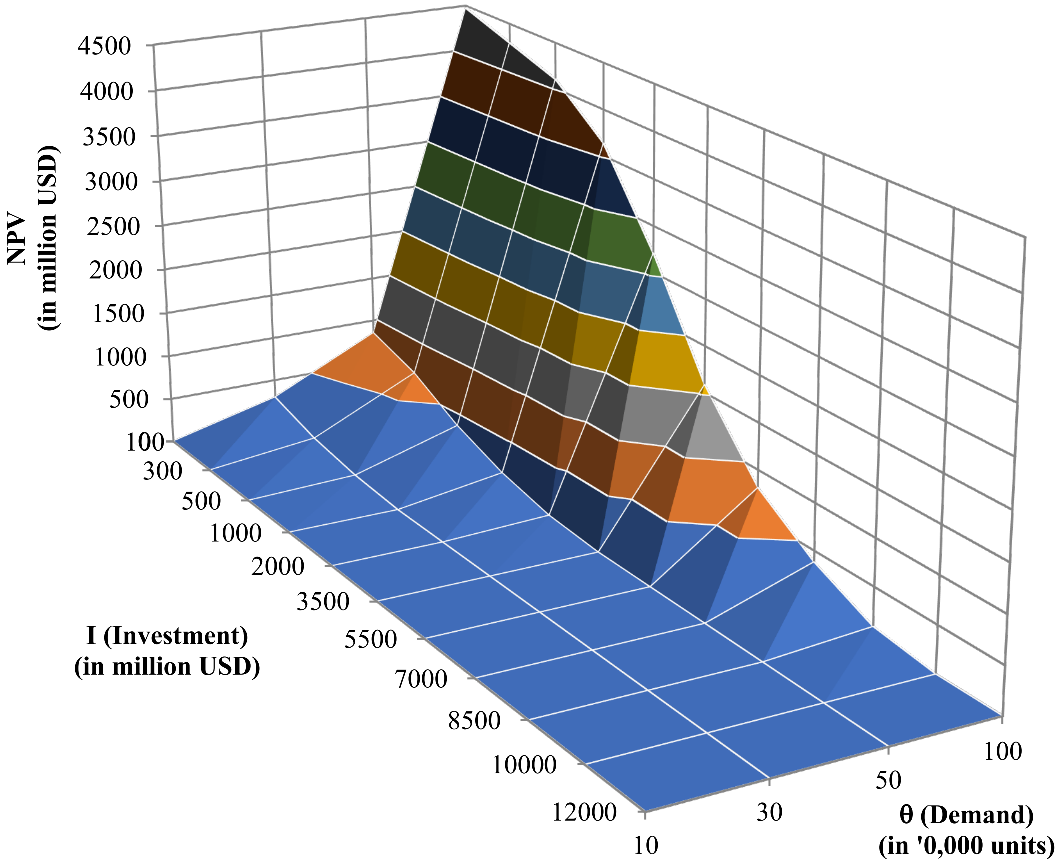


Figure 6.23 Behavior of B's NPV changes under low levels of Demand

Firm B's case is same as firm A, so the general situation is also same as A. I will express some different points against A. The NPV rage is less sensitive than A's. Firm B cannot feel any loss because it has no initial investment and so, its least NPV will become zero even if it chooses to defer under unfavorable conditions. On the other hand, the follower company B without initial investment tends to more decrease the profit amounts for NPV with expansion of the cost effect of the pioneering A as an initial R & D investor. This effect can be checked in Figure 6.23 with low levels of demand.

However, the total NPV images in two graphs for both firms bring out that it is possible to attain considerably coming close level to the base case by a certain combination of investment and demand. Moreover, it is even possible to set a condition to exceed the NPV level of the base case to some extent under this strategy although their results are very similar with the base case.

4) Observing on NPV Gaps between Firms A and B with 3-D graph

This is the opportunity costs between A and B if firm A use proprietary strategy during the game. It can be seen the constant positive gaps for A after demand 50 (in ten thousand units) for all investment amounts in Figure 6.24 of wide ranged demand. As resulted in Figure 6.25 with low ranged demand levels, there are sudden rise shifts and drop shifts whenever they change their decisions to invest or defer. In this way, the bigger the cost reduction effect, the more advantage against rival firm is possible for the pioneer, especially under some low ranged demand.

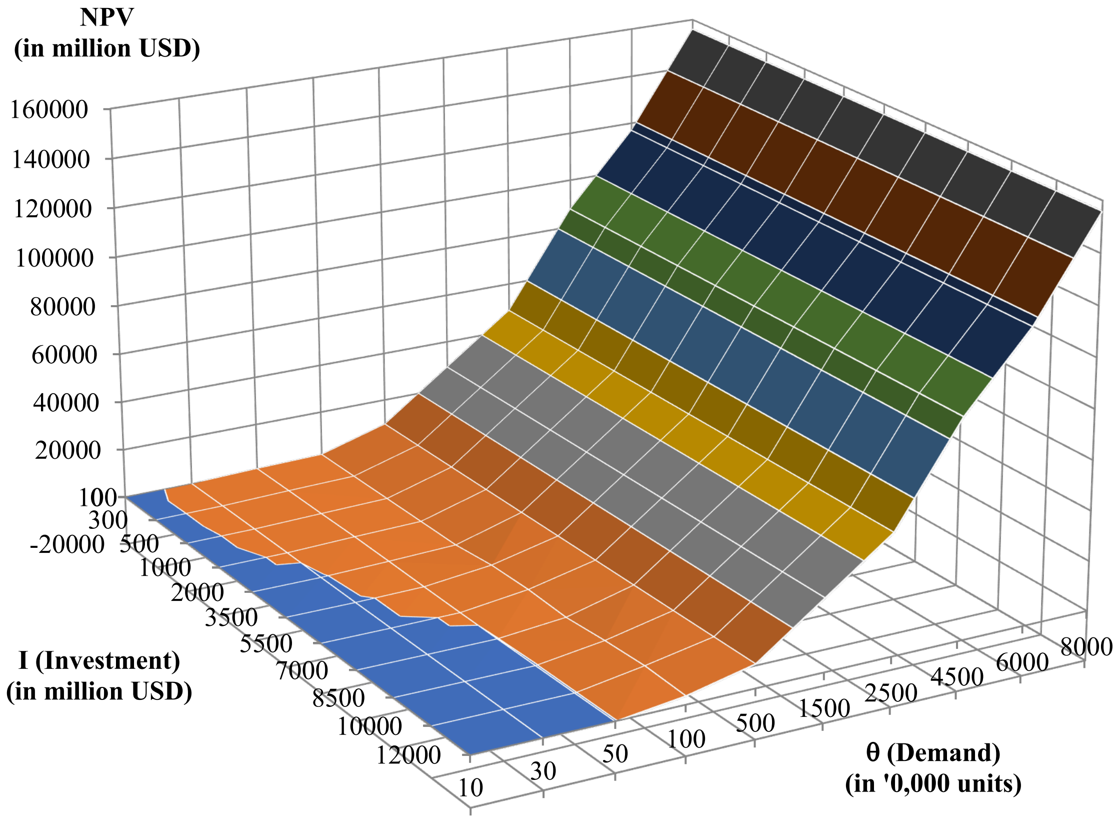


Figure 6.24 The NPV Gaps between A and B by the A Side (A – B)

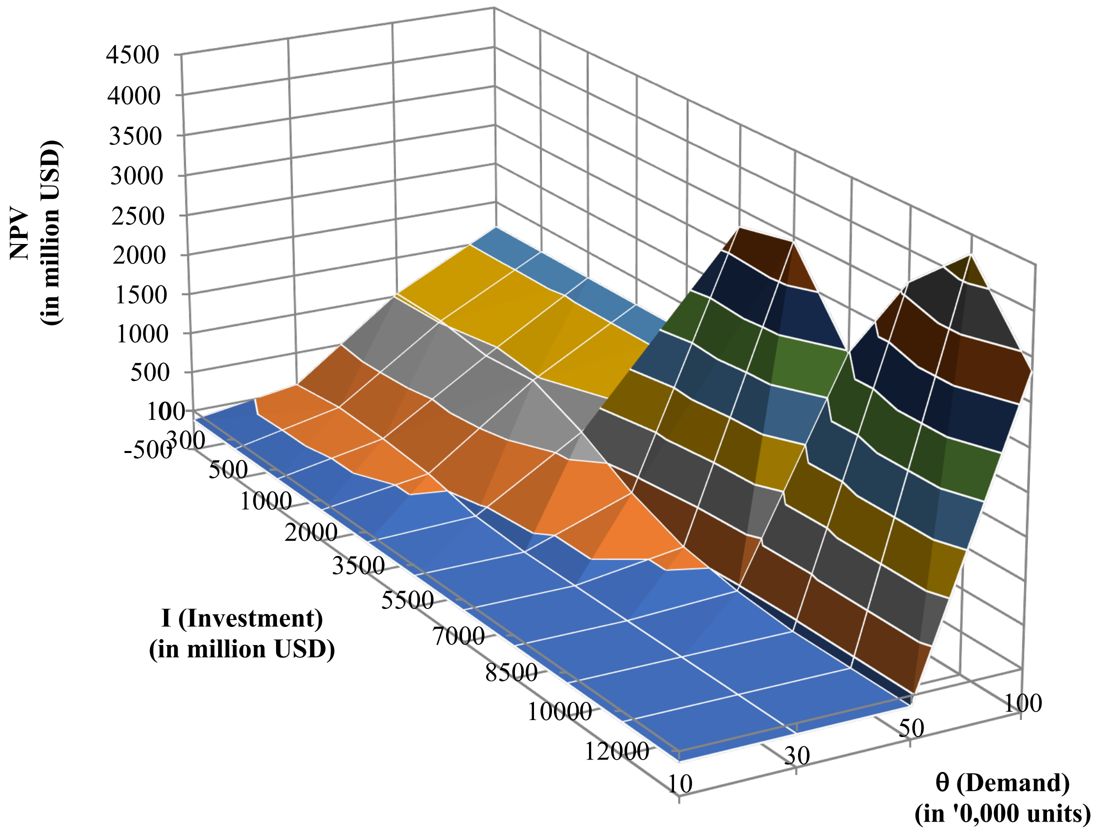


Figure 6.25 NPV Gaps between A and B with narrow ranged Demand shifts

6.6.2 Sensitivity Analysis for the Pricing Competition

In this competition, the analysis will be made on the basis of changes in demand and volatility parameter under the base case and share investment strategy. For the Base Case of no initial basic research investment in first stage by A, the procedure of the analysis is as below.

1. Analysis for the changing behavior of NPV by shifting the two parameter values, θ and σ, with 3-dimension graph
2. Analysis for the Impact of Demand, θ, on NPV only with 2-dimension graph
3. Analysis for the Impact of Volatility, σ, on NPV only with 2-dimension graph

The analysis procedure of the Sharing Investment Case (at the initial stage by A) is:

1. Analyzing the Impact on NPV by changing simultaneously θ and σ, with 3-D graph for firm A

2. Analyzing the Firm B's NPV result when the θ and σ change at the same time with 3-D graph

3. Study on NPV gaps between firms A and B with 3-dimension graph

(A) Base Case Analysis

1) Analyzing the Impact on NPV when Market Demand and Volatility change at the Same Time

The best own policy for maximizing NPV can be decided by the optimal arrangement of each decision type – Invest or Defer or the combination of Invest and Defer as in the Table 6.6 below.

Table 6.6 Tree types in Base Case of price Competition at the1st period (Start of Game) of 2nd stage

θ / σ	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
10	D for u & d	D	D	D	D	D	D	D	D	D	D
50	D	D	I for u & D for d	D	D	D	D	D	D	D	D
100	I for u and d	I	I	I	I	I for u & D for d	D	D	D	D	D
150	I	I	I	I	I	I	D for u and I for d	D & I	D	D	D
200	I	I	I	I	I	I	D & I	D & I	D & I	D & I	D
275	I	I	I	I	I	I	D & I	D & I	D & I	D & I	D & I
350	I	I	I	I	I	I	D & I	D & I	D & I	D & I	D & I
425	I	I	I	I	I	I	D & I	D & I	D & I	D & I	D & I
500	I	I	I	I	I	I	I	D & I	D & I	D & I	D & I
600	I	I	I	I	I	I	I	D & I	D & I	D & I	D & I
700	I	I	I	I	I	I	I	D & I	D & I	D & I	D & I

(I = Investment, D = Defer, u = up move, d = down move)

The optimal strategy can be selected with each parameter from a viewpoint of option-game by using the graph as a map. As it is also a base case, there is no difference between A's NPV and B's NPV. In the following Figure 6.26, we can see clearly the optimal strategy for maximizing their NPVs at the highest level of demand and highest range of volatility. Although the rising speed for NPV is not so obvious in the most regions of demand and volatility, later the NPV profits jump sharply in the area of very high demand and high degree of volatility. This shows that they want to take the high riskiness with the increase in demand level.

By seeing this figure, we can know that the profits rise gradually without any drop again after demand level – 50. At demand level – 10 (in ten thousand units), they can they can retain their constant level of profit at any range of volatility even though they stay flexibility for investment, but their profits cannot be so high.

The most distinct point is demand level – 50 (in ten thousand units), at that point they can get no profit at all or some low profits no matter how much degree of volatility parameter increases.

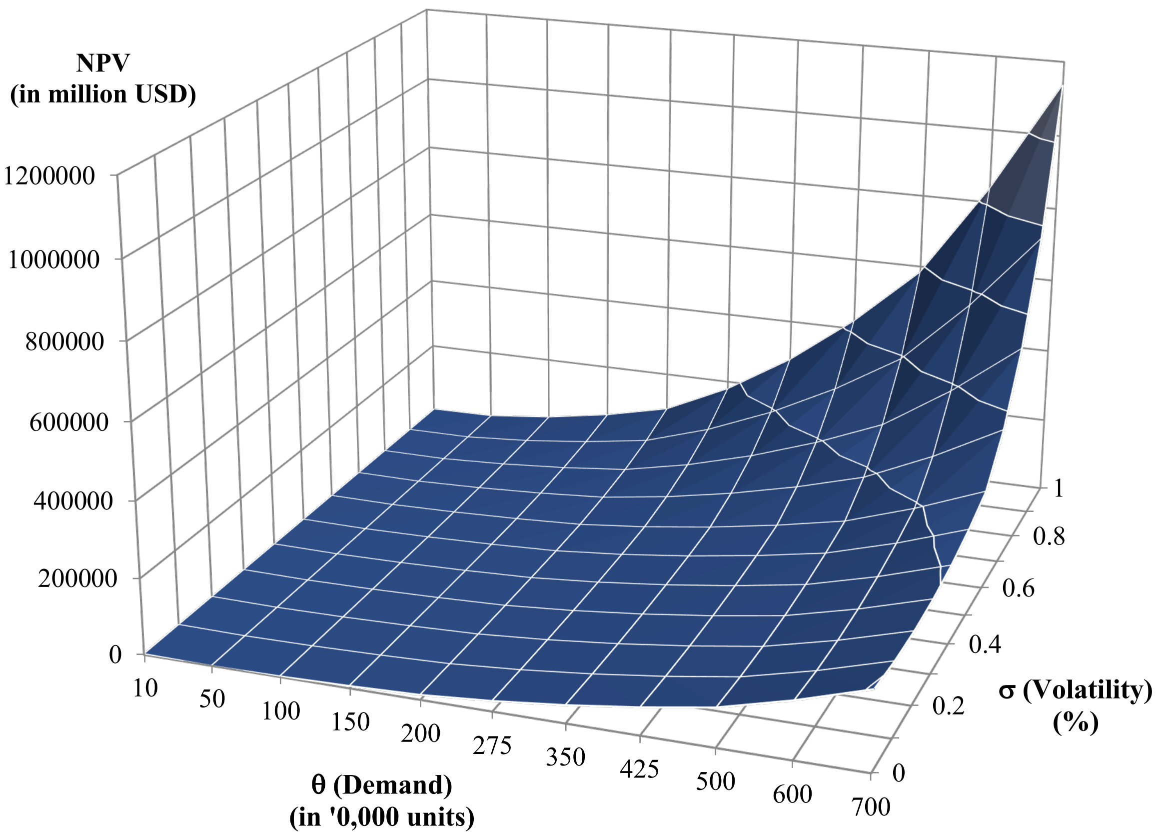


Figure 6.26 The Behavior of NPV Changes with the shifts of Demand and Volatility

Analyzing the Behavior of NPV Changes Separately with the Movements of θ and σ

In this section, the NPV changes due to the impact of demand and the impact of volatility can be observed separately as seen in the following graphs.

2) Impact of Demand on NPV

We can see in Figure 6.27 that the NPVs rise dramatically at any level of demand after 50 (in ten thousand units) for various ranges of volatility. The figure obviously shows that they prefer high market demand. But we can find that the NPV declines intensely together with the low riskiness (Volatility).

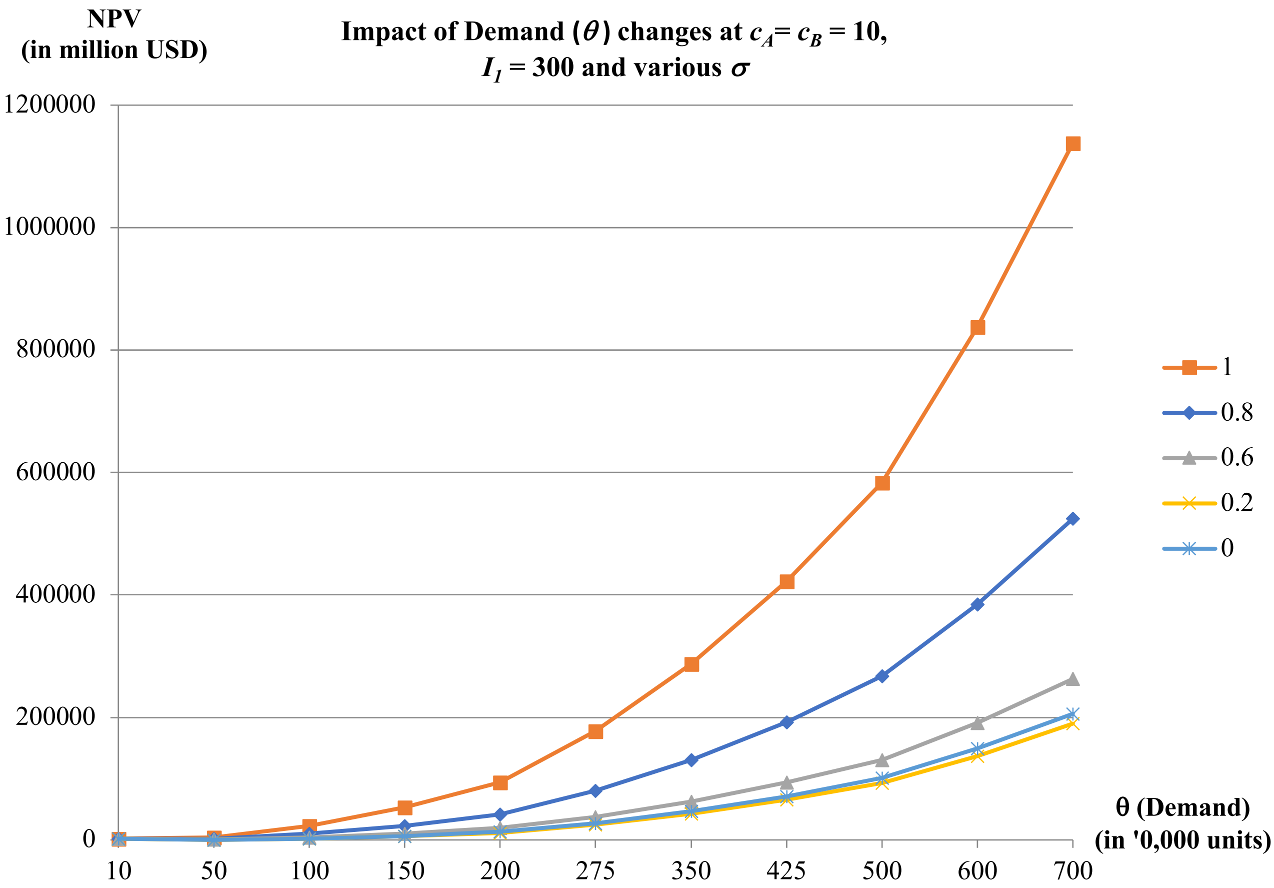


Figure 6.27 Impact on the NPV depending on the Demand changes

3) Impact of Volatility Parameter on NPV

Under this analysis, the graphs are separated as two figures, Figure 6.28 and 6.29, to be able to express the results of impact obviously. At the demand level – 10 (in ten thousand units), both firms keep a constant level of NPV with small amount of profit for all risk levels. This result can be viewed clearly in Figure 6.29, just a show for two values of demand – 10 and 50 (in ten thousand units). And until demand level – 50 (in ten thousand units), it reveals out both firms will maintain a uniform pattern for little NPV or zero sum NPV regardless of riskiness. Over demand – 50 (in ten thousand units), there is an effect of immense rising shift for NPV with the high risk. On the other words, the higher the volatility is, the steeper the slopes of the curves to the upward direction happens. Thus, it is possible to apply real options for hedging the risk and gaining access to opportunity.

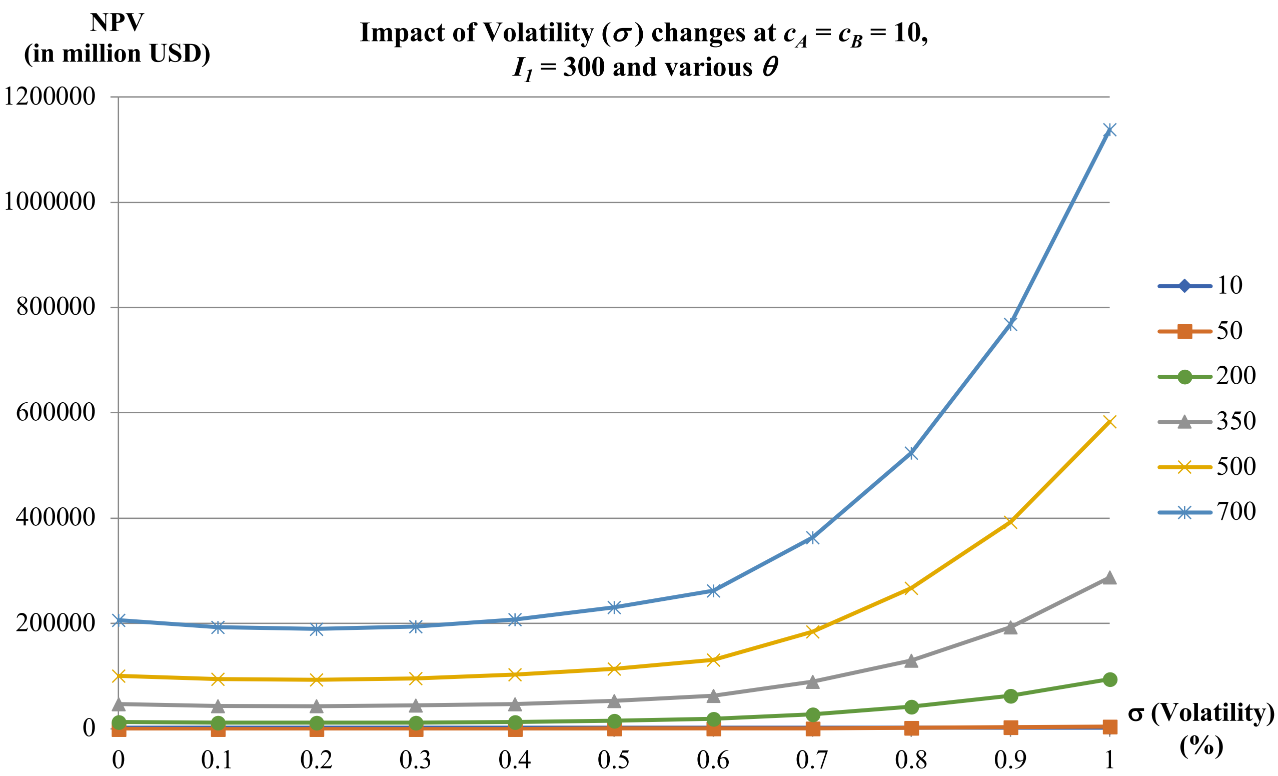


Figure 6.28 Impact on the NPV with the shifts of the Volatility Parameter

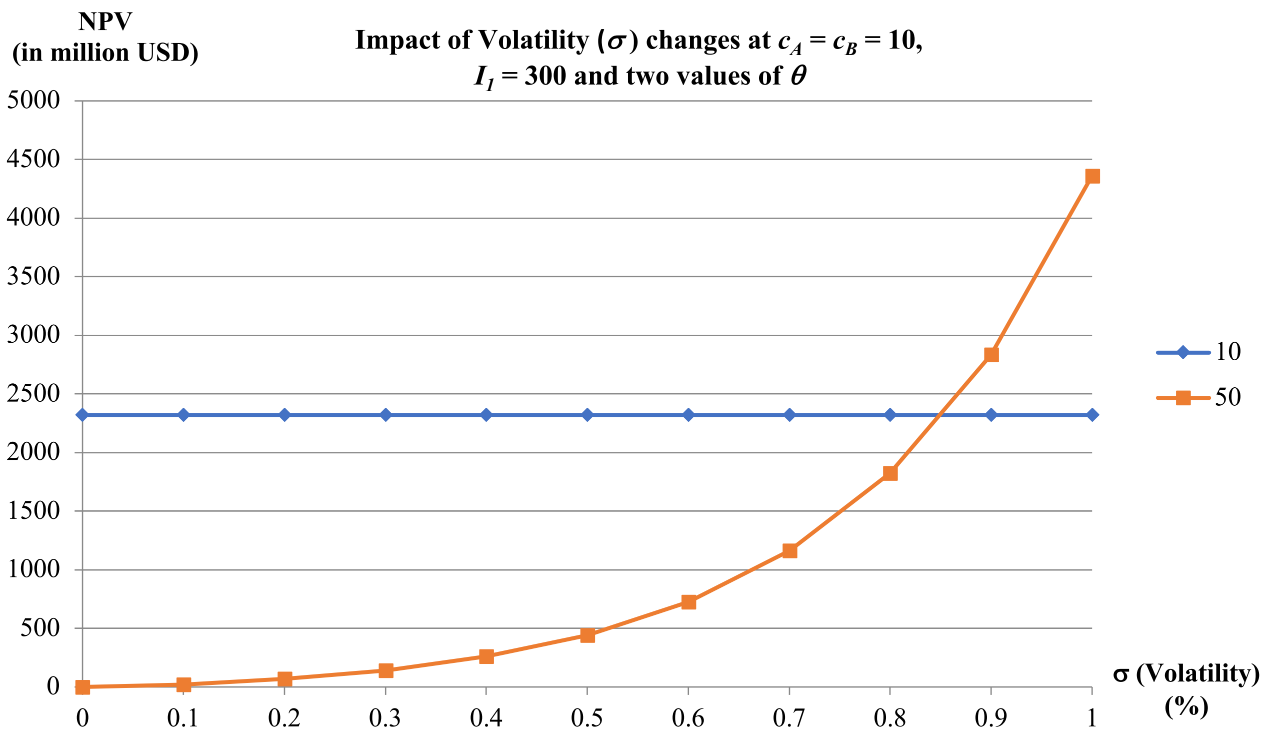


Figure 6.29 Behavior of NPV only with Two Values of Demand under various Riskiness

(B) Making Analysis under the Sharing Strategy of Investment

Analyzing the Impact on NPV due to the Simultaneously Changes of Various Market Demands and Volatility Parameter

By studying the analysis results in the graphs, it is possible to find the optimal NPV level for each firm on the basis of demand shifts and volatility changes. There is no mean to benefit from initial investment and thus, pioneering firm (A) has the ability to share development findings with the rival firm (B). So, they can generate the larger demand for both of them. As a result, their respective NPVs will be increased. This can be checked in their respective NPV graphs as below.

1) Analyzing the Firm A's NPV when the θ and σ Change Simultaneously

The optimal decision for maximizing its own NPV can be made by the best transition between the decision types of Invest or Defer or the combination of both types and under this analysis, A follows the decision map as in the Table 6.7.

Table 6.7 Tree Types of Firm A in Shared Investment Case at the Start of Game

θ / σ	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
10	D for u & d	D	D	D	D	D	D	D	D	D	D
50	I for u & d	I	I for u and D for d	I & D	I & D	I & D	D	D	D	D	D
100	I	I	I	I & D	D	D	D	D	I & D	D	D
150	I	I	I	I	D	D	D	I & D	I & D	I & D	I & D
200	I	I	I	I	I & D	D	I & D	I & D	I & D	I & D	I & D
275	I	I	I	I	D	D	I & D	I & D	I & D	I & D	I & D
350	I	I	I	I	I	D	I & D	I & D	I & D	I & D	I & D
425	I	I	I	I	I	D	I & D	I & D	I & D	I & D	I & D
500	I	I	I	I	I	D	I & D	I & D	I & D	I & D	I & D
600	I	I	I	I	I	D	I & D	I & D	I & D	I & D	I & D
700	I	I	I	I	I	D	I & D	I & D	I & D	I & D	I & D

In Figure 6.30, the common senses are the same as the base case. Therefore, the best strategy for maximizing NPV can be chosen at the point of uppermost demand and volatility. In addition, it is also obviously pointed out the NPVs depend upon the increases in the demand level and volatility. Together with the becoming large of the demand, it is possible to change the level of returns on investment (profits) into the higher one than the base case.

As seen in the figure, the pioneer A can acquire the profits even in some low levels of demand and volatility. But in the area of large demand with the high risks, there is a situation to take more advantage for the profits by the pioneering company. In summary, although the sharing strategy of R & D findings can appear a possibility for disadvantageous result, it also has an opportunity to enhance its NPV rather than the base case. Then, company A can select optimal strategy by observing and following each parameter condition at this map.

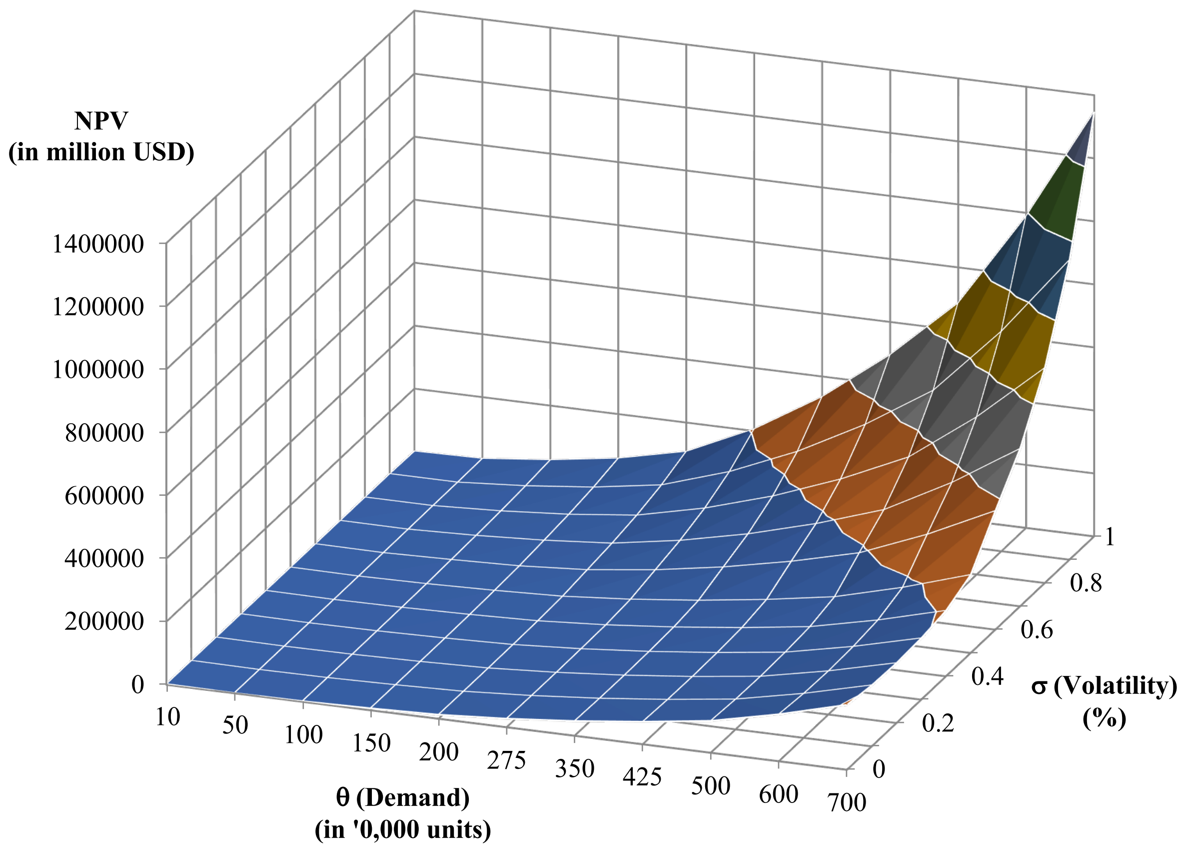


Figure 6.30 The Changing Behavior of A's NPV with the shifts of two parameter values, θ and σ

2) Analyzing the Firm B's NPV Result when the θ and σ Change at the Same Time

The Firm B's decisions for the optimal investment strategy selection during the game are different form Firm A and the maximization of the own profits follows the decision tree diagram of the Table 6.8.

Table 6.8 Tree Diagram of Firm B under Shared Investment Case of the Game

θ / σ	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
10	D for u & d	D	D	D	D	D	D	D	D	D	I & D
50	D	D	D	D	D	D	I & D	I & D	I & D	D	D
100	I for u & d	I	I	I	I	I	I for u and D for d	I & D	D	I & D	I & D
150	I	I	I	I	I	I	I	D for u and I for d	D & I	D & I	D & I
200	I	I	I	I	I	I	D & I	D & I	D & I	D & I	D & I
275	I	I	I	I	I	I	D & I	D & I	D & I	D & I	D & I
350	I	I	I	I	I	I	D & I	D & I	D & I	D & I	D & I
425	I	I	I	I	I	I	D & I	D & I	D & I	D & I	D & I
500	I	I	I	I	I	I	D & I	D & I	D & I	D & I	D & I
600	I	I	I	I	I	I	D & I	D & I	D & I	D & I	D & I
700	I	I	I	I	I	I	D & I	D & I	D & I	D & I	D & I

Firm B results are very similar with the base case. But there is a superior fact to the base case that it has a chance to boost NPV to the higher level through a parameter setting of demand and volatility.

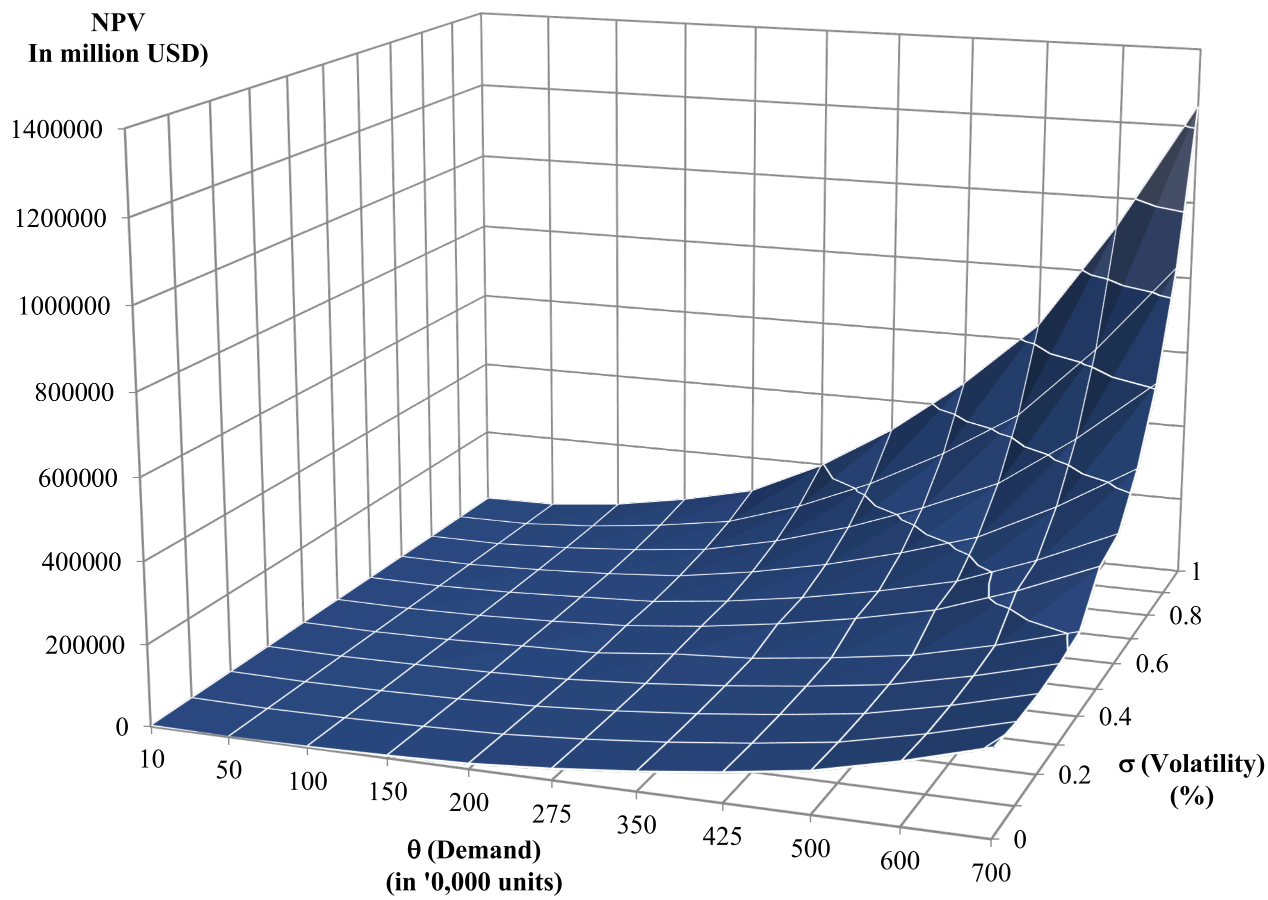


Figure 6.31 Changes of Firm B's NPV with the movements of θ and σ

Common Overview over Two Graphs, 6.30 and 6.31

This sharing strategy is the best one since the total of both companies' numerical NPV results is the biggest one compared with the results of Base Case and Proprietary strategy. Then, it has the ability to attain the plus-sum (additional) return on investment by preliminarily preventing a free-riding of a late departure through adopting this strategy. This is very important for pioneers to take risk by attaining the fair incentives.

Besides, it also has the mutual benefits for both companies. Therefore, a pioneering company should decide to practice it after taking into account a method to recover its some investment returns from the view of benefit enjoyment. In order to build such Win-Win relationship, it is very useful to refer to the conditions of each NPV of the base case, proprietary strategy and sharing strategy discussed above.

3) NPV Differences between Firms A and B by the A Side

To check the NPV gaps between two firms, two graphs are presented for the both broad view and narrow view. In Figure 6.32, the trend of their NPV gaps can be seen as a broad view under which the demand level goes to 700 (in ten thousand units). And the next graph of Figure 6.33 presents for the narrow view in which the demand is limited to only 275 (in ten thousand units) and we are able to check the appearance in more detail how the changes occur in their NPV gaps under that limited range of demand. In this Figure 6.33, we can see that there are sudden rises from loss to profit in A'*s* NPV in some low area of demand with some high risks. This shows that the possibility for pioneer A to grasp the change of getting more profit than the follower B even with low demand.

According to the result in figures, there is negative gaps continuously regardless of any demand, huge or little, until volatility reaches 50%. The maximum gaps that is loss to follower can be found at $\sigma = 0.5$ along with all demand levels. The more growth in the demand happens, the more gaps in NPVs becomes for A at that percentage of that volatility. On the other hand, pioneer A has the opportunity to receive the positive gaps when the volatility is over 50% and largest profits over the follower B can be found at the maximum demand with highest risk. Thus, we can see the trend for positive gaps constantly for all the area of various demand levels, except for very few demands, with high volatilities. Generally, higher volatility is, thus, a superior situation for higher or lower demand for the pioneer under that circumstances. Pioneer A can follow this guideline for avoiding negative gaps and maximizing its own payoff by adopting the sharing strategy with competitor to achieving the win-win relationship and mutual benefit. That is why an investment size as a sunk cost; a market volatility and size for both entrance and; risk hedge affected by real options seem to have the influence power over the firm.

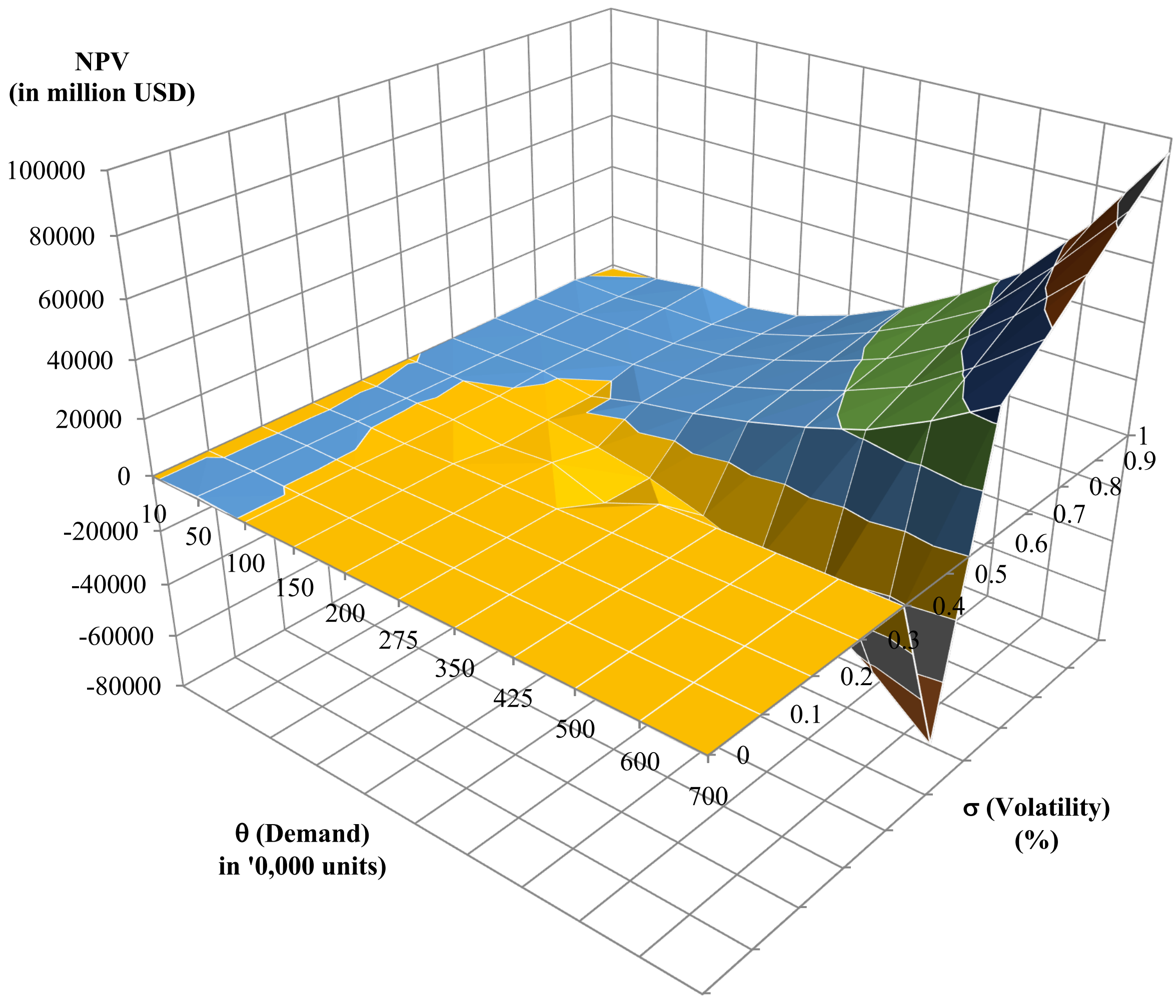


Figure 6.32 The NPV Gaps between A and B by A Side under broad range of Demand

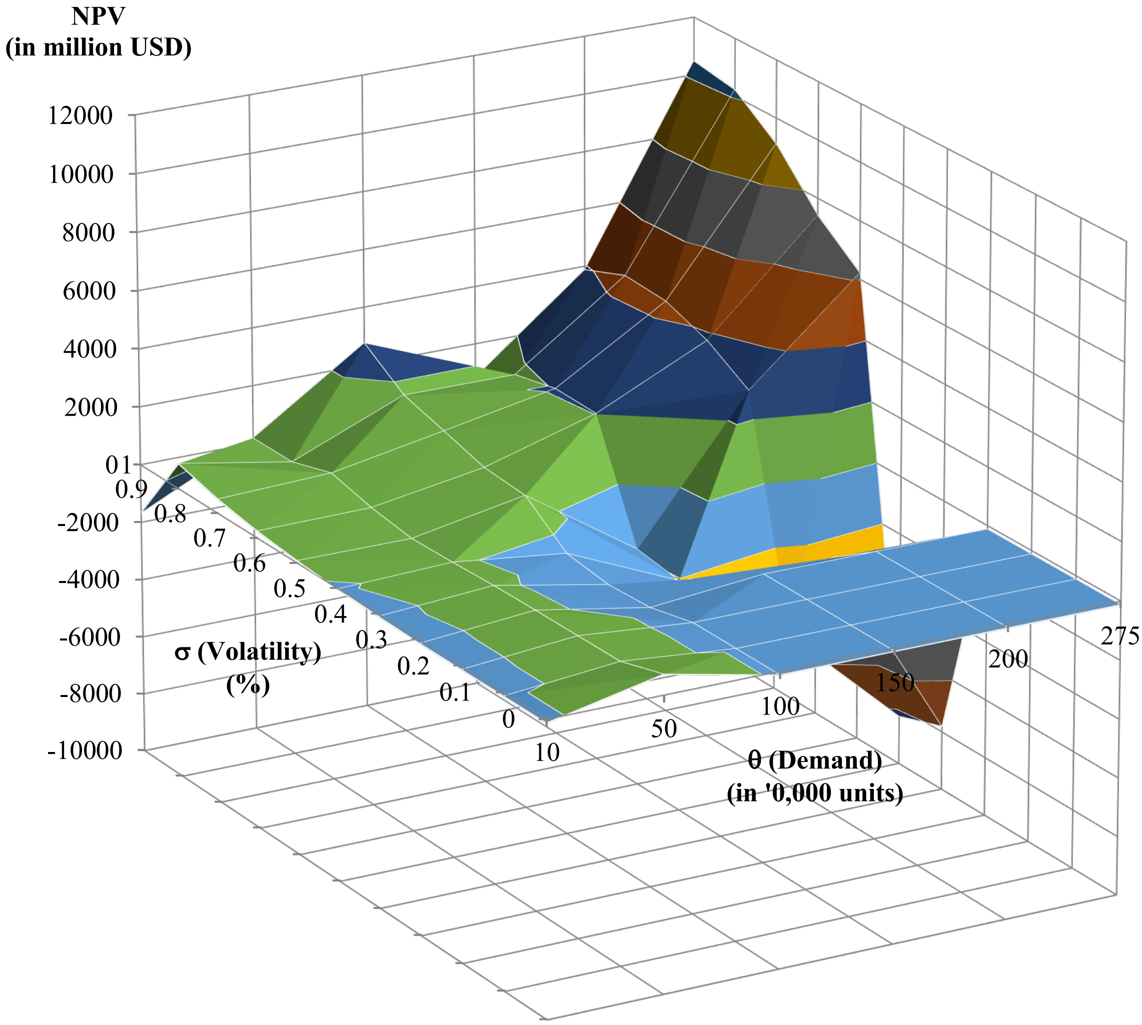


Figure 6.33 NPV Differences between A and B (A – B) by narrowing the Demand range

6.7 Overall Summary

In 3D models on NPV of both quantity and pricing competitions, demand and volatility can contribute to a rise of NPV. However, the investment takes the reverse reaction for profit. As we know, the emerging energy industry of new technological power generation project is characterized by huge capital investments with a corresponding high degree of risk and high level of demand in the market.

Together with the utilization of the above facts as the guidelines for developing such kinds of power project that increases the energy generation and efficiency, it is advisable as the good way to take action with the rival firm by sharing the R&D strategy findings during the commercialization stage, by pursuing the wait-and-see approach under the market uncertainties, by making efforts for the large demand with high risk. And it may enable the cooperating firms in the projects to fully appropriate the flexibility value for the immense immediate investment, avoiding the competitive pressures of an innovation race to preempt the market. Moreover, strategic interactions with the rival firms clearly influence the value of a sequential investment plan of the power project for energy efficiently use under technological or demand uncertainty.

From above all parameters setting, it basically becomes possible to maximize NPV on Option-Games Analysis for development of existing project or start the new attractive project as well as to avoid the market-entry threat by accompanying a partner, local or foreign, for a new idea generation power project in Myanmar. Furthermore, in the new dynamic competitive global world, it is necessary to decide the optimal switching time to convert investment strategy from non-investing or proprietary into sharing strategy in order to overcome the death-valley for the start-up energy industry, to deter an entry of a new rival and to maximize the own NPV.

The marriage of real options valuation with game theoretic industrial cluster formation principles thus enables simultaneously the determination of different market structure equilibrium games with the binomial option valuation, as well as proper accounting of the interdependencies among the early strategic commitment and sequential investment decisions along with competitive quantity or price setting in a dynamic competitive environment. Since the R&D program is very critical for all companies including huge capitalized and advanced technological power project to be able to survive in the long run and joint research can achieve the same research benefits with shared R&D costs by each company, the learning option and perfect game is inevitably necessary as the next challenge of my research study.

CHAPTER 7[3]

BAYESIAN MCMC ANALYSIS AND APPLICATION OF BAYESIAN GAMES TO POWER PROJECTS

7.1 Introduction

In the previous chapters, option-games methodology, a combination of real options and game theory, addresses the possible ways to continue the investment in R&D and survive even in the period of deficit and; then to compete within the firms without killing each other and taking advantage over the sharing effect and cooperation between them (Florida, R. L., 1988 and, Smit, Han T. J. & Trigeorgis, L., 2004). It is found that the real options analysis can contribute towards the achievement of irreversible investment under uncertainty by converting a negative NPV into a positive Expanded Net Present Value (ENPV) (Copeland, T., 2001, Dixit, A. K. and Pindyck, R. S., 1994 and; Trigeorgis, L., 1996). In principle, it is the idea to evaluate the option value and game with complete information in the flexibility for the decision-making of R&D process among the competitive firms under uncertainty (Black, F. & Scholes, M., 1973, Merton, R. C., 1973 and Kester, W. C., 1984). Another promising research direction, in this chapter, is the integration between option-games and Bayesian method for the analysis on the irreversible investment within the game competition under information asymmetry (Gilising, V., 2005, Granovetter, M., 1973, Grenadier, S. R., 1995 & 2000, Joaquin, D. C., 2000, Moodysson, J., & Jonsson, O., 2007 and; Powell, W. W., Koput K. W. and Smith-Doerr, L., 1996).

Under the Bayesian analysis, it is first to find the optimal energy mix of electricity supply among the clean and renewable energies as solar, hydro or biomass for sustainability and eco-system protection. Next, electricity revenue can be treated as the option value that will affect the firm's decision to make the considerable investment and to deliberate on a compensation for their payoffs by a perspective of Bayesian revenue analysis (Gelman, A., Carlin, J. B., Stern, H. S., Dunson D. B., Vehtari, A. and Rubin, D. B., 2013 and; Davidson-Pilon, C., 2016). Then, it is to make the perfect competition among the firms of incomplete information in a dynamic game.

[3] Parts of the content in this chapter have been published as paper earlier named by Nyein Nyein Aye & T. Fujiwara, 2019

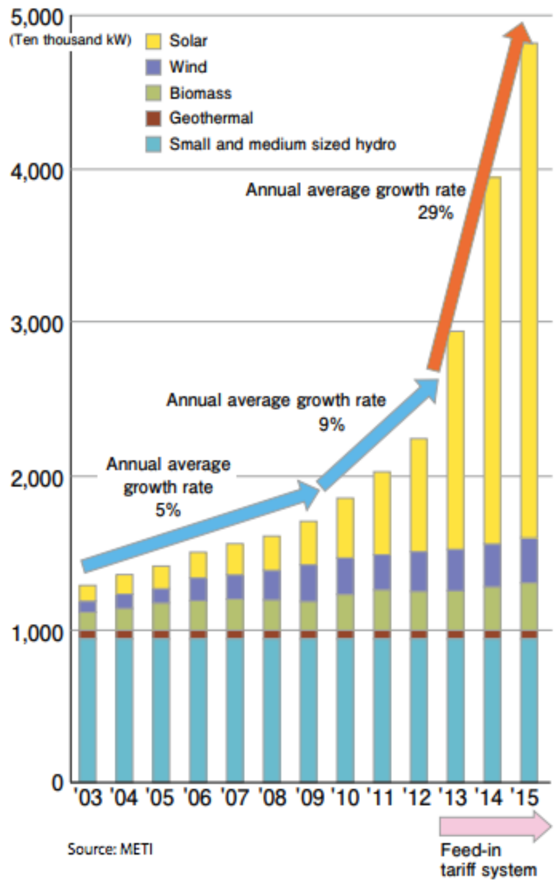
Bayesian Markov Chain Monte Carlo (MCMC) method is useful and effective for the parameter estimation of the risk factors even with incomplete information. Bayesian method has its advantages over such kind of analyses because it has signaling effect on options-game theory of asymmetric information for the government, joint-ventures, start-ups, etc., among noisy conditions.

Moreover, Bayesian Method is possible to make analysis when the availability of data has limitation. If it is compared with statistical frequency method, it can be run with the small amount of data. Then in many cases, Bayesian parameter estimation is really faster than conventional likelihood estimation. On the other hand, the implementation of Bayesian analyses of complex data sets containing missing observations and multidimensional outcomes can be facilitated by recent findings in MCMC methodology although it also has some weaknesses (David, B. D., 2001). Thus, it is useful for the analysis of this paper which has the limitation of data availability and some data nosiness for the government.

7.2 Electricity Review for japan

Japan is the most developed nation, in my opinion, in management as to commercialization technique. The country, Myanmar, is a developing country, and needs modern technology in strengthening the energy related infrastructures and construction of the country to be a developed nation. Under the above grand view, this section will be focused on Japan's electric power business and approached to power providing plan in searching of the potential for secure and sufficient electricity generation and supply in Myanmar.

In the online source of "www.fepc.or.jp", it has stated that electric power companies in resource-poor Japan are committed to developing an optimal combination of power sources including renewable energy, thermal and nuclear power in order to provide electricity, which is essential for modern living, in a stable manner at the lowest prices. Hydroelectric, geothermal, solar, wind, and biomass energy are all clean and renewable, and the electric utilities are striving to develop them for the decarbonization of energy on the supply-side. Especially, it is developing mega-solar power generation in large scale. According to Chubu Electric Power business, Japan stands for world's No. 3 in solar power (Chubu Electric Power, 2018). The amount of generating capacity of renewable energy and its annual growth rate can be checked in Figure 7.1 (The Federation of Electric Power Companies (FEPC) of Japan, 2018).



Source: FEPC, Electricity Review Japan, 2017

Figure 7.1 Amount of Generating Capacity (Renewable Energy) in 2017

7.3 Bayesian Inferences on the Power Project by using MCMC Analysis

An effort for the parameter estimation among the arrival rates of disaster occurrences, firm's expected income-based electricity tariffs of households, and investment expenses estimation for the new energy industry development will be made by using Bayesian Markov Chain Monte Carlo (MCMC) Analysis (Davidson-Pilon, C., 2016).

Particularly in this research, Bayesian MCMC Analysis will be utilized to the assessment on natural disaster occurrences due to the climate changes in connection with the construction of hydropower generation projects and then, on firm's revenue to search for the possibility of switching between or developing the renewable energy sources and, search for survival probability and sufficient power supply.

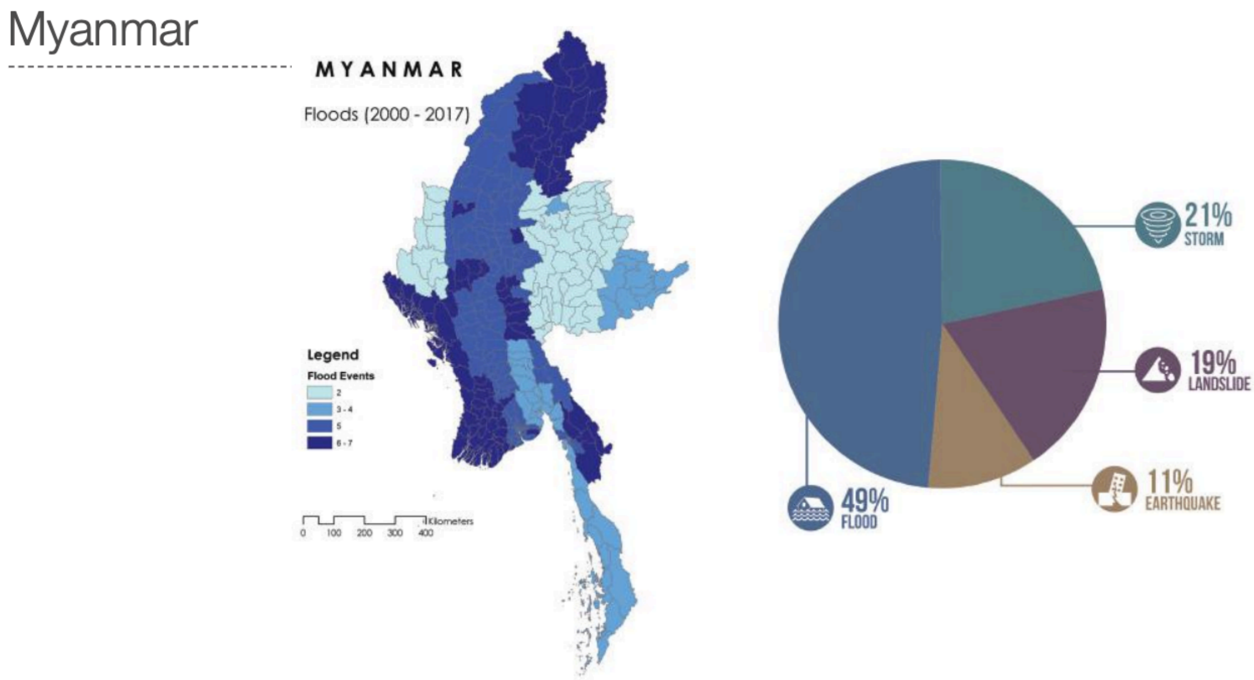
7.4 Analysis to Trace Out the Optimal Energy Mix in Electricity Supply

The current generation capacity of energy resources as hydro-power, renewable energy and gas and coal is insufficient for future demand. And it involves some risks in power supply. The identified renewable energy source of hydro-power has limitation in its generation during the dry season, and flood disaster cases during the monsoon season. Thus, the focus is on developing another possible renewable energy source such as solar energy generation for the backup of hydro-power energy source and the best energy mix in commercial power supply. Contributions of this analysis provide another set of risk management practice, which offers rational and logical information for the decision-making process by policy makers on power generation by considering other renewable energy source. Moreover, it can recommend key points in the policy making of power generation taking into consideration the environmental impacts.

7.4.1 Flood Disasters and Dams in Myanmar

Continued heavy rain across parts of Myanmar since early July every year and the building of large dams without enough capacity for power generation projects have triggered further flooding and landslide in several regions and states in Myanmar. As the consequence of the construction of large dams, the resulting deforestation leads to climate changes, worldwide Ozone layer deterioration and global warming that destroy the natural environment. Floods are amongst the most damaging and recurrent of all disasters. During the monsoon season, there was heavy rain in most parts of Myanmar and, at that time, the capacity of the dams was not enough to store all the water. Sometimes excess water was not collected or it provoked overflows.

Usually such kinds of challenges and dangers came from the dams located in upper parts of the country. It caused damages to households and loss of life, destruction of the people's property and of physical facilities. Most of the rivers in Myanmar are used for irrigation, fishing, and navigation, and especially for hydro-power generation, so finding a solution to this flood problem is particularly important after building the large-scale dams. The average annual loss due to the flooding in the rainy season (July and August) is the maximum amount of losses among all kind of natural disasters like earthquake, storm, tsunami, etc. Figure 7.2 shows the percentage of floods from 2000 to 2017 in Myanmar (SEEDS and CRED, 2018).



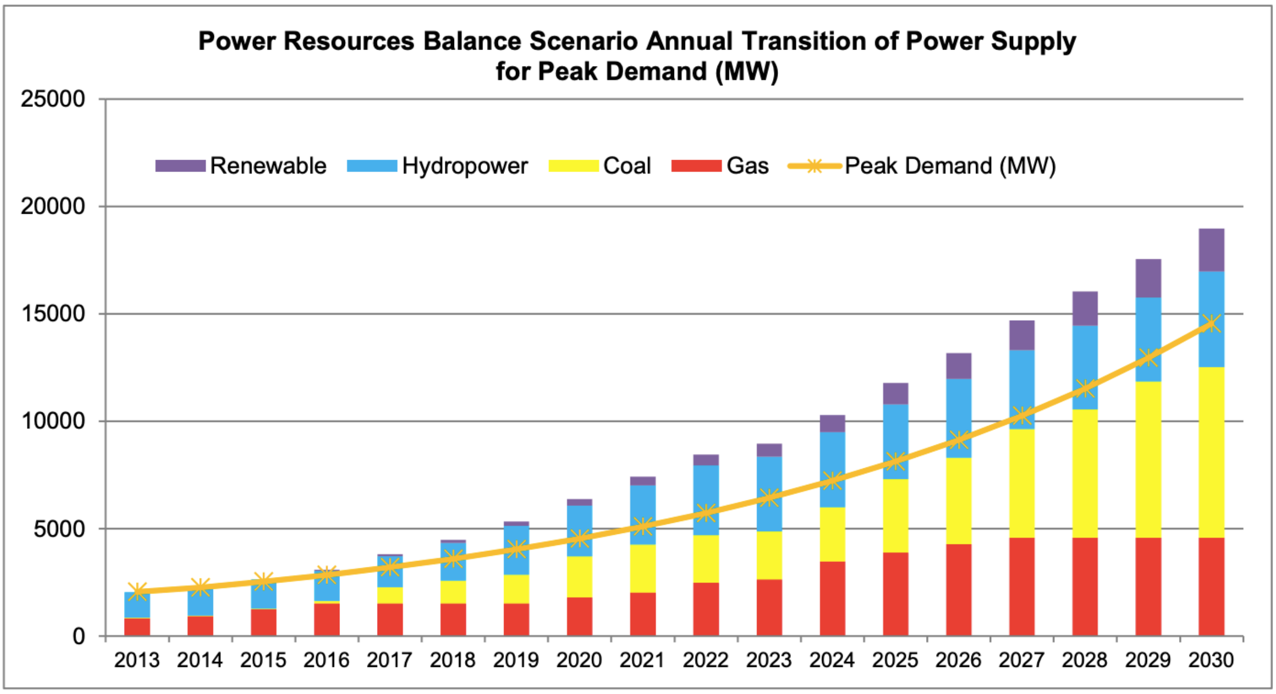
Source: SEEDS and CRED (Online access)

Figure 7.2 Monsoon Floods in Myanmar

The major source of power generation business is mainly based on hydro-power projects. In Myanmar, currently, there are almost 200 large dams built from 1990 to 2015. Several large dams are planned on increasing the future hydro-power utilization. In their final report for the implementation of the Master Plan, JICA Survey Team stated that existing power generation development plans had been oriented on large-scale hydro-power projects and were revised to balance power resources composition appropriately.

It was a turning point for policies of the electric power sector in Myanmar. It is also a remarkable aspect to include environmental and social considerations like Strategic Environmental Assessment (SEA) to set the criteria for the environmental impacts of decision making and policies. The best combination of power resources is shown in Figure 7.3. The feasibility of project implementation and the primary energy demand forecast can be guessed by this figure. According to the survey, JICA found that this would be the most effective and efficient while it is balancing the power resources in term of energy security.

This section will be focused on applying the Bayesian inference to draw conclusion and find the best solution to flood disaster effects on the construction of dams for hydro-power projects since hydro-power plants will be selected as a high priority to maintain power resource balance in the future.



Source: Final Report Summary on Power Sector Development in Myanmar by JICA

Figure 7.3 Annual Transition of the Electricity Supply for Power Resources Balance

7.4.2 Data and Problem Statement

Figure 7.4 shows the dataset of flood disaster occurrences due to the flooding in the monsoon season during the years covered by the study. It appears that the rate is high in the later part. We are truly interested in locating the change-point during the study period of the time series, which may be related to building of the dams and consequent climate change/natural environment. Thus, to know whether the disaster occurrences have really changed over time, the Bayesian MCMC data analysis will be applied here.

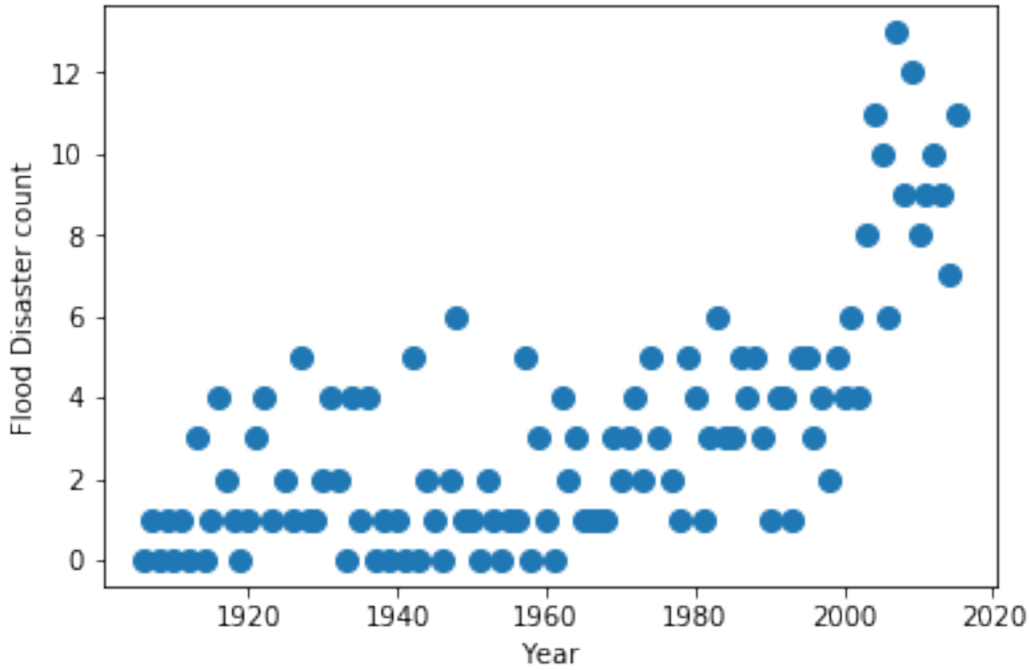


Figure 7.4 Recorded Flood Disasters in Myanmar

7.4.3 Conceptual Model Building

$$(D_t|s, e, l) \sim \text{Poisson}(r_t),\ rt = \begin{cases} e \text{ if } t < s \\ l \text{ if } t \geq s,\ t \in [t_l, t_h] \end{cases} \quad (7-1)$$

$$s \sim \text{Discrete Uniform}(t_l, t_h) \quad (7-2)$$

$$e \sim \text{Exponential}(r_e) \quad (7-3)$$

$$l \sim \text{Exponential}(r_l) \quad (7-4)$$

The symbols are defined as:

Dt: The number of disasters in year t

rt: The rate parameter of the Poisson distribution of disasters in year t

s: The year in which the rate parameter changes (the switchpoint)

e: The rate parameter before the switchpoint s

l: The rate parameter after the switchpoint s

tl, th: The lower and upper boundaries of year t

re, rl: The rate parameters of the priors of the early and late rates, respectively

The expected (mean) values of early and late rates with Poisson and exponential distributions are:

$$E[e|r_e] = 1/r_e \text{ and } E[l|r_l] = 1/r_l \qquad (7-5)$$

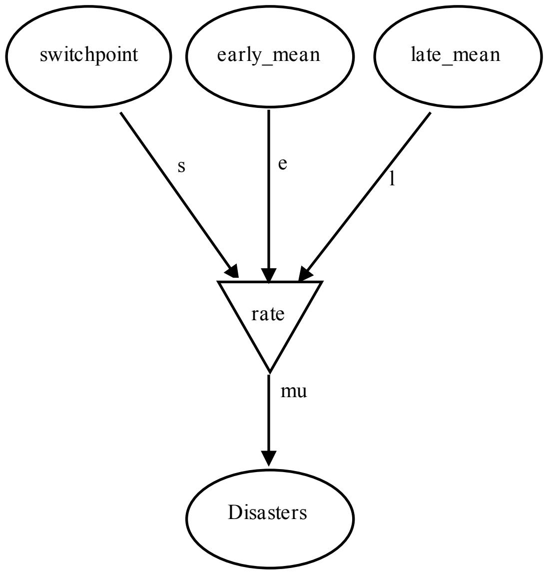


Figure 7.5 Graphical Model for the Parameters Generated in the Observations

After constructing our model, specifying our priors, setting our observing data, run in the PyMC programming. Iterations are 15,000 samples, discarded burn-in samples are 5, 000 and thinning is 5.

```
>>> from pymc.examples import disaster_model
>>> from pymc import MCMC
>>> mcmc = pm.MCMC(model)
```

```
>>> mcmc.sample(iter=15000, burn=5000, thin=5)
```

```
 [-----------------100%-----------------] 15000 of 15000 complete in
3.1 sec
```

```
early_mean_samples = mcmc.trace('early_mean')[:]
late_mean_samples = mcmc.trace('late_mean')[:]
switchpoint_samples = mcmc.trace('switchpoint')[:]
```

```
>>> from pymc.Matplot import plot
>>> plot(mcmc)
```

7.4.4 Result and Inferences

The final results can be checked in Figure 7.6 and the Bayesian inference on our unknown parameters can be drawn. The usefulness of the trace plot is the evaluation and diagnosing the algorithm's performance of the program. All traces express our strong belief in posterior distribution.

The autocorrelation plots state that there is no correlation between variables because of data noisiness. It means flood disaster occurrences are not connected to each other because of data noisiness as heavy rains, storms or others.

The right-hand panels show a histogram of visualizing the posterior distribution. The thick vertical lines represent the posterior mean. The intervals between the two dash lines represent the 95% credible interval (95%CI) that can see 95% uncertainty area and values within CI have a total probability of 95%.

Posterior distributions of the two rates are clearly distinct, e's value, early rate is around 2 indicating that little chance of occurrences before switchpoint and l's value is around 8 which reveals to have more frequency of occurrences after switchpoint.

In switchpoint plot after the large-scale construction of dams started from the year 1990, there was a maximum possibility of change in flood disaster occurrence. Potential switchpoints might occur only three or four times during the observation period.

In conclusion, the proposal is that it is necessary to study a development plan against the types of hydro-power stations such as reservoirs, regulation-pond and run-of-river. Additionally, it is also needed to have enough capacity to store the large quantities of water during the heavy rain season in order to avoid flood disasters and prevent people's losses. Reforms and progress will have to be made on the core issues of (i) uncertainty and lack of policy over planning of the dam's construction projects; (ii) outdated/absent legal rules and regulations for the whole sector; (iii) introduction of new policy frameworks, regulation and commercial performance; (iv) concerns about sector sustainability; and (v) weak capacity of government and institutions.

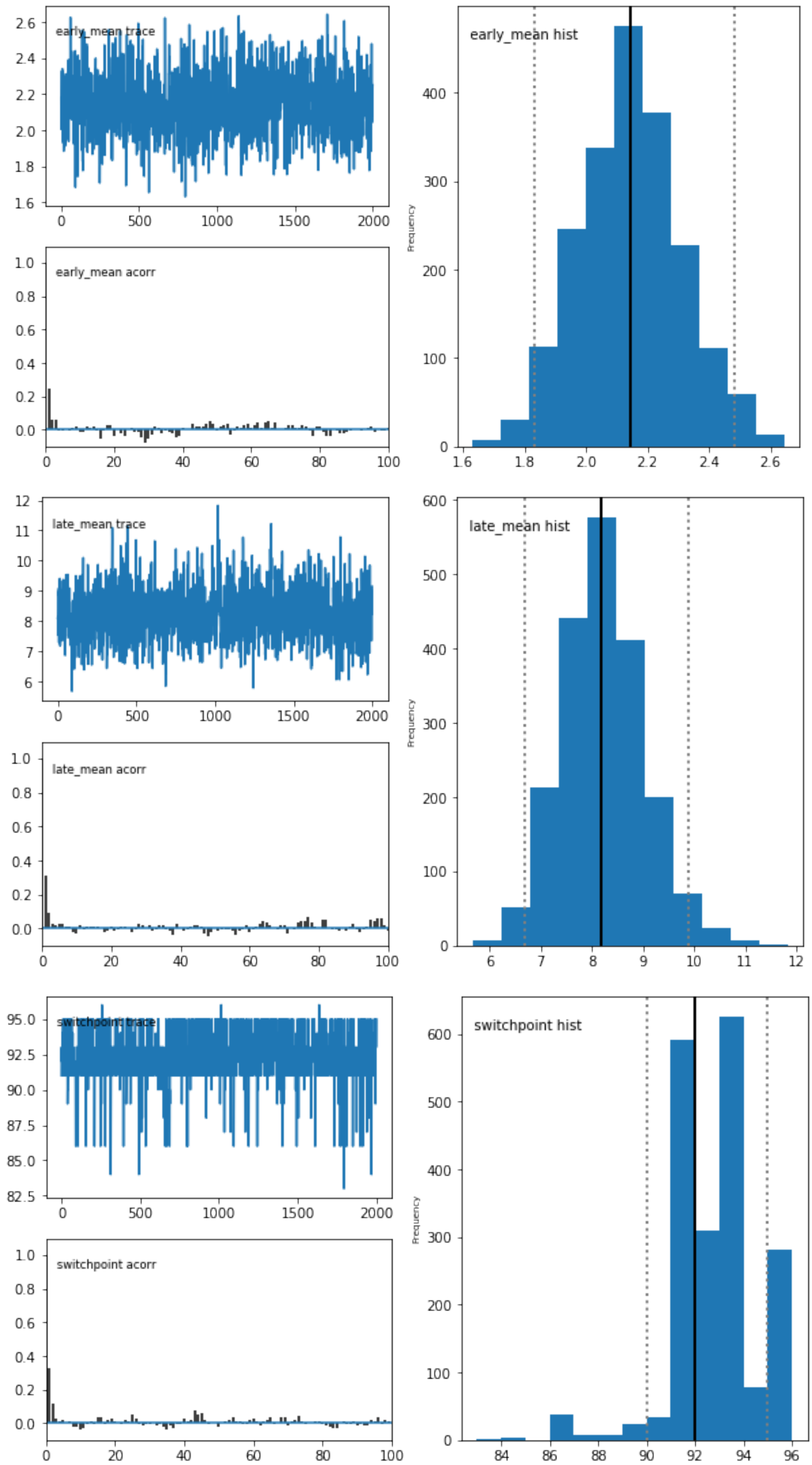


Figure 7.6 Output of PyMC Internal MCMC Plotting Tool

7.4.5 Model's Goodness of Fit

Comparison between the actual data and an artificial dataset that we simulate is one way to measure the model's goodness of fit. The following graphs in Figure 7.7 and 7.8 represent how well data simulated from the prior model and posterior parameters reflects the raw data.

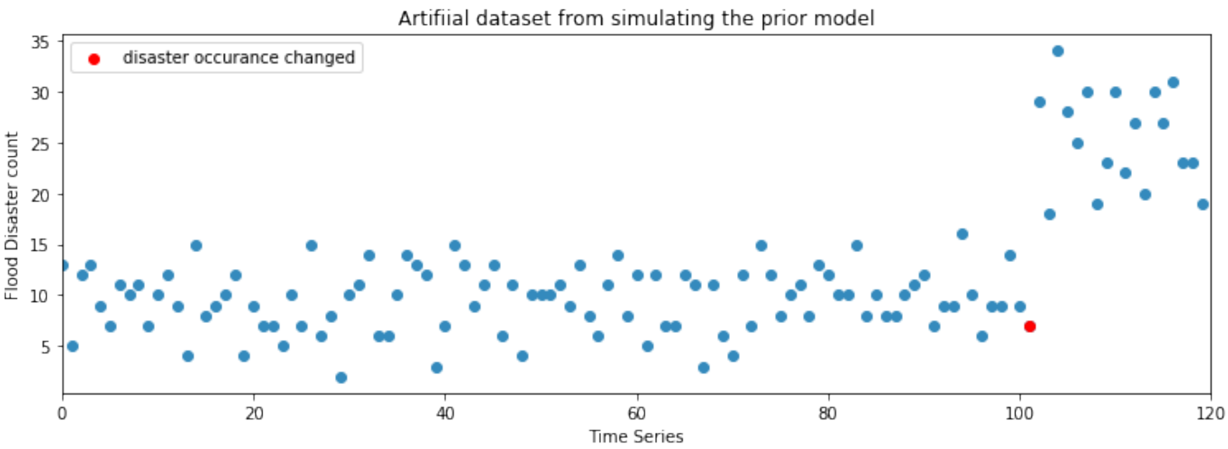


Figure 7.7 Artificial Dataset from the Priors

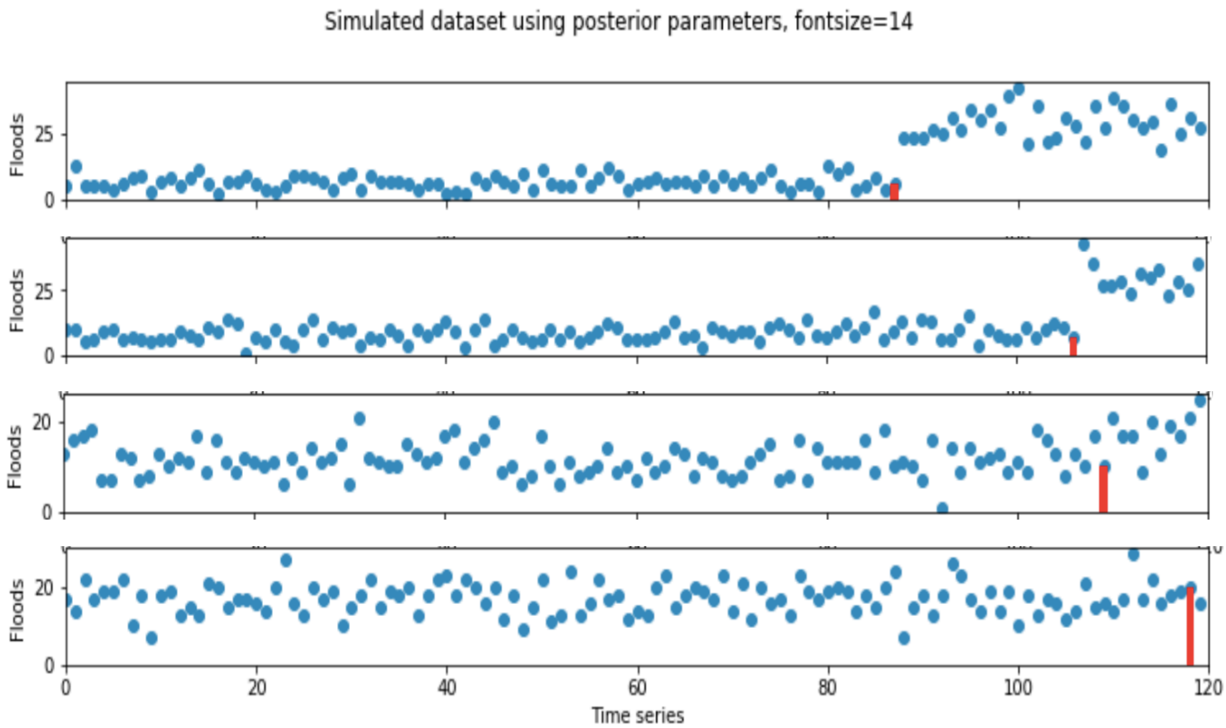


Figure 7.8 Simulated Dataset using Posterior Parameters

From the figures, we can see that the actual data show no appearance to deviate from our constructed model although randomness makes them appear different. There are high rates of change in disaster occurrences in the late parts that reflect our prior belief that it is highly probable it is due to the large-scale dam constructions and consequent climate/natural environmental changes.

7.5 Economic Assessment on Electricity Generation Business

In Myanmar, climate change is expected, with a high forecast, to become a major impact on causing continuous increased flooding, increased temperature variations and sea levels rises due to its low industrial development and predominantly hydro-based power generation. Therefore, the priority concern for Myanmar is to consider facilitating climate change adaptation (ADB, 2016). According to JICA and ADB, it was proposed to develop the solar-powered electricity generation together with the hydro-power for the optimal energy mix in commercial electricity supply. Myanmar has rich hydro-power potential as well as it has a strong solar radiation level. The solar energy potential drops during the rainy season but compensates for the decline of power production from hydropower and wind sources during the dry season. Moreover, mini-grids and solar energy home systems are renewable energy solutions that could solve power shortage problems in rural communities because they are not directly connected to the electric power grid. As a result, the government is committing sizable resources for off-grid renewables (Lwin, K.W., 2019). Here, the comparison table of strong and weak points between hydro and solar power generation projects can been seen in Table 7.1.

Table 7.1: Strong and Weak Points of Hydro and Solar Power Projects

	Hydro	Solar
Strong Point	Easy to use production technology	Comfortable for environment without natural disaster effects
Weak Point	Environmental impacts like deforestation, floods and consequent climate change	Difficult to get technology and cost more

Nevertheless, the energy industry is one of the most capital-intensive high-tech industries. Using the Bayesian MCMC Analysis on the revenue side will make the economic evaluation on such kind of capital investment project. To carry out the tasks of Master Plan, JICA prepared the overall development cost depending on the year of project phases of operational for power resources balancing. This can be seen in Table 7.2.

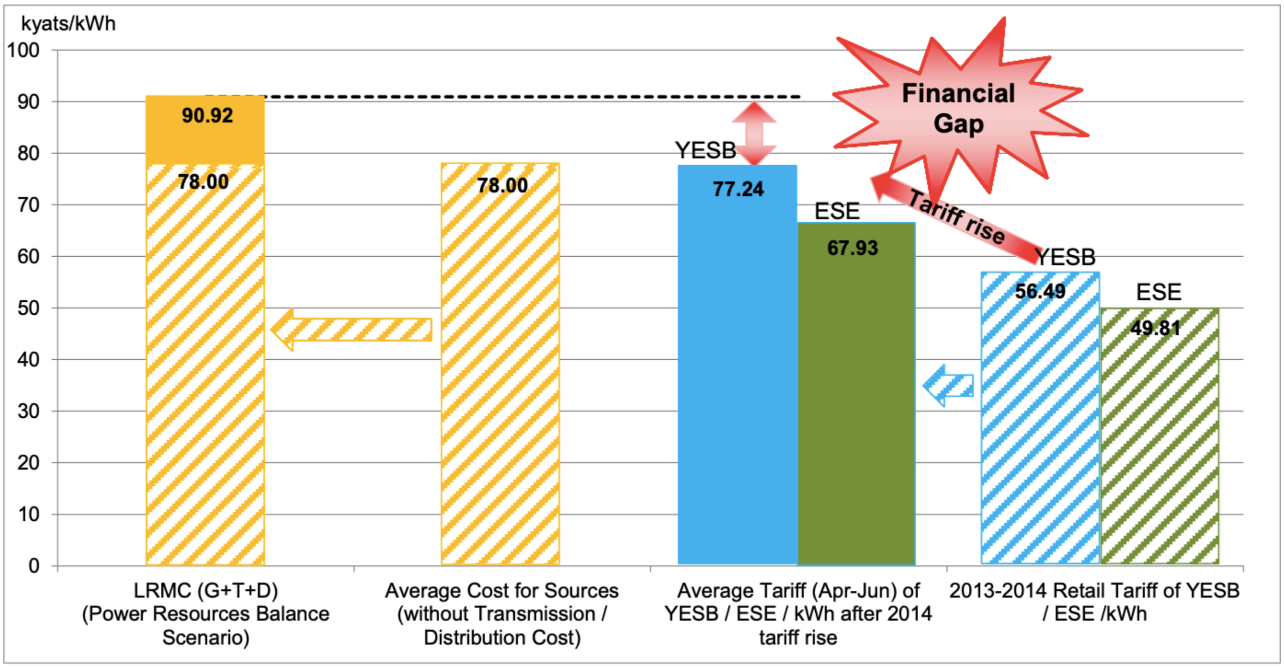
Table 7.2 Main Indicators of Power Resources Balance Scenario

Indicators			2013	2020		2030	
				High	Low	High	Low
Power Demand Forecast	Power Consumption		8,613GWh	22,898GWh	19,514GWh	77,730GWh	48,639GWh
	Maximum Power Demand		1,969MW	4,531MW	3,862MW	14,542MW	9,100MW
Primary Energy	Hydropower		2,361 MW	4,721 MW		8,896 MW	
	Gas		247 bbtud	348 bbtud		679 bbtud	
	Coal		300,000 ton	5,795,000 ton		23,373,000 ton	
	Renewable Energy		0 MW	200 MW		2,000 MW	
Power Supply Composition for Myanmar	Hydropower		2,361 MW (65.0%)	4,721 MW (53.6%)		8,896 MW (37.7%)	
	Gas		1,152 MW (31.7%)	1,969 MW (22.3%)		4,758 MW (20.2%)	
	Coal		120 MW (3.3%)	1,925 MW (21.8%)		7,940 MW (33.6%)	
	Renewable Energy		0 MW (0.0%)	200 MW (2.3%)		2,000 MW (8.5%)	
	Total		3,633 MW (100%)	8,815 MW (100%)		23,594 MW (100%)	
Power System Facility	Transmission (km)	500kV	0 km	1,029 km		2,659 km	
		230kV	3,047 km	7,434 km		9,624 km	
		132kV	2,109 km	2,389 km		2,511 km	
	Substation (MVA)	500kV	0 MVA	50,000 MVA		17,500 MVA	
		230kV	3,760 MVA	11,500 MVA		16,030 MVA	
		132kV	1,323 MVA	2,153 MVA		2,873 MVA	
Overall Development Cost	Power Generation		–	13.8 Billion USD		55.2 Billion USD	
	Transmission		–	2.7 Billion USD		5.6 Billion USD	
	Total		–	16.5 Billion USD		60.8 Billion USD	

Source: Final Report Summary on Master Plan prepared by JICA survey team

7.5.1 Expected Revenue Analysis by the Electricity Tariffs of Myanmar

The Myanmar Times said that the government's net income shows K284 billion losses per year at the rates of that period (Myanmar Times, 2014). In the data source of Ministry of Planning and Finance, it has mentioned that the loss amount rose up to MMK630 billion (USD414 million) in 2018-2019. The annual transition of power supply as well as the financial gap between previous electricity tariffs until June 2019 and Long Run Marginal Cost (LRMC) were finalized by JICA and shown in Figure 7.9.



Source: JICA Report Summary for Electricity Master Plan

Figure 7.9 Financial Gap between Power Tariffs and LRMC at Old Rate of Tariffs

In an effort to reduce state spending, there was a proposal in the Parliament in 2014 to increase the price of electricity usage for the households by as much as 42.8% on the electricity units which are used over a certain threshold. On the other hand, increasing rates will push up the cost of business and impact commodity prices. Some economists suggested that the government should subsidize through tax collection for the future development of industry instead of raising rates. It also should try to extend power access to other off-grid regions and expand to more households. At the present time, Myanmar government is carrying out all basic reforms, and the development of infrastructure resources, technologically and financially, by the international assistance for the transmission and distribution of electricity that will effectively reduce the rate of loss through power leakage. As a result, it will cover annual financial losses to some amount.

In its report, JICA stated that although financial issues in the electric power sector were of concern to stakeholders, it had been suggested that, due to the lack of systematic scheme, they should be expressed by qualitative opinions and the electricity tariffs by quantitative analysis. It indicates that it should formulate and adjust the appropriate tariff level which corresponds to the realistic power generation and transmission costs by the development and fund procurement scheme.

Table 7.3 Current Electricity Tariffs in Myanmar

No.	Types of Consumers	Rate for Consumption	
		Unit	**Kyat**
1	**Private Consumption**	1 - 30	35
	Domestic Consumption	31 - 50	50
	Power Meter at Home	51 - 75	70
	Religious Building	76 - 100	90
		101 - 150	110
		151 - 200	120
		Over 200	125
2	**Commercial Consumption**	1 - 500	125
	Industries	501 - 5,000	135
	Businesses	5,001 - 10,000	145
	Temporary	10,001 - 20,000	155
	Lamp Posts	20,001- 50,000	165
	Governmental Buildings	50,001 - 100,000	175
	State-owned Businesses	Over 100,001	180
	River Pumping Stations		
	Municipal Departments, Works		
	Non-Governmental Organizations		
	Embassies		
	International Organizations		

Source: Global New Light of Myanmar and Myanmar Times – Business

As described in section, 2.3.6, the government increased electricity rates for both residential and business users starting from July, 2019 in order to recover some losses and; as well as for the implementation of new electric power generation projects and electricity infrastructure development. The current electricity tariffs are shown in Table 7.3. And the exchange rate from MMK (Myanmar Kyat) to USD is 1MMK = 0.0007USD as of April, 2020.

7.5.2 Model Construction and Analyzing for Bayesian Result

If the electricity supply can extend locally, it will also enable raising revenue. Based on the current electricity tariffs for both consumption types of households that can use electricity and commercial usage in FY2018-19 together with their respective percentage by tariff levels, the analysis will be made on electricity revenue using the Bayesian A/B test for an economic assessment in the purpose of endurability and overcoming the financial deficit period. The numbers of users in the analysis for both consumption types are based on the actual data from the source of MOEE.

Company's expected revenue for the household side can be calculated from:

$$E[R] = 35p35 + 50p50 + 70p70 + 90p90 + 110p110 + 120p120 + 125p125 + 0p0$$

where *p35* is the probability of selecting the MMK35 tariffs plan, and so on. It is also included a fictional MMK0 tariffs plan for some households who do not pick any pricing plan or do not use the electricity at all. It is added in order to the sum of the probability becomes 1.

The analysis is made first separately for households' consumption types by the Bayesian MCMC analysis by Python Programming (Davidson-Pilon, C., 2016 and Hilpisch, Y., 2019). By the use of Dirichlet/Multinomial model, the result of posterior probability of user rate and the revenue analysis for household consumption can be seen in Figure 7.10 and 7. 11 respectively.

In accordance with the Bayesian Analysis steps, first we construct with our prior model as Dirichlet function. Then we use the Multinomial distribution for our observed data. After combining our prior model with our observed data function, we can obtain our posterior distribution by using the Dirichlet distribution again as in the following programming code. In the program, *N* represents for the total numbers of household/private electricity users (in ten thousand units) that have access to the electricity in FY2018-19 that comes from the data source of MOEE.

```
N     = 2322
N_35 = 207
N_50 = 245
N_70 = 286
N_90 = 314
N_110 = 352
N_120 = 475
N_125 = 400
N_0   = N - (N_35 + N_50 + N_70 + N_90 + N_110 + N_120 + N_125)
observations = np.array([N_35, N_50, N_70, N_90, N_110, N_120, N_125, N_0])

prior_parameters = np.array([1,1,1,1,1,1,1,1])

posterior_samples = dirichlet(prior_parameters + observations,
                              size=10000)
```

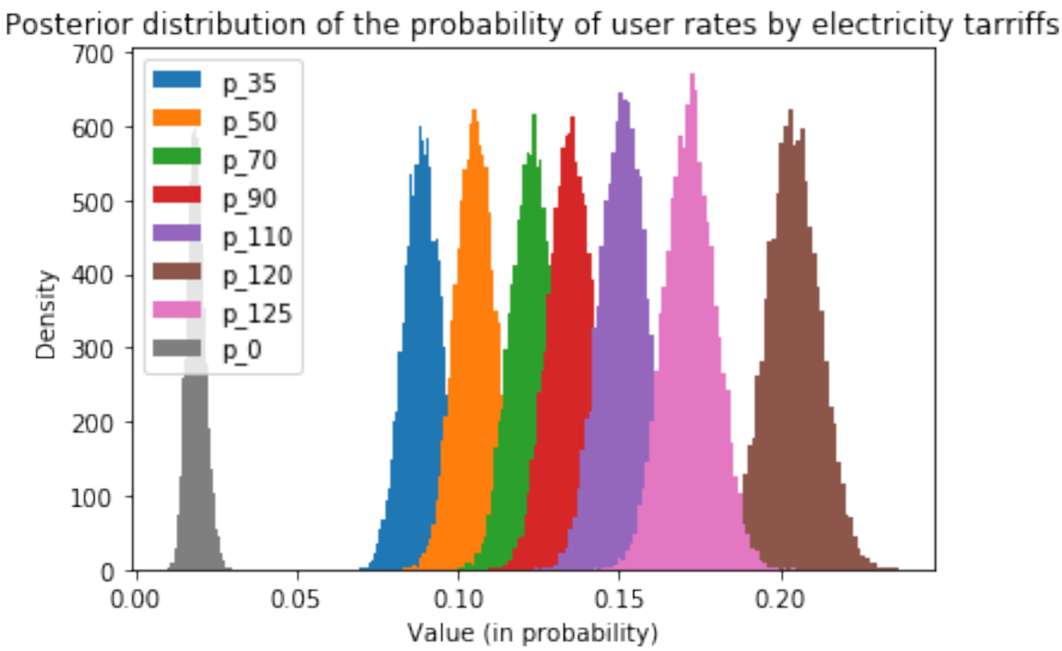


Figure 7.10 Posterior Distribution of the Probability of User-rates by Electricity Tariffs

As we see in above Figure 7.10, there is still uncertainty in probabilities of user rates and so there will also be uncertainty in our expected value. In figure, the price of MMK120 per unit has the highest probability indicating that most of the households use the electricity between 151 to 200 units. The second one is MMK125 per unit which indicates some households use over 200 units. Moreover, we can know that a few households' electricity usage is between 101 and 150 units per month. The probability of other price plans can also be checked in that figure. And very little households don't use electricity at all. It may be because of some reasons as they are cut to use electricity by the company due to the absence of paying monthly usage fee, leaving their homes, etc.

After the parameters had been estimated, then we passed them thorough the expected revenue function to guess power company's real financial situation. Its function can be checked as expressed in following programming code. We can see from Figure 7.11 below that the expected revenue is likely between MMK9 Billion and MMK9.4 Billion, unlikely to be outside this range.

```
def expected_revenue(P):
    return 35*P[:,0] + 50*P[:,1] + 70*P[:,2] + 90*P[:,3] + 110*P[:,4] + 120*P[:,5] + 125*P[:,6] + 0*P[:,7]

posterior_expected_revenue = expected_revenue(posterior_samples)
```

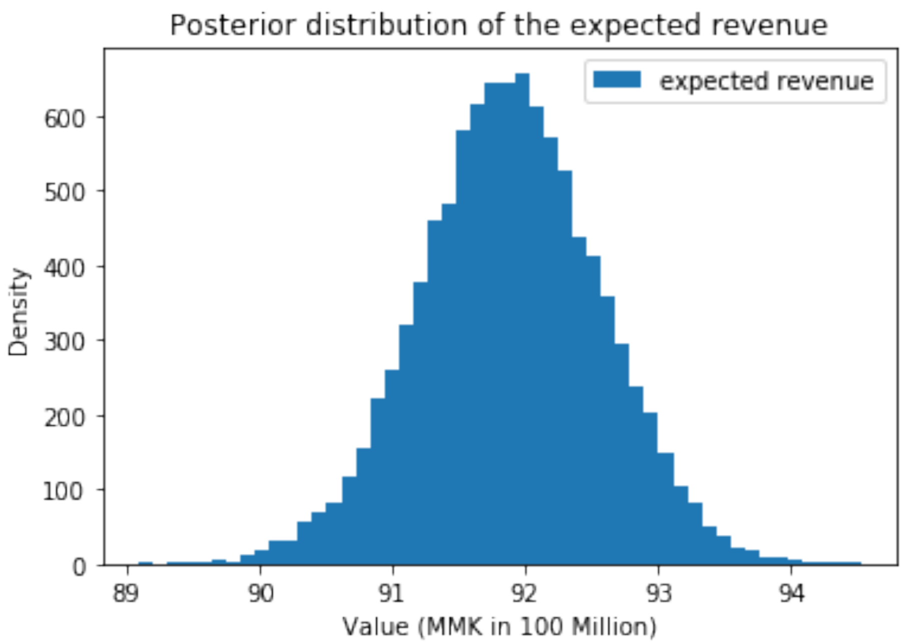


Figure 7.11 Posterior Distribution of the Expected Revenue from Household Consumption

Next, the analysis will be continued to the posterior revenue estimation by combining the both types of consumers. In the program, the symbol code *N_H* represents for the numbers of household/private electricity users (in '0,000 units) among the total population of Myanmar in 2018-19 and *N_C* is for the total numbers of commercial consumption. The analysis result for total expected revenue between two types of consumptions is shown in Figure 7.12.

```
N_H     = 2322
N_H_35 = 207
N_H_50 = 245
N_H_70 = 286
N_H_90 = 314
N_H_110 = 352
N_H_120 = 475
N_H_125 = 400
N_H_0   = N_H - (N_H_35 + N_H_50 + N_H_70 + N_H_90 + N_H_110 + N_H_120 + N_H_125)
observations_H= np.array([N_H_35, N_H_50, N_H_70, N_H_90, N_H_110, N_H_120, N_H_125, N_H_0])


N_C     = 1448
N_C_125 = 60
N_C_135 = 155
N_C_145 = 258
N_C_155 = 250
N_C_165 = 275
N_C_175 = 250
N_C_180 = 200
N_C_0   = N_C - (N_C_125 + N_C_135 + N_C_145 + N_C_155 + N_C_165 + N_C_175 + N_C_180)
observations_C = np.array([N_C_125, N_C_135, N_C_145, N_C_155, N_C_165, N_C_175, N_C_180, N_C_0])


prior_parameters = np.array([1,1,1,1,1,1,1,1])


posterior_samples_H = dirichlet(prior_parameters + observations_H,
                                size=10000)
posterior_samples_C = dirichlet(prior_parameters + observations_C,
                                size=10000)

posterior_expected_revenue_H = expected_revenue(posterior_samples_H)
posterior_expected_revenue_C = expected_revenue(posterior_samples_C)
```

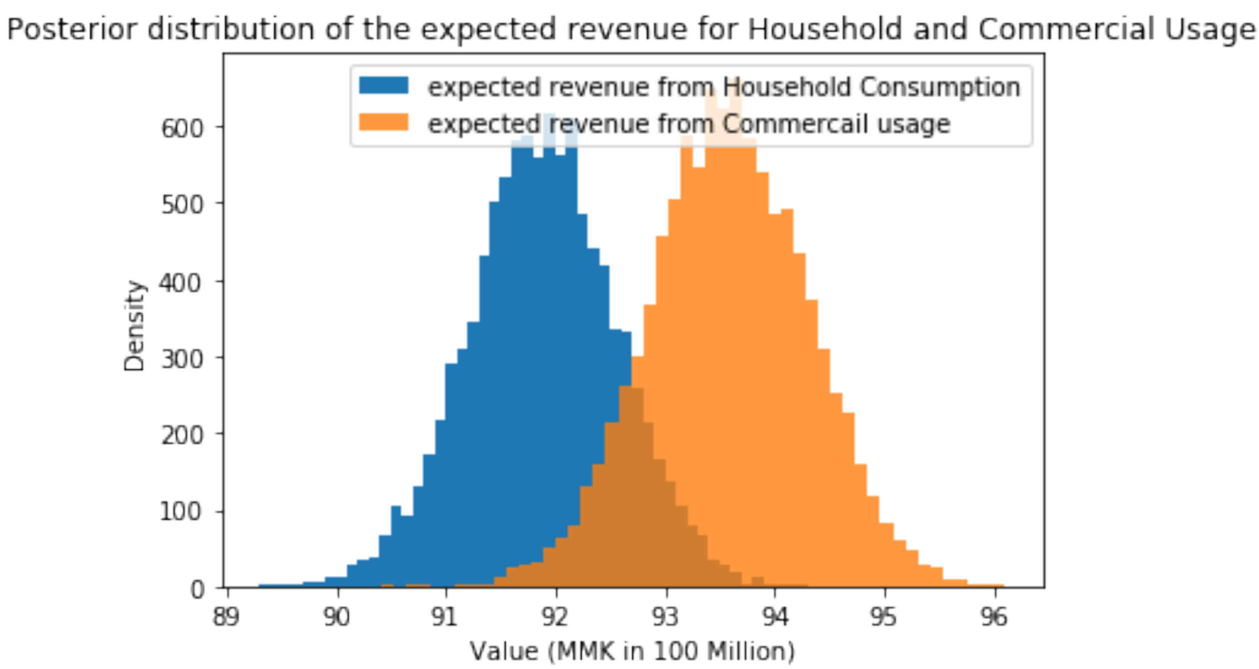


Figure 7.12 Posterior Distribution of the Expected Revenue from Both Types of Users

In above Figure 7.12, it is noticed how far apart the two posteriors are, suggesting the a significant difference in the two types of consumption. The average expected revenue for private consumption type is over MMK0.2 Billion less than that of commercial consumption as seen in figure although the number or percentage of the commercial electricity users is lower than the that of private user. It is simply due to fact that the difference between the two tariffs levels are high enough. To confirm this difference exists, we can look at and check the probability that the revenue for commercial electricity consumption is larger than households/private consumption's as in following print by the program.

```
p = (posterior_expected_revenue_C > posterior_expected_revenue_H).mean()
print ("Probability that C has a higher revenue than H: %.3f"%p)
```

```
Probability that C has a higher revenue than H: 0.959
```

This value, 96%, indicates that there is sufficient difference between two types of consumption. Another important plot is the posterior summation of revenues for both types of consumption and it is shown in Figure 7.13.

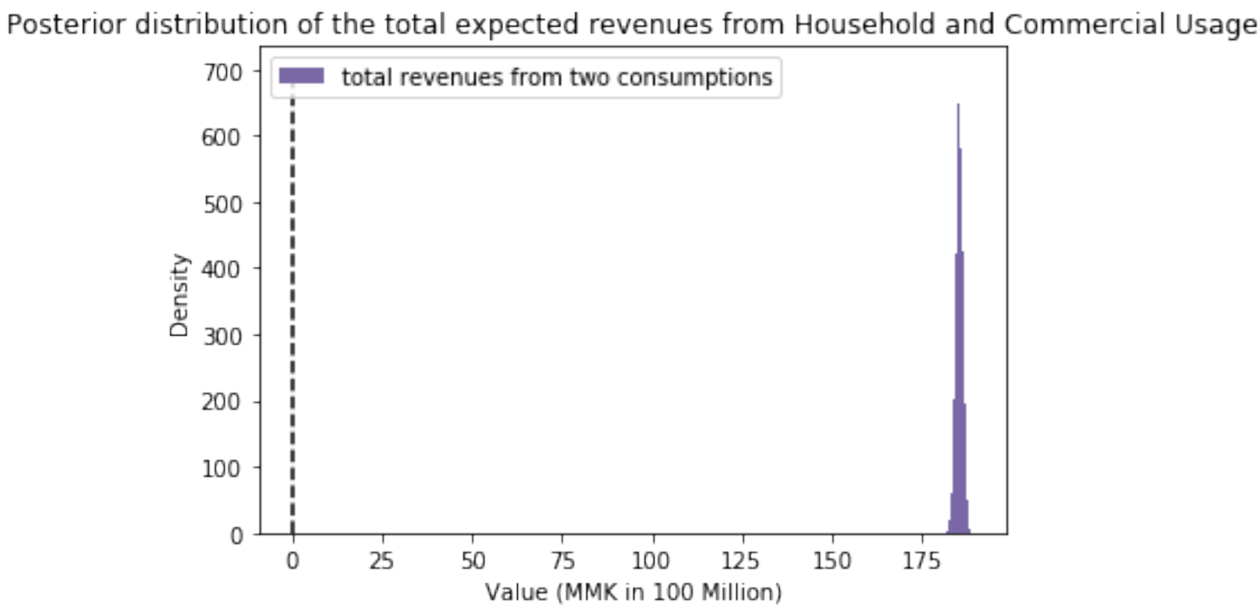


Figure 7.13 Posterior Distribution of the total revenues from Both Types of Consumption

In this figure, we can see that there is almost absolutely certainty to get these total revenues, the bell shape distribution is very sharp and narrow. Finally, we can draw the inference and conclusion that the chance for the government that can receive the revenue about MMK19 Billion (about USD13.6 million according to the exchange rate as of May, 2020) at the current electricity prices with a certain low percentage of electrification to the population that has only 69.81% of the total population in FY2018-19 (43% of private consumption and 26.81% for the commercial consumption). Current population of Myanmar is 54 million.

7.6 Bayesian Games under Incomplete Information

So far, the games are looked at the situations of complete information, where all players know everything about everything about everybody else. In reality, it is often not the case. Under the incomplete information, the firm does not know its rival's precise characteristics or type. In this section, the game competition will be continued under the asymmetric and incomplete information as the perfect game.

7.6.1 Approaching to Perfect Bayesian Equilibrium by the Signaling Games

In a dynamic game, ill-informed player is able to learn something about the game being played by observing the moves of better-informed opponent. The solution approach is that it requires the players to rationally update their beliefs about the game using the procedure of Bayesian updating. Also, this is the extension of the concept from Nash equilibrium and subgame perfection to reach out the perfect Bayesian equilibrium. Since there can be frequently a very large number of possible strategies and beliefs, the signaling game, a type of game with incomplete information, is very useful in that situation.

7.6.2 Patent as A Signal for Game Perfection Between Competitive Firms

The Model Construction

It will be continued as the two-player game which involves an entrepreneur denoted by E for the new energy industry and potential investor, foreign company denoted by F, as the business partner. The entrepreneur is the domestic firm who has started a company, but it needs outside financing if he wants to undertake an attractive new project for energy generation as the project extension. The domestic firm has the private information about the existing company. Thus, the domestic firm also has the private information about the productivity of the new project although the generation amount of the new project cannot be same as the amount of generation from the existing one.

Under that circumstances, the domestic company will make a proposal of investment to a potential investor for the necessary financing. The foreign investor has to decide whether to join the new project or not. For that decision, he needs to consider such that under what circumstances the new project will be undertaken, and what will be the cost of acquiring patent right. This problem will be illustrated as a signaling game under the following conditions.

The electricity productivity of the new project can be either high or low, which is denoted by π, $\pi = 30$ (high) and $\pi = 20$ (low). But this information is hidden from foreign investor. On the other hand, domestic company can continue the existing project, where it only earns ${}^{2}/_{3}\pi$ for himself, so this is the opportunity cost for above offering. If the new project is attractive, the required investment by foreign company is I, that is, in other terms, cash inflow for domestic firm. If the foreign investor joins the new project and invest in it, his payoffs is $\pi - I$ and the domestic company's payoff equals $I - {}^{2}/_{3}\,\pi$. If the foreign investor doesn't join the project, then both earns a payoff of zero. The Pareto optimal outcome for foreign investor here is to join the project and accepts the investment offer amount between ${}^{2}/_{3}\pi$ and π.

Foreign Investor has a prior belief about the productivity with a probability of $q = {}^{1}/_{3}$ (high) and low probability of $1 - q = {}^{2}/_{3}$ (low) based on his experiences and past observations. In this game, Nature moves first with the probability, $q = {}^{1}/_{3}$ for the type of high productivity and with probability, $(1 - q) = {}^{2}/_{3}$ for the low type of productivity. Domestic firm observes that for his next move and then chooses either to abandon or to extend the new project. The game tree for their payoffs only from the new attractive project is displayed in Figure 7.14.

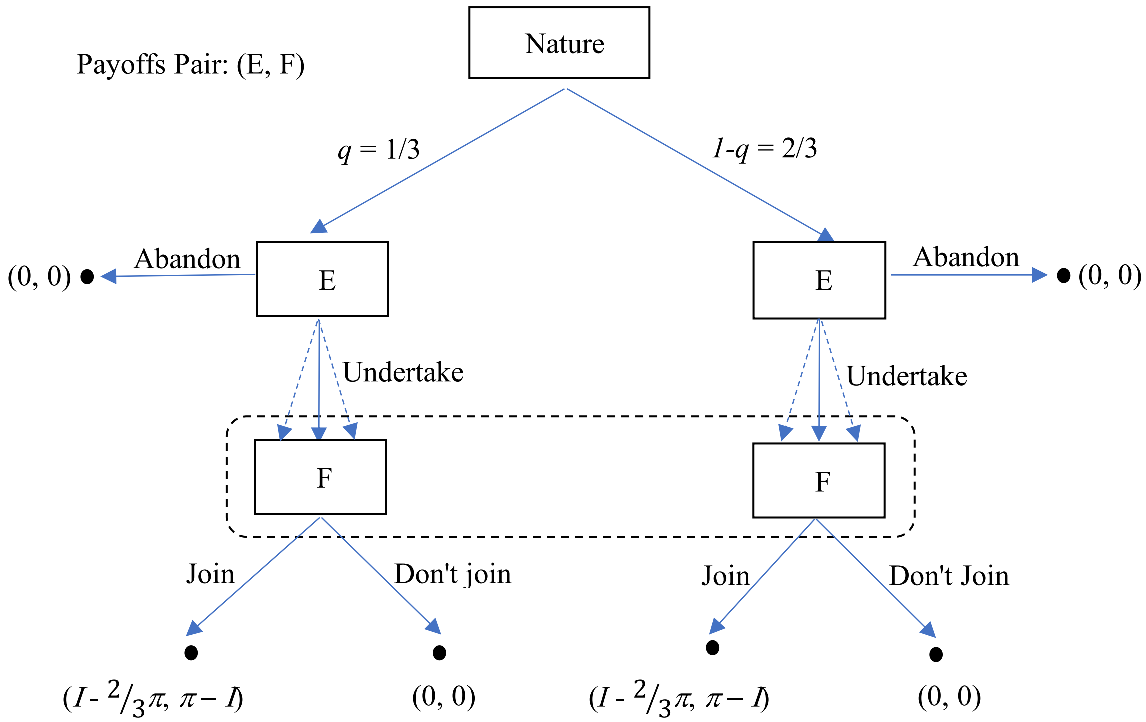


Figure 7.14 The Game Tree for the Potential Payoffs from New Project

7.6.3 Analyzing for the Equilibrium Result by Updating Beliefs against Strategies

Perfect Bayesian Equilibrium (PBE)

A pure strategy for the domestic firm that consists of a function: $b(\pi)$ states the behavior for profitability when his type is π. A pooling strategy is one for which the domestic firm behaves the same regardless of his type for productivity, that is, $b(30) = b(20)$. A separating strategy is one in which the domestic firm behaves differently depending on his type, that is, $b(30) \neq b(20)$. After learning the behavior for productivity of the domestic firm, foreign investor updates his beliefs $p(b)$ about the productivity for being domestic company's type is high. With these belief, the expected payoffs from joining the new project equals: $(30 - I) \,.\, p(b) + (20 - I) \,.\, (1 - p(b))$.

A pure strategy for foreign company consists of a joining decision for acquiring profit: $a(\pi)$ for each investment I that the domestic company might propose for financing.

The following strategies and beliefs form a perfect Bayesian equilibrium for the game:

Domestic Firm's Strategy: Proposes an investment of 20 (in million USD) when the firm's productivity type is low and retreats his proposal when the productivity is high type.

Foreign Investor's Strategy: Joins the new project if and only if domestic firm proposes an investment less than or equal 20 (in million USD).

Foreign Investor's Belief: Domestic firm is certainly a low productivity type whenever he makes an offer, regardless of the investment amount he proposes.

Proof for Perfect Bayesian Equilibrium

To prove that the above strategies and beliefs profiles satisfy the condition for a perfect Bayesian equilibrium, it is started with foreign investor's beliefs. Given domestic firm's investment proposal of 20 (in million USD), the conditional probability that he is a high productivity type according to Bayes' Theorem is:

Bayes' Theorem:

$$P(E_i|F) = \frac{P(F|E_i)\ .\ P(E_i)}{P(F)} \qquad (7-6)$$

$$P(F) = \sum_{i=1}^{N} P(F|E_i).P(E_i) \qquad (7-7)$$

$P(\pi = 30|I = 20)$

$$= \frac{P(I = 20|\pi = 30)\ .\ P(\pi = 30)}{P(I = 20|\pi = 30)\ .\ P(\pi = 30)\ +\ P(I = 20|\pi = 20)\ .\ P(\pi = 20)}$$

$$= \frac{0\ .\ \frac{1}{3}}{0\ .\ \frac{1}{3} + 1\ .\frac{2}{3}}$$

$= 0$

Above proof of Bayes' Theorem implies that condition (3) is satisfied. It is perfectly all right for foreign investor's belief that the any investment proposal up to 20 (in million USD) also implies that the domestic firm is certainly low productivity type.

For the foreign investor's expected utility, given his updated beliefs and domestic firm's investment proposal, his strategy is obviously optimal. He is willing to invest up to the amount of 20 (in million USD) that he believes the new project is worth to him. This means that condition (2) is satisfied.

Finally, domestic firm's strategy is evaluated. Since the foreign investor will only accept a proposal of investment less than or equal 20 (in million USD), domestic firm should only make an offer if he is a low productivity type. If he does this, then he should get the highest profit he can. Thus, domestic firm's strategy is optimal and condition (1) is satisfied.

The outcome of the equilibrium is that domestic company makes an offer if and only if he is a low productivity type. When the domestic firm has high productivity of the new project, he is willing to certify for that.

Entering the Signaling Game

The above game will be modified to make the patent as a signal. Before the domestic firm makes an offer to foreign investor, he has the option of obtaining a "Patent". As the foreign investor cannot observe the productivity of new project from domestic firm prior to accepting the offer of joining new project, he can observe the firm's level of image with patent. Thus, this will serve as a signal. Here, y is denoted the power of license conferring a right by the patent. It is assumed that the patent has no effect on the productivity of the firm, but it is costly for domestic firm to acquire. The cost is denoted by $c(\pi)$ and depends on the firm's performance for productivity. After domestic firm chooses to acquire the patent with its cost, he proposes a higher investment to foreign investor. It is noted that domestic firm cannot recover the cost of acquiring the patent if the foreign investors doesn't join the new project. The game tree is depicted in Figure 7.15.

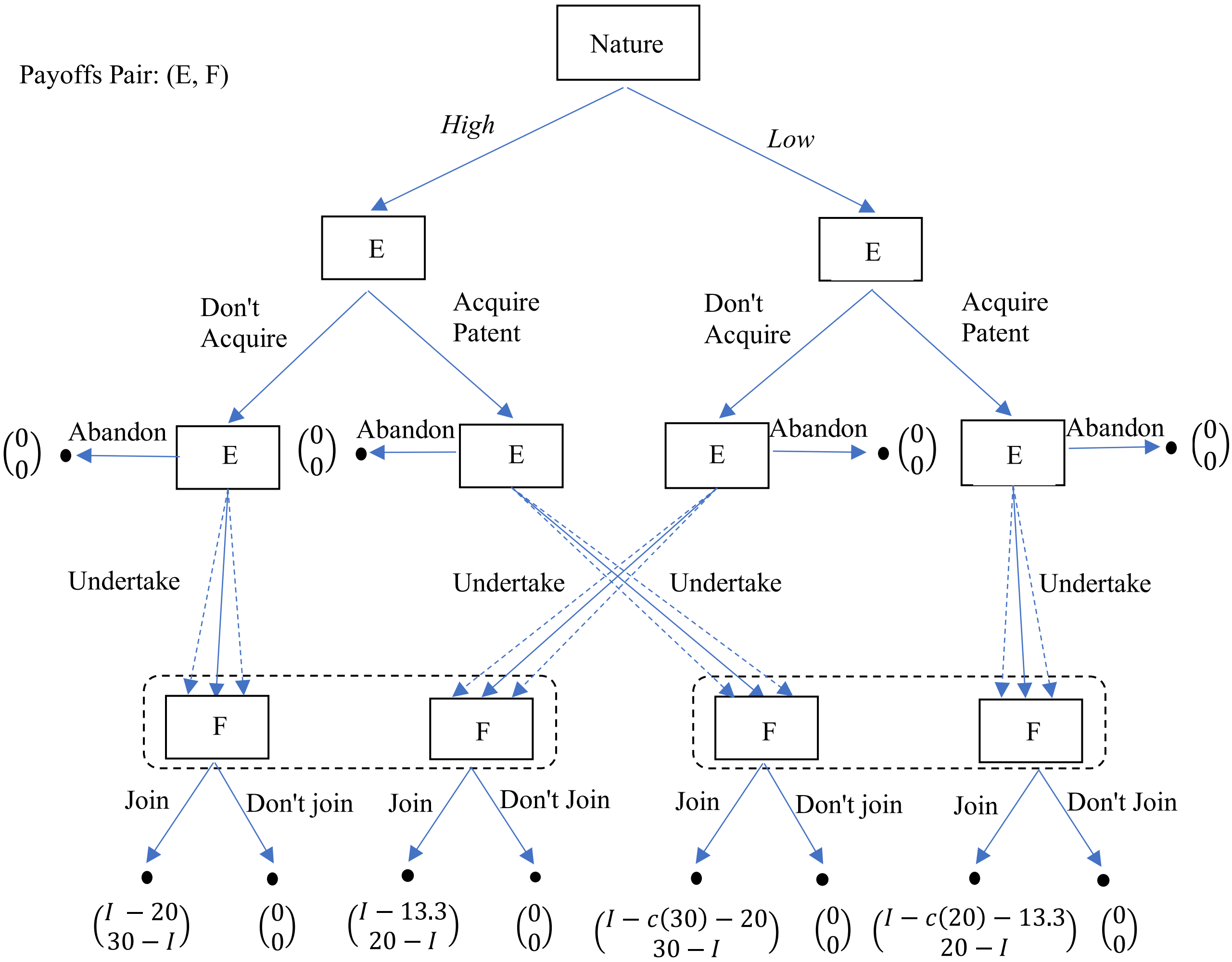


Figure 7.15 The Game Tree for Patent as Signal

In this signaling game, a pure strategy for domestic firm of two decisions based on his productivity: patent acquiring, $y(\pi)$, and his behavior of productivity $b(\pi)$. His pure strategies can be pooling or separating. A pure strategy for foreign investor consists of a decision whether to join the new project when the domestic firm acquires patent (y) and proposes an investment (I). A belief for the foreign investor includes a function p(y, I), where $0 \geq p(\text{y}, I) \geq 1$, which describes the probability that the domestic firm is a high type of productivity when he acquires patent (y) and proposes the investment I. Here, the necessary condition for cost of acquiring patent to serve as a signal is:

$$c(20) > c(30)$$

Assume that $c(20) = 14$ (in million USD) and $c(30) = 2$ (in million USD). With these costs, perfect Bayesian equilibrium can be formed from following strategies and beliefs.

Domestic Firm's Strategy: Does not acquire a patent and proposes an investment amount of USD20 million when he is a low productivity type and, acquires the patent and proposes an investment of 30 (in million USD) when he has high productivity type.

Foreign Investor's Strategy: Joins the new project if and only if the domestic firm does not get a patent and proposes for an investment less than or equal to 20 (in million USD) or gets a patent and proposes an amount of investment less than or equal to 30 (in million USD).

Foreign Investor's Belief: Believes that the domestic firm is certainly a high productivity type when he gets a patent and believes he is certainly a low productivity type when he does not.

Verification for perfect Bayesian equilibrium

It is started with foreign investor's beliefs and calculate the following conditional probability.

$P(\pi = 30 | I = 30, y = 1)$

$$= \frac{P(I = 30, y = 1 | \pi = 30) \,.\, P(\pi = 30)}{P(I = 30, y = 1 | \pi = 30) \,.\, P(\pi = 30) + P(I = 30, y = 1 | \pi = 20) \,.\, P(\pi = 20)}$$

$$= \frac{1 \,.\, \frac{1}{3}}{1 \,.\, \frac{1}{3} + 0 \,.\, \frac{2}{3}}$$

$= 1$

Bayes' Theorem verification implies that a foreign investor's belief for domestic firm has the high productivity type works perfectly with its proposal for a high investment 30 and acquiring the patent.

With these beliefs, it can verify for the strategies of both firms. For foreign investor, accepting any investment proposal less than or equal to 30 is better than rejecting it. The sound reason for this strategy is that domestic company proposes an investment of 30 and has acquired the patent only if he is the high productivity type. Then if he offers an investment amount of 20 and does not have the patent, then the highest acceptable amount for investment is limited to 20.

Finally, it is verified for domestic firm's strategy. If he is a high productivity type, getting the patent will give him a payoff of 30 – 2 (cost for patent) = 28 (in million USD). This move is better than self-running the existing one since it is greater than his self-running payoff $2/_3 \times 30 = 20$. It is also is better than the one without having the patent which payoff is only 20. On the other hand, if his firm has low productivity, getting the patent will result in a payoff of 30 – 14 = 16. Self- running the existing one will only yield a payoff of $2/_3 \times 20 =$ 13.33. In that case, the best option for him is not to get the patent, resulting in a payoff of 20. Their equilibrium results are depicted in the payoff game tree of Figure 7.16. These all are shown for a case of separating equilibrium in perfect Bayesian equilibrium.

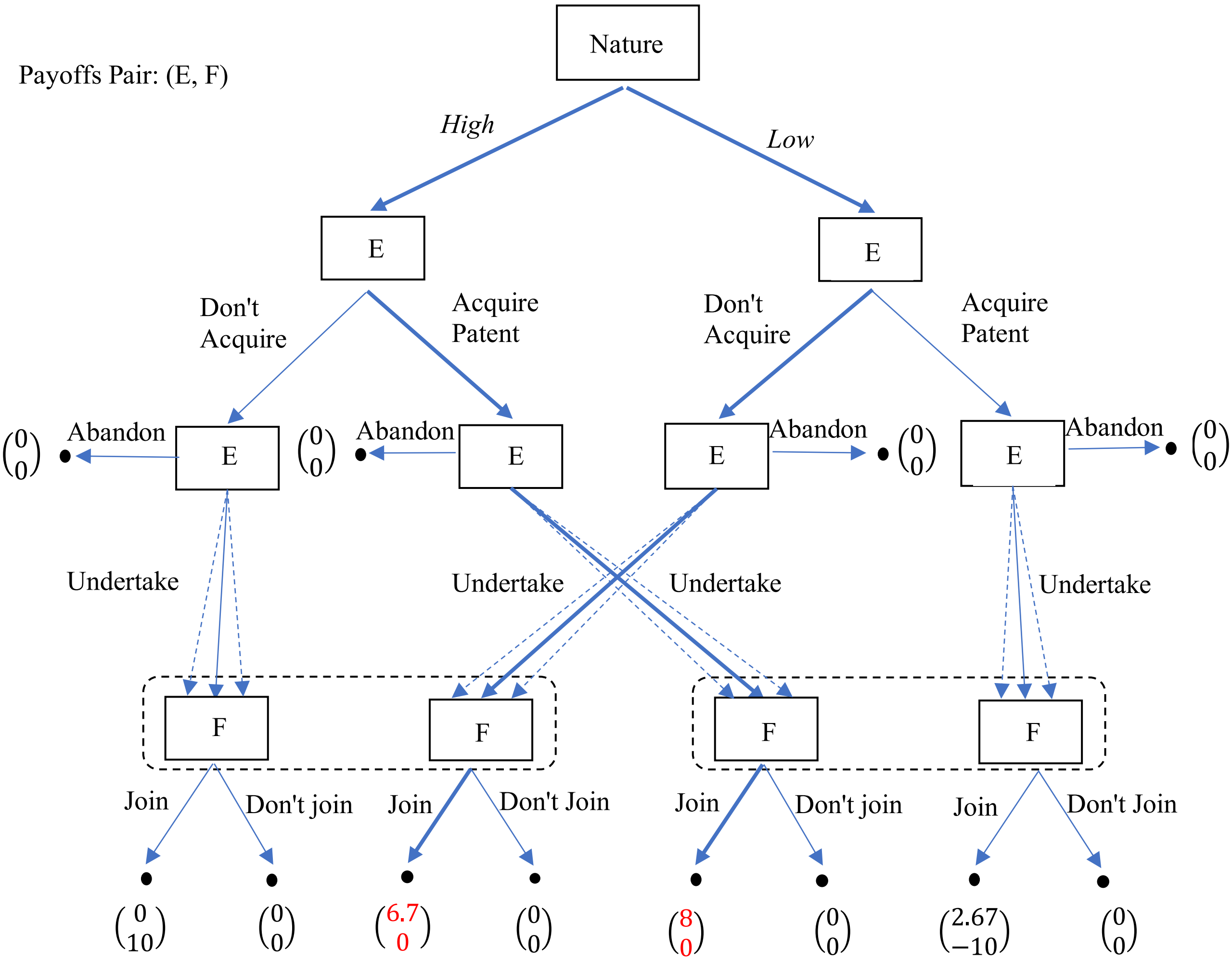


Figure 7.16 The Perfect Bayesian Equilibrium and Payoffs Tree for Signaling Game

7.7 Summary for Bayesian Methods

In our previous research, we used the combination of real options analysis and game theory for the assessment of investment strategies with managerial flexibility against rival companies to enter the market. In the above research, the Bayesian analysis is the preliminary stage and it needs further deeper and more effective analyses in connection with the power supply side by the government, and generation side by the private companies. Finally, we will have to integrate all kinds of analyses harmoniously to sum up our research objectives.

CHAPTER 8

CONCLUSION AND FUTURE RESEARCH

8.1 Introduction to Conclusion

In the new dynamic competitive landscape that high-tech and other industries are facing today, it becomes essential for firms to be more flexible in their investment programs, allowing management to change the amount, rate, timing or scale of investment in response to new, unexpected developments and competitive moves. Managerial flexibility to adapt and revise future decisions in order to capitalize on favorable future opportunities or to limit the loss has proven vital to long-term cooperate success in an uncertain and changing marketplace (Trigeorgis, L., 2000). Then, the advantage of Bayesian analysis is expected to be in the probability estimation of interested parameters. As we know, high technological energy industry needs to invest very huge amount that takes very long time to recover and has very high risk together with the innovation and utilization of high technology in new energy project.

8.2 Research Findings

The research study of this thesis suggests prominently that the integration of real options, game-theoretic industrial organization principles and strategic management concepts provides a useful framework for viewing strategic adaptability in such a dynamic competitive environment. This thesis also proposed an expanded NPV decision rule and valuation process for analyzing various competitive strategies by integrating real options with basic principles from game-theoretic industrial organization and strategic management.

The option-games (Real Options Analysis and Game Theory) approach to evaluating competitive strategies is an attempt to subject strategic intuition to the discipline of a more rigorous analytical process. The combined framework can help guide managerial judgment in deciding whether and when it is appropriate to grow locally or globally depending on their owns, and when participation in a network or strategic alliance is the preferred route. I found that simplified versions of the option-games framework can gradually find their practical implementation in many key domains, such as the valuation of joint research ventures, strategic alliances or platform acquisitions.

The distinction between one-stage and two-stage option games is important. Most strategic opportunities involve path-dependent staged or sequential investments. Such strategic investment may affect the relative growth option values for rivals and their investment behavior. When the analysis involves two-stage option games of R&D, market positioning or strategic acquisitions, the managers of the new energy generation project must take into consideration that an early strategic investment commitment may not only result in future commercialization or growth opportunities but it may also influence the competitor's future behavior in desirable or potentially damaging ways. First-stage R&D strategy can influence the production outcome and the incumbent's profit value in a later stage. Thus, a pioneer may use a first-stage strategic R&D investment to gain a strategic advantage via lower future operating costs or an expanded market share in case of contrarian competition. However, this study revealed that an early investment commitment may create a strategic disadvantage if it reduces the firm's ability to respond towards aggressive competitors who can exploit shared benefits resulting from the strategic investment, or if it provokes retaliation and intense rivalry that may badly damage both competitors.

In this thesis, studying another model of option-games for optimizing between flexibility and commitment values can prove that demand and volatility can contribute to a rise of NPV from the view on 3-dimension models on NPV of both quantitative and pricing competitions. But they should wait and stay flexible for the immense capital investment under market uncertainty. From each type of option-games trees, it was found that the demand and investment is specially related to the commitment and the volatility is to the flexibility. From the three parameters, it becomes possible to select the optimal strategy to maximize NPV on game theory and real options.

It was understood that a proprietary strategy works profitably for a pioneering company on a change of cost, demand, volatility and investment for both competitive styles. On the other hand, a sharing strategy provides for a pioneering company an opportunity loss from a free-riding by a non-investing company.

However, it is possible to get a net return from investing, depending on the conditions of demand and volatility, if ignoring a free-riding. In addition, it can be said that a sharing strategy is basically superior to a proprietary strategy from Pareto optimum perspective if sum up the NPVs of both companies.

Consequently, we can know that a joint research venture enabling the firms to cooperate in R&D during the second stage may be a way to avoid the prisoners' dilemma. Continuously, it can achieve the same research benefits with low costs by each firm, and it can make the cooperating firms to get the option value through wait or see under technology or demand uncertainty to avoid competition pressures from innovation of market. In addition, joint R&D ventures may have a more positive strategy effect in high-tech industry. Therefore, it is advisable to select a sharing strategy with partnership, through a method of preliminarily preventing a free-riding, and then to redistribute total returns among the parties (Fujiwara, 2008). For that reason, it may utilize results here as a preparation of guideline forming for an investment in basic research exploration of new power project with newly developed and advanced energy efficiency technology.

After that, the Bayesian MCMC data analyses are made. For the analyses, the energy-related data indices of Myanmar were studied and applied in order to find the optimal energy mix for safe and secure electricity supply and, to examine the R&D investment continuity of new energy industry start-ups at the 'Valley of Death' during the financial deficit period of the government.

In the section of tracing the best mixing of energy sources for the stable supply of electricity all the seasons, we made the flood disaster analysis that is assumed to be the side-effect from the building of the dams on a large scale for hydro-electricity projects as well as a proposal for the other renewable energy sources is made in order to reduce some negative impacts on the natural environment and climate changes. Myanmar commercial energy production and supply mainly depends on hydropower projects. According to the power balance scenarios drawn by JICA that has figured out the best energy mix in electricity supply, solar electricity is an interesting renewable energy source in a dry zone like Myanmar as a backup to hydroelectricity and for the risk management of disasters from the building of dams. Especially, the implementation of a solar power project is totally possible if it is available for financing alternatives with low interest rates from international development banks and national Export-Import banks or foreign investments keen to invest in renewable power projects and eager to support their manufacturers.

The revenue analysis from Bayesian perspective pointed out for the government to guess how much amount of investment should be made in new energy industry and how to continue the business development investments in 'Valley of Death' as negative financial period under such financial crisis by the measurement of user rates and expected revenue together with being able to see uncertainty of the probable revenues. At that time, firm's revenue as the sort of real options can be guideline to facilitate the risky but promising investments. In addition, this analysis is expected to be the basis for the study development scheme for the policy maker in the future based on the number of electricity users. But in practice, there are other core variables and influenced factors that must take into consideration and critical measurement as market uncertainty and demand forecast with some degree of risk to facilitate the irreversible capital investment.

Currently, Myanmar government has already commenced the infrastructure development and huge capital investment in the electricity sector. But it is still necessary to clarify the difference between electricity productivity and infrastructure investment cost by the scale of firm's net income for long-term survival probability. In addition, ongoing and expedited progress is also a necessity to ensure the sector's performance is improved and the required scale of investments is reached, such that an efficient, adequate and sustainable distribution and supply of eco-energy to the entire population are met in line with the government targets.

After the estimation of the parameters that are the main indicators for the best energy mix and the investment in the new project, the two-players' game is extended for the perfect competition between the competing firms under incomplete information. As it is needed for the development of the existing project for the additional generation of electricity, another capital investment will have to be made and invite the outside investors for more necessary financing. When there is information asymmetry between the rival firms of entrepreneur and new entrant in regard with the project quality of productivity, it may result in averaging of project quality by the other rival and an adverse selection of problem since entrepreneur possibly would have an incentive to offer lower than average quality due to the information asymmetry. With information asymmetry in attracting to invest in a project, firms may try to signal their project quality to the competing firms by acquiring patent as in signaling game of perfect Bayesian equilibrium. However, it should be noticed that cost of acquiring the patent may reduce future profitability of their options in the market (Smit, Han T. J. & Trigeorgis, L., 2004).

The integration of real options analysis, game theory and Bayesian method can be important and play a major role for evaluating the merits of investment under uncertainty, competition, and information asymmetry (Fujiwara, T., 2016; Schwartz, E. S. and Trigeorgis, L., 2001).

8.3 General Conclusion

This thesis is especially related to efficient and effective energy production for Myanmar society. For the research, Japanese electric-power businesses were focused on and approached in some parts of analyses. Although the country, Myanmar, riches in natural resources for energy production, she is a developing country and needs modern technology in construction of the country to be developed nation. Actually, energy technology innovation is essentially necessary for Myanmar in all areas of residential homes, private sectors, public and commercial sectors, and then the society as a whole. If some Japanese corporations of electric power business take priority the investment in smart mobility and optimizing energy efficiently production field of Myanmar, I believe that the mutual advantages will result and can grasp the investment profits as the future gold outcome. It is good opportunity for the enterprises at this present time of Myanmar Government's political, social and economic positive changes as well as open invitation for foreign direct investments.

Japan electricity business says on its web page that they are striving for strengthening international communication and cooperation for environmental conservation in the aspect of electric power generation and supply. Moreover, they said, "they are also sharing Japan's top-level environmental technologies with the World". On the other hand, JICA is supporting aids and loans to Myanmar for her development including the power sector. As mentioned in some previous sections, we can clearly see such effective and efficient supports by the Japanese government and JICA. We propose to cast the result, through cooperation between Japan and

Myanmar, to appear as strategic energy productivity and supply from a perspective of ecology and quality of life in Myanmar as a pioneer.

8.4 Research Proposal and Expectations

After examining original theory and approach for the energy industry from a new perspective of my research, I wish to apply them compatibly to the practical condition in the country. And I propose the promising aspect for Myanmar in generating secure and sustainable electricity to the people. Besides, I also hope reliable, adequate and stable energy supplies throughout the country for strong economic growth in the long-run benefits. Finally, I expect a vision for the new energy project of clean and renewable energy sources from a viewpoint of ecology and quality of life (QOL) and then, the result to appear efficient electricity productivity in terms of cost-effective way and stable manner as the consideration for long-term survival and regional development.

8.5 Future Research

As the next challenge for my research, Bayesian inferences on stock returns and a Bayesian Regression Analysis for the potentiality to make the R&D investment in new project will be newly tried by referring to a study that analyzes the growth opportunity for the sustainability of energy industry from a viewpoint of jump valuation. To enable this approach as a practical aid to corporate business planners of newly extended power generation project, it is useful for the project development and can assess the possibility of expansion for necessary investment. For this capability, the daily returns of some large companies can be looked first, where stock returns are so filled with noise that it is very hard to estimate this parameter. Furthermore, the parameter might change over time with rises and falls. In that case, Bayesian inference on these stock returns estimation is a very appropriate procedure since the uncertainty along with probable values can be seen (Davidson-Pilon, C., 2016).

Then, the regression analysis, by using Bayesian MCMC, for parameter estimation between stock returns on investment, net income and R&D investment expenses of the companies will be made to see as the major indicators which account for endurability the 'Valley of Death' in the financial deficit period. The assumption behind this methodology is that the integrated uncertainty regarding the respective stock gets resolved when the concrete parameter estimation becomes available and then can simulate it to the new power generation project by focusing on these analyses. At that time, separate efforts and some additional investment for R&D project will be required to learn more about the situations of the project and reduce the uncertainty. The way to do this is to keep the major uncertainties separate from each other and, to model their interaction effect on the project's value explicitly. By this mean, the development or expansion of new power generation project with high technology can find a strategy to overcome the valley of death for its survival and finally, may be able to penetrate into the market extensively.

References

Asian Development Bank (2016). *Myanmar Energy Sector Assessment, Strategy, and Road Map*, Institutional pdf. Document, Mandaluyong City, Philippines Publishing.

Aung, H., Ministry of Electricity and Energy, Republic of the Union of Myanmar (2017). *Current Status Of Myanmar's Energy Statistics*, Workshop document On Energy Statistics for ASEAN Countries, Kuala Lumpur, Malaysia, 21-23 November [Google Scholar].

Benninga, S. (2000). *Financial Modeling*, 2nd Edition, Massachusetts Institute of Technology, Library of Congress Cataloging-in-Publication Data, United State of America.

Bierman, H. Scot & Luis Fernandez (1988). *Game Theory with Economic Applications*, 2nd Edition, Addison-Wesley Publishing Company, Inc.

Black, F. & Scholes, M. (1973). *The pricing of Options and Corporate Liabilities*, Journal of Political Economy, 81 (3), 637–654.

Chubu Electric Power, *Renewable Energy*, http://hamaoka.chuden.jp/english/n-power/refreshable.html (accessed on 2nd August, 2018).

Cooperate Finance Institute (2018). *What is the Net Present Value (NPV)?*, CFI Education Inc.

Copeland, T. and Antikarov, V. (2001). *Real Options*, Texere: New York.

Copeland, T. and Antikarov, V. (2003). *Real Options (A Practitioner's Guide)*, Cengage Learning, New York: Texere LLC.

Copeland, T., Koller, T. and Murrin, J. (2000). *Valuation: Measuring and Managing the Value of Companies*, 3rd Edition, New York: John Wiley & Sons.

David, B. D. (2001). *Commentary: Practical Advantages of Bayesian analysis of Epidemiologic Data*, American Journal of Epidemiology, 153(12), 1222-1226.

Davidson-Pilon, C. (2016). *Bayesian Method for Hackers: Probabilistic Programming and Bayesian Inference*, Crawfordsville, Indiana, US.

Dixit, A. K. and Nalebuff, B. J (1991). *Thinking Strategically: The Competitive Edge in Business, Politics, and Everyday Life*, W. W. Norton & Co., Ltd. Press, London.

Dixit, A. K. and Pindyck, R. S. (1994). *Investment Under Uncertainty*, Princeton University Press, Princeton, New Jersey, United Kingdom.

Economic Research Institute for ASEAN and East Asia (ERIA) (2019). *Myanmar Energy Statistics 2019*, Published by ERIA, Jakarta, Indonesia.

Emerton, M., Thorncraft, S., Oksanen, S. and Soe, M. (2015). *Myanmar Energy Master Plan*, Final Report for ADB and MOEE, prepared by IES associated with MMIC.

Encyclopedia of the Nations, *Myanmar - Economic sectors*, https://www.nationsencyclopedia.com/ economies/Asia-and-the-Pacific/Burma-Myanmar-ECONOMIC-SECTORS.html (accessed on 30th March, 2020).

Energypedia, *Burma (Myanmar) Energy Situation*, https://energypedia.info/wiki/Burma_(Myanmar) _Energy _Situation (Accessed on 1st April, 2020).

Florida, R. L., and Kenney, M. (1988). *Venture Capital, High Technology and Regional Development*, Reg Stud, 22(1), 33-48.

French Myanmar Chamber of Commerce and Industry (2019). *Myanmar Electricity Rates to Soar Next Month*, Newsletter Article published on 25th June by CCI France Myanmar [Google Scholar].

Fujiwara, T. (2008) *Modeling Strategic Partnership of Biotechnological Start-up by Option-Game: Aiming at Optimization Between Flexibility and Commitment*, Journal of Advances in Management Research, Vol. 5 (I) (pp. 28-45).

Fujiwara, T. (2016). *Bayesian MCMC analysis on R&D investment of biotech start-up in the "Valley of Death"*, Technology Transfer and Entrepreneurship, 3(2),119-130.

Gelman, A., Carlin, J. B., Stern, H. S., Dunson D. B., Vehtari, A. and Rubin, D. B. (2013). *Bayesian Data Analysis*, 3rd Edition, Chapman & Hall/CRC, Boca Raton, Florida.

Gibbons, R. (1992). *Game Theory for Applied Economists*, Princeton University Press.

Gilsing, V. and Nooteboom, B. (2005). *Density and Strength of Ties in Innovation Networks: An Analysis of Multimedia and Biotechnology*, Eur Manag Rev, 2(3), 179-197.

Global Energy Network Institute, *National energy grid Myanmar*, http://www.geni.org/globalenergy/library/national_energy_grid/myanmar-burma/myanmarnationalelectricitygrid.shtml (Accessed on 3rd April, 2020).

Global Petrol Prices, *Burma (Myanmar) electricity prices*, https://www.globalpetrolprices.com/ Burma-Myanmar/electricity_prices/ (Accessed on 3rd April, 2020).

Granovetter, M. (1973). *The Sterngth of Weak Ties*, Am J Sociol, 78(6), 1360-1380.

Grenadier, S. R. (1995). *Valuaing Lease Contaracts: A Real Options Appraoch*, J Finance Econ, 38(3), 297-331.

Grenadier, S. R. (2000). *Option Exercise Game: The Intersection of Real Options and Game Theory*, J Appl Corp Finance, 13(2), 99-107.

Hilpisch, Y. (2019). *Python for Finance: Mastering Data-Driven Finance*, 2nd Edition, published by O'Reilly Medial Media, Inc., Canada.

Hu, Yuhua (2010). *Options-Games Analysis on Software Industry: Dilemma between Open Innovation and Clustering in India and China*, Department of Knowledge Based Information Engineering, Toyohashi University of Technology.

International Energy Agency (2017). *Myanmar Energy Master Plan*, https://www.iea.org/policies/6288-myanmar-energy-master-plan (Accessed on 13th April, 2020).

JICA, NEWJEC Inc., The Kansai Electric Power Co., Inc. (September 2015). *Final Report Summary for data collection survey on capacity development of power sector development planning in The Republic of The Union of Myanmar*, Published Report by JICA.

Joaquin, D. C. and Buttler, K. C. (2000). *Competitive Investment Decisions*: *A Synthesis. In Brennan, M. J., Trigeorigis. L., Eds., Project Flexibility, Agency, and Competition*, Oxford University Press,New York, pp. 324-339.

Kenton, W. (2019). *Net Present Value (NPV)*, Cooperate Finance & Accounting, Financial Ratios [Google Scholar].

Kester, W. C. (1984). *Today's Options for Tomorrow's Growth*, Harvard Bus Rev, March-April, 153-160.

Kodukula, P. and Papudesu, C. (2006). *Project Valuation Using Real Options: A Practitioner's Guide*, Fort Lauderdale, Florida: J. Ross Publishing.

Kruschke, J. K. (2014). *Doing Bayesian Data Analysis: A Tutotial with R, JAGS, and Stan*, 2nd Edition, Academic Prss: London.

Luenberger, David G. (2009). *Investment Science*, International Edition, Oxford University Press.

Lwin, K.W., US Commercial Service (2019). *Burma-Energy*, Burma Country Commercial Guide [Google Scholar].

Merton, R. C. (1973). *Theory of Rational Option Pricing*, The Bell Journal of Economics and Management Science, 4(1), 141-183.

Mon, H. K. (2014). *Amid Burma Tourism Boom, Calls for Govt to Aid Development*, Published Article pressed on 6th January, 2014 by English/Myanmar News Magazine and Online News namely as The Irrawaddy.

Moodysson, J., Jonsson, O. (2007). *Knowledge Collaboration and Proximity: The Special Organization of Biotech Innovation Projects*, Europe Urban and Regional Study, 14(2), 115-131.

Myanmar Times (2020). *Economy to improve as Myanmar opens up to foreign investment*, Published Article pressed on Monday, 30th March by English/Myanmar Daily Newspaper titled by Myanmar Times.

Myanmar Times (2014). *Electricity Price Hike Set for April 1*, https://www.mmtimes. com/business/9947-electricity-price-hike-set-for-april-1.html (accessed on 2nd August, 2018).

Myanmar Times (2019). *Rural areas to receive electricity powered by renewable sources: Minister*, Published Article by Myanmar Times, 3rd March, 2019.

Nyein, N. A. (2013). *A Study on the Irreversible Investment for a New Energy Industry in Myanmar Under Uncertainty and Competition: Focused on Potential of Smart House*, Master Thesis, Toyohashi University of Technology, Japan.

Nyein, N. A. and Fujiwara, T. (2014). *Application of Option-Games Approach to the Irreversible Investment for a New Energy Industry in Myanmar by simple One-Stage Strategic Model: Focused on Potential of Smart House*, Global Journal of Flexible System Management (GSFM), Volume 15, Issue 3, pp. 191-202.

Nyein, N. A. and Fujiwara, T. (2017). *Option-Games Analysis on Strategic Partnership for an Innovative High-Tech Energy Industry of the Smart Houses: Targeting at Optimizing between Flexibility and Commitment Values*, Technology Transfer and Entrepreneurship (TTE), Volume 4, Issue 1, pp. 3-26.

Nyein, N. A. and Fujiwara, T. (2019). *Analysis on the Trade-off between an Hydro-power Project and Other Alternatives in Myanmar*, Asian Journal of Innovation and Policy (AJIP), Volume 8, No.1, pp. 31-57.

Osborne, M. J. (2002). *An Introduction to Game Theory*, Oxford University Press, Oxford, New York.

Osborne, M. J. and Rubinstein, A. (1994). *A Course in Game Theory*, Massachusetts Institute of Technology, MIT Press, Cambridge, Massachusetts, London, England.

Powell, W. W., Koput K. W. and Smith-Doerr, L. (1996). *Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology*, AdminSciQ, 41(1), 116-145.

Schwartz, E. S. and Trigeorgis, L. (2001). *Real Options and Investment Under Uncertainty*, Massachusetts Institute of Technology, The MIT Press, Cambridge, Massachusetts, London, England.

SEEDS and CRED, *Decoding the Monsoon Floods in Bangladesh, India, Myanmar and Nepal, 2018*, https://reliefweb.int/sites/reliefweb.int/files/resources/Decoding-the-monsoon-floods-report180118v-min.pdf, (accessed on 9th May, 2018).

Smit, Han T. J. & Trigeorgis, L. (2004). *Strategic Investment: Real Options and Games*, Princeton University Press, Princeton, New Jersey.

The Federation of Electric Power Companies of Japan (FEPC), *Electricity Review Japan*, 2017, https://www.fepc.or.jp/library/pamphlet/pdf/04_electricity.pdf (accessed on 2nd August, 2018).

The World Factbook., *Burma*, U.S. Central Intelligence Agency, Archived from the original on 28th March, 2020. https://www.cia.gov/library/publications/the-world-factbook/geos/bm.html (accessed on 28th March, 2020).

Thein, M. (2005). *Economic Development of Myanmar*, Singapore: Inst. of Southeast Asian Studies. ISBN 978-9812302113.

Trading Economics, *Myanmar - Access To Electricity*, https://tradingeconomics.com/myanmar/ access-to-electricity-percent-of-total-population-wb-data.html (Accessed on 1st April, 2020).

Trigeorgis, L. (1996). *Real Options*, MIT Press: Cambridge, Massachusetts, London, England.

Trigeorgis, L. (2000). *Real Options: Managerial Flexibility and Strategy in Resource Allocation*, The MIT Press, Cambridge, Massachusetts, London, England.

Tun, M. M. and Juchelkova, D. (2019). *Biomass Sources and Energy Potential for Energy Sector in Myanmar: An Outlook*, Renewable Energy and Chemical Sources from the Thermal Conversion of Biomass, Resources 28th May, 8(2), 102; doi:10.3390/resources8020102.

Uvm.edu. (2015). *Gems of Burma and their Environmental Impact*, http://www.uvm.edu/envnr/gemecology/index.html (accessed on 5th April, 2020).

Vakulchuk, R., Hlaing, K. .K., Naing, E. D., Overland, I., Suryadi. B. and Velautham, S. (2017). *Myanmar's Attractiveness for Investment in the Energy Sector: A Comparative International Perspective*, Research Gate paper [Google Scholar].

Worldometer, *Demographics of Myanmar*, https://www.worldometers.info/demographics/myanmar-demographics/#urb (accessed on 28th March, 2020).

Worldometer, *Myanmar Population*, https://www.worldometers.info/world-population/myanmar-population/ (accessed on 28th March, 2020).

World Bank (2013). *Report of Project Appraisal Document for an Electric Power Project in Myanmar*, Report No: PAD586.

World Climate Guide (2020). *Climate of Myanmar*, pdf. document for Myanmar Climate [Google Scholar].

Wu, Liang-Chuan; Li, Shu-Hsing; Ong, Chorng-Shyong and Pan, Chungteh (2012). *Options in Technology Investment Games: The Real World TFT-LCD Industry Case*, Technological Forecasting & Social Change 79, 1241–1253.

Zaw, H. (2019). *Current Status of Myanmar's Electricity Sector*, Greater Mekong Sub-region Meeting of the Sub-Regional Energy Forum, Bangkok, 21st March, 2019 [Google Scholar].