MINISTRY OF EDUCATION AND TRAINING

UNIVERSITY OF ECONOMICS

HOCHIMINH CITY

LE QUOC THANH

INVESTMENT DECISION UNDER UNCERTAINTY: THE CASE OF CARBON TAXATION IN DEVELOPING COUNTRIES

The Dissertation of Economics

Major: Finance & Banking (9340201)

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Major: Finance & Banking (9340201)

Scientific Instructors: Associate Prof.Dr. Nguyen Huu Huy Nhut

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My name is Le Quoc Thanh, PhD student in the major of Finance-Banking at University of Economics Hochiminh City. I would like to confirm that the research results in this thesis is from my own works and has not been published.

Le Quoc Thanh

TABLE OF CONTENT

ABBREVIATION

ACCA	The Association of Chartered Certified Accountants
B/C	Benefit/Cost
BCC	Business Cooperation Contract
DCF	Discounted Cash Flow
FDI	Foreign Direct Investment
GDP	Gross Domestic Products
GNP	Gross National Products
IRR	Internal Rate of Return
K	Capital Stock
L	Labor level
M&A	Merger & Acquision
NPV	Net Present Value
PMI	Project Management Institute
$\boldsymbol{\Pi}$	Firm's Profit Function
$\boldsymbol{\pi}$	Yearly firm profit
ROA, RO	Real Option Analysis, Real Option
UNCTAD	Uninited Nations Conference on Trade and Development
V	Value of the firm
WACC	Weighted average cost of capital

LIST OF TABLES AND DIAGRAM/GRAPHS

SUMMARY

The thesis: "Investment decisions under uncertainty – The case of carbon taxation in developing countries" takes Vietnam as a typical one, aims to study the impact of uncertainties related to the carbon taxation on the investment decision, the choices of capital/technology level and the labor level of the FDI firm into the large asset project (also known as irreversible project) in Vietnam.

The thesis focuses on building the theoretical model based on the basic model of corporate profit function (Varian, 1992), reflecting the relationship between firm's profit and main inputs such as capital/technology (K) and labor (L), and other costs, including carbon taxation costs. Theoretical model was developed using optimization algorithms and simulations using hypothetical approximate data.

The thesis provides theoretical findings that the application of carbon taxation has the negative effect that lowering the investment level of the firm, however, at the same time, it also has the positive effect of restricting investors with low technology level and encouraging investors with higher technology level at the same carbon tax rate. Thus, if the carbon tax is used as a regulatory tool, the government may develop policies that will encourage high-tech investors leading to the higher quality of foreign investment in Vietnam.

Key words: profit function, investment decision, irreversible project, uncertainty, capital/technology and labor, optimization.

CHAPTER 1: OVERVIEW OF RESEARCH

1.1. Research setting and motivations

Three important financial decisions of the firms are (1) investment decision; (2) divided decision; (3) financing decision. Among these, the investment decision in foreign countries is always considered as the most challenging because the firms will face with many uncertainties due to differences in political system, new culture and law, new market with new customer behavior. Research on “investment decision under uncertainty” is a popular research strand in the academics, initializing by Hirshleifer (1965) in the 1960s. Then, it has been developing further by many scholars such as Lucas Jr & Prescott (1971); Abel (1983); Dixit & Pindyck (1994); and Abel & Eberly (1994, 1997); and currently be a concerned topic in the academic world. The reasons behind this development come as follows.

Firstly, investment in large fixed assets projects (so-called as irreversible projects) is promised to be profitable in medium to long term. In addition, the firms expect to grow up significantly thank to the investment in large projects. However, investment in large project is always gone with significant risks due to uncertainties from both the internal and external environments of the firms. External factors may include uncertainty of the market (e.g. price changes, market size, reaction of competitor to large projects of firms), uncertainty of new technology which can replace the technology of the firm’s project, changes in institution, law and political instability of the country where the project is planned to locate.

These above uncertainties, when occurring negatively, will increase the investment cost of project during both periods: the project investment and commercial production phases, leading to higher production cost and resulting in less competition and thus lowering profitability of the project. The firm as rational investor is always cautious with uncertainties. The firms and their consultant experts always seek to quantify measure and transform these uncertainties into the risks which are easier to predict the probability of occurrence and cost of risk management, so that the firm can bring it into project financial appraisal, increasing the likelihood of project success (Munns & Bjeirmi, 1996).

The second, after World War II, the market of multinational enterprises from the West has been expanded. Many Western economies have entered a period of rapid growth, helping large corporations in these countries to invest heavily in large-scale projects abroad for high profit, rather than primarily producing in their home country and exporting to other markets. This investment trend led to the emergence of fierce investment competition among multinational corporations in other countries. In particular, strong economies are always seeking to influence the countries in which their firms are interested to invest in order to obtain more advantages over their competitors. Competition in investment has brought pressure to multinational enterprises so that they must make faster investment decisions even when investment-related information is limited or investment decisions need to be made when the level of uncertainty affecting the investment decision is high. In another word, they have to accept the higher uncertainty/higher risk when investment decision is made.

The third, although many countries are committed to international economic integration and are calling on other countries to do the same, however, each country tries to create barriers to trade and investment in order to protect their domestic firms. These barriers in various forms such as technical barriers, complex regulations and/or poor transparency in the investment environment, unclear in the interpretation of investment policies and regulations as well as investment restrictions related to local cultures and religions, environment and conservation, in order to avoid commitments in bilateral and multilateral international trade commitments while limiting the investment and trade of foreign enterprises. The policies and regulations related to these barriers create uncertainty in both number of and higher level of uncertainties which is negative to foreign investment and international trade of the foreign firms. (Williamson, 1999; Nicholas & Anthony, 2003).

The above three reasons contribute to an increase in the number of uncertainties and its uncertain level, creating considerable challenges for firms' investment decisions. These challenges have contributed to the development of research on "investment decisions under uncertainty". Especially in the current situation, when multilateral and bilateral trade and investment policies are developed day by day, it creates the best investment opportunities for firms in the member countries of these agreements. As a result, the host governments of investment need to understand the behaviors of foreign firms in investment decision so that they could be able to develop appropriate policies attracting investment. Viet Nam is also in the trend of global economic integration by committing in international trade and investment agreements resulting in the changes of the external environment of the firms. Therefore, factors affecting the investment decision are increased in both number of uncertain factors and its uncertain levels.

Since the issuance of United Nations' Climate Change Declaration in 1992 and after that there were many countries entering the Kyoto Convention 1997, to commit cutting greenhouse gas emissions by several measures in which carbon taxation is a prime example. Some developing countries like Vietnam are not yet committed to the immediate adoption of compulsory carbon emission reductions such as carbon taxes, but it could be possible in the near future. Therefore, it can be reasonably said that the future investment environment in Vietnam is likely to be characterized by uncertainties related to carbon taxation that could be imposed on carbon emissions-generating projects and fossil energy extensive projects (energy based on coal, oil and natural gas). According to Yang & et.al (2008), after the year 2012, the risk of carbon taxation is getting bigger. Vietnam is still a developing country and thus the demand for foreign direct investment is one of the top priorities, especially large irreversible

FDI projects. As the forecasts of investment in infrastructure projects by the Global Infrastructure Hub and Oxford Economics, Vietnam needs to invest in infrastructure about 608 billion USD during the period of 2016 to 2040 (Global Infrastructure Outlook, 2017). Among these projects, investment in large-scale fossil fuel energy projects could be 265 billion USD. This number is a huge investment which requires the participation of local government and domestic and foreign companies. Investment decisions made by foreign firms in these projects must take into account of carbon related uncertainties due to the future application of the carbon taxation.

From the perspective of academic research, there are many researches related to the research direction of the thesis and it can be divided into two main research strands: (1) theoretical research on "investment decision under uncertainty"; and (2) empirical research on some important uncertainties such as price volatility, cost increase, fluctuation of exchange rate, etc, and taxes affecting investment decisions.

In theoretical research, some typical authors could be such as Lucas & Prescott (1971); Hartman (1972); Abel (1983); Dixit & Pindyck (1994); Abel & Eberly (1994, 1997); Hartman (1972) and Albel (1983). These authors all concluded that if the marginal profit function of a firm is increased when the uncertainty level is increased, the firm will have an incentive to increase the level of investment and production. Pindick (1991), Dixit & Pindyck (1994) found an important characteristic of irreversibility or so-called as irreversibility of investment in a large scale asset project on which investors can delay the investment when the level of uncertainty of a particular factor is increased and they will wait for the better information about such the uncertainty to ensure that the project is feasible to be profitable in future.

Thus, if increased uncertainty creates an option value of waiting, good information can come in the future. Theoretical studies of the relationship between uncertainty and investment include two groups of uncertainty: (1) uncertainty affecting the investment point (timing uncertainty) and (2) uncertainty affecting the level of investment.

The theoretical research of "investment decisions under uncertainty" has also been developed for only one or more than one uncertainty in which uncertainties associated with taxation will directly reduce the level of FDI in general. In particular Pindyck (1986) showed that the uncertainty in tax policy led to a reduction in the level of firms' investment. The same result as Pindyck (1986) was also discovered by Hassett & Gillbert (1999) in which mathematical techniques was developed by using a randomized continuous-time algorithm. Alvarez et al. (1998) suggested that if investors predicted that the tax rates would decrease, they tend to accelerate investment and vice versa. Hassett & Metcalf (1999) and Agliardi (2001) had similar research results that uncertainties in tax policy will undoubtedly delay investment projects.

A notable type of research is the theoretical study in which the simulation method will be used to reflect the effects of future uncertainty on the investor's investment decision behavior at the current time. Uncertainties are expected to emerge in the future (not happening yet), but it has influenced the investment decision in an irreversible investment project. These researches were conducted by developing a net present value (NPV), using algorithms and computational simulations, analyzing options that the project may have due to some future uncertainties of carbon taxation. These researches are conducted only for one type of project such as the coal-fired power plant project (William & et.al, 2007); iron and steel plant project (Ozorio, et.al, 2013) which are very close research to the thesis.

In Vietnam, there are quite a few researches on the factors affecting FDI inflows in general. The typical researches should be referred to Nguyen Thi Lien Hoa & Bui Bich Phuong (2014); Le Van Thang & Nguyen Luu Bao Doan (2017). Both studies used the quantitative approach to estimate the relationship of factors affecting

FDI inflows into Vietnam such as GDP, foreign exchange reserves, degree of infrastructure development, labor costs, national trade openness, labor quality, level of urbanization, and concentration of domestic enterprises. These researches are quite useful for designing of macro policies that attract FDI.

As the survey of Vietnam's related academic researches, there are no researches on investment decisions of foreign firms in irreversible projects under uncertainty related to carbon taxation. In the academic world, researches about the effects of carbon taxation related uncertainties have been developed in the form of single case study only such as coal fired power plant projects. Therefore, the generalization capability of these research results for policy making is not so high. We could see that the study of foreign investment decisions on irreversible FDI projects in Vietnam under uncertainty is necessary and it would bring many benefits as listed below.

(1) Research on investment decision under uncertainty will help policy makers understand the investment behavior of foreign firms when investing in large FDI projects in Vietnam, thereby its results will support designing of policies and mechanisms for attracting foreign investment better.

(2) Research on investment decision under uncertainty will help domestic firms to understand the investment behavior of foreign firms in FDI projects, thus facilitating domestic firms to develop more appropriate cooperation strategies which could increase success of cooperation with foreign investors, as well as taking of advantage of spillover effects from these FDI projects.

(3) Research on investment decision under uncertainty will also provide comprehensive analysis and discussion on methods for evaluating the financial viability of irreversible projects, and recommending more in-depth research aiming at improving knowledge of financial analysis, project appraisal and financial evaluation of investment projects under of carbon-tax related uncertainties.

(4) For academics and teaching community, this thesis may provide the additional knowledge related to project appraisal, investment behavior of foreign firms under uncertainty which could be useful for the specialized training of students.

(5) After more than 30 years of attracting foreign direct investment in Vietnam, it is necessary to design the policy for improving of the investment quality, especially the quality of technology/equipment and labor in FDI projects. This is a big challenge for researchers and policy makers because there is no research on improving this issue in FDI projects. This research is expected to provide a scientific basis for designing investment attracting policies that could support to limit out-of-date technology which is potentially harmful to environment and to improve the skills of Vietnamese workers in large FDI projects.

1.2. Research targets and research questions.

1.2.1. Research targets.

The thesis will focus on discovering new theory by building mathematical economic model which is profit function of firm in investment project including uncertain factors of carbon taxation. The model of thesis relects the relationship between firm's profit which is based on profit function of Varian (1992) in combination with uncertain factors of carbon taxation affecting investment decision. After the model is built, the thesis uses the optimization algorithm (optimization technique) to detect the relationship between carbon tax factor and other elements in the profit function such as capital stock (K) and labor level (L). Calculation results will be interpreted in order to detect corresponding theoretical proposals.

Based on reviewing results of theoretical and empirical researches, the research gaps will be identified for the thesis's research concentration. The important part of thesis is to build the research model in mathematical form to fill the identified research gaps. The thesis will focus on the effects of carbon taxation related uncertainties on the investment decision behavior of investors from developed countries (carbon taxed countries), investing in irreversible projects in developing countries (non-carbon taxed countries) which are similar to Vietnam. Through the development of mathematical models and calculations, investment decision and the selection of capital/technology and labor levels in irreversible FDI projects in Vietnam will be examined under the carbon tax related uncertainties.

1.2.2. Research questions

In order to fulfill the research objectives of the thesis, the following two research questions were studied and answered by the thesis.

(1) How are effects of carbon taxation uncertainties on investors’ investment decision in irreversible FDI projects?

(2) What are the capital / technology and labor levels selected by the investors in irreversible FDI projects?

1.3. Research objectives and scope of research.

1.3.1. Research objectives.

The main objective of the thesis is the firm’s investment decision in the irreversible project under the uncertainties associated with the carbon taxation. This type of taxes is commonly imposed in some developed countries aiming at greener and sustainable development which would be applied in Vietnam in the near future. The impacts of these carbon tax related uncertainties on the investment decision behavior of foreign firms will be examined, especially the optimum level of capital / technology and labor choices that the foreign investors can decide to choose in their investment projects in Vietnam.

Based on the above research results, the managerial and policy implications will be recommended for attracting better FDI project while minimizing environmental impacts as well as raising the quality of technology and labor in these projects.

1.3.2. Scope of research

The scope of the research is large fixed assets of foreign companies in Vietnam that cause carbon emissions and therefore there are potential uncertainty/carbon tax risks in these projects. This type of project is referred in academic community as irreversible investment projects by (McDonald & Siegel, 1986). In practice, these projects are very large value ones producing/supplying basic commodities of the economy or infrastructure projects in transportation, telecommunications, energy, oil and gas exploitation, power plants, oil refinery, iron and steel plants, chemicals production, real estates. Investors of these projects are often large industrial companies from developed countries (MNEs / MNCs).[1] Since the phenomenon of carbon tax avoidance mainly from developed countries where the carbon taxation is already applied or about to apply, to non-carbon taxation developing countries, therefore, this study in Vietnam context can be generalized to other developing countries.

1.4. Methodology.

The thesis has applied quantitative approach by mathematical modeling and simulation techniques using reasonable assumption data and collected data in practices if available. The choice of research method is considered on the nature of the research nature, the relevant studies and the availability of actual data as follows.

This thesis explores a new research direction and there is no similar research in Vietnam on investment decision under uncertainty which may appear in the future regarding carbon taxation. If the qualitative method is conducted by using in-depth interviews with experts about the impacts of carbon taxes on investment, it can be expected that the bias in interviews shall be considerable as carbon tax related uncertainties are not present yet and thus discussing about the future uncertainty in the today interview tends to be difficult leading to more bias. Therefore, the collected

[1] MNEs/MNCs (Multinational Enterprises/Companies)

information by interview would not be reliable for analysis. If the quantitative research is used by collecting empirical data to test hypotheses, it shall be not feasible as carbon taxation is not applied yet and thus empirical data will not reflect the effects of carbon tax uncertainty. Thus, the choice of empirically quantitative methods is not feasible.

The thesis is considered to apply quantitative method using algorithmic modeling tools and computational simulation in numerical form. By modeling the profit function of a firm depending on the uncertainties associated with the carbon taxation, and developing the model by mathematical techniques and calculating, the effects of carbon taxation uncertainties on the firm's investment decision about capital/technology and labor levels are expected to be answered.

The profit function model of the firm according to Varian (1992) has been chosen after comparing the advantages to the traditional net present value (NPV). The profit function model according to Varian (1992, p. 23) has the general form as follows:

$$\boldsymbol{\Pi} = pF(K,L) - C(r,w) - T(\tau)$$

Where:

- $\boldsymbol{\Pi}$: is profit function of the firm.

- F (K, L): is the production volume of the firm depending on capital level (K) and labor level (L).

- C (r, w): is the cost of the business operation depending on the cost of capital (r) and labor wage (w), not including the cost of carbon tax.

- T (τ): is the cost of carbon tax that the firm needs to pay when the government imposes carbon tax on the volume of carbon emission.

- p is average selling price of products

The above function is based on basic assumption that the firm is always investing when $\boldsymbol{\Pi} > 0$ and expecting to maximize their profit as rationale investor. Therefore, the firm will to choose optimal input levels of K, L, r, w, to maximize their profit. Detailed discussion of research method and selection of research model are presented in Chapter 3 of the thesis.

1.5. Expected outcomes of the thesis:

The thesis is expected to contribute to academic knowledge, research methods and practical application in project appraisal. In terms of academic knowledge, the thesis will provide a theoretical framework and empirical evidences of uncertainties and investment decision into irreversible project in Chapter 2 in which uncertainties of carbon taxation will be given priority. In addition, the results of the model development using mathematical techniques in the thesis are expected to provide new theoretical discoveries: carbon taxation is likely to limit low-tech investors. Consequently, if the carbon tax is used as an adjustment tool, the government may develop carbon tax related policies to increase the quality level of FDI projects. This theoretical discovery is a clearly novelty of the thesis.

In terms of research method, the thesis also uses methods and tools which are new in Vietnam's academic community: modeling and model development by mathematical techniques and simulation calculations. This help to diversify the research tools in research practice of Vietnam.

On the aspect of practices, a part of the thesis will analyzes the different method of project appraisal (DCF & RO) of large asset projects which are of great importance in industry and economic development of a nation. Thus, the thesis can be considered as a reference for applied research on appraisal of investment projects, as well as providing knowledge of project finance, appraisal and project management for training of students.

1.6. Structure of the thesis.

The thesis consists of 5 chapters. Chapter 1- Overview of Research provides the most common parts related to the content of the thesis such as the research context, the motivation of research, research targets and objectives, scope of research, expected outcomes of the thesis on academic values and practical applications.

Chapter 2 - Theoretical framework and empirical evidence, focusing on the analysis of previously theoretical researches in the world and developing the framework related to the main research direction of the thesis is the relationship between the firm's investment decision and uncertainties in the irreversible project. A number of relevant empirical studies will also be analyzed and commented to identify research gaps. The final part of Chapter 2 is to analyze and select the basic research model which is the profit function of firm for further modeling and simulation of the thesis.

Chapter 3 - Research Method is to focus on comparative analysis for selection of research method on the given research settings, research targets, research questions, objectives and scope of research. Chapter 3 also discusses the basic assumptions in the research model and simulation data to ensure both the convenient development of the model, but such the assumptions do not distort the research results.

Chapter 4 - Research results is to focus on the development of investment decision model of the firm to invest in the investment project in different cases such as (1) carbon tax is not applied and applied; (2) carbon tax is expected to be applied during the project life cycle; (3) investment decision behavior of two different firms in selecting of capital/technology/labor levels subject to the same carbon tax rate. Correspondingly, the theoretical findings of each case will be presented to set the basis for simulation works.

Chapter 5 - Conclusions and managerial/policy implications are developed on the basis of research results in Chapter 4. This chapter will summarize and interpret the results of theoretical findings. Based on these findings, a number of policies and managerial implications are proposed. Chapter 5 will also discuss some further research directions to better deepen the researches on the relationship between carbon taxes and the firm’s investment decision.

CHAPTER 2: THEORETICAL FRAMEWORK AND EMPIRICAL EVIDENCES

Research on the relationship between the firm's investment decision and uncertainties in irreversible investment projects is a popular research direction in the world, starting from the general research of "investment decision under uncertainty" in which the researches of investment decision under tax related uncertainties are typical ones. This thesis has a strong relation with the researches of firms' investment operation, characteristics of irreversible investment projects, project appraisal and project finance, uncertainty and risks, firm's investment decision under uncertainties. Chapter 2 of this thesis will summarize these relevant researches, aiming to build theoretical framework for research model of thesis.

2.1 The firm and investment operation.

2.1.1 The rationality of the firm's investment decision.

The simplest definition of a firm is a legal entity for profit, established based on the law and the firm is operated for profit as the ultimate goal (Chandler, 1992). All activities of the firm are directly or indirectly designed to obtain profits in short, medium and long term. In the early days, the main activity of firms was to trade goods only, including buying, storing, sorting, preliminarily processing, packaging, transport & delivery and selling products. When the artisanal and industrial production comes into being, the machinery and equipment are an integral part of the firm. Firms began to shift into the era of service and industrial production. In addition, according to this author, development of the firm consists of 3 important factors including (1) the continuous learning and experiencing of managers and employees; (2) production equipment and technology; and (3) capital.

As the firm expanded to manufacturing establishments in many countries, the model of multinational company was born. East India Co., Ltd., established in 1600, is considered as the world's first multinational company to purchase, transport, stockpile, sell agricultural products, exploit colonial resources and invest in agriculture in the colonies thereafter to be imported back to the United Kingdom (Sen, 1998).

The modern form of the recent firm is believed to be an industrial enterprise which has begun to emerge in the 1880s and has grown to this day (Chandler & Hikino, 2009). Modern industrial enterprises are characterized by the skills of high-educated labor combining with modern machineries (capital intensive production) which allow optimizing the inputs in production, so-called as economy of scale : the more products to be produced, the lower unit cost is archived.

These industrial enterprises operate mainly in the fields that requiring modern technology and equipment such as automobile assembly, production of transportation vehicles/equipment, energy, oil and gas, chemicals, pharmacy, etc. Recently, the new industrial enterprises have emerged as the firms focusing on digital services and information-communication technology such as Intel, Google, Microsoft, Apple, and Samsung, are typical examples. Most of the firms in the S&P 500 are considered as large industrial/technology enterprises. Their new investment is usually focused in large projects characterized by huge capital and complexity in technology, demanding for highly skilled labor and producing/supplying high technology products/services.

In addition to being a producer/supplier of goods, the firm also acts as an investor who always looks for opportunities to invest in order to maintain its traditional market position and entering new potential markets (Carlton & Perloff, 2015). Therefore, these industrial enterprises tend to focus on seeking, evaluating and making investment decisions in large industrial projects. In other word, the large industrial project is a strategic investment of modern industrial enterprises.

The general profit function of an enterprise is denoted as Л calculated as turnover minus production cost.

$$\boldsymbol{\Pi} = \mathbf{pq - C(q)}$$

Where p is the average selling price, q is the total quantity produced/sold and C is the cost of production which is proportional to production volume: the more production, the higher cost of production. Thus, with the goal of maximizing profit, the firm always decides to choose production level at the output q such that Л has the maximum value with the given price p, we have the profit maximization function as follows.

$$\boldsymbol{Max\ \Pi\ (subject\ to\ q) = \mathbf{pq} - \mathbf{C(q)}}$$

If we give the output **(q)** as a production function of the firm in the form Cobb-Douglass ($q = AK^{\alpha}L^{\beta}$) with the inputs of production as capital (K) (or technology), and labor (L), we will have the function expressing the relationship between project or firm profit and capital / technology, labor. Based on this basic function, the profit function can be further developed to reflect other production costs which would be arrived in future such as a new type of tax as part of the operational cost.

Modern firms including large family owned ones, are typically led and managed by a team of closely-governed managers based on strict internal governance policies designed to ensure all operations of a business are directed towards maximizing profits, or maximizing dividends for shareholders, agreed and strictly adhered to by board members (Bernard S. Black, Hasung Jang & Woochan Kim, 2006). These internal governance policies can be always changed according to the actual situation of production and business activities in order to maximize profits. As a result, decisions made by the firm as an investor tend to make rational decisions, based on the best possible information, reliable evidence, and appropriate arguments, limiting sentimental views/arguments (Carlton & Perloff, 2015).

When investing in the project, rational investors always set the target profit of the project to the top priority and considered this is the most important criteria in making investment decisions. Contrary to rational investors, it is possible to take the typical example that social investors or social enterprises tend to choose projects that may have lower financial returns but have a larger social impact. In other words, the rational investor always thinks that the most important criterion for investing is the expected financial return of the project.

With the ultimate goal of maximizing profits and fierce competition for the firms that want to survive, in addition to constantly adopting good governance practices to maintain existing business as well as reducing the operational cost, looking for new customers, expanding the market, the firms must always research and make investment decisions in new projects that promise to obtain profits in medium and long-term.

Investment as a regular activity of the firm and/or an individual is understood as putting the amount of capital being held in a low risk state into a higher risk state in order to find greater profit in the future than that of keeping it in its original state. Investments are always faced with the uncertainty or instability of the investment market and thus investment is always potential for risk, except for some forms of investment such as investing in government bonds of the strong and stable economy which is considered as a non-risk portfolio (Barry, 1980).

According to Reilly & Brown (2002), there are three characteristics of an investment: (1) commitment to spend capital in a certain amount of time; (2) undergo inflation; (3) be affected by uncertainty or risk for future returns. Activities that investing in buying and keeping materials, commodities, buying stocks, bonds, financing for weak companies, lending, injecting capital into new projects, etc. all are considered investment activities. From the economic perspective of investment, under the conditions of perfect competition, according to Marshall (Bridel, 1987), enterprises the firm increase their production and/or expand investment as well as will probably have more competitors if the selling price is higher than the average production cost in the long run (Dixit, 1992). It is easy to understand that the firms will consider investing if they predict that there will be a considerable profit in the medium and long term.

Investment activity can be done by both individual investors and institutional investors. Individuals can invest money in various forms such as buying stocks, real estate, contributing capital to companies. From an economic point of view, investing is any purchase of a commodity, not used/consumed immediately but retained for future use/sale. Similarly, with a financial perspective, trading in assets with the expectation of future income or resale in the future with higher value (profitable) is considered investment. Firms can make direct investment through the financial market, through projects directly invested and investment managed by enterprises or indirect investment through financial intermediaries, investment funds. Usually with large projects of strategic importance, the firms directly invest and manage the investment. This research focuses on the study of institutional investor as the firm who is making rational investment decision, investment in tangible assets as large production projects. For the firm, investing in new projects is considered a strategic business activity because: (1) the project will use a large amount of capital for many years; (2) it is time and resource consuming to prepare for investment and may not be immediately recoverable; (3) These large projects often face a number of uncertainties that are likely to become a risk to the project's profitability and financial health of the firm. Hence, a commitment to invest in a large project can be considered as a sufficiently large event to affect the stock price of the business if it has been listed on the stock market (Healy & Palepu, 1993).

In case the project evaluation and investment decision are made correctly as well as the effective project implementation management, when the project goes into commercial operation of producing, selling products and services to the market, it will boost up the firm's business in many aspects such as market share, increased sales and stability, high profitability. To do this well, one of business tasks that must be handled correctly is to quantify the uncertainties to reduce number of uncertainty as well as the uncertainty level that strongly affect the investment decision.

2.1.2 Methods of project appraisal.

Project appraisal is important before making a project decision, which includes series of many tasks such as legal appraisal, technology appraisal, and the most important is the work of project financial appraisal which can be made in several methods. Typically, the discounted cash flow method (DCF) is represented by two fundamental indicators of NPV and IRR and the second one is ROA. When appraising a single project so that the firm will consider investing in that project, three important criteria to make investment decision are: (1) the project is legally formed at the low legal risk and there should be no political risk and/or war; (2) Financial benefits represented by NPV, IRR are big enough; (3) Financial risk is at acceptable level by the firm. The method of discounted cash flow represented by NPV, IRR which is a traditional method is simple, easy to understand and easy to implement. So far, most of the investment projects have been applied the DCF method to calculate the financial indicators of projects for the decision of investors. According to a review by Krychowski & Quélin (2010) based on a survey from Rigby & Gillies (2000); Graham & Harvey (2001); Ryan & Ryan (2002), around 75 to 85% of firms use NPV while ROA is only 6 to 28%. The formula for calculating NPV is as follows.

$$NPV = \frac{(B_0 - C_0)}{(1+r)^0} + \frac{(B_1 - C_1)}{(1+r)^1} + \frac{(B_2 - C_2)}{(1+r)^2} + ... + \frac{(B_n - C_n)}{(1+r)^n}$$

Or the formula can be shortening as below.

$$NPV = \sum_{t=0}^{n} \frac{(B_t - C_t)}{(1+r)^t}$$

Where B is the sales volume of the business, C0 is the cost of the initial investment, the Ct from C1 is the cost of doing business in the years of commercial operation, t is the project life cycle in number of years, and r is the project's discount rate that can be calculated as the weighted average cost of capital (WACC)[2] over the operational years of the project.

The discounted cash flow method of calculating NPV contains some points that investors need to be cautious. Although the formula for calculating NPV is quantitative, however, it is based on a number of highly qualitative assumptions (Zopounidis, 1999). Specifically and perhaps most importantly, that is sales of the project's products over the years which are measured by the number of sold products multiplies by the expected sales price or the estimated selling price across all the years in the project operation. Uncertainties have been hidden in above assumption at least in the following three points: (1) Assuming that the project always sells out all the products at the forecast price; (2) Assuming that the price is always stable at the forecast price; (3) The input costs both in the initial investment period and in the commercial operation for many years in the future are stable. It is clear that these indicators, although appeared in quantitative terms, are actually based on qualitative/predictive/forecasting criteria which are sensitive to the market fluctuation. As a result, the value of NPV may have a certain degree of fluctuation (or bias). Likewise, the operational cost, Ct, of a project includes a number of elements that are impacted by the non-business environment such as tax policies, input prices, environmental costs, etc. For the input costs, the firm can use a variety of preventive measures to reduce the fluctuation such as building long-term purchase price formula

[2] The discount rate of a project can be calculated using a number of methods and the WACC is a popular one.

for many years, long term purchase contract, and off-take purchase contract. However, for policy-related uncertainties, especially tax policies, it is almost beyond the control of the firm. In practice, large firms can co-operate each other to form associations (or cartel) and carry out formal/informal policy lobbying activities in favor of their business operation.

It can be concluded that the NPV calculation method by DCF is clear and easy to implement. However, it contains many hypothetical and / or predictive data on a qualitative basis with the accuracy of these forecasts/assumptions depend on the capability, experience, level and ethics of the experts (Tran Ngoc Tho, 2014). Thus the NPV is rather relative and highly dependent on the effort, experience, expertise level and ethics of the project experts and appraisers. This approach reveals major constraints in irreversible projects that have a long project life cycle and be influenced by a number of uncertainties such as high fluctuations in output prices of product and service, altering policies change the cost of doing business. With future fluctuations, the NPV is rigid and less flexible, confining investment project in the fixe frame and thus limiting the chances overcoming future uncertainties.

The Real Option Analysis (ROA)[3] was used by Myers (1977) in the study of investment in new investment projects in large assets and financial options. This method is thought to be very useful in evaluating project types that have uncertain revenue streams or fluctuations. In these types of projects, the self-learning ability in projects' business operations enhances the firm's ability to generate revenue that has a large impact on the profitability of the project. Pindyck (1991) has shown that ROA is well suited for irreversible project with many uncertainties as ROA provides a quantitative framework for various options for options value as well as the best investment point. Adner & Levinthal (2004) argue that if the level of uncertainty and

[3] ROA, real option analysis is also known as Market Based Valuation - MBA

irreversibility of the project is low then NPV is more appropriate than ROA. According to Krychoowski & Quélin (2010), ROA solved the weaknesses of NPV to better deal with uncertainty by structuring investment decisions in at least three ways: (1) ROA stimulation, which allows investors to implement projects of higher risk; (2) ROA allows the investment project to continue diverging to reduce the cost of risk management; (3) ROA tends to pressure managers to be more proactive in leading the project because the value of the project may change depending on uncertainties in the future, so actively researching and clarification are needed.

Some of the following studies after Myers (1977) have applied the ROA method in evaluating power plant projects that have a variety of uncertainty effects. Laughton et al. (2003) argued that the traditional discounted cash flow model will negatively impact project appraisal as the DCF method does not adequately reflect market risk and uncertainty. The studies of Lin et.al, (2007), Laurikka (2006), Kuper & et.al (2006) in project appraisal of the energy project have shown good results demonstrating that ROA is a more appropriate method comparing to the DCF in case the project has many input uncertainties to calculate the project efficiency. Thus, it can be concluded that NPV and ROA are valid for project analysis and appraisal. However, ROA tends to be more useful when investors consider investing in irreversible projects that are likely to experience many uncertainties and high irreversible level, especially for energy projects using fossil fuels or large-scale fossil-fuel-based industrial projects that generate large carbon emissions due to carbon emissions may be subject to carbon taxation in the near future. This is a major uncertainty that rational investors need to include in the investment project appraisal.

2.1.3 Uncertainty and risk.

In day-to-day business operations as well as in making investment decision into projects, especially new investment projects in a new business environment of another country, investors are faced with many uncertainties that directly or indirectly affect the decision to invest in the project. As FDI projects from developed to developing countries, it faces a number of factors such as political risk, institutional risk, exchange rate uncertainty (Froot & Stein, Klein & Rosengren, 1994; Blonigen, 1997). In addition, some uncertainties are likely to translate into risks such as future taxation in the project life cycle, possible trade barriers, and unpredictable impacts of international trade commitment on domestic production.

Such situations are called as risks or uncertainty in general. However, from the academic perspective these two concepts are not exactly the same. According to Tversky & Fox (1995), in the view of future perspective, the theory of investment considers that risk and uncertainty are different. Risk is the occurrence of events and investors can estimate the probability of occurrence and consequences of these events. For example, when using dice in gambling, if the dice assumption has six identical faces, and good quality and players do not cheat. Then the rationale players can be sure that there are six possibilities and the probability of each is 1/6. However, the player cannot make any impact on probability of occurrence or probability for each occurrence.

Uncertainty is a situation where an investor or an investment advisor is uncertain whether the problem is likely to occur, as well as probability of the problem's ensured occurrence and if occurred, it is difficult to predict how it will occur. A firm when investing cannot be certain if the project will succeed or fail as well as the rate of success or failure. However, with the capability and experience of the entrepreneur and expertise of the supporting professionals, a firm can use many measure to increase the probability of success higher, such as increasing the budget for market research, collecting reliable information on prices, technology, competitors, use good experts to consult and evaluate projects. These efforts cost extra of the project preparation budget but clearly, it could increase the project's probability of success. Responding to uncertainty, the first thing to do is that the investor should intensify the gathering of best information regarding that uncertainty, in order to eliminate uncertainty or be able to transform uncertainty into risk and apply probability to this risk and estimate the cost of risk management. This risk management cost will be included in the financial analysis and appraisal as a part of the investment cost. In practice, for taxes that are likely to be applied in the future as an example, investors often maintain direct or indirect channels of relationship with policy makers, authorities to collect relevant information of taxation application. With large investment projects in large fixed assets with strategic importance to the business, when it is not possible to shift important uncertainties into risk, investors can delay and wait for better information. .

So why do the firms and their managers need to distinguish risks and uncertainty in making investment decisions? In practice, the firm often faces uncertainty rather than risk. What will happens in practice is mostly uncertain, the firm do not know everything that may happen and cannot accurately calculate the probability of the occurrence of each uncertainty, as well as difficult to change either the probability of occurrence or the outcome of the occurrence. A small investor buying a small amount of stock cannot influence the stock price movement in the market and the investor is facing the risk caused by the uncertainty affecting the price of the stock. However, if the activities of investor such as seeking and analyzing market information, and regularly observing the market movement will equip them with better knowledge of stocks, in order to have best measures to avoid effects of the stock volatility. Obviously this investor can increase the success probability of their stock investment. Similar to the firm in the real investment project, especially with marginal projects[4], as the fluctuation of input prices is uncertain, the firm can reduce

[4] The project which has the profit margin is small and easy to switch to not feasible if the cost is increased due to some uncertainties happened.

such the uncertainty by off-take, setting a ceiling price, or increasing the ability to predict the market to reduce uncertainty at a certain threshold. Such activities can reduce the damage due to uncertainties happened. That is the meaning of firm's attitude to consider the future as uncertainty or risk. In short, the difference between risk and uncertainty is the ability of the firm to influence the changes of the probability of uncertainty occurrence and its outcomes. In particular, the case of non-carbon taxation in Vietnam, during the project preparation process, investors will consider carbon taxation as uncertain factors if: after collecting relevant information to clarify the ability to impose carbon taxes, they judged that temporarily there is no possibility of application of carbon taxes during the project life cycle. And vice versa, after the information gathering and clarification process, experts/investors conclude that it is likely that the carbon tax will be imposed, factors of carbon taxation will be a risk and experts will estimate the probability of risk and its scale. When carbon tax is a risk, the cost of risk management and/or carbon tax costs payable will be estimated and included in the project's financial model, in order to calculate project financial indicators (NPV, IRR ... etc) for project appraisal for investment decision.

When calculating project financial indicators to assess profitability and performance of simulation of project risk analysis, investors often have to transfer uncertainty into risk. Investors must assume probability distributions for uncertain factors and estimate the scale of uncertainty to convert uncertainty factors into quantitative values so that project financial indicators can be calculated as NPV, IRR. The same transformation of uncertainty into risk must be done to be able to run simulation techniques, for example Monte Carlo simulation to see how the results will change when the input values change. Thus, investors have changed uncertainly into risks or can say this is a way to convert the uncertain problem into a risk problem, to be able to run the model. However, this is only a hypothesis to make the mathematical model workable. In practice it is difficult to clearly identify the values and probabilities of risk occurrence. Assigning these assumptions is to provide an overall picture of the analysis only: what the project result will be, if something happens like the assumption? (What-If Analysis). By doing this, the decision maker of the firm can understand the different possibilities and scope of simulated results and thus better decision-making.

In short, through the above explanations, it can be concluded that the future is uncertain, not risky. If it is uncertain then the firm can have a positive impact on reducing the probability of bad occurrence (increasing the probability of success), creating more positive events and adding value to the future. Thus, it can be concluded that in order to deal with the uncertainty firstly, it is to increase the collection of relevant information at a reliable level to clarify uncertainties and convert uncertainties into risk and apply risk management measures, and thus estimating cost of the risk in the financial model of project such as NPV. The process from discovery, clarification, and transforming uncertainty into cost of risk is repeated process from the beginning of the project research, completing the feasibility study and appraisal. Even after appraising of project and making investment decisions, these uncertainties of projects, despite being turned into risks with probability of occurrence and quantitative magnitude, are always updated as these uncertainties can be changed. if these uncertainties tends to change more negative. Investors may decide to pause and transfer the project to a "wait and see" state. (Wait & See status).

2.1.4 Classification of investors based on risk response.

Thus, technically when facing with risks and uncertainties, investors can perform the task of collecting relevant information, clarifying information to assess uncertainty and determining uncertainty: this uncertainty can happen or not, when and how? If an investor can identify the above information clearly, it means that uncertainty is converted into risk by imposing the probability of occurrence. The application of this probability is based on the experience of investors and experts, the market information that investors can update and clarify about the possibility of risk accurrance and most importantly the psychology of investors with the project risk. This is a risk which mutually agreed by administrators and experts involved in project evaluation (so-called as perceived risk).

Normally, based on investors' reactions to project risks, investors can be divided into 3 main categories (1) risk adverse investor; (2) risk neutral investors and (3) risk-taker investors. In more detail, according to Wiseman & Gomez-Mejia (1998), there are 5 types of investors mentioned as Table 2.1.4 below.

Table 2.1.4: Classifying investors according to risks

Type of investor	Reponses to risk
Risk adversion	Prefering lower risk options at the expense of return.
Risk bearing	Perceived risk to agent wealth that can result from employment risk or other threat to agent wealth.
Risk neutral	Prefering options with highest expected value and in which the risk is fully compensated.
Risk seeking (loving)	Accepting the options in which the risk is not fully compensated in hopes of realizing the up-side potential of the option
Risk taking	Choice of investment risk from among the firm investment opportunities.

Source : Wiseman & Gomez-Mejia (1998)

Thus, it can be concluded that, when making investment decision for the same project, each type of investor may have different decision-making behaviors depending on investor's psychology of estimated risk. Risk-taking investors tend to accept higher risk projects and vice versa.

2.2 Foreign direct investment and its impact factors.

Since the end of the Second World War, the large corporations in Western countries have expanded into new markets. FDI has become an important factor in the economic development of nations and the world (UNCTAD, 2004). The study of FDI flourished in the 1960s and 1970s, most notably Hymer (1960); Caves (1971) argued that FDI is a tool to exploit the advantages of fixed assets of firms in foreign markets. The firms have easier access to raw materials by FDI project in another country instead of importation dependence. They could allocate the specialized labor and production facilities as well as dividing their whole production process in the whole production system in both home and foreign countries to archive economy of scale. For example, they could use the production line in foreign countries for preliminary treatment and importing essences back for further processes and completion. Some studies also suggested that FDI is a tool to avoid trade barriers and reduce transportation costs. Dunning's (1971) study argued that FDI serves as a strategically defensive step for firms to avoid over-concentration on the home economy and diversifying to reduce risks to the whole system; Watters (1995) demonstrated that FDI projects help the firm reducing the constraints of the domestic market, especially when the domestic market is increasingly saturated.

Foreign direct investment (FDI) has been implemented in various forms such as setting up representative offices to research and explore market of the host country for the promotion of products and joint ventures in simple forms such as business cooperation contracts (BCC), buying shares of existing domestic companies and engaging in business operations using existing production facilities, participating in joint ventures to establish new legal entities, or invest in green field projects and established a company with 100% foreign capital. In general, FDI is generally understood as the establishment of a firm in another country under the laws of that country but the owner is a foreign firm or individual having a foreign nationality. Foreign enterprises can be acquired through the acquisition of capital in existing domestic enterprises (M&A) or developing of new projects (green field projects). These firms can be 100% owned by foreign parties or joint ventures with domestic firms/individuals (Geringer 1988; Geringer & Hebert, 1991). Normally, according to UNCTAD (2004), if the foreign party owns 10% or more of the voting capital, it is classified as a FDI firm. For foreign investors, FDI is said to have the following benefits: (1) take advantage of many inputs from the domestic market with low cost such as human resources, raw materials, land rental; (2) close the domestic market; (3) have good conditions for both manufacturing and researching domestic customer's behaviors; (4) Diversification of production plans/locations create a production network across multiple countries, facilitating easier allocation of cost / benefit across the system (transfer pricing) to optimize costs / benefits. In many types of oversea investment, the one in the form of foreign direct investment is always paid attention by firms in the trend of globalization. However, foreign direct investment in developing countries is often accompanied by risks such as the risk of political / diplomatic relations, imperfect legal systems, low levels of employment, and complex cultures, etc, especially the tax system of developing countries tend to be highly unstable.

Among many studies on FDI are published, it can be divided into two main directions: (1) analysis of the benefits of FDI; (2) Critically review the limitations of existing FDI such as over-exploitation of local resources, resulting in unsustainable development, badly affecting the natural environment and natural landscapes of the host country; projects with old technologies, refurbished old equipment causing large / noxious waste are common causes (Harrison, 1994).

Studies assessing the benefits of FDI have been fairly similar in terms of the benefits that FDI brings to the host country as follows: (1) increasing the wages and employment (UNCTAD, 2004); (2) using of raw materials and inputs from local production, leading to the promotion of domestic investment/production; (3) the spillover effect from FDI to domestic firms (Javorcik & et.al, 2007; Kneller & Pisu, 2007); (4) technology transfer to domestic firms and contribute to the increased productivity (Kokko & et.al, 1996; Gorg & Strobl, 2001; UNCTAD, 2004; Potterie & Lichtenberg, 2001); (5) contributing to increased exports and foreign currencies to the host country (Nigel Pain & Katharine Wakelin, 2002); (6) help shift the manufacturing structure towards industrialization (Dunning & Narula, 2003).

One common direction of FDI study closely related to the thesis is the research of factors influencing FDI flows into a country. Since the 1970s, there have been studies on factors affecting FDI inflows in developed countries at the national, sectorial, and firm levels. Factors can be grouped into the following ones: (1) group of factors relating to the characteristics of the firm; (2) group of factors relating to the characteristics of the investment project that the firm is going to invest; (3) group of external factors such as the exchange rate, tax, institutional quality, location of the host country, protection of trade, the impact of trade commitments. The reviews of Root and Ahmed (1978) divided these studies into four main groups: (1) economic group including indicators such as GDP/GNP, GDP growth, purchasing power of the domestic currency, exchange rates, the development level of transport infrastructure, communication and electricity supply; (2) social group such as the quality of human resources, the level of labor mobility, the level of urbanization; (3) Political groups relating to political such as times of government change, military coups or internal military conflicts, administrative performance of the government; (4) Government policy-related groups such as FDI related taxes, foreign manpower limitation, localization level regulations. In the research direction of the thesis, the following uncertainty of taxation is discussed.

Tax uncertainty has a direct impact on reducing project profitability. Investors always try to clarify the statutory tax liability as well as assess the possibility that the government will raise new tax rates in the future, such as environmental and carbon emissions taxes. Taxation related researches such as Root & Ahmed (1978), examine the response of FDI investors to increase in tax rates showing that corporate taxes have reduced FDI; Swenson (1994) proved that FDI was increased following the US government's reform of the FDI-related taxation in 1986; Bellak & Leibreacht (2009) argued that corporate income tax reduction had a positive impact on FDI inflows in Central and Eastern Europe between the year 1995 and 2003. Most of the studies have shown that tax rates and tax-related policies of FDI host countries have a clear impact on FDI inflows. These researches showed that tax and tax-related policies had significant impacts on FDI inflows and FDI investors are likely to be very cautious when considering tax-related uncertainties when deciding to invest in a FDI project.

2.3 Irreversible project

In the form of FDI, investments in large projects, or irreversible projects is given special priority by states and policy makers, as these projects are of vital importance to any strong economy. Most irreversible projects are huge capital projects, requiring long time of preparation and up to the time of investment decision, the firm must usually spend around 10% of total investment capital for survey, market research, technical design, pre-feasibility and feasibility study reports. These are projects classified as projects requiring design, purchasing/bidding and installation of equipment and construction. According to the survey of Archibald & Voropaev (2004) shown in Table 1 below, the irreversible projects include group 3 (3.1 and 3.2), group 5 (5.1 to 5.4), and group 7 (7.7). These projects can be named as follows: (1) transport infrastructure project, telecommunications infrastructure; (2) energy infrastructure projects (refineries, power plants); (3) projects to produce basic commodities of the economy (steel, raw materials, chemicals, etc.). It can be seen immediately that these projects are of vital importance to any strong economies in the world. The developing countries as Vietnam, for example, have a great demand for investment in the development of large fixed assets projects is irreversible ones. Therefore, investment in this kind of project is very important to and given priority by any country, especially developing countries.

Table 2.3: Project classification

Categorized Project	Typical Example
1. Aerospace/Defense Projects 1.1 Defense systems 1.2 Space 1.3 Military operations	New weapon system; major system upgrade. Satellite development/launch; space station mod. Task force invasion
2. Business & Organization Change Projects 2.1 Acquisition/Merger 2.2 Management process improvement 2.3 New business venture 2.4 Organization re-structuring 2.5 Legal proceeding	Acquire and integrate competing company. Major improvement in project management. Form and launch new company. Consolidate divisions and downsize company. Major litigation case.
3. Communication Systems Projects 3.1 Network communications systems 3.2 Switching communications systems	Microwave communications network. 3rd generation wireless communication system.
4. Event Projects 4.1 International events 4.2 National events	2004 Summer Olympics; 2006 World Cup Match. 2005 U. S. Super Bowl; 2004 Political Conventions
5. Facilities Projects 5.1 Facility decommissioning	Closure of nuclear power station. Demolition of high rise building.

5.2 Facility demolition 5.3 Facility maintenance and modification 5.4 Facility, design, procurement, construction in Civil, Energy, Environmental, High rise, Industrial, Commercial, Residential, Ships	Process plant maintenance turnaround. Conversion of plant for new products/markets. Flood control dam; highway interchange. New gas-fired power generation plant; pipeline. Chemical waste cleanup. 40 story office building. New manufacturing plant. New shopping center; office building. New housing sub-division. New tanker, container, or passenger ship
6. Information Systems (Software) Projects	New project management information system. (Information system hardware is considered to be in the product development category.)
7. International Development Projects 7.1 Agriculture/rural development 7.2 Education 7.3 Health 7.4 Nutrition 7.5 Population 7.6 Small-scale enterprise 7.7 Infrastructure: energy (oil, gas, coal, power generation and distribution),	People and process intensive projects in developing countries funded by The World Bank, regional development banks, US AID, UNIDO, other UN, and government agencies; and Capital/civil works intensive projects—often somewhat different from 5. Facility Projects as they may

industrial, telecommunications, transportation, urbanization, water supply and sewage, irrigation)	include, as part of the project, creating an organizational entity to operate and maintain the facility, and lending agencies impose their project lifecycle and reporting requirements.
8. Media & Entertainment Projects 8.1 Motion picture 8.2 TV segment 8.2 Live play or music event	New motion picture (film or digital). New TV episode. New opera premiere
9. Product and Service Development Projects 9.1 Information technology hardware 9.2 Industrial product/process 9.3 Consumer product/process 9.4 Pharmaceutical product/process 9.5 Service (financial, other)	New desk-top computer. New earth-moving machine. New automobile, new food product. New cholesterol-lowering drug. New life insurance/annuity offering.
10. Research and Development Projects 10.1 Environmental 10.2 Industrial 10.3 Economic development 10.4 Medical 10.5 Scientific	Measure changes in the ozone layer. How to reduce pollutant emission. Determine best crop for sub-Sahara Africa. Test new treatment for breast cancer. Determine the possibility of life on Mars

Source: Archibald & Voropaev (2004)

An important characteristic associated with the investment decision in the large asset project is the project's irreversibility which was first mentioned in 1986 by

McDonald & Siegel (1986) and then it has opened a study strand on investment decision in this type of project (Bertola, 1998). Pindyck (1990) argued that most of large-scale projects such as investments in refineries, power plants, steel, chemical plants requires multiple stages of design and considerable cost of project preparation. Usually, the large asset project has two important characteristics: (1) irreversibility : in the period of investment preparation or project execution, if the investor cancels the project, the entire expenditure up to the time of cancellation will be lost (becoming sunk cost) because the developed results of the project until the time of cancellation cannot be used for other economic purposes; (2) Irreversible projects may be paused for more positive information so that the investors can be able to make investment decision, such as the rise of product/service prices, lower initial investment cost, better policies for the project.

Irreversible investment projects which typically have a long project life cycle of up to 20-30 years or more, such as production projects of high value products, infrastructure projects, power plants, oil refineries, oil and gas exploitation, etc. Common characteristics of these types of projects include: (1) long project life cycle, (2) large initial investment capital, (3) long time required for project preparation, design, purchasing equipment and construction; (4) time for making the investment decision can be prolonged; (5) when making investment decisions, many uncertainties, information need to be considered. These types of investment projects usually have many phases, such as the following diagram.

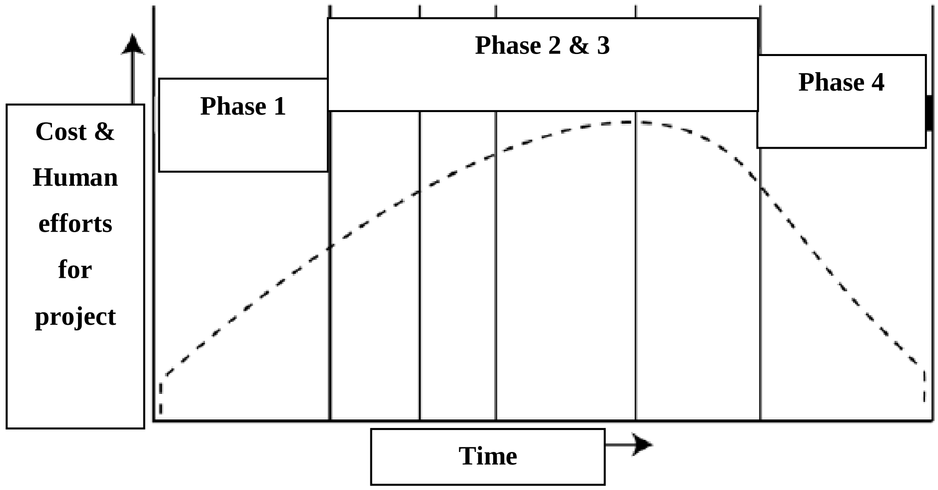

Diagram 2.1: Typical Project Life Cycle (Burke, 2003)

- Phase 1 (Concept / Initial Phase): This is a preliminary investment preparation research phase. The project will be evaluated in many aspects, especially if the project is suitable to support the firm's strategy or not? Many analyses are performed and often expressed in the document, so called as pre-feasibility study (Pre-F/S), for decision-making purpose: should the project proceed to the next phase of the detailed feasibility study (Detailed F/S) or not (Stage 2).

- Phase 2 (Intermediate/Development): This stage is most important in the preparation period of investment reflecting by the feasibility study. The inputs of the feasibility study for project evaluation are quantified as accurately as possible. The financial analysis presented by the project financial indicators (NPV, IRR, B/C, etc.) is calculated in this phase as exact as possible. The investment decision into project is made when the feasibility study is completed and the total project investment cost has been as accurately determined as much as possible reasonable assumptions. However, during the period of making investment decision, there would be existence of uncertainties and thus, the rationale investors may pause the project's investment decision and wait for better information or when the level of uncertainty decreases to an acceptable level. The pause of project investment decision to wait for better or clearer information is called as the "wait and see" status (Bjerksund & Ekern, 1990; Stokey, 2016). For the firm, making investment decision in irreversible projects (Dixit & Pindyck, 1994) is one of the strategic financial decisions besides other important financial decisions such as dividend policy, financing decision. In the early time of project investment preparation when the firm may spend little cost, if the project preparation is well developed in combination of good public relations, it will make the market value of the project higher, leading to better corporate value or higher stock price of the firm in general (Fuss & Vermeulen, 2008).

-Phase 3 (Intermediate - Execution): After making an investment decision into project, the investors start to spend a significant amount of cost on detailed design, consultant works, advance payments for equipment suppliers/contractors, and construction costs. At this point, the project can be considered as totally irreversible because if the investors cancel the project, they will lose significantly as total expenditures at this time is very big and becoming the sunk cost.

- Phase 4 (Final phase- Transfer): After completion of the execution phase (phase 3), the project goes into the period of trial and commercial operation which produce and sell product/service for the market.

By the end of the second phase, investors usually spend around 5-10% of the total project's investment cost for market survey and research, project design, feasibility study (Burke, 2003). If the investors cancel the project, they will lose this expenditure entirely as the feasibility study of this project cannot be used for another one. In this period of feasibility study, if the investors discover a considerable uncertainty, they will pause and wait for more positive information to make an investment decision, and it makes the situation of "wait-and-see" appears.

CASE STUDY OF IRREVERSIBLE AND REVERSIBLE PROJECTS

Theoretically, through the review of related publications, the author has not found any empirical studies about distinguishing these two types of projects by quantitative data such as the scale of capital or labor in the project. Currently, the main difference between the two types of projects is based on the size of sunk cost for investors if the investor decides to withdraw the project. The sunk cost for project preparation can not recovered if the investor abandons the project: the higher sunk cost, the higher irreversibility of project and vice versa. In practice, there are many examples of irreversible and reversible projects. Investment decisions for these two types of projects can be described in below situation.

Irreversible project: A typical example is the Nghi Son refinery and petrochemical project invested by the Joint Venture between Vietnam Oil and Gas Group (PVN), Idemitsu Group, Mitsui Chemical and Kuwait National Oil and Gas Group. This project has a total investment of about US $ 9 billion, approved by the Government of Vietnam and put into master plan since 2003 after these investors have preliminary designs and preliminary cost estimates. After approval of the master plan, investors begin the process of studying the detailed feasibility study (F/S) before making investment decisions in 2008. Up to the time of investment decision in 2008, investors spent 5 years preparing the project (detail survey, technical design, cost estimate, prject appraisal, etc) and the sunk cost was several hundreds million USD. By 2008, investors were granted investment licenses and capital construction investment period of over 10 years. It can be seen that if the project appears uncertain factors during the project preparation period or considerable uncertainty is predicted to appear in the operation period of about 40 years affecting the project feasibility, the best solution that investors will choose is "wait and see" (they will wait to clarify uncertainties and convert into risks, recalculate project financial indicators), to increase the possibility of sunk cost recovery of hundred million USD if the project operates commercially. With Nghi Son Refinery and Petrochemical Project, during the preparation of the project investment, the investor proved that the project should be compensated for the import tax on wholesale price at the factory gate to be able to compete with the same imported product (imported by Petrolimex and some petroleum trading companies). This is a significant uncertainty that investors have used a government guarantee to transfer uncertainly into a controlled risk in order to improve the feasibility of the project.

Reversible project: Also in this big project, Nghi Son Refinery and Petrochemical Joint Venture also has sub-projects that are retail stations of petroleum products. The project will build a series of high-standard and multi-purpose gas stations (including fuel oil, gas, liquefied gas, pit-stop stations, catering services, short-term accommodation services, repair and maintenance services of transport equipment ...) along major highways and industrial parks in Vietnam. It is easy to see that these multi-purpose gas station projects will have similar design and the location of the station is not bound too much hard conditions such as oil refineries: For example, the refinery must be accompanied by deep water ports, thousands of hectares of land, good geology, low possibility of earthquakes. Thus, the investment preparation cost (sunk cost) for gas station projects such as designing cost of stations will be very small and only need to be designed a few times for hundreds of stations. So if the investor considers that it necessary to move the investment position of gasoline station, or to stop investment of such stations in a certain area because of an uncertainties affecting the feasibility of specific gasoline station, they can easily make a decision to stop because the cost for preparing a gas station project is very small or it can be said as "low level of reversibility", in contrast to Nghi Son Refinery and Petrochemical Plant project which is highly irreversible.

The decision to invest in a large project is influenced by many factors including the qualitative and quantitative ones at both micro and macro levels. Macro factors may include the political status of the host country, the level of development and growth of the industry in which the investment project is expected to invest, the stability of the exchange rate of the host country, stabilization of laws and policies related to investment such as administrative procedures on investment, land, taxes, local labor for the project.

Micro-level factors at the firm level can include the relationship of investor with regulatory authorities, degree of industry competitiveness, market size, stability of the price of project products in the domestic market and in the world, the average profit level of industry, the average interest rate of the market, etc. When considering investing in a project, investors firstly focus on the feasibility of the project reflected by the financial indicators. In some types of small, simple and short-lived projects, financial indicators have a decisive role on the decision-making of investors. For the large asset project, these financial indicators are calculated based on many assumptions about market price, capital cost, tax policy stability as well as selling ability of the project products/services, when the project comes into operation. Most of these assumptions are quantified by experts on a qualitative basis, so the project financial indicators are appeared as quantitative ones, however, these quantitative indicators is originated from qualitative foundation. Therefore, beside the financial indicators, the investors need to consider uncertainties and their ability to control these uncertainties effectively or not? It can be concluded that making of investment decision into new investment project is always a complicated task that involves many uncertainties and risks including those that can be controlled effectively or those that are uncontrollably. Therefore, research on the influence of uncertainties to investment decisions of investors has always been and will be important subject those academics and managers, project financial specialists must strongly concern. Firms' investment is of great importance to economic development, but our understanding of the investment behavior of the firm, the whole industry or a country is still limited. According to Pindyck (1990), the econometric models do not explain and predict the level of investment as well as it cannot explain why an industry/country could invest more than other industries/countries. Also from Pindyck (1990), one of the weak points of DCF to appraise the project is that it is strongly replied based on the qualitative assumptions and the important condition that the project costs are reversible. However, in practice, many types of investment projects are irreversible when investment project is developed to a certain stage and investment decisions can be delayed but irreversible (Pindyck, 1990, p. 4, part 1). Regarding the discussion on investment attracting policies, the author stated that it is possible to improve the stability of the business environment stabilizing the macroeconomic environment and better credit than reducing the interest rate, loans or tax incentives. It can be seen that uncertainties have a greater impact on investment decisions than cost reduction such as lower interest rates, or lower taxes. So, this study has showed that how importance of uncertainty to investment decision of firms.

In terms of macroeconomic management of investment, the development of policies to encourage investors, especially FDI in new projects, is of great importance to the economy. This problem has been studied and confirmed empirically in many emerging and/or developing economies. The host countries of investment benefit from FDI such as technology transfer, export growth, job creation and higher incomes for workers (Harrison, 1994), increase in domestic demand for raw materials, creating a spillover effect on domestic firms (Kokko, Tansini, & Zejan, 1996). Thus, the research of investment decision-making behavior and uncertainties influencing this investment decision will help policy makers to propose appropriate policies to increase foreign direct investment (FDI) into large asset projects which are of great importance to the economies of developing countries including Vietnam.

2.4 Investment decision under uncertainties

The investment decision of a firm in practice can be divided into two categories according to McMenamin (2002) as a tactical and strategic investment decision. Investment decisions are considered as tactical when a firm invests in financial instruments such as stocks, bonds, intangible assets such as intellectual property, patents, copyright, trademarks. The investment decisions into these financial assets can be made very quickly depending on the market conditions, especially the current situation of the stock market and financial markets. Firms may decide to hold financial assets long-term or sell quickly because these financial assets are always highly liquid. In contrast to strategic investment decisions when the firms invest in large irreversible investment projects. These projects are strategic in medium- and long-term projects, consuming a large amount of capital, promising to maintain their market position in medium- and long-term when such the projects are profitable. According to Al-Ajmi,et.al (2011), the strategic investment decisions play an important role in firm management; ensuring long-term development of the firm as well as it is expected to increase firm value. However, the irreversible projects always face many uncertainties affecting the expected return and thus, the study of investment decisions made by firms in uncertain conditions is investigated by many authors in both theoretical and empirical ones.

Lucas (1971) can be considered as a pioneer in modeling of a firm value by a mathematical techniques in which the firm value (V) depends on a number of factors such as product price (p), production output (q), the investment level (x), and the discount rate (β), over the time (t), assuming that the firm is always maximizing its value. Abel (1983) studied the impact of a single factor of price volatility on neutral risk investors' investment level, applying mathematical techniques to develop models. The basic model used by Abel (1983) is the production function in form of Cobb-Douglas with capital stock (K) and labor (L) that are two main inputs in addition to the price factor, examining the effect of price volatility on the capital stock (K). The result of Abel (1983) showed the same findings as Hartman (1972) is that if the selling price is increased leading to an increase in value of a marginal unit of capital, the firm will invest more. Abel & Eberly (1994) developed the model of the firm value (V) which is the expected total value of operating profit ($\boldsymbol{\Pi}$) minus the total operating cost of the project lifecycle with the uncertainty of shadow price (q) of the installed capital. Abel & Eberly (1994) discovered that the firm will always tend to maximize their value by solving the problem of optimizing their value (V) by capital stock (K) and technology (ε) which are two main inputs of their production.

Caballero (1991) summarizes the researches of Hartman's (1972) study, Abel (1983, 1984, 1985) about the relationship between uncertainties and investment to build a firm's value model (V), depending on profit ($\boldsymbol{\Pi}$) which depends the capital (K) and labor (L), cost of capital conversion and other costs in two types of perfect and incomplete competition markets. Caballero's (1991) concluded that the adjusted investment cost due to asymmetric or symmetric information does not significantly affect the relationship between uncertainties and firm's investment while the effect of investment capital cost and marginal profit caused by increased investment capital are main factors that have a great influence on this relationship. Dixit & Pindyck (1994) used the formula of NPV in explicit form of arithmetical assumption to examine the effects of product price, interest rate, and plant construction cost to illustrate the impacts of these uncertainties on the NPV and indirectly influence the value of the firm (V). The research results in explicit form of Dixit & Pindyck (1994) could be used for illustrative purpose only, however, it is difficult to generalize this research results for similar studies because the function of NPV was not developed in general form as the Abel (1983), Abel & Eberly (1994), or Caballero (1991). Recent research by Stonkey (2016) has developed a theoretical model of firm's investment decision under tax policy uncertainty. This research proved that the firm will suspend the investment project and implement the policy of "wait & see ".

These above researches, except one of Dixit & Pindyck (1994), have the following general characteristics: (1) these authors used the firm value (V) including the profit function ($\boldsymbol{\Pi}$) in the form of gross profit or operating profit which depend on many factors including capital stock (K) and labor (L). Those are most important inputs of a firm. In addition, several uncertainties such as product selling price, cost of capital were also combined in the model with the fundamental assumptions that the firm always maximizes their value or maximizes project profitability; (2) The form of the profit function or operating profit of a firm is in the general form of Cobb-Douglas with two main inputs namely the capital stock (K) and labor (L).

Researches of investment decision under uncertainty are also developed specifically for one type of irreversible project such as steel plant, coal-fired power plant, or real estate project. These are "high irreversible" project types and their project value or project profit heavily depend on the future policies of the government. For example, a coal-fired power plant will suffer a considerable impact on its revenues when the government applies the policy of carbon taxation. These researches were applied the method of ROA conducted by Sekar (2005), Reedman et al. (2006), Herbelot (1992), Titman (1985), Wang & Zhou (2006). Due to the impacts of uncertainties changing the project's expected profitability, the feasibility of the project depends on the project appraisal method and the method of ROA has demonstrated its ability to adapt to the uncertainties which are assumed to occur in the future. Sekar (2005) conducted a research in the form of case study on project appraisal for a coal-fired power plant project using two different technologies which generate different carbon emission levels leading to different environmental costs or different cost of carbon taxation. In other words, carbon taxed uncertainty impacts greatly the operating cost of project, indicating that NPV has underestimated input costs over ROA.

Empirical researches on the influence of uncertainty on firm investment decision at sector level is also quite diverse, such as the impact of fluctuations in inflation and US sales prices on the investment level of the firms using the database of Citibank from 1954 to 1989 (Huizinga, 1993); the impact of price fluctuations on the current and future investment of US manufacturing firms (Ghosal & Loungani, 1996); the impact of price fluctuations and the demand for that product on business investment (Peters, 2001); stock market volatility on firms' investment in developed economies (Lensink, 2002); exchange rate fluctuations affect investment (Byrne & Davis, 2005).

Through an overview of theoretical and empirical studies related to "investment decision under uncertainty", it can be concluded that the theoretical and empirical researches are quite diverse. Theoretical studies form the basis of the firm's value function (V) by the firm's profit function minus the cost function which includes the cost caused by uncertainty that the study focuses on. The profit function of the firm is used as a Cobb-Douglas function with two inputs: capital (K) and labor (L). The study of Abel (1983), Caballero (1991), Pindyck (1990), Abel & Eberly (1994, 1998) all developed theoretical model in the above format. Uncertainty factors that the study focused on as the selling price of the product, the cost of capital investment in the perfect competitive market, or incomplete information asymmetric or proportional. At the same time, the above studies are based on a basic assumption that firms always maximize profits and / or maximize business value.

Table 2.4 below summarizes some publications that the thesis will base on its basic principles such as the form of model, main variables, assumptions in these publications to build and develop the research model of this thesis.

Table 2.4: Summary of related theoretical/empirical studies on investment decisions under uncertainties.

Authors	Model & forms of function	Main variables	Basic assumptions
Lucas (1971)	Value of the firm (V) Cobb-Douglas production function with K and L are two main variables	Product price (p), production volume (q), investment level (x), discount rate (β), according to time (t)	(1)Firm always maximize their profit; (2) production function is constant returns to scale.
Abel (1983)	Cobb-Douglas production function	Captial stock (K) and labor level (L), price fluctuation,	(1) Firm always maximize their profit; (2) Competitive market, risk neutral firm;
Caballero (1991); Hartman (1972), Abel (1983, 1984, 1985).	Value of firm (V) in perfect competition and imperfect competition market.	Profit function (***Π***) capital stock (K); labor level (L), cost of capital and other cost	(1) Perfect and imperfect competition market; (2) Constant economy of scale; (3) Risk neutral firm
Abel & Eberly (1994)	Value of firm (V) is the sum of expected present value of operating profit (***Π***)	Capital stock (K), labor level (L) Shadow priec (q) of installed capital	Firm always maximize their firm value by solving the optimization of firm

	minus the sum of operational cost.	Product price (p); technology (ε);	value (V) according to (K) and (L) as main variable.
Sekar (2005)	Case study of project appraisal for caol fired power project with different technology. Function of NPV/RO in explicit form (numerical function in stead of variable function.	Explicit number of initial investment capital, carbon emission volumeand cost of carbon taxes.	Author using explicit data to calculate and compare three investmet plans, using the basic assumption as of NPV.

Source: Summary by author

2.5 Investment decisions under carbon taxation uncertainties

2.5.1 Carbon taxes and carbon leakages

The earth's temperature rises due to the accumulation of greenhouse gas emissions, mainly carbon dioxide (or carbon in short) or carbon emissions, in the ozone layer creating of greenhouse effects which causes global climate change. Carbon emissions derive from the production of electricity based on fossil fuels such as coal, kerosene, oil and gas, and other activities of human being such as fossil fuel-based transportation, farming, etc. Efforts to combat global climate change through various measures, including the reduction of global emissions are approved by many countries in 1997 in Japan (the Kyoto Protocol 1997 on Climate Change). In the Kyoto Protocol 1997, many countries have pledged to apply different measures to reduce carbon emissions from each country. By the year 2011, there were 36 developed countries having commitment to reduce carbon emissions. In the above 36 developed countries, the Europe including 29 countries is counted as only one country. These 36 countries are in the Annex I (mostly developed countries) and 137 developing countries agreed to reduce carbon emission in future without specific commitment is not in the Annex I (Non-Annex I). The committed countries in the Annex I have gradually adopted emission reduction measures such as emission quotas, carbon taxation, and encouraging the production of renewable energy.

Carbon taxes are designed to impose on producers that emit carbon emissions. These taxes are typically imposed on the volume of carbon released to the environment or on electricity generation capacity in the case of power plants using fossil based inputs. Carbon taxation increases production costs which force high-carbon emission producers to change technology to reduce carbon emissions, also called as green investments. Some empirical studies have demonstrated the effectiveness/impact of carbon taxation on the reduction of corporate income and contributed to change the technology at lower carbon emissions, such as Speck (1999). Zhang (2004); Bruvoll, & Larsen (2004); Wier (2005); Liang (2012). Carbon taxes can be applied at different stages of the production chain, such as imposing directly carbon emission producers or on suppliers of carbon emission materials such as coal, gas or on end-users through final product prices or energy consumers. Such the imposing of tax through the value chain is called vertical targeting (Bushnell & Mansur, 2011). For example, the firm exploits coal and sells it to the electricity generation plant. Then, the electricity generation plant will sell to the electricity consumers. Therefore, imposing of carbon taxation can be considered to place on the coal producer (upstream) or coal-fired power generation producers (directly responsible for the carbon emission) who benefit directly from carbon emission.

However, according to Bushnell & Mansur (2011), the study shows that direct carbon taxation on the firms that emit carbon emissions, as the case of a coal-fired power plants as example, would lead to "carbon leakage" or offshore investment to avoid carbon tax (Babiker, 2005)[5]: the investors of coal fired power plants will consider to invest in non-carbon taxed countries. Carbon leakage is a concept that refers to the phenomenon in which the carbon emission firms will switch their investment from carbon-taxed countries to non-carbon taxed ones and then imports commodities back to avoid taxation. This phenomenon may explain why foreign investors are very interested in investing in considerable carbon emission plants in developing countries such as steel, chemicals and electricity because they do not have to pay carbon tax. In addition, according to several studies, the proposed imposition of carbon taxation on products of upstream manufacturing process of the value chain would be better than the imposition of carbon tax on downstream products. The reason is that imposing carbon tax on downstream will increase the possibility of shifting investments to non-taxed countries (carbon leakage) in comparison with the case of upstream. A good example of above is the coal-to-electricity value chain: applying carbon taxes on coal is better than on power plants in the view of limiting carbon leakage. In addition, the application of some other carbon-related taxes, such as border adjustment tax, export carbon tax, or carbon trading mechanism, also has the potential to reduce carbon leakages (Bushnell .et.al, 2011).

In response to the carbon taxation policies in a country, the producers in carbon-taxed country will have several options as follow.

(1) Firms who have to pay carbon taxes may decide to invest in greener (less carbon emissions) technologies in comparison with the currently being used

[5] Carbon leakage or investment to avoid carbon taxation is understood as a shift of production from carbon-taxed countries to a non-carbon-taxed countries and then importing of non-carbon taxed commodities back. Total carbon emission is increased as the longer transportation of imported commodities (Wei et.al, 2016).

technology to lower carbon emission rate. The firm's investment in greener technology leads to more initial investment and ultimately the cost of greener products is higher than that of current technology. Products produced by green technology will be less competitive in price than products produced by old technology. In addition, it will take considerable time for such the technology transformation from the current one to the greener technology.

2) The firm will retain the old technology but they will separate the production segment: they can hire other firms in a non-carbon taxed countries to produce a heavily carbon emission parts of products and then import that components back to the mainland to assemble the finished product (Wei et al, 2016). In this case, the decision can be made and executed faster than the case (1). Therefore, in the short and medium term, the firm can use this solution to reduce production costs. However, they also need to restructure their production assembly in their carbon-taxed country to match the order-making operations in other non-carbon taxed countries. In addition, it is more difficult for the firm to control production quality abroad.

(3) the most strategic option of the firm in the medium and long term is that the firm may consider deciding to move their existing production equipment to invest in non-carbon taxed countries. This phenomenon has been identified by Branger & Quirion (2014). The firm can also invest in new projects instead of moving their existing facilities. However, they normally keep the old technology which is same level of carbon emissions and then, they import non-carbon taxed products back to consumption in the carbon-taxed countries. This is called as carbon leakage or investment for carbon tax avoidance. By In this case, the total carbon emission is increased because of increasing the distance of transport when importing goods to the carbon taxed countries. In this case, the targets of carbon taxation are completely failed. Countries that do not apply carbon taxation are mostly developing countries like Vietnam, where investors enjoy lower input costs, more investment incentives,

and they are not subject to carbon taxes. By investing in non-carbon taxed countries, the firms can keep their products competitive in term of price. The status of investment to avoid carbon taxation has been increasing since the event of Kyoto Protocol 1997. In the context of a sharp decline in world freight rates since the 1990s, it has contributed to increase such the investment to avoid carbon taxes. According to a study by Peters et al. (2011), between 1992 and 2008, total carbon emissions in developing countries have doubled while carbon emissions from developed countries are almost unchanged. At the same time, however, developed countries have more imports from developing countries, nearly doubling in 16 years. The conclusion of Peters et al. (2011) is that developed countries indirectly generate greater carbon emissions by more consumption. Peters et.al (2009) also argued that international trade has helped to transfer carbon emissions from carbon taxed countries (the Annex-I countries in the Kyoto Protocol 1997) to non-carbon taxed countries (Not in Annex I – the Kyoto Protocol 1997).

Various empirical studies of different authors have shown that the value of carbon leakage related investment in different industries is different. When studying of carbon leakage related investment in the region by geography and in a sector, Paltsev (2001) declared the value of carbon leakage related investment is about 10% while Babiker (2005) suggested that of 130% when studying of the displacement of more energy-consuming production (which is also subject to carbon taxation due to using fossil-based energy) while other studies suggest that this ratio is only 5 to 25%. Explaining for this significant difference in studies of carbon leakage related investment, Babiker (2005) argued that most of other studies yielded similar results because of using a similar paradigmatic structure while the author used a computational model which combine more variables and thus produce different results. Elliott et al. (2010) estimated the carbon leakage rate or carbon tax avoidance investment from countries in Annex B of the Kyoto Agreement in 1997 to be 20%.

Some authors agreed that carbon leakage rates are very uncertain (Barker et al., 2007; Harstad, 2010). However, the general view in many empirical studies is that the carbon leakage related investment are clearly raised, moving from carbon taxed countries to non-carbon taxed ones which are mostly developing countries.

Making decisions to invest in non-carbon taxed country to avoid carbon taxation will have to deal with a number of uncertainties including carbon taxation related uncertainties such as: (1) when will the non-carbon taxed country apply the carbon tax?; (2) what would be the carbon tax rate? These are two of the many uncertainties that the firm needs to pay attention to. For rational investors, they will incorporate these uncertainties in the project appraisal to make investment decision in order to increase the reliability of the project financial indicators so that they could make investment decision with greater confidence.

2.5.2 Taxpayers and rates of carbon tax.

Carbon taxes are designed primarily towards sources of emissions (eg coal-fired power plants that directly emit carbon, or sources of emission materials such as coal, gas, and petrol. In current industrial practice, carbon emissions mainly come from industries that use fossil fuels such as coal, crude oil and natural gas. According to statistics of the US-based Center for Energy and Climate Change Solutions (www.c2es.org), as of 2013, about 72% of carbon emission came from energy and energy-intensive industries such as steel, construction materials, 11% from agriculture (pesticides), 6% from land development and deforestation, 2.2% came from transportation using heavy fuel oil, so it can be seen that the projects of producing electricity from coal, oil, gas, projects using coal burning such as cement, construction materials, steel mills and chemicals are the most emission-causing firms. These projects require long-term project preparation with high costs and irrevocable or highly irreversible projects.

The goal of carbon taxes is (1) to reduce greenhouse gas emissions; (2) encourage the development of low carbon technology; (3) generate tax revenue for the budget to support carbon mitigation activities (Marron & Toder, 2014). Carbon taxes can be imposed on the sources of emission materials such as coal, oil (materials that cause emissions), or directly into firms that cause emissions or at the end of production value chain at which firms benefit from emissions such as energy intensive firms. Studies from developed countries suggest that carbon taxes should be imposed on firms that exploit the emission materials to disperse the impact of carbon taxation and thus reducing the negative impact on their emission firms. These policies will support to reduce investment of carbon tax avoidance which benefits developed countries to keep investment in their home country and reduce oversea investmet in developing countries where low input costs and no carbon taxes are imposed (Bushnell & Mansur, 2011).

The proposal for tax rates of carbon taxation are studied by many scholars and they widely agree on the view that carbon tax rate should ensure the tax revenue to compensate social costs due to emissions. However, in practice, calculating costs of social losses is very complicated, requiring modeling and big data. According to a survey of Marron & Toder (2014) in 75 studies of carbon tax design, this social loss cost fluctuates greatly with an average of USD 196/ton of carbon and 322 USD as standard deviation (USD price in 2010).

Most countries agree on the way to impose tax per an absolute value of carbon emission (per ton of carbon emissions) or if carbon taxes are in the form of energy taxes, it will be imposed per kilowatt-hours (kWh). As of 2016, there are 24 countries and territories worldwide, including some special economic zones in China, having imposition of carbon taxes as well as similar restrictions. The country with the highest tax rate is Sweden at 149.74 EUR/ton of carbon, the second is Switzerland at 60.61

EUR/ton of carbon. Some countries have low carbon taxes like Mexico from 0.46-2.28 EUR/ton of carbon emissions. (Zimmermannová et.al, 2016).

Revenue from carbon taxes is mainly used for major tasks such as (1) Regulating energy prices by compensating for renewable energy types with high prices compared to fossil energy prices ; (2) Investing in research and development of new technologies related to renewable energy development; (3) Study the policy mechanisms related to carbon pricing.

2.5.3 Investment decision under carbon taxation uncertainties

Carbon taxes affecting project investment decisions have been addressed in a number of studies around the world in which different notions are used for carbon taxation such as "carbon risk" or "carbon pricing." As discussed in the previous sections, the uncertainty that influences investment decision making for a project is referred to the case where the information needed to evaluate the project and make the investment decision is insufficient or unreliable so that the firm cannot make a decision to invest in an irreversible project. With uncertainties that may come in the future, especially uncertainties such as carbon tax related uncertainties that the firm have no previous experience, the assumptions relating to carbon taxation uncertainties are only made based on expert’s experience and information arriving at the point of calculation. Generally, the firms will have to make high assumptions to ensure that the risks of such uncertainties will be offset if the risk occurs. Such the high assumptions lead to the higher cost in project appraisal and then the firm must include higher revenues than the case that they have sufficient and reliable information, to cover the cost of high assumptions. Specifically, William et.al (2007) studied the case of coal-fired power plants emitting greenhouse gases and thus facing the risk or policy uncertainties of reducing carbon emissions. The investor must anticipate the cost of hedging it due to the policy uncertainty of carbon emissions. Therefore, investors have to expect the price of electricity to increase from 5 to 10% than normal expectation, so that their project can be feasible.

The uncertainties in investment will also affect the optimal level of capital/technology and the optimal number of employees in the project to ensure maximum profitability. In addition, the impacts of uncertainties will affect the timing of investment: the project investors may have to accept the "wait and see" status as pointed out by Fuss & Vermeulen (2008). Among the different types of investment projects, for the irreversible investment project, investors can delay investment for better information such as better market prices, better policies to ensure the best condition for their project (Pindyck, 1990). Therefore, if they anticipate any uncertainties to be significant, they may choose one of the following solutions: (1) increase the measurement effort to quantify the uncertainties into reasonable risks and put it into calculation model for decision making and/or (2) wait for better information to be able to evaluate those uncertainties more accurately.

If rational investors do not know exactly what the carbon tax rates will be and when they will be imposed, they will consider these two issues as two uncertainties that need to be reflected in the investment decision. Niemann (2004) constructed a cash flow model with tax expense (τ) and concluded that the uncertainty of the tax rate would directly affect the cash flow and the interest rate of the investment. For uncertainty of unspecified tax rates, the rational investors often have to assume a certain level of taxation and therefore, the expected return of project will be decreased. Some studies of taxation affecting firm’s investment level such as Alvarez et al. (1998), found that if investors believed that the tax rate would decrease, investors would tend to accelerate investment and vice versa; Hassett & Metcalf (1999) and Agliardi (2001) concluded that uncertainties in tax policy will undoubtedly delay investment projects. Bockem (2001) argued that the rumor of tax increase always influences investment decision-making behavior of firms and they tend to slow down investment decision-making. As the research results of Bokem (2001) in theoretical model development by mathematical techniques, the author found that with the monopoly firms, the tax uncertainty does not greatly affect the implementation of investment.

By combining of an overview of the previous theories of investment decision under uncertainties (Section 2.4) and investment decision under uncertainties of carbon taxation (Section 2.5.2), it can be seen that theoretical and empirical studies on investment decision under uncertainty are quite common, but researches of investment decision under uncertainties of carbon taxation are very few and only in the form of case study for single type of irreversible project instead of generally theoretical form. Some studies of investment decision under carbon taxation uncertainties were developed in the form of case studies: constructing, developing NPV functions, and using hypothetical data to calculate numerical results for one type of particular project with different investment plans that use different technology and thus different carbon emission. These case studies are of practical value for similar types of projects in practices but it is difficult to convince if the results of these case studies are generalized for many types of irreversible projects.

2.6 Research gaps

2.6.1 Research gap 1

Through the literature review of the underlying theories related to firms, their investment activities, uncertainty and risk, characteristics of irreversible project, theoretical and empirical studies related to investment decision under uncertainty, it can be concluded that the research of investment decision under uncertainty is important research direction which is useful to academic scholars, business executives, and investment advisors. There are many uncertainties influencing the investment decision of FDI investors in which uncertainties relating to taxation have considerable impacts. Most of the theoretical and empirical studies on the impact of taxes on investment widely agree that imposition of tax negatively affects and lowers investment level of the firms.

However, the theoretical and empirical studies about the impact of uncertainties associated with carbon taxation on investment decisions of firms in irreversible projects are quite limited. Only a few researches on the effects of carbon taxes on investment decisions are made in the form of case studies for a certain type of project such as researches of Sekar (2005); Shahnazari & et al (2014) about the carbon taxation related uncertainties affecting coal-fired power project in Australia; Reedman & et al (2006) applied ROA to model technology selection in the context of carbon taxation related uncertainties for the Australian power generation sector. These researches have been conducted specifically for one type of project in which two different technologies are applied, resulting in different volumes of carbon emissions and thus there will be huge differences in carbon tax related costs when carbon taxes are imposed. These studies could be valid for the same type of project, but it is not convincible to use these results to generalize into macro policies for other types of investment projects in whole sector or the whole economy. Meanwhile, the carbon taxation is likely to apply in the near future and it is great interest of investors (Barradale, 2014). The conclusion of Barradale's (2014) coincides with the ACCA's Carbon Taxation and Corporate Behavior Report in 2012 that carbon taxation will be increased in the coming years, but its rates and levels of growth rate are unanswered problems.

It can be concluded that the research about the uncertainties of carbon taxation on investment decisions of the firms into irreversible projects is still very limited. This leaves the first research gap on which this thesis will focus on.

2.6.1 Research gap 2

Through the analysis of theoretical researches on the effects of general uncertainties and tax related uncertainties in particular, on the firm' s investment decision into irreversible project, it could be seen that the theoretical model is basically built on capital stock (K) and labor level (L) as two main inputs. The capital stock (K) and labor (L) in investment projects reflect the size of investment capital and manpower used in the project in which labor is mostly from the domestic market. The K/L ratio is called as the capital-labor ratio which is an important indicator of the level of technology development in a firm or a project. The higher the ratio means that the higher the worker per capital in production was leading to the possibility that the project has likely used the higher level of technology or more modern technology. This point was confirmed by Sollow (1957) and recently empirical study of Kim (1997). Broersma & Oosterhaven (2004) demonstrated that this ratio is very sensitive to firm productivity: If this ratio is increased leading to increase in the productivity (Frenken & et.al, 2007).

However, the reviewed theoretical researches do not focus on how the uncertainties will affect K and L or how the firm will choose K and L under uncertainties so that they will maximize their profit. These researches mainly focus on assessing the impact of these uncertainties on corporate value of the firm, or net present value of the project. This is the second research gap that the thesis will be expected to discover any useful evidences as a basis for policy development which will contribute to increasing capital/technology level and quality of labor in investment projects in general and FDI in particular. Recently, China has also begun considering the use of export carbon tax, which is targeted at energy intensive exports in order to reduce carbon emissions and encouraging energy-saving production which is one of several indicators reflecting the level of technology in production (Li et al., 2012).

The current status of technology and labor levels used in FDI projects in Vietnam is believed to be alarming and there should be having the measures and policies to improve better technology and labor quality in FDI in Vietnam. In most FDI projects, the production technology is decided by the foreign party due to some reasons such as: (1) the foreign party usually occupies the major shore in total investment capital, so they have the right to decide; (2) the foreign party has better knowledge of technology and markets than Vietnam side. In practice, there have been phenomena that the foreign parties bring old technologies and/or renovated equipment or old technology in new equipment for their joint venture or 100% foreign capital firms. These types of equipment and technology may have been economically inefficient in developed countries, but if it is installed in developing countries such as Vietnam, the project could still be cost-effective due to low cost of the inputs, incentives from the government and investors can avoid environmental costs. Through the review of previous researches, there are no researches on policies to improve capital/technology and labor level in FDI projects in Vietnam. If we are lack of academic research on this subject, so there is no solid scientific basis for designing appropriate policies to boost up capital/technology and labor levels in FDI projects while the administrative restriction on old technology-equipment that may do harm for environmental pollution as well as the technology appraising capability of functional authorities in Vietnam is still inadequate. Therefore, it is necessary to do the research to boost up capital/technology and labor levels in FDI project in Vietnam.

2.7 Conclusion of Chapter 2

The investment decision of foreign firms into FDI project always depends on a number of uncertainties/factors in both quantitative or qualitative forms, which may include: (1) quantitative factors such as exchange rates, market prices of products, capital costs, inflation, taxes and fees; (2) qualitative factors such as institutional quality, location of investment, stability of the law, political stability of the host country, diplomatic relations between the two countries, commitments of the host country in the agreements of investment protection, multilateral and bilateral trade agreement, etc. Investors should consider and incorporate uncertainties which could be realized to become high risks into their investment decision model. Firms as rationale investors always make the rational investment decisions based on the most important criterion of profit maximization under uncertainties. Therefore, when the firms consider making investment decision, they shall take all the risks and uncertainties in the investment appraisal of their project.

Among the others, the uncertainties of carbon taxation are being strongly concerned by the firms as the carbon taxation is likely to be applied in the future as well as they also think that there will be increase of carbon tax rates in the countries where carbon taxation is being applied. However, the research of carbon taxation related impacts on the investment decision has only been developed in the form of case studies for certain types of projects and thus, the results of this research type are difficult to generalize for the whole sector or whole economy of a country or another type of irreversible investment projects.

Therefore, the thesis will focus on research gap of the theoretical model that reflects the firms' investment decision under uncertainties of carbon taxation for irreversible projects. At the same time, the thesis also seeks the scientific basis for the policy recommendation that contributes to improve the quality of technology and labor which are currently being concerned in Vietnam.

CHAPTER 3: RESEARCH METHOD

3.1 Selection of research methods.

As described in Chapter 1, Section 1.4, the quantitative approach is selected to apply in this thesis to find the answers the following two research questions.

(1) How are effects of carbon taxation uncertainties on investors' investment decision in irreversible FDI projects?

(2) What are the capital / technology and labor levels selected by the investors as well as the investment decision behavior of investors in irreversible FDI projects?

First of all, this is a new study and so far, there is no similar research in Vietnam on future uncertainties of carbon taxation that have impacts on investment decisions of irreversible project. In general, we can apply different research methods, such as qualitative and quantitative ones for this study. However, it is necessary to analyze the practical conditions and research settings to select the most appropriate method for finding the best answer to the research questions.

If we use qualitative research methods such as developing in-depth, focus interviews with professional experts such as CEO and investment consultants, about impacts of carbon taxation on investment decisions, it is possible to predict that the bias in interviews would be significant because the uncertainties of carbon taxation have not occurred and we need to assume that if it happens, then interviewing of experts' ideas about future is much more complicated. All lead to considerable bias in interviewed information/data. In other word, such the interviewed information will not be reliable enough for further analysis of the research. Therefore, the qualitative method by in-depth and focus interviews will not be selected for this thesis.

The second choice is that we can apply quantitative method by forming econometric models, constructing hypotheses about the possible impacts of carbon tax related uncertainties on investment decision as dependent variable and we have regression function reflecting firm profit and independent variables including uncertainties of carbon taxation. Then, we collect the quantitative data to run the regression function. However, collecting quantitative data such as firms' investment level and other quantitative data to test hypotheses will not be feasible because carbon taxes have not yet applied and thus its impacts will not be reflected in the data. So, the quantitative method of empirical data is not possible. In addition, the summary of empirical researches conducted in some developed countries in Chapter 2, has showed that the investment data of firms are highly specialized ones made by banks, lenders and investment funds and it is not available in Vietnam yet, especially investment data relevant to irreversible projects.

Beside above, there is the fact that there is no empirical study of the uncertainties affecting the investment decision in irreversible project in Vietnam. Therefore, there are no econometric models which have been tested to check the consistent of the form of empirical model, so it is difficult to ensure that research in this direction is feasible in terms of empirical model. In order to be successful in empirical research by econometric model, it needs to meet several basic criteria such as (1) reliable research models; (2) research data must be reliable, sufficient and large enough over many years of observation, so that it can ensure the reliability of regression results. Pindyck (1990) also stated that econometric models often fail to predict changes in investment, especially for "irreversible projects" with "high irreversibility." Therefore, it could be reasonable to conclude that empirically quantitative research method should not be applied.

In order to overcome the above constraints, the quantitative research approach by mathematical modeling could be possible. After forming the research model in form of mathematical one, it can be further developed by the algorithm techniques, calculating the results and performing simulations with hypothetical data. This method can be considered as appropriate approach for theoretical research. Simon & Blume (1994) concluded that mathematical modeling is a valuable tool for economists at various levels of research. According to Lawson & Marion (2008), an algorithmic modeling tool has the following strengths: (1) An algorithm is the correct language for establishing formulas for elements and assumptions in research model; (2) algorithm is a concise language with clear rules for detailed development and computation; (3) mathematical calculation techniques have been validated for hundreds of years; (4) Today development of computational software allows to carry out complex calculations with the highest accuracy.

Quantitative methods using algorithmic modeling were applied by many studies relevant to the research direction of this thesis, such as Lucas et al. (1971); Abel (1983); Majd & Pindyck (1987). Recently, Milne & Whalley (1999) develops a firm's value model with the assumption that firms always invest when firms' value is increased and/or maximized. Agliardi (2011) and Kauffman et.al (2015) use ROA and apply algorithm development to assess the impact of taxes and investment decisions of firms. In addition, it should be noted that other authors, such as Abel (1983), Dixit & Pindyck (1994), and Abel & Eberly (1994, 1997), all used the modeling method of firm's investment decision using mathematical techniques. Some authors choose the profit function of the firm as the basic model with the argument that the firm as a rational investor always aiming to maximize the firm profit and/or project profit, will make an investment decision into the project when the profitability of the project is positive. Then, they will try to maximize the profit by choosing the optimal level of capital (K) and labor (L) for their production operation.

3.2 Research model

Based on researches close to the research direction of the thesis presented in Chapter 2, it is possible to come up with the following statements which will form a basis for selecting the research model for the next steps. The firm always makes rational decision when they consider investing for profit and the most important objective of firm is to always maximize the return on investment in the project. From a macro perspective and the objective of developing policies to attract FDI, it is necessary to formulate policies based on a highly general model as it will increase the convincible generalization of research results. In this thesis, the economic profit function in Varian (1992) is selected same as in the researches of Hartman (1972), Abel (1983, 1984, 1985), Dixit & Pindyck (1994). The basic profit function of the firm consists of the revenue function minus the cost function in which the revenue function includes average price multiply with production function as output of the firm.

The profit function in researches used by Abel & Eberly (1993, 1997), Caballero (1991) include the production function in the form of Cobb-Douglas. The research results of the development of the profit function model of firms in these researches by well-known above scholars provide the basis for selecting the profit function as the basic model in this thesis due to several reason as following: (1) This theoretical model of profit function is presented in the famous book: "Microeconomics Analysis" which is currently used by many famous universities in official teaching and it has a very high citation index of over 9,000 citations from the first edition of the year 1992 (according to Google Scholar); (2) It is likely that the results of model development and calculation will have useful theoretical and scholarly implications; (3) The profit function will include the factors of capital stock (K) and labor (L) which are two main inputs in production reflecting the quality of the investment. As the result of relationship inside the model, if we can put the carbon tax related uncertainties into the model, we can examine the relationship between K, L and such uncertainties. Therefore, the second research questions can be expected to be answered.

Based on the above discussion, the profit function model according to Varian (1992) was constructed in general and put into development, calculated as follows:

$$\mathbf{\Pi = pF(K, L) - C(r, w) - T(\tau)} \qquad \mathbf{(1)}$$

Where:

- ***Π***: the profit function of the firm.

- F (K, L): is the production volume of the firm depending on capital level (K) and labor level (L).

- C (r, w): is the cost of the business operation depending on the cost of capital (r) and labor wage (w), not including the cost of carbon tax.

- T (τ): is the cost of carbon tax that the firm needs to pay when the government imposes carbon tax on the volume of carbon emission.

- p is average selling price of products

The above function is based on basic assumption that the firm is always investing when Л> 0 and expecting to maximize profit (rationale investor). Therefore, firm will to choose optimal input levels of K, L, r, and w, to maximize profits. Using of the above model at the reasonable assumptions which will be discussed in details in Chapter 4 - Results of the research, we have a profit function that reflects the relationship between the project's profitability (***Π***) and the affecting factors such as K, L, r, w and cost of carbon tax. We can easily add other costs due to one or more uncertainties leading to research expansion.

3.3 Model development based risk response of investors.

As discussed in Chapter 2, according to the theory of investment decisions, investors will decide whether to invest based on the value of the profit function (Л). Usually when the value of the profit function or NPV is greater than zero, the investor will decide the investment. In order to have the calculated result of the profit function (***Π***) or NPV, the investor must then convert the uncertainty factor into a risk with probability of occurrence and scale of risk as discussing the difference between uncertainty and risk in Section 2.1.3. Then the uncertainty factor is quantified and therefore the investor can calculate the value (***Π***) as arithmetic instead of in the form of a function.

However, when the investors estimate the probability of risk occurrence and its cost with the existing quantitative tools, investors must rely on the experience of the expert group and the managers participating evaluation. One of the most common ways that investors often implement is to organize survey according to the Delphi method. Participating experts will be required separately to answer same questions about the probability and size of carbon tax risks to the project. The next step is focus group discussion investor in the form of "brainstorming" among experts who responded according to Delphi method. Although there is controversy among academic researchers about the effectiveness of the "brainstorming" approach, according to Furnham's study (2000), this is the method that managers prefer to use in combination with other methods, generating a certain level of reliability and above all it creates a general understanding and consensus among responsible managers in important decisions such as investment decisions. The results of group discussion among managers will be considered by the board of directors and they will make the final decision for investment or not investment, based on agreed results of experts/amangers.

At this stage, the investor's reaction (or attitude of investor to the risk) will play an important role in investment decisions. Based on investors' response to risk, according to Wiseman & Gomez-Mejia (1998), there are 5 types of investors mentioned as Table 2.1 Section 2.1.4. However, if the investor is classified according to the size (risk cost) of the risk that the investor accepts when making an investment decision, assuming the same probability occurs, there are two types of typical investors below:

(1) ***Risk adverse investors***: Investors do not bear risk risks or only take risks at a very low level. For example, there are 2 investment options; investors will choose the lowest risk option. For this investor, the cost function for carbon tax will be at its maximum and if the profit function (***Π***) after subtracting the highest cost of carbon tax,

so that the value of the project profit (***Π***) is still positive, this investor will decide to invest. In other words, for risk-adverse investors, the profit function for deciding investment must include the highest cost of carbon tax with a probability of 100% or equal to 1. Then we have the profit function of risk adverse investor is as follows.

$$\boldsymbol{\Pi} = \mathbf{pF(K,L) - C(r,w) - T(\tau)}$$

(2) ***Risk-taking investor*:** Risk investor (risk tolerance/risk taker): this investor prioritizes profitability criteria and if investor has two project options, they will choose the highly profitable investment option even higher risk. In contrast to risk-adverse investors, the profit function for investment decision of risk taker will not combine carbon tax costs as riask taking investors take risks and will consider that risk of carbon tax could be zero. The profit function of risk taking investor will take the following form.

$$\boldsymbol{\Pi} = \mathbf{pF(K,L) - C(r,w)}$$

3.4 Optimization techniques by maths.

Optimization techniques include one of two techniques: (1) maximizing profit or revenue; or (2) minimizing of cost. Specifically the case of this thesis is the maximization of profits in the project that firm can be achieve. Optimization is a popular technique that has a history of many years and applied in the fields of economics, administration, and technology (Kiranyaz, Ince & Gabbouj, 2014). Optimization techniques in this thesis are developed by algorithms. With the profit function (***Π***) depending on variables such as: p, K, L, r, w, τ, ..., we can find input sets of K and L to (***Π***) maximum under certain conditions.

To answer the thesis's research questions, it is necessary to find pairs of K and L, so that (***Π***) is maximized with the assumption that the remaining variables are given. Then optimization techniques are implemented as follows:

- Step 1: Consider reasonable assumptions close to practice and in accordance to common managerial, financial and tax economics, to ensure that the profit function

($\boldsymbol{\Pi}$) has economic significance and can be developed and solved mathematically. Specifically, the values p (product price), K (capital), L (labor), r (cost price), w (salary), τ (tax rate), must be positive.

- Step 2: We apply the rule of first-order derivative according to variable K and variable L, and set up the system of two equations of two variables K, and L.

- Step 3: Solve the two-variable equation system with reasonable assumptions to find optimum value pair K * and L *, so that the profit value ($\boldsymbol{\Pi}$) reaches the maximum. Rational investors has a tendency to pursue and maximize their profits by investing at K * and L *.

It is expected that we will have pairs of values K * and L * depending on other variables such as: r, w, and tax level (τ). Thus we have the relation function of K* and L* with variables r, w, τ and other variables. Detailed optimization results for different cases with different investors are presented in Chapter 4.

3.5 Simulation of research results

As Pindyck (1990, page 48) suggested that simulations can be used as a tool to test the effects of "irreversible nature" and uncertainty on investment decision. After developing of model, the calculation of the results by optimization techniques will be presented in Chapter 4. Then, the thesis applies the technique of simulation in the form of numerical solution. Simulation using assumed arithmetical data allows theoretical results to be illustrated in a clear and simple form that is easily understood and compared with each other. In addition, the results of numerical simulations also allow for the illustration of graphs between two factors, or a composite graph between multiple factors. Such graphs will help improving the ability to express relationships between two or more factors.

According to Batz (2007), simulation is considered to be most appropriate for optimization problems. The example given by this author is when a product manufacturer wants to optimize the investment process by selecting inputs such as factories (technology), the number of equipment, workers, and other inputs to optimize the investment process according to predefined criteria. This is a complex problem and after optimal calculation, the simulation makes it easy for the manufacturer to compare different options by changing the inputs, which are always changing over time, so that there can be a set of options for managers. And in fact, the manufacturer or investor may have to choose the “second best option” because the first best option given by calculation may not be achieved.Simulations not only help investors better visualize investment options, but also better imagine results of investment plans according to hypothetical figures near reality.

In the case of investment to avoid carbon taxes (carbon leakage), investors always face uncertainties about carbon taxes such as: (1) the government of country where they intend to invest, may impose carbon taxes in the future? (2) If yes, what is the carbon tax rate, so that the project can still be profitable or profitable at a competitive level in the long-term. These two questions are completely unanswered by experimental/empirical research because the empirical data is completely unavailable due to the fact that the carbon tax has not been imposed.

Therefore, in this thesis, after modeling the profit function and optimization to generate theoretical results, the simultation by numerical solution will be performed. Input data in the form of arithmetic will be assumed close to practice and discussed in detail in Section 4.4.1.

There is a number of software that can be used for arithmetic simulations such as Simulink, Maple, MathLab. Math Lab software is selected to be used in accordance with the recommendations of Brandimarte (2002), thanks to the strengths of the Math Lab software as following reasons: (1) Math lab is a highly interactive computing environment that allows processing of functions from basic to complex ones; (2) Math lab is capable of providing powerful graph functions; (3) Math Lab is allowed to handle both linear and non-linear functions.

3.6 Simulated data

Due to the inability to collect sufficient real data of large asset investment projects in both quantitative and qualitative manner for simulation, the assumed data will be reasonably created. The data is collected from reliable sources, missing data will be assumed with closer to the value collected from practice or compared with reliable secondary sources.

Specifically with carbon tax data, will be based on data on carbon tax rates published in countries listed by reputable organizations such as the World Bank and / or specialized organizations such as Carbon Tax Center in the US (https://www.carbontax.org), or according to a review of Zimmermannová et al. (2018) on the European carbon tax rate. Detailed assumptions are presented in Section 4.4.1.

3.7 Conclusion of Chapter 3.

Considering the nature of the research, research questions, and researches similar to the thesis's research direction, the quantitative method of algorithmic modeling tool is employed. In addition, the results of model development and calculation will be simulated in the form of numerical solution to better illustrate the discoveries of theoretical researches.

CHAPTER 4: INVESTMENT DECISIONS UNDER UNCERTAINTIES OF CARBON TAXATION

4.1. The Basic model

As discussed in Chapter 3, the profit function of a firm by Varian (1992) is used as the basis function for estimating and modeling investment decisions by algorithm techniques as follows. As rationale investors, they will invest when: max $\boldsymbol{\Pi} \geq 0$.

$$\boldsymbol{\Pi = pF(K,L) - C(r,w)}$$

Where :

- $\boldsymbol{\Pi}$: the profit function of the firm.

- F (K, L): is the production volume of the firm depending on capital level (K) and labor level (L).

- C (r, w): is the cost of the business operation depending on the cost of capital (r) and labor wage (w), not including the cost of carbon tax.

- p is average selling price of products

If the symbol (τ) is the tax payable by the investor, the function $\boldsymbol{\Pi}$ is expanded as follows:

$$\boldsymbol{\Pi = pF(K,L) - C(r,w) - T(\tau) \text{ or } \Pi = pAK^{\alpha}L^{\beta} - rK - wL - T(\tau)}$$

- T (τ): is the cost of carbon tax that the firm needs to pay when the government imposes carbon tax on the volume of carbon emission.

- A is total factor productivity. Normally, the higher technology leads to higher value of A.

Given the capital of the investor (K), it should be assumed that the amount of capital supply (for K) assumed to be infinitely elastic and the supply of domestic labor (for L) for the project is not limited. In other words, investors can mobilize unlimited capital and labor supply from domestic market, so that they could have amount of capital and labor large enough as they want.

In order to simplify the mathematical work without changing the nature of the model, it is assumed that p = 1 because K is assumed to be amount of capital, not the number of machinery, productivity A = 1 and without inflation (δ) and the discount rate of the project over the years is assumed to be zero over project life cycle (£ = 0). Because of the discount rate, inflation is always assumed in the calculation of NPV as constant; we have the profit function as follows:

$$\boldsymbol{\Pi} = \mathbf{K^{\alpha}L^{\beta} - rK - wL - T(\tau)}$$

Where: α and β are the elasticity of output of capital and labor respectively. These are fixed and determined by technology level.

If $\alpha + \beta = 1$, the production function yields a constant rate of change to scale.

If: $\alpha + \beta < 1$, the yield function decreases by the scale.

If: $\alpha + \beta > 1$, the yield function increases with scale.

The capital stock varies from the year (0) to the year t, (K_0, K_1, K_2 ... .Kn). Denote I_0 as the initial investment capital and (I_1, I_2 .... In) is the operating capital in the years of operation. We have the following K value:

$K_0 = I_0$; $K_1 = (1-\delta) K_0 + I_1$; $K_t = (1- \delta) K_{t-1} + I_t$

If we assume that the project discount rate £ = δ = 0 to simply the calculation, we have the below.

$K_0 = I_0$; $K_1 = K_0 + I_1$; $Kt = K_{t-1} + I_t$

Table 4.1: Summary of abbreviation using in Chapter 4

Abbreviation	Explaination	Measurement
$\boldsymbol{\Pi}$	Project profit	Amount of money
K	Capital stock	Amount of money
L	Labor level	Number
(r)	Cost of capital	Percentage or Number

(w)	Average Wage of worker	Amount of money
(α)	Elasticity of K	Number
(β)	Elasticity of L	Number
(θ)	Carbon emission coefficient	Number
(τ)	Carbon tax rate	Percentage or number
P	1	Index
($\boldsymbol{\Pi}$ *)	Optimum or Maximized profit	Number
K*	Optimum capital stock at which the profit is maximized	Amount of money
L*	Optimum labor level at which the profit is maximized	Number
A	Productivity of investor	Number or coefficient

4.2 Modeling the cases of carbon and non-carbon taxation

In these cases, we consider the profit function of a foreign-invested firm from carbon taxed country in projects in developing countries such as Vietnam for two cases (4.2.1) without carbon taxes applied; and (4.2.2) with the applicable carbon tax. Then, we find the optimum value of K* and L* in both cases. By comparing K* and L* in both cases, we could propose theorem 1 as below.

4.2.1 The case of non-carbon taxation

We have the following profit function in case the government has not yet applied carbon taxation.

$$\boldsymbol{\Pi_1 = F(K_1, L_1) - r_1 K_1 - w_1 L_1} \qquad \textbf{(1)}$$

With the condition that α >0, β >0, we have the equation (12):

$$\boldsymbol{\Pi_1} = \boldsymbol{K_1^{\alpha} L_1^{\beta} - r_1 K_1 - w_1 L_1} \qquad (2)$$

Denote {K_1*, L_1*} are optimal values which are solution of the equation (13) as below:

$$\boldsymbol{max\ \Pi_1\ (K_1, L_1, r_1, w_1) = max\left[K_1^{\alpha} L_1^{\beta} - r_1 K_1 - w_1 L_1\right]} \qquad (3)$$

With the conditions that:

$$\boldsymbol{K_1, L_1 \geq 0 \ \text{ and } r_1 > 0;\ w_1 > 0} \qquad (4)$$

In order to find the optimum value of K1 and L1 so that at that values of K and L, the profit function is maximized, we take the first order derivatives according to K_1 and L_1. Then, we have the below equations.

$$\boldsymbol{\frac{\partial \Pi_1}{\partial K_1} = \alpha {K_1}^{(\alpha-1)} {L_1}^{\beta} - r_1 = 0} \qquad (5)$$

$$\boldsymbol{\frac{\partial \Pi_1}{\partial L_1} = \beta {K_1}^{\alpha} {L_1}^{\beta-1} - w_1 = 0} \qquad (6)$$

Let call {K_1*, L_1*} as optimul value of K and L. We move $\boldsymbol{r_1}$ and $\boldsymbol{w_1}$ to the right sides and divide the equations (5) by (6), we have the equation (7) and then K and L as below:

$$\boldsymbol{\frac{\alpha L_1}{\beta K_1} = \frac{r_1}{w_1}} \qquad (7)$$

$$\Rightarrow \boldsymbol{L_1^* = \frac{\beta r K_1}{\alpha w_1}} \qquad (8)$$

$$\textbf{or} \quad \boldsymbol{K_1^* = \frac{\alpha w_1 L_1}{\beta r}} \qquad (9)$$

We substitute L1 of equation (8) into equation (5), and we have the value K_1* as follows.

$$\boldsymbol{K_1^{*(\alpha+\beta-1)}} = \left(\frac{\mathbf{r}}{\boldsymbol{\alpha}}\right)\left(\frac{\boldsymbol{\alpha}\mathbf{w}}{\mathbf{r}\boldsymbol{\beta}}\right)^{\boldsymbol{\beta}} \qquad (\mathbf{10})$$

By taking natural logarit for both sides of equation (10), we have the below.

$$(\boldsymbol{\alpha}+\boldsymbol{\beta}-\mathbf{1})\mathbf{ln}\,\boldsymbol{K_1^*} = \mathbf{ln}\left(\frac{\mathbf{r}}{\boldsymbol{\alpha}}\right)+\boldsymbol{\beta}\mathbf{ln}\left(\frac{\boldsymbol{\alpha}\mathbf{w}}{\mathbf{r}\boldsymbol{\beta}}\right) \qquad (\mathbf{11})$$

$$(\boldsymbol{\alpha}+\boldsymbol{\beta}-\mathbf{1})\mathbf{ln}\,\boldsymbol{K_1^*} = \mathbf{ln}\left(\frac{\mathbf{r}}{\boldsymbol{\alpha}}\right)+\boldsymbol{\beta}\mathbf{ln}(\boldsymbol{\alpha}\mathbf{w})-\boldsymbol{\beta}\mathbf{ln}\,(\boldsymbol{r\beta}) \qquad (\mathbf{12})$$

$$(\boldsymbol{\alpha}+\boldsymbol{\beta}-\mathbf{1})\mathbf{ln}\,\boldsymbol{K_1^*} = \mathbf{ln}\left(\frac{\mathbf{r}}{\boldsymbol{\alpha}}\right)+\boldsymbol{\beta}\mathbf{ln}\boldsymbol{\alpha}+\boldsymbol{\beta}\mathbf{lnw}-\boldsymbol{\beta}\mathbf{lnr}-\boldsymbol{\beta}\mathbf{ln}\boldsymbol{\beta} \qquad (\mathbf{13})$$

$$(\boldsymbol{\alpha}+\boldsymbol{\beta}-\mathbf{1})\mathbf{ln}\,\boldsymbol{K_1^*} = \mathbf{ln}\left(\frac{\mathbf{r}}{\boldsymbol{\alpha}}\right)-(\boldsymbol{\beta}\mathbf{lnr}-\boldsymbol{\beta}\mathbf{ln}\boldsymbol{\alpha})+(\boldsymbol{\beta}\mathbf{lnw}-\boldsymbol{\beta}\mathbf{ln}\boldsymbol{\beta}) \qquad (\mathbf{14})$$

$$(\boldsymbol{\alpha}+\boldsymbol{\beta}-\mathbf{1})\mathbf{ln}\,\boldsymbol{K_1^*} = \mathbf{ln}\left(\frac{\mathbf{r}}{\boldsymbol{\alpha}}\right)-\boldsymbol{\beta}\mathbf{ln}\left(\frac{\mathbf{r}}{\boldsymbol{\alpha}}\right)+\boldsymbol{\beta}\mathbf{ln}\left(\frac{\mathbf{w}}{\boldsymbol{\beta}}\right) \qquad (\mathbf{15})$$

$$(\boldsymbol{\alpha}+\boldsymbol{\beta}-\mathbf{1})\mathbf{ln}\,\boldsymbol{K_1^*} = \mathbf{ln}\left(\frac{\mathbf{r}}{\boldsymbol{\alpha}}\right)(\mathbf{1}-\boldsymbol{\beta})+\boldsymbol{\beta}\mathbf{ln}\left(\frac{\boldsymbol{w_1}}{\boldsymbol{\beta}}\right) \qquad (\mathbf{16})$$

Because that $(\alpha+\beta-1) \neq 0$, we could divide both sides for it and we have the $(\mathbf{ln}\,\boldsymbol{K_1^*})$ below.

$$\mathbf{ln}\,\boldsymbol{K_1^*} = \frac{\mathbf{ln}\left(\frac{\boldsymbol{r_1}}{\boldsymbol{\alpha}}\right)(\mathbf{1}-\boldsymbol{\beta})+\boldsymbol{\beta}\mathbf{ln}\left(\frac{\boldsymbol{w_1}}{\boldsymbol{\beta}}\right)}{(\boldsymbol{\alpha}+\boldsymbol{\beta}-\mathbf{1})} \qquad (\mathbf{17})$$

By the same methematical development, we have the $\mathbf{ln}\,\boldsymbol{L_1^*}$ as below.

$$\mathbf{ln}\,\boldsymbol{L_1^*} = \frac{\mathbf{ln}\left(\frac{\boldsymbol{w_1}}{\boldsymbol{\beta}}\right)(\mathbf{1}-\boldsymbol{\alpha})+\boldsymbol{\alpha}\mathbf{ln}\left(\frac{\boldsymbol{r_1}}{\boldsymbol{\alpha}}\right)}{(\boldsymbol{\alpha}+\boldsymbol{\beta}-\mathbf{1})} \qquad (\mathbf{18})$$

So, we have the optimum values of {K_1*, L_1*} as (17) and (18), so that the investors will choose to maximize their profit by choosing production at the output level corresponding to optimal capital and labor {K_1*, L_1*}, which is the solution of the equations (5) and (6).

4.2.2 Modelling the case of carbon taxation

Assuming that the host government of investment project decides to apply carbon taxes to carbon emission producers. Typically, this carbon tax is levied on the volume of carbon emissions (Donald & Eric, 2014). Normally, this volume is subject to production that the larger the production, the greater the volume of emissions. In other word, the volume of carbon emissions will be proportional to the quantity produced. We denote that the symbol (τ) is the carbon tax rate and (θ) is the emission coefficient depending on the production technology. We have profit function of the firm in case the government applies the carbon tax as follows with the assumptions that the interest rate (r_1) and wage (w_1) are same as the case of non-carbon taxation:

$$\boldsymbol{\Pi_2 = F(K_2, L_2) - r_1 K_2 - w_1 L_2 - \tau\theta F(K_2, L_2)} \qquad \textbf{(19)}$$

Or

$$\boldsymbol{\Pi_2 = K_2^{\alpha} L_2^{\beta} - r_1 K_2 - w_1 L_2 - \tau\theta K_2^{\alpha} L_2^{\beta}} \qquad \textbf{(20)}$$

Or

$$\boldsymbol{\Pi_2 = (1 - \tau\theta) K_2^{\alpha} L_2^{\beta} - r_1 K_2 - w_1 L_2} \qquad \textbf{(21)}$$

The first condition is that (1- τ θ) must be larger than 0 to secure that $\boldsymbol{\Pi}_2$ >0 so that the firm will invest and otherwise not**.**

If we denote the symbol {K2 *, L2 *} is the solution of function (18) or this is the optimal value of K and L, then, we have the maximed profit value symbolized as $\boldsymbol{\Pi}$2 *, is maximized as follows:

$$\frac{\partial \Pi_2}{\partial K_2} = (1 - \tau\theta)\alpha K_2{}^{(\alpha-1)} L_2{}^{\beta} - r_1 = 0 \qquad (22)$$

$$\frac{\partial \Pi_2}{\partial L_2} = (1 - \tau\theta)\beta K_2{}^{\alpha} L_2{}^{\beta-1} - w_1 = 0 \qquad (23)$$

$$\frac{\alpha L_2}{\beta K_2} = \frac{r_1}{w_1} \qquad (24)$$

$$\Rightarrow L_2^* = \frac{\beta r K_2}{\alpha w_1} \qquad (25)$$

$$\text{or} \quad K_2^* = \frac{\alpha w_1 L_2}{\beta r} \qquad (26)$$

By taking the same method and technique as the section 4.2.1, we have the below.

$$\ln K_2^* = \frac{\ln\left(\frac{r_1}{\alpha}\right)(1-\beta) + \beta \ln\left(\frac{w_1}{\beta}\right) - ln\,(1-\tau\theta)}{(\alpha+\beta-1)} \qquad (27)$$

By the same methematical development, we have the $\ln L_2^*$ as below.

$$\ln L_2^* = \frac{\ln\left(\frac{w_1}{\beta}\right)(1-\alpha) + \alpha \ln\left(\frac{r_1}{\alpha}\right) - ln\,(1-\tau\theta)}{(\alpha+\beta-1)} \qquad (28)$$

+ Theorem 1: We decalare the theorem 1 (proposition 1) as follows.

If a non-carbon taxed country has imposed a carbon tax on carbon emission producers/investors, and the investors decide to invest: They would invest at the optimal levels of {K_2*, L_2*} smaller than the levels of {K_1*, L_1*} in case of non-carbon taxation.

+ Proof:

Comparing {K2*, K1*} by using the equation (17) and (27), we have the below.

$$\ln K_2^* - \ln K_1^* = \frac{\ln\left(\frac{r_1}{\alpha}\right)(1-\beta) + \beta\ln\left(\frac{w_1}{\beta}\right) - \ln(1-\tau\theta)}{(\alpha+\beta-1)} - \frac{\ln\left(\frac{r_1}{\alpha}\right)(1-\beta) + \beta\ln\left(\frac{w_1}{\beta}\right)}{(\alpha+\beta-1)}$$

Or

$$\ln\frac{K_2^*}{K_1^*} = \frac{-\ln(1-\tau\theta)}{(\alpha+\beta-1)} < 0 \qquad (29)$$

Because that $0<(1-\tau\theta)<1$ → $\ln(1-\tau\theta) <0$ → $\ln(1-\tau\theta) >0$, while $(\alpha+\beta-1)<0$ → we have above result of (29). It means that $\frac{K_2^*}{K_1^*} < 1 \rightarrow K_2^* < K_1^*$.

Similarly for {L2 *, L1 *}by using equation (18) and (28) we also found that $\frac{L_2^*}{L_1^*} < 1 \rightarrow L_2^* < L_1^*$

Conclusion 1: The above research results show that the carbon tax would have the effect of reducing the firm's investment in capital and labor in irreversible investment projects. This research results answers the first research question of the thesis.

4.3 The ratio of capital/labor in case of carbon and non-carbon taxation.

+ **Theorem 2 (Proposition 2)**: When a country has applied the carbon tax and if the firm decides to invest, they would invest at optimum capital (K) and optimum labor (L) which have the ratio of optimal capital over labor level higher than that ratio in the case of non-carbon taxation.

+ Proof:

The capital-labor ratio is an important indicator reflecting of the technology level in an investment project. The higher this ratio, the better technology is used in the projects. According to the theoretical study of Sollow (1957) and Kim's experimental research (1997); Broersma & Oosterhaven (2004), demonstrated that this ratio is very sensitive to firm productivity: if this ratio is increased and then the productivity will be increased (Frenken et.al, 2007).

From the calculation result in Section 4.2, we have $\ln K_1*$; $\ln L_1*$ (Equation 17 and 18), $\ln K_2*$; $\ln L_2*$ (Equation 27 and 28), we could canculate the below.

$\mathbf{\ln (K_1*/L_1*) - \ln (K_2*/L_2*) = \ln (1- \tau\theta)}$

or

$$\boldsymbol{ln\frac{K_1^*/L_1^*}{K_2^*/L_2^*} = \ln(1 - \tau\theta) \;\; \text{or} \;\; \frac{K_1^*/L_1^*}{K_2^*/L_2^*} = (1 - \tau\theta)}$$

If (1- $\tau\theta$) > 1, the the value ($\tau\theta$) is smaller zero, it is impossible as both carbon tax rate (τ) and emission rate (θ) are larger than zero. Therefore, (1- $\tau\theta$) < 1.

We have **: $\{(K_1*/L_1*)/(K_2*/L_2*)\}= (1- \tau\theta) <1$ or $(K_1*/L_1*) <(K_2*/L_2*)$**

Above assumption is perfectly applicable in practice if (1 - $\tau\theta$) <0, it means that the tax rate (τ) is applied at a extremely high value so that after multiplied by the emission coefficient (θ) it is greater than 1, so that (1 - $\tau\theta$) <0. It means that the firm cannot invest when (τ) is too high. If (1 - $\tau\theta$)> 1, it means that ($\tau\theta$ <0), it is impossible.

+ Conclusion:

Thus, the optimal capital/labor ratio in case of non-carbon tax is smaller that ratio in the case of carbon tax application. In other words, imposing carbon taxes will make the firm choose to invest in a higher capital size relative to labor size which lead to higher technology level and thus better skilled labor. Through the results of the calculation we can express the following findings.

This finding seems to be consistent with the business practice that when carbon tax is applied, leading to higher cost of production than that of non-carbon taxation. As the result, the profit will be reduced in case of carbon taxation. Thus, only high-profit firms are likely to remain profitable after the imposition of carbon tax. It can be concluded that the carbon tax, if applied, will help screening of only firms with high capital/labor ratio (or more modern technology) to invest as they tend to be profitable enough to survive.

4.4 Modeling the case of uncertain timing in application of carbon taxation

We study the behavior of foreign investor responding to the uncertain timing of carbon taxation when they consider investing in a non-carbon taxed country. At the present time of consideration, there is no carbon taxation. However, through information gathering and analysis, investors are convinced that the carbon tax will be applied in their project life cycle. Let say the project life cycle is (m) years and carbon taxation would be imposed in the year (n). It means that (n) can take the value from zero if the carbon tax is applied right after the year in which the project is commercially operated or (n=m) when the project is closed. Obviously, the unknown timing of tax application is uncertainty that investors will need to transform it into the risk and combine this risks in their calculation for their decision making of the investment.

Assume that the investor is risk-averse and the host government does not inform when they will apply carbon tax. So, investor’s s risk adverse will choose the worst case scenario is that the carbon tax will be imposed as soon as the project commences commercial operation in the first year: n = 0.

If the government informs clearly that the carbon taxes will be applied at the year (n) in the project life cycle, then the firm will not have to pay tax in (n) years and have to pay carbon tax for the rest of their project life cycle, i.e (m-n) years. We compare the total maximized profit π^* of the project in two cases: (4.4.1): the government does not announce the application timing of the carbon tax representing by the optimal profit value of π_3^* and (4.4.2): the government announces the imposition of carbon tax in year (n) representing by the optimal profit value of π_4^*, as follows.

4.4.1 The Government does not announce timing of carbon taxation:

Risk-averse firm will respond to the risk by choosing/assuming their projects are taxed in the first year of commercial operation n = 0. Therefore, their maximized profit is same as maximized one in Section 4.2.2 that the whole project lifecycle is levied by carbon taxation. Denote (π_3^*) as total maximized profit of project in whole life cycle of (m) years, then, we have the follows:

$$\pi_3^* = \pi_2^* = m\,\boldsymbol{\Pi}_2^*$$

Accordingly, they choose the optimum capital and labor to produce is $\{K_3^* = K_2^*, L_3^* = L_2^*\}$. We can write the total inputs (K) and (L) for production as below:

$$\boldsymbol{k_3^* = mK_2^* \ and \ l_3^* = mL_2^*}$$

With k_3^* is total optimal capital and l_3^* is total optimal labor in whole project life cycle of (m) years.

4.4.2 The Government announces application timing of carbon taxation at the year $\boldsymbol{n}^{\text{th}}$

Denote that π_4^* as the total maximized profit of the firm when the governmet clearly inform that they will impose a carbon tax at the year $(n)^{th}$, the firm do not need to pay carbon for (n) year (as Section 4.2.1), but they have to pay (m-n) years (as Section 4.2.2). Then, we have π_4^* as below.

$$\pi_4^* = n\Pi_1^* + (m-n)\Pi_2^*$$

So, we have the total optimal inputs ($k_4^* and\ l_4^*$) for production of project in case the govement informed timing for application of carbon taxation as below:

$$k_4^* = nK_1^* + (m-n)K_2^* \ ;\ l_4^* = nL_1^* + (m-n)L_2^*$$

+ **Theorem 3 (Proposition 3):** If the government of non- carbon taxed country is going to apply carbon tax and they announce the timing of when the carbon tax will be imposed, the investors would decide to invest at higher capital and labor level than those in the case of non-announcement.

+ Proof:

Let compare $k_4^*\ and\ k_3^*$ as below

$$k_4^* - k_3^* = nK_1^* + (m-n)K_2^* - mK_2^*$$

Or it is equal to:

$$k_4^* - k_3^* = nK_1^* + mK_2^* - nK_2^* - mK_2^* = n(K_1^* - K_2^*) > 0$$

Because $K_1^* > K_2^*$ as proved in Section 4.2. Similiarly, we have $l_4^* > l_3^*$ as below.

$$l_4^* - l_3^* = nL_1^* + mL_2^* - nL_2^* - mL_2^* = n(L_1^* - L_2^*) > 0$$

+ Conclusion:

If the government of non-carbon taxed country informs clearly the timing of carbon taxation on carbon emission producers/investor, it helps to reduce the timing uncertainty and thus, the investors would choose to invest at higher level of both capital and labor.

4.5 Modeling the case of investors with different technology level

Assuming the case that we have two investors with different technologies, investing in a non-carbon taxed country. The L is symbolized for investors with lower carbon emission and H for investors with higher carbon emission. The host government prefers to encourage investors of low-emission technology. The problem is that it is possible to design policies that encourage low-carbon emission investors or not? We consider the profit function of these two investors.

Denote K_L is the capital stock of the investor with low carbon emission technology. Denote K_H is the capital stock of investor with low carbon emission technology. Let r_L be the capital cost of investor with low carbon emission technology. Let r_H be the capital cost of investor with high carbon emission technology. Assume that the two investors hire the same wage w. We have the production function of two investors as functions (30) and (31) below.

$$F^L(K_L, L_L) = A_L K_L^{\alpha} L_L^{\beta} \qquad (30)$$

$$F^H(K_L, L_L) = A_H K_H^{\alpha} L_H^{\beta} \qquad (31)$$

In which: $\alpha + \beta < 1$, $\alpha > 0$, $\beta > 0$. Assume that the productivity $A_L > A_H$.

4.5.1 The case of non-carbon taxation.

Investor L will choose to maximize their profit based on the below function:

$$Max_{K_L L_L}\left[A_L K_L^{\alpha} L_L^{\beta} - (r_L K_L + wL_L)\right] \qquad (32)$$

$$s.c\ K_L, L_L \geq 0 \qquad (33)$$

The first order derivative is as below.

$$\frac{\partial F^L(K_L, L_L)}{\partial K_L} = \alpha A_L K_L^{\alpha-1} L_L^{\beta} - r_L \qquad (34)$$

$$\frac{\partial F^L(K_L, L_L)}{\partial L_L} = \beta A_L K_L^{\alpha} L_L^{\beta-1} - w \qquad (35)$$

Note: we assume that the labor cost (w) in both care are the same ($w_H = w_L = w$).

Let the first derivative in equation (34) and (35) are equal to zero to find the solutions, we could develop these equations to be respectively equal to (36) and (37).

$$\alpha A_L K_L^{\alpha-1} L_L^{\beta} = r_L \qquad (36)$$

$$\beta A_L K_L^{\alpha} L_L^{\beta-1} = w \qquad (37)$$

Thus, we have the below.

$$\frac{\alpha}{\beta}\frac{L_L}{K_L} = \frac{r_L}{w}; or\ L_L = \frac{\beta r_L}{\alpha w} K_L$$

Replace L_L into (36), we have:

$$\alpha A_L K_L^{(\alpha-1)} (\frac{\beta r_L}{\alpha w} K_L)^{\beta} = r_L$$

Or :

$$K_L^{(1-\alpha-\beta)} = A_L \frac{\alpha}{r_L} (\frac{\beta r_L}{\alpha w})^{\beta}$$

Or:

$$K_L = (\frac{A_L \alpha^{(1-\beta)} \beta^{\beta}}{r_L^{(1-\beta)} w^{\beta}})^{\frac{1}{1-\alpha-\beta}}$$

The same calculation is applied to have L_L as below.

$$L_L = (\frac{A_L \alpha^{\alpha} \beta^{(1-\alpha)}}{r_L^{\alpha} w^{(1-\alpha)}})^{\frac{1}{1-\alpha-\beta}}$$

Then, by applying the above calculation, we K_H, L_H as follow.

$$K_H = (\frac{A_H \alpha^{(1-\beta)} \beta^{\beta}}{r_H^{(1-\beta)} w^{\beta}})^{\frac{1}{1-\alpha-\beta}}$$

$$L_H = (\frac{A_H \alpha^{\alpha} \beta^{(1-\alpha)}}{r_H^{\alpha} w^{(1-\alpha)}})^{\frac{1}{1-\alpha-\beta}}$$

We have the ratio of K_L over K_H below.

$$\gamma = \frac{K_L}{K_H} = (\frac{A_L}{A_L} \frac{r_H^{(1-\beta)}}{r_L^{(1-\beta)}})^{\frac{1}{1-\alpha-\beta}}$$

So, this ratio is increased when A_L and r_H are increased and this ratio is decreased when A_H and r_L are decreased. This ratio will be larger than 1 if and only if:

$$\frac{A_L}{A_L} \geq \frac{r_L^{(1-\beta)}}{r_H^{(1-\beta)}}$$

4.5.2 The case of carbon taxation.

We shift to modeling the case of carbon taxation when the government of the host country decides to impose a carbon tax on the carbon emission volume of each investor. Assume that the carbon emission volume released by the two investors is as follows.

$$E_L = e_L K_L$$

$$E_H = e_H K_H$$

Two different technologies are denoted by (L) for low carbon emission and by (H) for high carbon emission. We have assumed the emission coefficient $e_L < e_H$. Denote that the symbol (τ) as the carbon tax rate applying for both investors.

The investor L will maximize profits by the following function and conditions:

$$Max_{K_L L_L}\left[A_L K_L^{\alpha} L_L^{\beta} - (r_L K_L + wL_L) - \tau E_L\right] \qquad ()$$

$$s.c\ K_L, L_L \geq 0 \qquad ()$$

The investor H will maximize profits by the following function and conditions:

$$Max_{K_H L_H}\left[A_H K_H^{\alpha} L_H^{\beta} - (r_H K_H + wL_H) - \tau E_H\right] \qquad ()$$

$$subject\ to\ condition\text{: } K_H, L_H \geq 0 \qquad ()$$

Applying the first order derivative and replacing K by L and vice versa, we have the following result for investor L to choose optimal capital / technology and labor when carbon tax is imposed at the rate of (τ):

$$K_L(\tau) = \left(\frac{A_L \alpha^{(1-\beta)} \beta^{\beta}}{(r_L + \tau e_L)^{(1-\beta)} w^{\beta}}\right)^{\frac{1}{1-\alpha-\beta}}$$

$$L_L(\tau) = \left(\frac{A_L \alpha^{\alpha} \beta^{(1-\alpha)}}{(r_L + \tau e_L)^{\alpha} w^{(1-\alpha)}}\right)^{\frac{1}{1-\alpha-\beta}}$$

Similarly as above, we have the following result for investor H choosing the optimal level of capital/technology and labor when carbon tax is imposed at the rate of (τ):

$$K_H(\tau) = (\frac{A_H \alpha^{(1-\beta)} \beta^{\beta}}{(r_H + \tau e_H)^{(1-\beta)} w^{\beta}})^{\frac{1}{1-\alpha-\beta}}$$

$$L_H(\tau) = (\frac{A_H \alpha^{\alpha} \beta^{(1-\alpha)}}{(r_H + \tau e_H)^{\alpha} w^{(1-\alpha)}})^{\frac{1}{1-\alpha-\beta}}$$

According to calculations in Section 4.2, when there is a carbon tax, investors always choose lower level of K and L than that of the case of non-carbon taxation.

$$K_L(\tau) \leq K_L(0)$$

$$K_H(\tau) \leq K_H(0)$$

+ **Theorem 4 (Proposition 4):** When the government of a country has applied a carbon tax on carbon emission investors, it would encourage the investment level of investors who have low carbon emission level in comparison to investors who have higher carbon emission level.

+ **Proof:**

Based on the results in section 4.5.1 and 4.5.2, we could calculate the ratio (γ) representing the ratio between the two capital levels/technologies of two investors L and H under carbon tax arte of (τ) as follows:

$$\gamma_{\tau} = \frac{K_L(\tau)}{K_H(\tau)} = \{\frac{A_L(r_H + \tau e_H)^{(1-\beta)}}{A_H(r_L + \tau e_L)^{(1-\beta)}}\}^{\frac{1}{1-\alpha-\beta}}$$

Or :

$$(\frac{r_H + \tau e_H}{r_L + \tau e_L})'_{\tau} = \frac{(r_L + \tau e_L)e_H - (e_H + \tau e_H)e_L}{(r_L + \tau e_L)^2} = \frac{r_L e_H - r_H e_L}{(r_L + \tau e_L)^2} > 0$$

As the ratio ($\frac{r_H+\tau e_H}{r_L+\tau e_L}$) increases if the carbon tax rate (τ) increases, we have the result that $\boldsymbol{\gamma_\tau}$ increases as (τ) increases. In other words, if the government raises the carbon tax rate (τ) and apply to both investors, the investor with lower carbon emission volume will choose to invest in higher capital than that of investor with higher carbon emission volume. Then, we have the theorem 4 (proposition 4).

4.6 Numerical results of simulation from the case of carbon and non-carbon taxation.

Due to the fact that the carbon taxation does not happen in Vietnam, we could not collect the empirical data to test the reulst of modeling. The possible solution is to assum the data and does the simulation as the best choice we have.

We use simulation technique to partially prove the results of modeling in Section 4.2 (including 4.2.1 and 4.2.2) by numerical solution. Firstly, we need to assume simulation data as shown in Table 4.6.1, in which some figures are assumed to be close to practices. By Mathlab software, the commands are presented in Appendix 2, we can have the results $\boldsymbol{\Pi}$*, K * and L * are reduced when the carbon tax (τ) increases, reflecting the theoretical findings. Based on the values ($\boldsymbol{\Pi}$*), K * and L * corresponding to (τ), we can draw the graphs shown in Appendix 4. Due to the model of $\boldsymbol{\Pi}$ is short run profit function, we do not input timing into the simulated model. The averge price is to be (1) as the capital (K) is measure in money (not by number of machinery).

4.6.1 Assumed data

Table 4.6.1: Assumed Data for Simulation

Abbreviation	Assumed Value
(r)	15% or 0.15
(w)	800 USD
(α)	0.3 as Ashfaq Ahmad & Muhammad Khan (2015)
(β)	0.6 as Ashfaq Ahmad & Muhammad Khan (2015)
(θ)	0.004 : current carbon coeficient of coal fired power
(p)	1
(τ)	10,50,100,150 USD/Ton
(***Π****), K* and L* depend on (τ).	???

4.6.2 Numerical results by graphs

After performing the simulation in the form of arithmetic results in which the optimal values K *, L * and Π * are calculated according to the formulas in Sections 4.2.1 and 4.2.2. The different levels of carbon tax rate (τ) are shown in Table 4.6.1. Calculation results of K *, L * and Π * are shown in Table 4.6.2. Then, we can graph the relation representation between K *, L *, Π * and (τ) as Appendix 2.

The results of calculation as presented in the Table 4.6.2 show that all value of K *, L * and Π * are decreased when the tax rates are increased. It means that if the carbon taxation is applied, the investors will reduce their optimal capital and labor level as theorem 1 (proposition 1).

Table 4.6.2: Calculation of optimized values K*, L* và Π *

τ	10	50	100	150
K^*	1.0e-17 * 0.189321481108516	1.0e-17 * 0.030576476160000	1.0e-17 * 0.001721868840000	1.0e-17 * 0.000029859840000
$\% = \frac{K^*_{after} - K^*_{before}}{K^*_{before}}$	0	-0.838494417110154	-0.943686485290527	-0.982658470084167
L^*	1.0e-21 * 0.709955554156934	1.0e-21 * 0.114661785599999	1.0e-21 * 0.006457008150000	1.0e-21 * 0.000111974400000
$\% = \frac{L^*_{after} - L^*_{before}}{L^*_{before}}$	0	-0.838494417110154	-0.943686485290527	-0.982658470084167
Profit	1.0e-19 * 0.946607405542602	1.0e-19 * 0.152882380800003	1.0e-19 * 0.008609344200000	1.0e-19 * 0.000149299200000

The simulation results performed for 5 cases of carbon taxes are 0, 10, 50, 100 and 150 USD / ton respectively, showing that the values of K *, L * and Π * decrease when the tax increases as the conclusion of Proposition 1.

4.7 Conclusion of Chapter 4

Through the different case of modeling, we have developed the basic model of profit function to be fit with different cases (1) non-carbon and carbon taxation for one investor; (2) timing of carbon taxation is uncertain for one investor; (3) the same carbon tax rate for two investors with different carbon emission volumes/levels. Then, based on the basic assumption that the investor is rationale and thus following the profit maximization rule, we apply optimization technique to find the optimum value of capital stock (K) and labor level (L) at which the investor can maximize their profit. The theoretical results of each case are novelty in theoretical meanings and could be used as scientific foundation for further research as well as policy and managerial implications in Chapter 5.

CHAPTER 5: POLICY AND MANAGERIAL IMPLICATIONS

5.1 General conclusions

This research is applied the quantitative method by mathematical modeling to examine impacts of carbon taxation related uncertainties on profit levels of the firm and thus reflecting the firm behaviors in investment decision. If the research results of mathematical modeling are accepted, there will be able to expand to other uncertainties affecting the firm profit and thank to its results, we could design additional and suitable policies to reduce both uncertain level of and number of uncertainties which help increasing FDI instead of using the traditional solutions such as tax reduction, lower land rentals, etc.

In another hand, this thesis also provides a new idea that the carbon taxes could be used to reduce lower technology investors while encouraging the higher ones. If the profit function of the firm including production and cost functions is to be in the form of Cobb-Douglas with K, L, it will allow the examination of relationship between K, L and carbon taxes. Therefore, we could develop the model reflecting such above relationship (K, L and carbon taxes) so that we could design the tax policies as the main tools to navigate the firm's behaviors in choosing K, L, etc. Conditions of this type of research model needs to be assumed reasonably and close to practices so that the model shall be practically viable. As the result, policy application of carbon taxation can be designed to increase the level of capital stock in FDI project, leading to higher technology level. At the present time, there is likely no economic measure which can navigate technology level FDI project. The government bodies purely use the administrative measures which are based on manufacturer's certificates, certificate of origin, manufacturer's catalogues and some qualitative criteria to evaluate the second hand equipment to be imported into FDI projects in Vietnam. These measures are purely administrative ones which could violate the commitments of WTO. In addition, it could allow the corruption in approving incentives and licenses to FDI projects.

Under different modeling cases involving uncertainties of carbon taxation affecting investor profitability, the results of algorithmic modeling and calculations show the interesting implication as follows.

Firstly, when comparing two cases with and without carbon taxation, it is clear that the application of carbon taxation will reduce the investor's optimal capital stock and labor level (Theory 1). However, the optimal capital/labor ratio in the case of carbon tax is higher than that of the case without carbon tax, suggesting that carbon taxation is effective to increase technology level in their project (Theory 2).

Secondly, when investors consider investing in a non-carbon taxed country, they will concern the uncertainties of carbon taxation such as: when will the government apply carbon tax? For the investor who is not risk taker, they will determine the worst case: the government will apply carbon taxation as soon as on the first year of their project life cycle. Therefore, they will choose low optimal capital/ technology and labor levels which are equal to case of carbon tax applied (Theory 3).

Thirdly, when the government has applied carbon taxation that will tends to lead investors with lower emission rate investing at the higher ratio of capital/labor in comparison with that ratio of higher emission investor. (Theory 4).

5.2. Policy and managerial implications

From the results of model development and calculations in different cases of carbon taxation related uncertainties affecting corporate profits, we have some policy implications as follows.

5.2.1 Policy implications

+ Policy to attract FDI

The government should inform in advance their schedule of imposing carbon taxation and possible carbon tax rates. It will help investors reducing uncertainties related to carbon taxation. As a result, the investors will make better investment decisions at higher capital stock and labor levels than the case that the government does not inform advance.

The advance notice of the possibility of applying carbon taxes should be formulated based on scientific foundation of signaling theory and information asymmetry, to ensure that investors are gradually receiving the information related to the process of preparing and imposing carbon tax, expected tax rates, taxpayers, tax bases, etc. At the same time, it is expected that the estimated tax rate should be notified as soon as possible to help investors who are preparing to invest with enough necessary adjustment time. With the taxpayer who already has operated, it is difficult to change the technology and thus, it is necessary to consider partial exemptions, according to the roadmap to help firms adjust gradually to new costs for carbon taxes.

To reduce the risk to investors in terms of carbon tax rates, governments need to actively study regional and international carbon tax rates in order to provide a reasonable carbon tax rate to investors, still ensuring the regional competition in investment attraction.

+ Attracting high technology investors for better environment:

Carbon taxation should be considered to apply in order to limit low-tech investors (expressed as carbon emission rate). When applying carbon taxes, the high-tech investors (with lower emission rates) tend to invest at higher in capital / labor than in low-technology investor (higher emission rates). Therefore, the government may consider to set up carbon tax rate at the threshold level that will allow investors at the certain level of technology (certain level of carbon emission rate) to invest and eliminating the investment from lower technology investors.

5.2.2 Managerial implications

Firstly, managers/CEO should bear in mind that uncertainty is different from risk. Not all uncertainties become the risks and they could make influence to calrify uncertainties to be risk or nothing. Therefore, the management view for uncertainty should be different from risk is that firstly we must spend efforts to clarify information relating to uncertainty as much as poissible and if it could become the risk, then we move to risk management technique.

Secondly, the uncertainties related to carbon taxation clearly influence the investment decision of the firm and the choices of optimum level of capital and labor in the project to ensure that the firm will achieve profit maximization. Therefore, the manager needs to incorporate uncertainties related to carbon taxes in the project profit model for better project appraisal. In addition, the selection of optimal capital in large projects is a very complex task, initially requiring the technical design, cost estimation and forming of the initial investment capital of the project. Managers should identify and clarify uncertainties related to carbon taxes and other uncertainties as soon as possible in the project preparation time, so that helping preparation works of the project, in particular to form the total initial investment cost more efficient. Then, the resulst of NPV, IRR and/or ROA will be more exact for project appraisal.

5.3 Research limitations and recommendation for further research directions

5.3.1 Research limitations

This is a study that focuses on theoretical research and uses hypothetical simulation to illustrate the results of the mathematical modeling. Then, the hypothetical data is employed to illustrate the theoretical results better. However, the hypothetical data cannot replace empirical data. Therefore, before applying the results of this research into reality, it is necessary to carry out additionally empirical research to calibrate theoretical results.

The responses of investors with carbon taxation related uncertainties are different depending on their psychological characteristics such as risk taker, risk neutral or risk adverse. This thesis does not include such characteristics in the research model, but assuming that all investors are equal in risk tolerance.

5.3.2 Recommendation for further research directions

In addition to further researches to overcome the limitations of the thesis, the following research directions need to be taken into account in practical requirements in Vietnam. Firstly, it may be necessary to develop deeper into the methods of project appraisal, in particular the method of real option analysis as it has been proposed by many scholars in the world for its benefit in acse of project appraisal for large fixed assets. Case studies of project appraisal in Viet Nam should be developed through combined data (collected and assumed ones) for certain types of projects. Thank to these empirical studies, we may have the basis for proposing a formal appraisal method of real option in Vietnam in addition to the traditional one of DCF method.

The next research direction should be to study how to design the optimal level of carbon tax to eliminate low technology investors with high carbon emission level. If this research direction could be successful, it is possible to propose an important policy that would use carbon taxes as regulatory instrument to regulate technology and labor levels in investment project in Vietnam, especially for FDI project.

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APPENDIX 1

Publications of author

(Related to the thesis)

ARTICLES

- Lê Quốc Thành (2018). Các nhân tố bất định ảnh hưởng đến quyết định đầu tư trong dự án FDI không thể hủy ngang tại Việt Nam. *Tạp chí Nghiên cứu Marketing* , số 48 Tháng 12 năm 2018.
- Phạm Khắc Quốc Bảo & Lê Quốc Thành (2019). Thẩm định dự án không hủy ngang trong điều kiện bất định: Trường hợp bất định về thuế carbon. *Tạp chí Nghiên cứu Marketing*, Số 49, Tháng 2 năm 2019.

SEMINAR

- Wei Zhou, Stefano Bosi & Le Quoc Thanh (2016), Carbon optimal taxation and carbon emission leakage. Hội thảo VEAM 2016, tại Đà Nẵng

APPENDIX 2

Coding in do.file of mathLab and Graphs

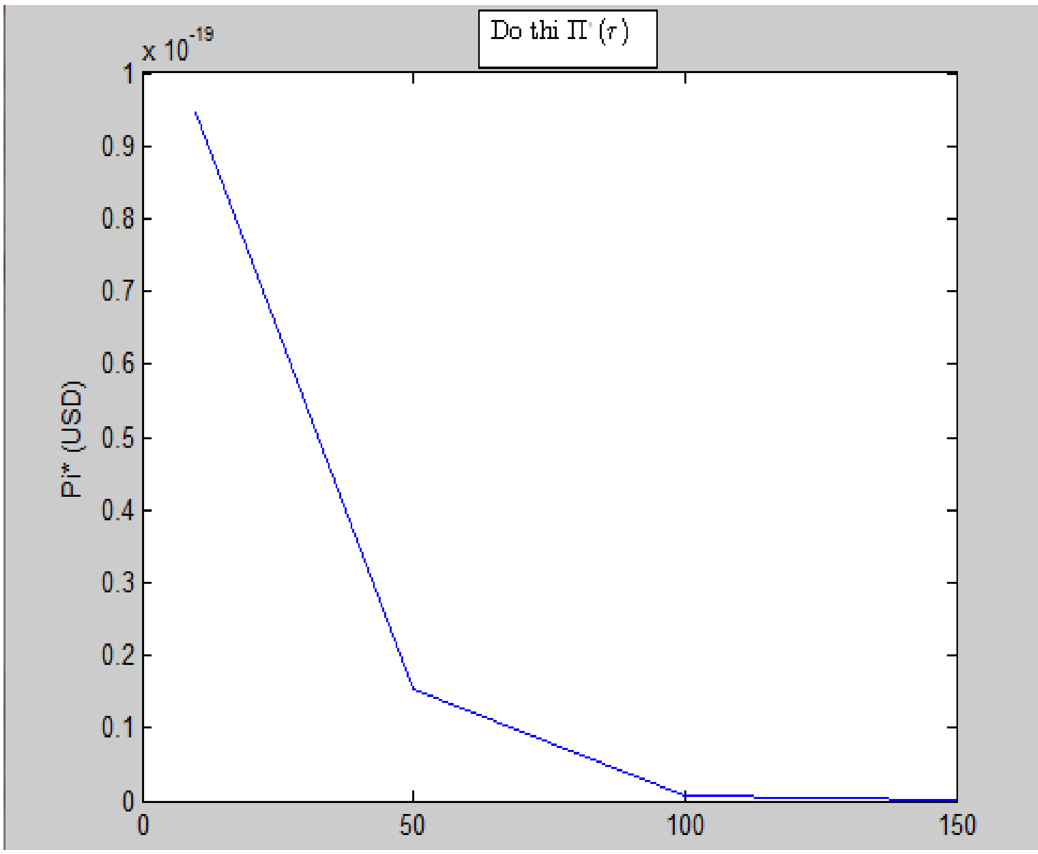
```
format long
r=0.15 %r la chi phi von
w=800 %w la chi phi lao dong
a=0.3
b=0.6
phi=0.004 %He so hieu suat = 0.004
tau=[0 10 50 100 150]tau la thue?
P=1 %gia san pham
%Truong hop 1: Khong thue
k1=nthroot(P*(b/a)^b*(r/w)^b*(a/r),1-a-b) %k1,l1 là toi uu TH1
l1=(b*r*k1)/(a*w)
Pi1=P*(k1^a)*(l1^b)-r*k1-w*l1 %Profit trong TH1
%Truong hop 2: Co thue
K=zeros(1,4)
L=zeros(1,4)
Pi=zeros(1,4)
kk=zeros(1,3) %su thay doi cua K
ll=zeros(1,3) %su thay doi L
for i=1:4
K(i)=nthroot((P-tau(i)*phi)*(b/a)^b*(r/w)^b*(a/r),1-a-b)  %k,l là toi uu TH2
L(i)=(b*r*K(i))/(a*w)
Pi(i)=(P-tau(i)*phi)*(K(i)^a)*(L(i)^b)-r*K(i)-w*L(i)
```

```
        if (i>1)
        kk(i)=(K(i)-K(i-1))/K(i-1)
        ll(i)=(L(i)-L(i-1))/L(i-1)
        end
    end
    %Ve do thi
    figure
    plot(tau,K)
    TB1 = annotation('textbox', [.45, .93, .17, .065], 'String', 'Do thi $K^*(\tau$)', 'BackgroundColor', [1, 1, 1], 'Interpreter', 'latex')
    TB2 = annotation('textbox', [.45, .0, .1, .05], 'String', '$\tau (USD)$', 'BackgroundColor', [1, 1, 1], 'Interpreter', 'latex')
    ylabel('K* (USD)')
    figure
    plot(tau,L)
    TB3 = annotation('textbox', [.45, .93, .17, .065], 'String', 'Do thi $L^*(\tau$)', 'BackgroundColor', [1, 1, 1], 'Interpreter', 'latex')
    ylabel('L* (USD)')
    TB4 = annotation('textbox', [.45, .0, .1, .05], 'String', '$\tau (USD)$', 'BackgroundColor', [1, 1, 1], 'Interpreter', 'latex')
    figure
    plot(tau,Pi)
    TB5 = annotation('textbox', [.45, .93, .17, .065], 'String', 'Do thi $\Pi^*(\tau$)', 'BackgroundColor', [1, 1, 1], 'Interpreter', 'latex')
    ylabel('Pi* (USD)')
    TB6 = annotation('textbox', [.45, .0, .1, .05], 'String', '$\tau (USD)$', 'BackgroundColor', [1, 1, 1], 'Interpreter', 'latex')
```

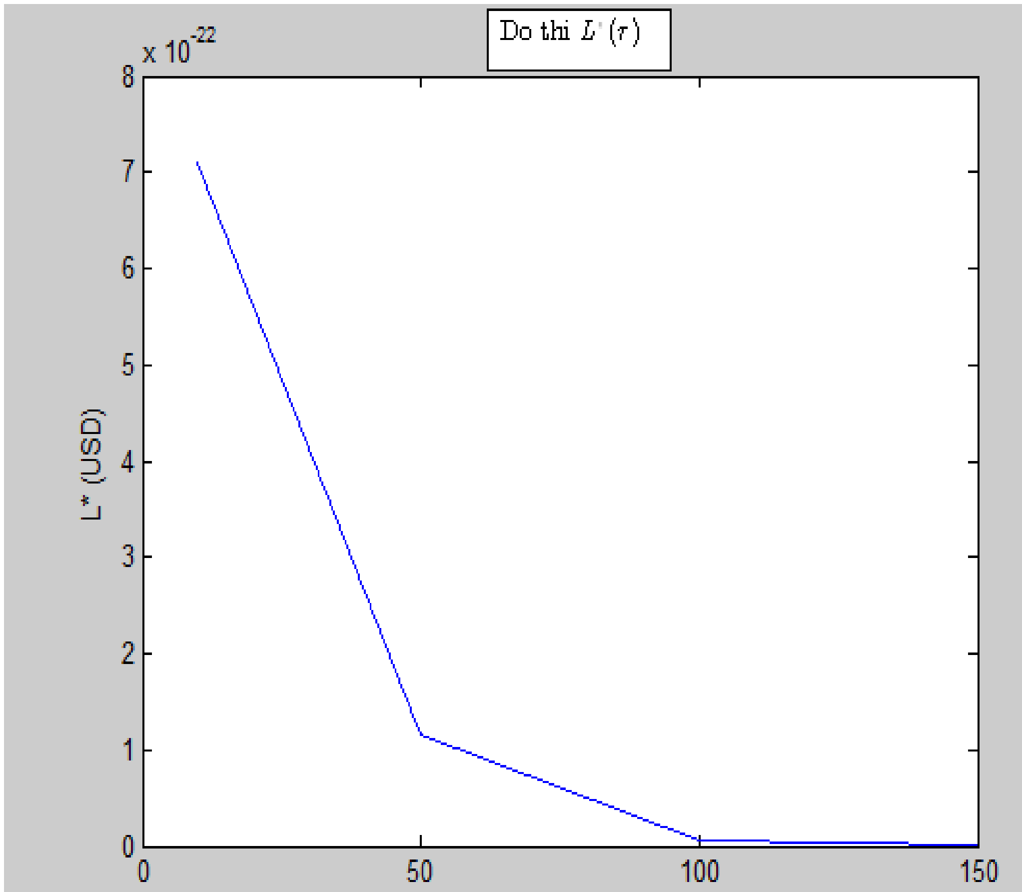
```
%Xuat ket qua
disp('Cac gia tri K*')
disp(K)
disp('Cac gia tri L*')
disp(L)
disp('Cac gia tri Pi*')
disp(Pi)
disp('Su thay doi cua K*')
disp(kk)
disp('Su thay doi cua L*')
disp(ll)
```

GRAPHS

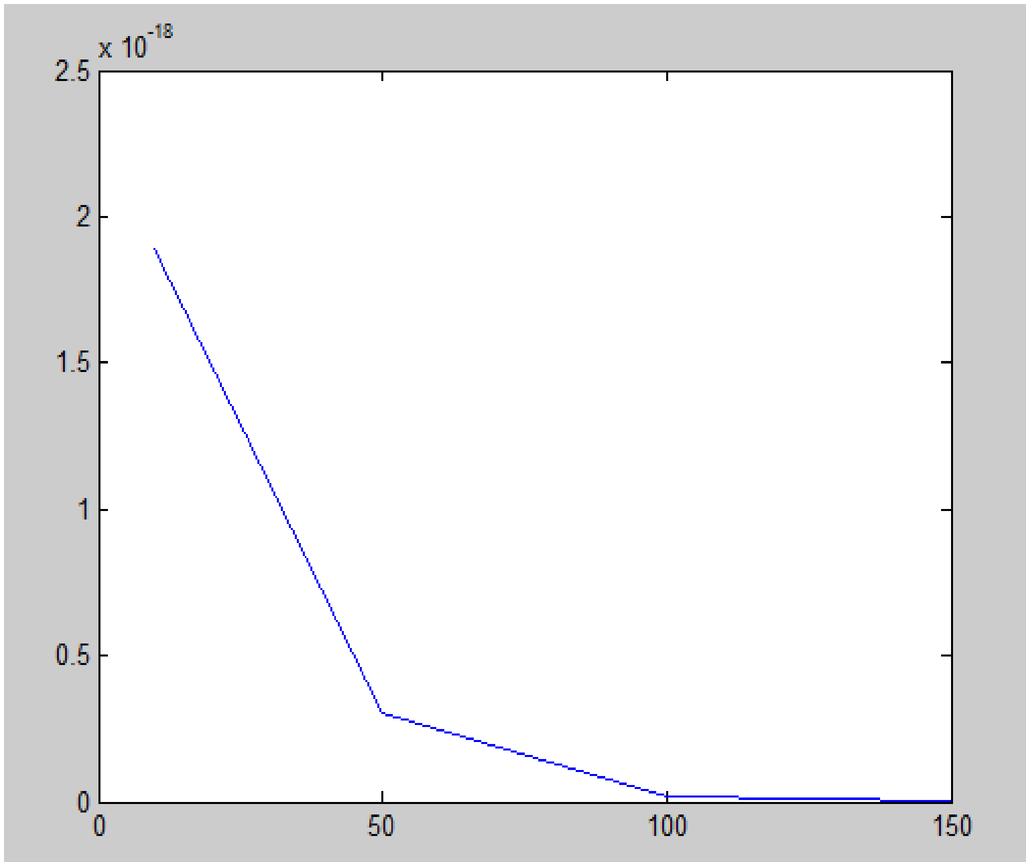
Π and (τ)



L and (τ)



K and (τ)



APPENDIX 3

Kyoto protocol 1997