WELFARE ANALYSIS OF WASTEWATER TREATMENT CHARGES: A CASE STUDY OF THE BANGKOK METROPOLITAN ADMINISTRATION WASTEWATER MANAGEMENT SYSTEM

Miss Nantarat Tangvitoontham

A Dissertation Submitted in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy Program in Economics
Faculty of Economics
Chulalongkorn University
Academic Year 2008

การวิเคราะห์เชิงสวัสดิการของการเก็บค่าธรรมเนียมบำบัดน้ำเสีย:
กรณีศึกษาของระบบการจัดการระบบน้ำเสียของกรุงเทพมหานคร

นางสาว นันทรัตน์ ตั้งวิฑูรธรรม

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาเศรษฐศาสตรดุษฎีบัณฑิต

สาขาวิชาเศรษฐศาสตร์

คณะเศรษฐศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

ปีการศึกษา 2551

Thesis Title	WELFARE ANALYSIS OF WASTEWATER TREATMENT CHARGES: A CASE STUDY OF THE BANGKOK METROPOLITAN ADMINISTRATION WASTEWATER MANAGEMENT SYSTEM
By	Miss Nantarat Tangvitoontham
Field of Study	Economics
Advisor	Assistant Professor Charit Tingsabadh, Ph.D.
Co-advisor	Associate Professor Sitanon Jesdapipat, Ph.D.
Co-advisor	Assistant Professor Worawet Suwanrada, Ph.D.

Accepted by the Faculty of Economics, Chulalongkorn University in Partial Fulfillment of the Requirements for the Doctoral Degree

.... Dean of the Faculty of Economics

(Professor Teerana Bhongmakapat, Ph.D.)

THESIS COMMITTEE

.... Chairman

(Associate Professor Sothitorn Mallikamas, Ph.D.)

.... Advisor

(Assistant Professor Charit Tingsabadh, Ph.D.)

.... Co-advisor

(Associate Professor Sitanon Jesdapipat, Ph.D.)

.... Co-advisor

(Assistant Professor Worawet Suwanrada, Ph.D.)

.... Examiner

(Sompong Hirunmassuwan, Ph.D.)

.... External Examiner

(Phonphot Kannasoot)

นันทรัตน์ ตั้งวิฑูรธรรม: การประมาณค่าผลกระทบสวัสดิการสังคมของค่าธรรมเนียมบำบัดน้ำเสีย: กรณีศึกษาของระบบการจัดการระบบน้ำเสียของกรุงเทพมหานคร (WELFARE ANALYSIS OF WASTEWATER TREATMENT CHARGES: A CASE STUDY OF THE BANGKOK METROPOLITAN ADMINISTRATION WASTEWATER MANAGEMENT SYSTEM) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ.ดร. จาริต ติงศภัทิย์, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: รศ.ดร. สิตานนท์ เจษฎาพิพัฒน์, ผศ.ดร. วรเวศม์ สุวรรณระดา, 175 หน้า.

การศึกษานี้มีวัตถุประสงค์เพื่อที่จะเสนอกรอบแนวคิดที่สามารถนำไปวิเคราะห์ผลของนโบบายสิ่งแวดล้อมต่อสวัสดิการสังคม การศึกษานี้มุ่งศึกษาผลกระทบต่อสวัสดิการสังคมโดยรวม ซึ่งประกอบไปด้วยผลกระทบทั้งด้านอุปสงค์ต่อครัวเรือนและผลกระทบต่อภาครัฐ การวิเคราะห์นี้ใช้ระบบการใช้จ่ายเชิงเส้นตรงในการประมาณค่าอุปสงค์ของครัวเรือนในกรุงเทพมหานคร และ ใช้แบบจำลอง Stochastic Frontier ในการประมาณค่าต้นทุนค่าบำบัดน้ำเสียของโรงบำบัดน้ำเสียของกรุงเทพมหานคร การศึกษาพบว่านโยบายเก็บค่าธรรมเนียมบำบัดน้ำเสียของกรุงเทพมหานครไม่ว่าจะเป็นแบบแผนใดๆ ก็ส่งผลให้สวัสดิการสังคมโดยรวมเพิ่มขึ้น นโยบายการเก็บค่าธรรมเนียมบำบัดน้ำเสียในอัตราหน่วยละ 2 บาทโดยไม่มีการชดเชยใดๆนั้น ทำให้สวัสดิการสังคมรวมเพิ่มขึ้นสูงสุดเมื่อเทียบกับแบบแผนอื่นๆ โดยเพิ่มขึ้นประมาณ 4.577 ล้านบาทต่อเดือน และมีผลทำให้อัตราการปล่อยน้ำเสียสู่แม่น้ำลำคลองลดลงมากที่สุดเมื่อเทียบกับนโยบายแบบอื่นๆ ด้วย โดยลดลง 3.338 เปอร์เซนต์ นอกจากนี้การศึกษานี้ยังพบว่านโยบายแบบรายได้ของรัฐคงที่ โดยการลดภาษีประเภทอื่นๆ เป็นนโยบายที่มีประสิทธิภาพมากที่สุด ในขณะที่การชดเชยครัวเรือนโดยการโอนเงินคืนให้กับครัวเรือนโดยตรงนั้นมีผลให้เกิดความเป็นธรรมมากขึ้น

นอกจากนี้การประมาณค่าส่วนเกินผู้บริโภคสามารถบอกได้ว่า นโยบายการเก็บค่าธรรมเนียมบำบัดน้ำเสียในอัตราหน่วยละ 2 บาทโดยไม่มีการชดเชยใดๆ ซึ่งเป็นนโยบายที่กรุงเทพฯเลือกใช้นั้นส่งผลด้านลบต่อภาคครัวเรือน โดยทำให้ครัวเรือนเสียส่วนเกินผู้บริโภค 42.579 บาท ต่อครัวเรือนต่อเดือน หรือรวมเป็นเงินทั้งสิ้น 85.159 ล้านบาทต่อเดือน รัฐได้รายได้จากค่าธรรมเนียมบำบัดน้ำเสียจากครัวเรือนเป็นจำนวนเงิน 83.870 ล้านบาทต่อเดือน ซึ่งถือแหล่งรายได้ใหม่ของกรุงเทพฯ และการลดลงของการปล่อยน้ำเสียทำให้ต้นทุนในการบำบัดน้ำเสียของกรุงเทพฯ ลดลงประมาณ 5.865 ล้านบาทต่อเดือน ซึ่งทั้งสองส่วนนี้ถือว่าเป็นการเพิ่มสวัสดิการในส่วนของภาครัฐ ดังนั้นนโยบายการเก็บค่าธรรมเนียมบำบัดน้ำเสียจึงมีผลให้สวัสดิการสังคมโดยรวมเพิ่มขึ้น

สาขาวิชา..........เศรษฐศาสตร์........... ลายมือชื่อนิสิต..
ปีการศึกษา.......2551........................ ลายมือชื่ออ.ที่ปรึกษาวิทยานิพนธ์หลัก ....
ลายมือชื่ออ.ที่ปรึกษาวิทยานิพนธ์ร่วม ....
ลายมือชื่ออ.ที่ปรึกษาวิทยานิพนธ์ร่วม ....

4786151029 : MAJOR ECONOMICS
KEY WORDS : ENVIRONMENTAL TAXES / INCIDENCE / WELFARE ANALYSIS

NANTARAT TANGVITOONTHAM: WELFARE ANALYSIS OF WASTEWATER TREATMENT CHARGES: A CASE STUDY OF THE BANGKOK METROPOLITAN ADMINISTRATION WASTEWATER MANAGEMENT SYSTEM. ADVISOR: ASST. PROF. CHARIT TINGSABADH, Ph.D. CO-ADVISOR: ASSOC. PROF. SITANON JESDAPIPAT, Ph.D.; ASSOC. PROF. WORAWET SUWANRADA, Ph.D., 175 pp.

This study objects to introduce the analysis framework of determining and emphasizing the total effects of the environmental policy on net social welfare which is defined as the changes in consumer surplus in household sector together with gains in governmental sector (Bangkok Metropolitan Administration). The study uses Linear Expenditure System (LES) to estimate households demand patterns and Stochastic Frontier Analysis (SFA) to estimate abatement cost of Bangkok's wastewater treatment plants. The results prove that any policy scenarios encourage net social welfare gains. The author finds that the policy, imposing the charge at 2 baht per m^3 without any compensation, creates the most net social welfare gain (4.577 million baht per month) when compared to other scenarios and affects decreasing of wastewater discharged the most equalling to 3.338 percent. Moreover, the revenue neutral scenario that reduces other taxes to compensate households is the most efficiency scenario while using the revenue to fund lump sum transfers actually creates better equity to the society.

In addition, the results show that BMA designed policy, imposing the charge at 2 baht per m^3 without any compensation, impacts lose in household sector 42.579 baht per household per month or the total is 85.159 million baht per month. BMA sector gains from this new source of revenues about 83.870 million baht per month. BMA also benefits from decreasing wastewater discharged by saving its abatement cost about 5.865 million baht per month. Indeed, the wastewater treatment charge creates net social welfare gain in a case study of Bangkok Metropolitan Administration's wastewater management system.

Field of Study: ......Economics…… Student's Signature: ………………………………...
Academic Year: ...2008................ Advisor's Signature: ………………………………....
Co-advisor's Signature: ....
Co-advisor's Signature: ....

ACKNOWLEDGEMENTS

The author would like to acknowledge many people who contributed to this dissertation in many ways. First, the author is indebted to her advisor, Assistant Professor Charit Tingsabadh, for his continuous support and advice. Throughout her doctoral work he encouraged to develop independent thinking and research skills. His self – discipline and patience have been the guiding principles for the author during her doctoral study. The author would like to express her gratitude to her thesis co-advisor, Associate Professor Sitanon Jesdapipat and Assistant Professor Worawet Suwanrada. Also, she would like to show appreciation to her thesis chairman, Associate Professor Sothitorn Mallikamas, for his helpful comments and compassionate advice and to Dr. Sompong Hirunmassuwan and Mr. Phonphot Kannasoot for serving on her committee members and for their support and valuable feedback.

The author is indebted to Professor Williams Mc Cleary, Faculty of Economics, Thammasat University for his times to comment on the paper. She would like to thank Ms. Chutima Triphob, Ms. Satinee Pisankunakit, and Mr. Rakdee Chotjinda for their contributions. Additionally, she is very grateful to the Faculty of Economics, Chulalongkorn University for the scholarship granted. She is particularly thankful to all faculty members and her friends who supported and helped in many ways while she attended Chulalongkorn University. The author is especially indebted to Dr. Papusson Chaiwat and Dr. Sawarai Boonyamanond, who always shared the difficult times, for their friendships, their enthusiastic help and positive encouragement. She would like to thank Dr. Roongroj Chokngamwong and Mr. Chareonchai Agmapisarn for his good heart, patience, support, inspiration and positive attitude.

Lastly, the author would like to sincerely and deeply thank her family, her greatest source of inspiration, for their understanding, infinite care, love and encouragement and support all the way through these difficult years.

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ABREVIATED

BMA = Bangkok Metropolitan Administration

C = abatement cost frontier of treatment plants

c_i = consumption of private goods i

DQ = wastewater discharge ratio (%)

DWL = dead weight loss

E = total consumption expenditure of household

EV_i = equivalent variation of household i

Fw = wastewater treatment charge rate

GE = BMA expenditure

i = commodities and i = 1, 2, 3, . . ., n

MWA = Metropolitan Water Authority

NSW = net social welfare

OE = other public goods expenditures

Pc_i = price of commodity i

Pw = price of tap water

PL = wage

PE = electricity price

PM = material price

Q = total wastewater discharged from households

qi = wastewater discharged from household i

R = BMA revenue

S = amount of supplementary fund and other BMA revenue

TEV = total equivalent variation

TCR = total revenue from the charge

TWA = total wastewater abated

U = households' utility

w = tap water consumption

γ_i = committed levels of expenditure of commodity i

β_i = consumption expenditure share of commodity i

α_i = unknown parameters of stochastic cost frontier function

CHAPTER I

INTRODUCTION

1.1 Significant of Problems

Wastewater from residential area is a main environmental problem in Bangkok as well as wastewater discharged from industrial area. Tuntoolavest (2006) claimed that river water got significantly more contaminated when the river passed through a community. The result of the research shows that households are also contributing to the significant increase in organic pollutants to the river. Therefore, wastewater from residential area should be taken into consideration if government needs to establish any water pollution controlled policies. Wastewater from residential area accounted for 60 percent of all wastewater discharged. Additionally, from the database of Bangkok's Sewage and Draining Department, the wastewater discharged from residential area is estimated to increase about 35 percent to 859.87 million m^3 per year or 2.3 million m^3 per day in year 2010 compare to year 2000[1]. Hence, water pollution is pervasive throughout Bangkok area.

Bangkok Metropolitan Administrative (BMA) foresees the situation and tries to provide sufficient wastewater treatment services and supporting activities. The current capacity of wastewater treatment of BMA is 1.03 million m^3 per day[2]. BMA also is planning to build other eight wastewater treatment plants in different areas to provide adequate wastewater treatment services. The expected capacity of cleaning up wastewater from BMA will be increased to 2.2 million m^3 per day which can treat all

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[1] Final report: Bangkok Metropolitan Administration wastewater user charge study (Bangkok: Bangkok Metropolitan Administration, 1998), pp. 94 – 96.

[2] Analysis results of water quality from Bangkok water quality control plants (Bangkok: Bangkok Metropolitan Administrative, 2005), pp. 1 – 7.

wastewater from the residential area in year 2010[3]. To achieve the investment plan, BMA needs at least 53,694.4 million baht for constructing the wastewater treatment plants[4]. Also, BMA has to prepare budgets for renovating and building discharged water pipe systems for efficient collection of wastewater from the sources and distribution of the wastewater to the treatment plants.

To achieve these projects, BMA needs a lot of financial support to provide a long term funding for wastewater treatment. Economics instrument seems to be an appropriated answer. According to "Polluter Pay Principle", BMA declares that households should respond to the public wastewater treatment costs. Then the most proper fiscal tools should be considered. Regarding to the meaning defined by Farlex and Sinclair (2006).

> **Tax** is citizens' obliged fee charged ("levied") by a government on a product, income, or activity. The purpose of taxation is to finance government expenditure such as expenditure on public goods and services.
>
> **User fee** is compensation for services rendered, specifically, payment for professional services. It is an amount or sum of money that someone is paid for a particular job.
>
> **User charge** is an amount of money asked as the price of something that people have to pay for a service. Normally, it is an amount or sum of money that someone is paid for a particular service. It is partly or fully proportional to the costs of the service that is provided in turn.

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[3] Final report: Bangkok Metropolitan Administration wastewater user charge study (Bangkok: Bangkok Metropolitan Administration, 1998), p. 96.

[4] Executive summary for Bangkok Metropolitan Administrative governor (Bangkok: Bangkok Metropolitan Administrative, 2005), p. 24.

Concerning to the fiscal legislation, the central government has full authority in tax collections. However, the local government can collect certain local taxes such as land taxes, sign board taxes, and local development taxes. The legislation also defines local government can impose any fees or charges to the residents as prices of providing the specific services in turn. Moreover, order 62/2533 of the royal decree stated that BMA has no right to collect an amount of money which has tax characteristics.[5] From these reasons, user charge is the most appropriated tool which BMA already has a full authority to use.

BMA, therefore, shortly plans to impose the wastewater treatment charge on households in service areas at the rate of 2 baht per m^3. In addition, BMA claims that this new source of revenue will be used for wastewater clean up, returning benefits to and improving social welfare of all Bangkok residents. However, before legally imposing the charge BMA should clearly present advantage and disadvantage along with cost and benefit of the charge to Bangkok residents, who will be directly affected, due to reduce the resistance.

Since an economic model which describes the environmental sector and utilizes for analyzing the government's environmental policy is seldom developed in Thailand. The environmental research formerly studies in Thailand mostly concern about valuation of environment. For example, Tapvong and Kruavan (2003) used CVM methods for finding willingness to pay for water quality improvements of the Chao Phraya River. Roomratanapun (2000) also studied the factors determining of centralized wastewater treatment in Bangkok by using willingness to pay. Also, the studies which analysis effects of environmental policies are mostly suggest the new regulation, analysis of advantage, disadvantage and limitation of the existing policies. Even the BMA studies on wastewater user charge, it only studies about willingness to

[5]Chapter 9, Final Report: BMA wastewater user charge study (Bangkok: Bangkok Metropolitan Administration, 1998), p. 26.

pay for the treatment and average cost pricing method. However, there is no analysis of the real effects of the policy in term of monetary.

In order to obviously illustrate costs and benefits of the wastewater treatment charge, and answer whether social welfare of Bangkok's residents actually improves after imposing a wastewater charge, an environmental policy analysis model must be developed.

1.2 Objectives of the Study

The main objective of this research is to present a basic conceptual framework to analyze consequences of the wastewater treatment charge policy. This model can be adapted to use with other environmental policies. It is a development of economic instruments in environmental protection. Also, it provides a substantive contribution and can be developed to an environmental general equilibrium model for local and nationwide.

This research presents the linkage between environment and development in the sense of effects of the wastewater treatment charge on social welfare, households' behaviors, and public service expenditures. It explains how wastewater treatment charge can be used to achieve efficiency and decrease distortion of the existing taxes.

Lastly, the research estimates the abatement cost frontier function which used for finding the treatment cost efficiency of the public wastewater treatment plants. This function can be used as a guideline for determining the optimal wastewater treatment charge rate. Moreover, this study aims to answer these questions:

- Does the wastewater treatment charge policy solve water pollution in Bangkok area?
- How the wastewater policy affects Bangkok households' behaviors?
- How the wastewater policy affects the social welfare of the community?

- Do Bangkok households' benefit from the policy?

1.3 Scope of Study

The areas covered in this study include 50 districts in Bangkok. The study analyzes and compares household expenditure, quantities of wastewater discharged from households, welfare change with and without the wastewater treatment charge, and public service cost savings of Bangkok Metropolitan Administration (BMA).

1.4 Data Used

The data used in this study are complied from several of sources. Data for estimating households' demands and expenditures is from the database of the National Statistical Office. The data file contains the statistics of socio economic survey for year 2002, 2004 and 2006. Prices of private goods are from the price index report of the Ministry of Commerce. Price of tap water is provided by Metropolitan Water Authority. Bangkok Metropolitan Administrative public expenditure data are from the Fiscal Department of Bangkok Metropolitan Administrative. The data for estimating abatement cost frontier function of Bangkok public wastewater treatment plants are from Sewage & Draining Department. The data are from year 2003 – 2005 of five wastewater treatment plants: Si Phraya plant, Rattanakosin plant, Tung Kru plant, Chong Nonsi plant, and Nong Khaem plant. Additionally, other supporting information and data will be received from Water Resource Management Division and Pollution Control Department, Ministry of Environment and Natural Resource.

1.5 Hypotheses of the Study

According to Goulder (1995), Hill (1998), Xie and Saltman (2000) and other researches on environmental taxes, this paper concludes that environmental taxes can provide long term economic and social welfare gains. Also, the policy reduces pollution emission. Consequently, the effect of the wastewater treatment charge on net social welfare hypothetically increases. Wastewater discharged to environment also hypothetically reduced since the wastewater treatment charge causes reducing households' tap water consumptions which directly affects decreasing the discharged.

1.6 Contributions and Benefits of the Study

As mention above, this study provides a substantive contribution and can be developed to environmental general equilibrium model for local and nationwide efforts. The model illustrates impacts of wastewater treatment charge to Bangkok households' behaviors including households' expenditures, wastewater discharged and public service cost savings.

Unlike previous studies, this study will examine the effect of the policy on private sector along with government sector. The model additionally includes both private sector consumptions and a government production cost into the consideration of net social welfare estimation.

CHAPTER II

BACKGROUND

2.1 Bangkok Socio Economic Overview

Bangkok, established in 1782 as Thailand's capital, is located in the central part of Thailand on the low-flat plain of the Chao Phraya River, which is the most important river. The city has long hours of sunshine, high temperature and humidity. The climate of the city is influenced by seasonal monsoon. The city has 50 districts, covering a total area of 1,568.737 square kilometers. The population density is 7,643 persons per km^2 with estimate 2,091,558 households in year 2005.[1] There are about 10 million inhabitants in Bangkok area. The average proportion of residential per household is 4 persons. Income per capita of people living in Bangkok is about 240,000 baht per capita per year.[2]

Total revenue of Bangkok Metropolitan Administration (BMA) was 43,661.886 million baht in 2006. Revenues, collected from other government organization such as Revenue Department, approximately accounted for 70 percent, with 30 percent of all revenues were collected by BMA itself. The revenues from taxes accounted for approximately 95 percent of all BMA's revenue. Local taxes such as land taxes, land development taxes, and sign board taxes are 8,057.645 million baht in 2006 or 18.45 percent of all revenues. Revenues from other sources were 1,057 million baht or accounted 3.27 percent of all revenues. BMA's total expenses were 30,622.428 million baht in 2006.[3] More than 70 percent of public expenditures are used for public service

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[1] Annual report 2005 (Bangkok: Bangkok Metropolitan Administration, 2006), p. 14

[2] Ibid., p. 16

[3] Budgeting Department: annual report 2007 (Bangkok: Bangkok Metropolitan Administration, 2008), p. 205

and social purposes. BMA expensed on water drainage and sewerage disposal about 8.6 percent and about 1 percent of all its expenditure for wastewater treatment.[4]

The city is increasingly populated with rapid urbanization brining about a number of infrastructures and other constructions. As Thailand's main port, Bangkok has always been more cosmopolitan than other cities of the region. The government sector plays a significant role in Bangkok along with the private sector. There are a number of activities in commerce, industries, construction, manufacture and various kinds of services including banking and other financial services. Bangkok's work force includes employees, private retailers, street vendors, entrepreneurs, government officials and etc. Bangkok is the cultural, educational, political and economical center of Thailand. This very highly populated city is currently faced with some unavoidable urban pollution problems.

Like many other large cities, Bangkok has been continuously developed without a proper development plan. The city has undergone many changes towards urbanization including the switching of water transportation to roadway transportation. Canals and rivers became throwing away sites of unwanted water and trashes from households living along the river bank and from those living farther. Wastewater from the residential community constantly deteriorated the city's canals and river. It creates bad smell and bad scene of the city. Together with other environmental problems such as air pollution and solid waste, Bangkok has now encounter serious environmental problems. However, given the competing needs for a piece of limited financial resources that are available, the wastewater treatment has been a low priority.

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[4] Sewage and Draining Department: annual report 2007 (Bangkok: Bangkok Metropolitan Administration, 2008), p. 38

2.2 Bangkok Wastewater Overview

Wastewater is difficult to measure and too expensive to set the wastewater meter to each household. Research papers usually estimate wastewater from water demand or water used. Normally, the estimation of wastewater is about 70 percent to 85 percent of water used.[5] From BMA report, BMA estimates wastewater is 80 percent of water consumption. This paper classifies sources of wastewater in Bangkok into four categories as follows.

Table 2.1: Show Wastewater Discharged in Bangkok Area from Different Sources

(million m^3: year)

Year	Total Water Used	Total Wastewater	Wastewater from Residential Area	Wastewater from Commercial Area	Wastewater from Industrial Area**	Wastewater from Other Sources
1999	1,384.96	1,107.97	629.13	54.39	158.00	266.45
2000	1,410.10	1,128.08	648.19	55.60	163.26	261.03
2001	1,444.45	1,155.56	668.07	56.85	168.70	261.94
2002	1,488.64	1,190.91	685.27	58.12	174.31	273.21
2003	1,540.20	1,232.16	704.96	59.44	180.12	287.64
2004	1,586.41	1,269.13	725.32	60.79	186.12	296.90
2005	1,634.00	1,307.20	746.46	62.18	192.31	306.25
2006	1,683.02	1,346.42	768.37	63.61	198.72	315.72
2007	1,733.51	1,386.81	790.62	65.10	205.33	325.76
2008*	1,785.52	1,428.41	812.92	66.62	212.17	336.70
2009*	1,839.08	1,471.27	835.98	68.20	219.23	347.86
2010*	1,894.26	1,515.40	859.87	69.82	226.53	359.18

* Use estimated numbers

** Data from Department of Industry

Source: Water Management Department of Bangkok Metropolitan Administration

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[5] Tchobanogious, G. and Burton, F.L., Wastewater engineering treatment, disposal, and reuse, 3rd edition (Singapore: McGraw – Hill International, 1991), p. 25.

2.2.1 <u>Wastewater from the Residential Area</u> including wastewater from houses, apartment, dormitory, and village. Approximately, the wastewater generated from residential areas in year 2005 is 746.46 million m^3 per year, which is 19 percent greater than year 1999. Also, the volume of wastewater is estimated to increase to 859.87 million m^3 per year in year 2010 or increasing approximately 15 percent compared to year 2005. Additionally, wastewater from the residential area accounted for 60 percent of all wastewater discharged in Bangkok area.

2.2.2 <u>Wastewater from the Commercial Area</u> includes wastewater generated from commercial buildings, hospitals, hotels, department stores, fresh markets and restaurants. The wastewater discharged from commercial areas in year 2005 is expected to be 12.18 million m^3 per year, which is about 15 percent greater than year 1999. This figure is estimated to increase 69.82 million m^3 per year in year 2010 or increasing about 12 percent compared to year 2005. Overall, wastewater generated from the commercial area is account for 5 percent of all wastewater in Bangkok area.

2.2.3 <u>Wastewater from the Industrial Area</u>: The wastewater from industrial areas in year 2005 was approximately 192.31 million m^3 per year, increased over 22 percent from 1999. Also, it is estimated to increase to 226.53 million m^3 per year in year 2010 or greater about 20 percent compared to year 2005. Additionally, wastewater from the industrial area accounts for 15 percent of all wastewater in Bangkok area. In general, all wastewater discharged from industrial areas have been controlled by department of industry. Practically, many industries do not run the wastewater treatment system efficiently. Otherwise, they closed the system due to minimize costs. Therefore, the quality of discharged water from industries still unqualified compared to the department of industry discharged water standard.

2.2.4 <u>Wastewater from Other Sources</u> means wastewater which discharges from other special activities and does not related to the first three categories above such as night entertainment places. It accounts for 20 percent of all wastewater discharged in Bangkok area.

2.3 Bangkok Wastewater Treatment Facilities Overview

Table 2.2: General Information of Bangkok Wastewater Treatment Plants

Plants	Capacity (m^3/day)	Water In (m^3/ day)	percent BOD Remove	DO Out (mg/ l)	Date of Operation
1. Si Phraya	30,000				Year 1999
1999		21,859	89.01	2.22	
2000		27,629	92.23	5.01	
2001		19,694	91.41	4.73	
2002		16,835	92.52	4.85	
2003		20,118	92.45	4.78	
2004		18,335	92	5.33	
2005		18,256	80.99	4.23	
2006		18,378	89.83	3.09	
2007		20,961	90.14	3.29	
Average		20,229	90.06	4.17	
2. Rattanakosin	40,000				Year 2001
2001		39,693	86.52	5.84	
2002		32,674	92.12	6.41	
2003		37,412	90.03	6.69	
2004		35,188	87.34	5.16	
2005		35,918	85.14	5.61	
2006		29,748	80.99	5.95	
2007		28,106	76.07	5.93	
Average		34,106	85.46	5.94	
3. Chongnonsi (Yanawa)	200,000				Year 2001
2001		118,991	89.99	6.96	
2002		105,038	90.44	5.83	
2003		94,436	83.51	5.57	
2004		126,407	79.58	5.82	
2005		129,033	81.55	6.75	
2006		124,576	81.64	6.53	
2007		124,282	78.84	6.37	
Average		117,538	83.65	6.26	

Table 2.2: General Information of Bangkok Wastewater Treatment Plants (Continued)

Plants	Capacity (m^3/day)	Water In (m^3/ day)	percent BOD Remove	DO Out (mg/ l)	Date of Operation
4. Ratburana (Tung Kru)	65,000				Year 2002
2002		36,557	86.36	6.56	
2003		33,464	87.38	6.55	
2004		36,560	89.71	6.93	
2005		35,549	86.42	6.36	
2006		48,124	83.66	6.47	
2007		59,882	86.80	6.85	
Average		41,689	86.72	6.62	
5. NongKhaem - Pasicharoen	157,000				Year 2003
2003		88,245	88.61	6.76	
2004		110,652	87.68	6.41	
2005		113,692	83.74	6.31	
2006		122,965	89.24	6.15	
2007		124,423	88.41	6.24	
Average		111,995	87.54	6.37	
6. Dindang	350,000				Year 2005
2005		175,484	85.96	5.87	
2006		206,067	86.26	7.10	
2007		198,805	88.11	6.89	
Average		193,452	86.78	6.62	
7. Chatuchak	150,000				Year 2005
2005*		109,400	70.40	6.11	
2006		129,080	66.59	7.10	
2007		154,463	67.18	7.11	
Average		130,981	68.06	6.77	
8. The 12 Community Plants**	40,000	14,000			
Total (million m^3/ d)	1,032,000	663,990			

*Estimated from April 2005 to December 2005

**Estimated from National Housing Authority Data

Source: Water Management Department of Bangkok Metropolitan Administration

BMA has recently built seven municipal centralized wastewater management plants. Some plants are already in operation and some plants are still under construction. Moreover, BMA has responded to running 12 community plants from National Housing Authority.

From Table 2.1, the average wastewater discharged is 3.58 million m^3 per day and wastewater discharged from residential area is 2.05 million m^3 per day in 2005. Comparing to the current capacity of wastewater treatment plants, shown in Table 2.2 which is 1.03 million m^3 per day; it shows that the capacity of wastewater treatment is less than wastewater discharged from all sources about 2.55 million m^3 per day. Also, the clean up capacity is less than wastewater discharged from residential area about 1 million m^3 per day

Additionally, from the Table 2.2 shows that the capacities of all wastewater treatment plants of BMA's are 1.03 million m^3 per day, but the wastewater treatment plants can clean up only 0.665 million m^3 per day. In other words, BMA is able to clean up wastewater only 64.56 percent of all capacity since the machines is inefficiency, damaged, and dilapidated.

As a result, other than wastewater treatment plants, BMA also faces additional problem. First, BMA has to allocate budgets for renovating and building discharged water pipe systems in order to efficiently collect the wastewater from the sources and distribute to the treatment plants. Consequently, BMA allocated the budget for build the new wastewater treatment plants in its future plan. BMA plan to build eight wastewater treatment plants in different areas in order to provide adequate wastewater treatment services which shown in table 2.3. Table 2.3 shows the wastewater treatment plants which BMA plans to build in different year of construction and the estimated budget for the plants' constructions.

Table 2.3: Investment Plan of Wastewater Treatment Plants in the Future[6]

Wastewater Treatment Plant Project	Area (km^2)	Capacity (m^3/ d)	Year of Construction	Expenditure (million US$)
Khlong Toey	56	36,000	2008	239.51
Bang Sue	20	126,000	2008	133.71
Thonburi	59	37,000	2009	355.43
Hauy Kwuang	15	124,000	2011	129.14
Lak Si	25	96,000	2011	84.00
Wang Thong Lang	35	141,000	2012	146.29
Bung Kum	43	148,000	2012	153.14
Don Muang	30	116,000	2012	101.14
Total	283	1,124,000		1342.36

Source: Executive Summary for Bangkok Governor, Water Management Department of Bangkok Metropolitan Administration

After completing the construction of new wastewater treatment plant projects, the capacity of clean up wastewater of BMA will be 2.15 million m^3 per day which can cover the wastewater from the residential area. However, in order to achieve the investment plan according to table 2.3, BMA needs at least 1,342.36 million $US or 53,694.4 million baht for constructing wastewater treatment plants.

According to Polluter Pay Principle, BMA designs to use economic instruments, the wastewater treatment charge, as a tool to decrease wastewater discharged and increase its revenues. Since, economic instruments tend to be favored by economists in comparison to traditional command and control regulations due to their costs minimizing characteristics, encouraging dynamic efficiency, lowering informational requirements and relatively ease of administration. The wastewater charge seems to be

[6] Executive summary for Bangkok Metropolitan Administrative governor (Bangkok: Bangkok Metropolitan Administrative, 2005), p. 24.

more efficiency and more effective compare to other tools. Moreover, the charge can be a new source of income to generate new clean up activities and recover the operation cost of existing wastewater treatment plants.

2.4 Wastewater Treatment Charge Setting

Regarding to the cost of abatement information from Water Management Division, Ministry of Environment and Natural Resources (1999), they concluded that there are four types of wastewater treatment plants in Thailand which are stabilization pond (SP), aerated lagoon (AL), activated sludge (AS) and open detonation unit (OD). As the variation of their costs, the suggestion charge rates for each type of plants are also different. For example, the charge rate for stabilization pond is 6.9 baht per cubic meter [7] while the rate for aerated lagoon is 5.95 baht per cubic meter. [8] The suggested charge rate for open detonation unit is 12.43 baht per cubic meter.[9] However, most of wastewater treatment plants in Bangkok are activated sludge for which the suggested charge rate from Water Management Division is approximately 12.34 baht per m^3.

BMA needs additional funding for the construction of new plants. It requires more budget allocation to run the current plants efficiently. BMA conducted a few studies about the cost recovery of current plants, which only illustrated the supply side of charge setting system. However, there are some researches discuss about willingness to pay for wastewater clean up activities which can represent the demand

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[7] Calculation of wastewater treatment charges of Sakonnakorn Province: stabilization pond (SP) wastewater treatment plant (Bangkok: Ministry of Environment and Natural Resources, 1999), p. 1.

[8] Calculation of wastewater treatment charges of Pichit Province: Aerated Lagoon (AL) wastewater treatment plant (Bangkok: Ministry of Environment and Natural Resources, 1999), p. 1.

[9] Calculation of wastewater treatment charges of Sriracha Province: Open Detonation Unit (OD) wastewater treatment plant (Bangkok:, Ministry of Environment and Natural Resources, 1999), p. 1.

side. This section will present the cost of running current wastewater treatment plants and willingness to pay of the people who live in Bangkok for the wastewater treatment services.

2.4.1 <u>Supply Side</u>

In BMA's studies such as Metcalf & Eddy International, Inc and Progress Technology Consultant, Co., Ltd (1998), project's expenses included all construction expenses and operation & maintenance expenses. They separated the cost recovery into 4 cases as follows:

Case 1: Recovery only operation cost and maintenance cost
Case 2: Recovery operation cost, maintenance cost and depreciation cost
Case 3: Recovery operation cost, maintenance cost and construction cost
Case 4: Recovery all costs which are operation & maintenance cost, depreciation cost and construction cost, but excluded land cost

Table 2.4 presents the average cost of wastewater treatment service from year 2003 to year 2007. The table shows that for the cost in the first case's cost is about 2,154.99 million baht or 3.46 baht per m^3 with the cost for the 2^{nd} case's cost, the 3^{rd} case's cost, and the 4^{th} case's cost are 2,787.19 million baht per year, 5,043.93 million baht per year and 5,672.12 million baht per year or 4.48 baht per m^3, 8.1 baht per m^3 and 9.11 baht per m^3, respectively. Therefore, BMA needs about 2,000 million baht per year for running system and 7,500 million baht per year for construction. According to the average cost pricing method, BMA should set up charge at a rate range between 3.46 baht per m^3 in order to cover costs or partly cover costs of wastewater treatment plants.

Table 2.4: Average Cost of Wastewater Treatment Service for

Each Wastewater Treatment Plant in 2003 - 2007

Name of the Project	Wastewater Treatment Service Cost (Baht/ m^3)			
	Case 1	Case 2	Case 3	Case 4
Estimate of Wastewater Treatment Cost (Baht/ m^3)	3.46	4.48	8.1	9.11
Si Phraya Treatment Plant	2.66	4.53	10.84	12.7
Rattanakosin Treatment Plant	3.98	5.3	10.09	11.4
Dindang Treatment Plant	4.01	4.93	8.21	9.12
Chonknonsi Treatment Plant	4.12	5.45	9.98	11.31
Ratburana/ Nongkeam Treatment Plant	2.4	3.32	6.8	7.71
Chatujak Treatment Plant	3.39	4.34	7.31	8.26
Huai Kwang Water Quality Control Plant	6.88	7.72	30.21	31.06
Klongjan Water Quality Control Plant	0.98	1.11	3.45	3.58
Rammintra Water Quality Control Plant	1.18	1.39	6.05	6.27
Bangna Water Quality Control Plant	0.59	0.75	3.17	3.33
Tung Song Hong Water Quality Control Plant	0.46	0.68	3.09	3.32
Hua Mark Water Quality Control Plant	1.27	1.34	2.41	2.48
Piboonpattana Water Quality Control Plant	1.14	1.34	5.42	5.63
Klong Toei Water Quality Control Plant	0.85	1.08	3.86	4.1
Tha Sai Water Quality Control Plant	0.37	0.61	5.22	5.46
Rom Kloew Water Quality Control Plant	0.22	0.46	2.7	2.94
Bon Kai Water Quality Control Plant	2.07	2.28	5	5.2
Bang Bua Water Quality Control Plant	0.6	0.78	3.41	3.59
Dindang Water Quality Control Plant	1.05	1.3	5.83	6.08

Source: Water Management Department of Bangkok Metropolitan Administration

2.4.2 Demand Side

Besides setting a charge rate according to the costs of wastewater treatment, policy makers must consider the demand side of charge paying. The study of "Willingness to Pay (WTP)" for improved water service and wastewater treatment is also important in this sense. Willingness to pay is the largest amount of money that an individual or group could pay, along with a change in policy, without being made worse off. It is therefore a monetary measure of the benefit and cost of the policy changed. For instance, if WTP is negative, it measures its costs. Economists can use WTP to estimate the willingness of Bangkok residents to pay for improved water quality by conduction a contingent valuation survey.

User charge for a plant is quite new for Bangkok. People who live farther away from the water courses usually have a low degree of awareness of the problems and are willing to pay only the minimum price. There are several methods which introduce determining the willingness to pay for the charge. For example, Tapvong and Kruavan (2003) researched about the willingness to pay for water improvement of Chao Phraya River by using contingent valuation method (CVM). Roomratanapun (2000) used questionnaire survey and the willingness-to-pay method. The study also used hypothetical-direct-question, bidding-game and scenario-building techniques. The research showed that the Bangkok residents preferred the convenience flat rate system. Metcalf & Eddy International, Inc. (1998) also did a research on WTP of wastewater treatment in Bangkok. The research is categorized by 2 focus groups. The first group consisted of Bangkok residential households and people who lived in commercial building such as townhouses. The second group represented the owner of businesses which wastewater discharges had already been controlled such as private educational institution, department store, hotel, hospital and restaurant.

Tapvong and Kruavan (2003) studied on 1100 households in 20 districts where central wastewater treatment facilities existed. They found that 60 percent of the focus groups agreed the existing water quality in Bangkok is very poor. They found that 78 percent willing and able to pay, 3.3 percent willing but unable to pay, 13 percent able but unwilling to pay, and 4.5 percent unable and unwilling to pay. Moreover, they found that 89 percent of people in Bangkok were willing to pay in the total of 100 to 115 baht per month per household. Additionally, Roomratanapun (2000) interviewed a random sample of 367 respondents focused only on Phayathai district which 157 living near a klong and 210 living away more than 100 meters from a klong. The study identified the factors that contribute to a positive attitude among an urban population to urban environmental improvement. His research discovered that average of willing to pay for wastewater service were 86.87 baht per month which consisted of paying for direct personal benefits 36.23 baht, followed by paying for society benefits 35.16 baht and paying for indirect personal benefits 15.53 baht. In other words, the overall willingness to pay for wastewater treatment was 3.28 baht per m^3, but the amounts varied widely. Unlike Tapvong and Kruavan (2003), this research found that distance to a waster courses and the experience of polluted surface water did not have any influence on the preferences. Monthly household income, level of education and environmental awareness were the principal factors that influenced acceptability of various aspects of the wastewater treatment system.

Metcalf & Eddy International, Inc. (1998)'s research found that about 90 percent of all interviewees agreed that wastewater from households was the main cause of water pollution in Bangkok, and about 80 percent of all interviewees agreed that BMA should collect the wastewater treatment service charges from the households in the serviced areas. It also showed that Bangkok resident willing to pay less than one percent of their income per month. The willingness to pay of the residential group was 1.8 baht per m^3 in average. However, the second group was less willing to pay for the treatment services because they had already been controlled from the BMA. Also, some buildings already set up their own wastewater treatment systems. The WTP of this group were range between 0.32 baht per m^3 to 1.28 baht per m^3.

Then Tapvong and Kruavan (2003) furthered their research on charge collection method and basis of the wastewater treatment charge. They found that half of respondents preferred a separate bill for wastewater treatment. Additionally, the research found that the interviewees had six different preference basses of the charge. Twenty-Five percent of all respondents preferred that the treatment charge should base on amount of tap water used while 21 percent preferred fixed rate. About 12 percent chose that types of house should be the appropriated basis of the charge and 2 percent though that family size should be the most proper basis. The amount of wastewater was one of the bases of the charges that interviewees suggested. It accounted for 10 percent of all while another 30 percent of the respondents thought that they should have a chance to choose the basis of the charge themselves.

Roomratanapun (2000) claimed that two-thirds (63.2 percent) of the respondents preferred a separate collection system and expressed a preference for the Bangkok Metropolitan Administration as the charge-collecting agency. However, the inclusion of the wastewater treatment charge in the water bill is more efficient, but the advantage of a separate collection is that the payer can clearly see what they are paying for, another application of the polluter-pays principle. The focus groups divided their preferences into 3 options which were a specific tax to the residents of the BMA (33.5 percent), a specific charge paid by households in the BMA (31.6 percent) and the general revenues of the central government (21.2 percent).

Table 2.5 shows the estimated costs of treatment service in different sources of wastewater and expected treatment charges which BMA plans to impose on Bangkok's residents. Considering only the comparison of the first case's cost (cover only operation cost and maintenance cost) and expected charge rates, most rates of the service charges per m^3 could not cover the operation cost and maintenance cost of running the treatment services. As a result, according to these rates, BMA still needs a subsidy for running the wastewater treatment plants and support the setting up new pipe systems. Additionally, BMA has to spare some budgets for new plants construction regarding to its master plans.

Table 2.5: Cost and Expected Wastewater Treatment Charges

Classified by User Class

	% of Wastewater Discharged	Wastewater Treatment Service Cost (Baht/ m^3)						Expected Wastewater Treatment Charges (Baht/ m^3)
		Case 1	Case 2	Case 3		Case 4		
				Excluded Land Cost	Included Land Cost	Excluded Land Cost	Included Land Cost	
Residential	54.12	3.03	3.95	7.25	8.01	8.17	8.93	2
Government & Business	36.5	3.03	3.95	7.25	8.01	8.17	8.93	2
Hospital	0.84	6.07	7.9	10.29	11.05	12.12	12.88	4
Hotel	3.99	6.07	7.9	10.29	11.05	12.12	12.88	4
Department Store	1.37	3.03	3.95	7.25	8.01	8.17	8.93	4
Fresh Market	0.35	36.41	47.43	40.63	41.39	51.65	52.41	4
Restaurant	0.28	18.21	23.71	22.43	23.19	27.93	25.58	2 or 4**
Message & Entertainment Places	0.36	3.03	3.95	7.25	8.01	8.17	8.93	4
Industries*	2.19	3.03	3.95	7.25	8.01	8.17	8.93	4 or 6 or 8***
Total	100							

*The wastewater treatment charge in industry sector apply only for industries which pass the standard tests

** Depend on square meter of the restaurant

*** Depend on quantities of wastewater discharged from the industries

Source: Water Management Division, Ministry of Environment and Natural Resources

BMA plans to levy the treatment charge on households and residential area in Bangkok first because the wastewater is mostly discharged from this area compared to other areas. The commercial area, industrial area and other area, which also generate wastewater to the environment and are accounted about 40 percent of wastewater generation, will be charged in the next step. Since the current legislation does not support the local government to impose environmental charges on every kind of economic activities, the federal government must change some legislation to support BMA to collect the charge from industrial and some commercial activities before BMA impose the charge on these area. Therefore, only residential area will be charged at this present. All wastewater from industrial areas are controlled by Pollution Control Department. It is also difficult to transfer the responsibility from federal government to local government, BMA. Additionally, hospitals, hotels, department stores, and restaurant are already controlled by BMA's command and control regulations. They have to establish the individual treatment system in order to treat the wastewater before discharging to the river. Consequently, imposing the treatment charge to their water consumption may be objection and it is not possible to impose the charge on business, hospital, hotel department stores and restaurants in the near future.

Considering the rates in Table 2.5, which BMA will impose on businesses, hospitals, hotels, department stores, and restaurants, the author found that the rates are unacceptable for these groups because willingness to pays are less than the imposing rates. In order to avoid potential conflict, BMA should do more researches on willingness to pay, public hearing and clearly present cost and benefit of the policy before announcing the charge imposition.

This paper considers only the charge on households' water consumptions. From willingness to pay researches of Bangkok resident lived in Bangkok, the author found that they were 100 to 115 baht per month (Tapvong and Kruavan, 2003), 3.28 baht per m^3 (Roomratanapan, 2000), and 1.8 baht per m^3 (Metcalf & Eddy, 1998). As a result, the residential charge rate at 2 baht per m^3 should be satisfied for both BMA and the residents. BMA has not yet researched on a wastewater treatment charge's effects on consumer behaviors and welfare changes. Although the rate at 2 baht per m^3 will be fulfilled, the welfare effects are still ambiguous. At this rate, social welfare may loss or gain. If the policy does not change people's water usage behavior, that policy is not effective. Then this policy only helps increasing the BMA's incomes but doesn't solve environmental problem. This research objects to develop the tools to analysis the welfare effect of the wastewater treatment charge policy whether it affects welfare gain or it is just the tools for BMA's to increase its revenues.

CHAPTER III

LITERATURE REVIEW

3.1 Tax Incidence Concept

The effect of taxes, user fees, and user charges are theoretically the same in an economic sense. These governmental policies have either direct or indirect negative effect on personal income. In order to analyze the economic effects of taxes, charges and fees, the tax incidence theory helps to clarify the way in which the tools actually affect individuals' well-being. Tax incidence theory is the study of the final burden of a tax and a fee after considering all market reactions to it. The theory of tax incidence is one of the oldest subjects of study in public finance. Ramsey (1927) derivation of an optimal tax formula referred to as the Ramsey Rule. Then Pigou (1947) introduced to the Pigouvian Tax which is levied to correct the negative externalities of the market activity. Pigou's concept is to internalize the externality effects and bring better allocative efficiency. Although deadweight loss calculation had been developed earlier by Fisher (1937) and Hicks (1956), the dead weight loss triangles made popular by the work of Harberger (1964). He developed a criterion for indicating whether the utility of a single consumer has increased or decreased from one situation compared to another situation by using Taylor series expansion. It shows the partial equilibrium effects of taxes on prices and quantities and the associated effects on deadweight losses. However, his welfare measure has the desirable property of being antisymmetric. He also worked on the incidence of the corporate income tax and simple general equilibrium models.

In addition, the generalization of excess burden formula measures how many units of income an individual must be given to move from a reference utility level to another utility level. Corlett and Hague (1953) made a seminal contribution to the theory of the efficient design of multiproduct excise taxes when some products are non – taxable or are taxed at an arbitrary rate. Then Diamond and Mirlees (1971) modernized

Ramsey's analysis. They showed the optimality of maintaining production efficiency, and derived the conditions that generalized the traditional inverse elasticity rules for optimal taxation.

Indeed, the impact of the charge will depend on the elasticities of the demand and supply. Intuitively, the actor with the more elastic response will be able more easily to push away the burden of the charge, leaving the actor with less elastic responses still in place to pay the most.

Figure 3.1 shows the tax incidences when tax imposed on households' water used. Metropolitan Water Authority responds for producing tap water. In this case, this paper assumes that MWA can infinitely supply on tap water to Bangkok resident, so the tap water supply is a horizontal curve. Since tap water is considered a necessity good, the demand of tap water is a steeply downward sloping curve. Households are the consumers and consume tap water according to the demand. In order to reduce water pollution, Bangkok Metropolitan Administration will impose wastewater treatment charge on tap water used of households. The policy has the effect of decreasing on tap water consumption of households, which directly causes a reduction in wastewater discharged from households.

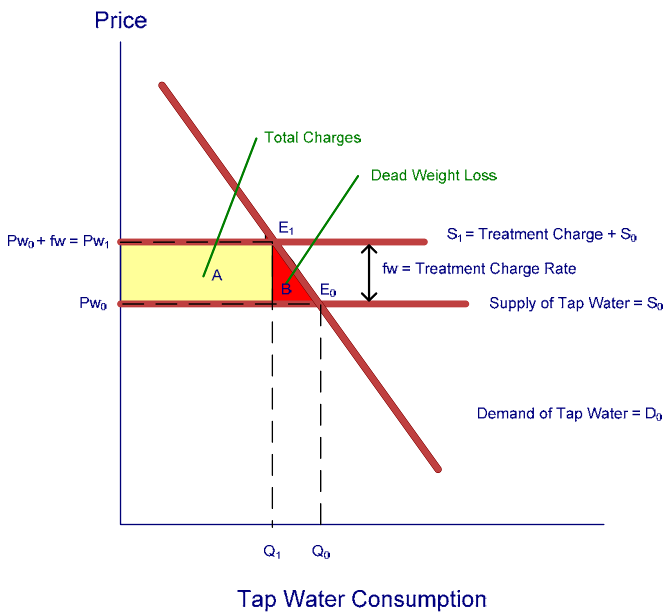


Figure 3.1: Diagram Shows Tax Incidence

Assume that D_0 is a demand curve of tap water and S_0 is a supply curve of tap water before BMA imposes the wastewater treatment charge. D_0 also reflects private marginal benefit of tap water consumption of households and S_0 reflects marginal cost of tap water production. The equilibrium before imposing the charge is at E_0. The price at the equilibrium point is P_0 and households consume tap water at Q_0. Consuming tap water creates water pollution and an external cost to the household itself and other consumers. To reduce wastewater discharged from households, BMA then imposes the wastewater treatment charge on tap water used on households at the rate fw baht per m^3. This policy increases price of water and affects supply, S_0, to shift up to S_1 and the distance between S_0 and S_1 equal to fw. In order words, BMA should impose the charge at rate which equals externality costs. In other words, the equilibrium point changes from E_0 to E_1 after BMA imposing the charge. Additionally, the price at the equilibrium point change to P_1 and households decrease consuming tap water from Q_0 to Q_1. Since tap water is necessity goods, so demand is generally inelastic. Morevover, the supply for water is a horizontal line. Households, therefore, bear all of the charge incidence in this case. The charge, which BMA collects if tap water consuming level is at Q_1, equals area A. The deadweight loss of the charge equals to B. In conclusion, the entire burden of the charge falls on households.

3.2 Incidence Measurement Methods

An ideal measure of tax incidence would begin by calculating the general – equilibrium changes in prices that would occur throughout the economy in response to the change in the tax rate, and then calculate the effects of those price changes on households' welfare. Then the welfare economics mostly discuss about the problem of welfare measurement. In this study, the obvious effect of an imposing wastewater treatment charge is to raise the water price, thus imposing a burden on water consumption of households. Using an incidence measure is important for measuring both the overall burden and the distribution of that burden. There are two main methods for the measurement. The classical measure of welfare change examined in elementary courses is consumer's surplus (CS). For example, in the case of imposing taxes, most taxes will affect individuals' welfare because they reduce purchasing power, also because they provide incentives to change behavior. The change in consumer surplus is defined as change in the area under the demand curve. It is also known as Marshall's consumer's surplus. Its relationship to Hicksian (1956) notions of compensating and equivalent variations is the measurement of the change in utility result from some policies which seems sensible and more clarified in the sense of welfare change. The compensating variation (CV) uses the new prices as the base and asks what income change would be necessary to compensate the consumer for the price change. Therefore, CV is proper for measuring welfare changed when the tax is already imposed. The second measure is known as the equivalent variation (EV). It uses the current prices as the base and asks what income change at the current prices would be equivalent to the proposed change in terms of its impact on utility.

Consumer's surplus measurement is different from the equivalent variation and compensating variation. Since equivalent and compensating variation is the area under the compensated demand curve but consumer surplus is the area under the uncompensated demand curve unless the income elasticity of demand is zero. Consumer surplus theoretically has some problems because income effects can lead to inconsistencies in the relationship between utility changes and the monetary measure of consumer surplus. Also, consumer surplus does not come directly from underlying consumer preferences. As a result, it has the serious flow of path – dependence problem. The equivalent and compensating variation avoid these potential problems. Consequently, this paper measures the welfare change in household sector by using equivalent variation. However, the change in consumer surplus will be a close approximation to the equivalent variation.

The equivalent variation (EV) is more suitable than compensating variation (CV) for measuring welfare changed when government want to impose the taxes because it measures welfare change based on an initial equilibrium prices rather than new equilibrium prices. This paper, consequently, uses EV for measuring the change in welfare of Bangkok's residents when BMA imposes wastewater treatment charge on households in Bangkok. To calculate the equivalent variation, however, requires an estimate of the indirect utility function, which is often unavailable.

$$EV = \mu(p^0; p^1, E^1) - \mu(p^0; p^0, E^0)$$
$$EV = e(p^1, u^1) - e(p^0, u^1)$$
$$EV = E^1 - e(p^0, u^1)$$

For the purpose of measuring welfare changes, using compensated demand curve (Hicksian Demand Curve) is more appropriate. Since, compensated demand curve drawn on the assumption that other prices and utility are held constant, and income effects of price changes are compensated for movement along the curve, it reflects only substitution effects of changing prices. Therefore, compensated demand curve can show the effect of tax policies in a very simple way and provide a way to measure its costs.

3.3 Externality Concept

One of the greatest areas of welfare economics is externalities. Once the new welfare economics was developed, economists found that the presence of external economies and diseconomies was one of the major exceptions of a Pareto Optimum. Externalities occur when the consumption or production of a good impacts on people other than the producers or consumers that are participating in the market for that good. They are the side effects borne by third parties. In each case, the firms or the individuals will bear some form of cost known as the external cost. In addition to negative externalities, there are positive externalities: the benefits accruing to non-participants in the market place arising from the consumption and production of goods and services. These are the external benefits. The most general definition is "a technological externality exists when some activity of party A imposes a cost or benefit on party B for which A is not charged or compensated by the price system of a market economy." (Whitcomb, 1972) There are some noteworthy definitions of externalities from other economists. For example,

> "Externalities occur when one person's actions affect another person's well-being and the relevant costs and benefits are not reflected in market prices. A positive externality arises when other get benefits from one's action. A negative externality arises when one person's actions harm another. When polluting, factory owners may not consider the costs that pollution imposes on others." (Tyler, 1976)

> "An external economy is an event which confers an appreciable benefit or inflicts an appreciable damage on some person or persons who were not fully consenting parties in reaching the decision of decision which led directly or indirectly to the event" (Meade, 1973)

Here are some examples of various types of externalities:

- Producer on producer externalities: A copper smelting firm contributing to acid rain which affects the crops of surrounding farmers;
- Producer on consumer externalities: A copper smelting firm causing air pollution that causes tuberculosis in surrounding households;
- Consumer on consumer externalities: Smokers causing smoking-related ailments in non-smokers;
- Consumers on producer externalities: Passenger cars causing congestion and slowing business traffic.

This paper focuses on consumer on consumer externalities. Emphasized on the household's water consumption creates wastewater which causes water pollution to surrounding environment and also leads to many problems to other people in the society.

Since the quality of the environment also has a public goods characters because of its non-rivalness (one consuming does not reduce the utility which other may derive from it), an economy, in the absence of taxes, fees, or charges with an externality is not efficient, because the externality itself creates a distortion. On the other hand, this distortion can be corrected by using fiscal tools that brings the economy back to the first-best. Basic welfare economics tell that many types of externalities can be remedied by proper use of corrective taxes and subsidies.

Economists believe that an efficient way to reach environmental goals is economic instrument, environmental taxes, charges and fees. The tools may create the incentives necessary to reduce environmentally damaging activities and simultaneously raise revenues that can be used to reduce other distorted taxes. Consequently, the government could use these tools to deter activities that have negative externalities, and subsidies to encourage activities that have positive externalities.

Taxes that control externalities were created by Pigou. The Pigovian approach to externalities is to impose taxes or subsidies on the firms or consumers experiencing externalities so as to restore them to a Pareto optimum at equilibrium. In order to use pollution tax, charge and fee to protect environmental quality, government should select a tax base and rate so that the external cost of the activity is internalized. The appropriate for the rate should be the damage caused such as the volume of emissions. The rate is set equal to marginal damage, which firms or consumers generate.

Then this amount of money becomes part of marginal private cost. In this case, the policy does not change social marginal costs because it is simply a transfer from one part of society, to another part of society. This policy forces firms or consumers internalize the damage done to others.

3.4 Literature on Analytical Methods

Normally, any tax policies cause distortion in consumption and production in the economy. Unlike other tax policies, environmental taxes, fees and charges have second dividend, the revenue raised together with reducing existing distortion taxes. Goulder (1996) said environmental taxes, fees and charges can finance a reduction of a distortionary tax and yield a non-negative welfare cost. Moreover, overall competitiveness of countries may be improved by well designed taxes which can motivate innovation and possibly encourage structural change towards sustainable development.

Western countries such as Scandinavian countries, Austria, France, Germany, United Kingdom, and United States have utilized environmental taxes, fees and charges for more than a decade. Some countries in Asia, China and Japan, as well as Australia have started to implement new environmental tax policies and abolish their environmental damage policies. Taxes on carbon dioxide, sulfur dioxide, leaded fuel, toxic waste and water pollution are good examples of the accepted environmental taxes, fees and charges.

There are several methods to identify the impacts of the policies. Mostly, the research studies used interview focus group on ETR, CGE (Computable General Equilibrium), IO Analysis (Input – Output Analysis), GTAP (Global Trade Analysis Project) and partial equilibrium analysis. This section will discuss and compare advantage and disadvantage of these methods.

3.4.1 Computable General Equilibrium Model (CGE)

There have been other national and international studies on the effects of environmental taxes, fees and charges using CGE approach to explain the costs and effects of environmental taxes, fees and charges such as Jorgenson and Wilcoxen (1993), Xie and Saltzman (2000), Hill (1998), Zhang (1996) and Kumbaroglu (2003).

CGE model specifies technical possibilities for industries and for consumers using either a calibration or an econometric approach. Though CGE is complicated, it is good at measuring the distributional impact of policy reforms in a completely specified model of the economy. Most CGE models focus on long term effects as well as they measure indirect effects of policy changes. The models determine the evolution of the prices and qualities of products produced, and sometimes the evolution of stocks such as the capital supply. CGE approach is superior to other modeling strategies because the models vary enormously in sectoral detail. The model can determine the responsive of various price and policy variables in many ways.

However, CGE model has some cautions. For example, the key parameters often lack empirical validation because they are calibrated rather than econometrically estimated. Also, CGE model does not investigate the difference in impact of the taxes on detailed sectors of the economy. This is due to the prohibitive computational and data requirements necessary for a detailed analysis. Second, because of their sophistication, CGE model can give a spurious impression of forecasting precision. Many of the central behavioral coefficients needed to do forecasting are calibrated. The calibration procedure often borrows a variety of elasticities from other studies, and the values of elasticities that are eventually chosen are difficult to defend. Sometimes the key parameters are disputed. For instance, some researches conclude that capital and energy are long term substitutes, while several papers suggest that they are complements.

Besides, CGE models do not inherently fail. They may offer the best hope of capturing such effects. From the research studies, it is clear that the behavioral responses critical to long – run and environmental policy have not yet been incorporated into the leading models in the field.

3.4.2 Input – Output Model (IO)

Economic systems must be grounded in facts. Therefore, theory follows as an instrument that helps explain facts. Input – Output Model (IO) allowed explicit solution of a multisectoral model to be computed, so the tool of IO has shaped the knowledge of how and in what measure the constituent parts of an economy interact. More than a tool of analysis, it can also reveal what combination of resources, called inputs, is required to achieve desired production goals, called outputs. IO analysis plays a central role in planning and even in prediction. Today, more than 60 nations construct input – output tables to guide them in making economic decisions.

Originally, an input – output table is a suitable model of the inter-industry relationships in an economy. The structure of the table is a matrix that lists economic sectors in the same sequence in both vertically and horizontally. Input – output analysis is an application of the modern systems approach that can describe the whole economy in terms of individual sector. It provides the means for observing and analyzing simultaneously the quantitative relationship between hundreds of variables while preserving throughout all the operation the identity of each of them.

There are plenty of IO models for analyzing environmental policies. Leontief Model is one of the most accepted IO models. It is appropriate to regard Leontief IO analysis as a form of CGE model in which the behavioral assumptions have been simplified to allow results to be more easily calculated. The computational and data demands of CGE models usually limit them of a fairly small number of sectors and fairly simple interactions between those. Where inter-industry material flows are important or a high degree of sectoral disaggregation is necessary, the IO analysis often remains the best tool available.

IO approaches have been used for a number of research studies to examine various questions relating to pollution emissions. These include distributional analysis by industry (both within industry and between industry effects) such as Goulder (1995) and Kardkarnkai (1992). Also, Nakamura and Kondo (2002) used IO model for analyzing environmental impacts and economic cost of waste treatment.

However, IO analysis is not suitable for assessing the impact of an environmental tax reform on macroeconomic aggregates. Generally, although it can be quite helpful in tracing the effect of exogenously determined changes through the economy, IO analysis treats these quantities as fixed. Also, whether the impact is positive or negative depends on the structure and assumption of the model. For example, the way the tax revenue is returned to the economy.

Also, there are several limitations for IO analysis. For instance, the fixed technological coefficients imply that all manufacturing inputs must be used in a fixed ratio to output. Thus, IO analysis is more appropriate for short term than for long term analysis. The results from IO analysis often overstate negative impacts of an increase when it is used for estimating the effects of the environmental taxes, fees and charges.

3.4.3 Interview Focus Group on Environmental Tax Reform (ETR)

Most of researches used interview focus group on ETR to estimate the effects of environmental policies are in European countries. ETR aims to address the question of how to make such a policy more acceptable. The researches described the base around the use of interviews and focus groups to inform the assessment of social responses to the policies and the development of improved designs for them. Interviews were conducted with selected policy makers and companies. For example, Dresner, Jackson, and Gilbert (2004) used ETR to define the social responses to fuel taxs and climate change levy in United Kingdom. Also, Deroubaix and Leveque (2004) used ETR to analyze French's energy consumption tax impacts. The issues emerged relating to awareness, trust, understanding of the purpose, visibility, incentives, and levels of taxation, terminology, communication about ETR and the use of alternative instruments. Together with these similarities, a pattern of differences between the countries can also be seen. Although ETR is widely accepted to be a policy with desirable effect, its implementation has been limited by problems of political acceptability.

3.4.4 Global Trade Analysis Project (GTAP)

The centerpiece of the GTAP project is a global data base describing bilateral trade patterns, production, consumption and intermediate use of commodities and services. The standard GTAP model is a multiregion, multisector, computable general equilibrium model, with perfect competition and constant returns to scale. The GTAP model and data base has also been extended to evaluate costs of abatement and to assess the spill-over effects of greenhouse gas (GHG) abatement policies via international trade and sectoral interaction. During the past decade, the Global Trade Analysis Project has filled an important need in the integrated assessment (IA) community by providing regular updates of world-wide input-output and bilateral trade data sets with significant disaggregation of regions and sectors, plus energy volume data.

3.4.5 Partial Equilibrium Methods

Besides, Partial Equilibrium Analysis also is accepted used for investigating the policies impacts. Most of them use estimating demand function to identify consumer responses of the policies. For example, Brannlund and Nordstrom (2004) used a household demand model to analyze consumer behaviors and welfare effects due to the carbon taxes on Sweden. Creedy (1997) used Linear Expenditure System to measure the welfare effect of carbon tax. West and Williams (2004) applied consumer demand system by using Consumer Expenditure Survey data to find the incidence of environmental taxes on gasoline, other goods and leisure in Taxes. There are more analysis methods used the partial equilibrium methods for analysis environmental policies in several countries such as dynamic game approach model by Rubio and Escriche (2001). They used the model to analysis the pigouvian tax on stock externalities and polluting non – renewable resources.

Table 3.1: Sample of the Previous Researches on Environmental Policy in Thailand and Other Countries

Country	Tax Rate	Tax Based	Objective of Taxes	Objective of Researches	Model
China Xie and Saltzman (2000)	Increase tax rate from 0.20 yuan per ton by 50, 100, 150 and 200 percent	Tax on household wastewater discharge and trash	To raise environmental treatment	To develop an environmental model for environmental policy analysis	GATP and CGE
Germany Bohringer, Rutherford (1997)		CO^2 emissions in domestic production and consumption	Reduction of CO^2 emissions by 10, 20 and 30 percent	To analyze the welfare costs of issuing a carbon tax	General Equilibrium with CES consumers' demand
New Zealand Scrimgeour, Oxley, Fatai (2004)		Energy Used, Carbon Emission, and Petroleum Product	Reducing GHG emission	To re-assess the effectiveness of environmental tax	CGE
Sweden Hill (1998)	35 percent	CO^2 Emissions and Fossil Fuel Products	Reduce CO^2 emissions between 5 to 25 percent	To examine the emission reduction target levels	CGE
Thailand Memapan (1996)	30 percent per kilo CO^2	Fuel		To examine the impact of CO2 tax on economy	Partial Equilibrium Model
Turkey Kumbaroglu (2003)		NOx emission, on SOx emission, and on all air pollution emission	Pollutant emission reduction	To explore economic effects of environmental taxation	CGE with CES Production Function

3.5 International Experiences Survey on Environmental Policies Reforms

This section discusses briefly of international experiences and research studies in Sweden, Turkey, France, China, Germany and New Zealand and how environmental taxation as a policy instrument guides the countries into a path of sustainable development. Although Thailand did not have any direct environmental taxes, fees and charges like other countries, there were research papers on the impact of indirect environmental taxes such as fuel taxes (Memapan, 1996). He analyzed the effects of fuel taxes on economic sectors in Thailand. Moreover, Kardkarnkai (1992) researched impact of waste disposal charge on Thailand industries. Therefore, the discussion also includes the effect of indirect environmental taxes on economy in Thailand. This section provides historical, theoretical, and empirical overview of the tax policies´ effectiveness on economic indicators such as gross domestic product (GDP), consumption, production, investment and also environmental effects.

Table 3.1 shows the sample of some researches on environmental policies in many countries. According to the table, there are several objectives, methods, tax based and tax rates. Mostly, the researches used CGE (Computable General Equilibrium), and IO Analysis (Input – Output Analysis) methods as tools to estimate the impacts of the policies. Some research studies which analyzed the impact of the policy on trade or international impacts, normally used GTAP (Global Trade Analysis Project). Still, the interview focus group on ETR method also accepted in European countries. For Thailand, Memapan (1996) used a partial equilibrium model with AIDS (Almost Ideal Demand System) to analyze the effects of fuel taxes on outputs. Kardkarnkai (1992) used IO analysis to determine the impact of environmental policy on Thai's industries. The study will discuss and compare advantages and disadvantages of these tools in chapter 6. From the literatures, the author concludes that the results from those researches are different and vary country by country. Some researches found that the environmental policy causes welfare gain but some found that the policy affected welfare loss in their countries. Since the limitations of data are difference in each country, also tax based in each research is difference, different researches have different results. Moreover, the policies scenarios and methodologies which used in the researches are differences. Next section presents advantage and disadvantage of those researches. Also, it summarizes the effects of the environmental policies on pollution emission, production, consumption, GDP, investment, government revenue and expenditure, and welfare.

3.5.1 Effect on Pollution Emissions and Environment Impacts

The direct effects of the environmental taxes, fees and charges are to reduce pollution emissions. Generally, imposing an environmental tax allows each emitter to reduce at a rate that is the most cost effective for them. An emitter heavily dependent on pollution emissions would reduce as much as possible to avoid the tax and pay a tax on their remaining emissions. On the other hand, a pollution emitting industry that can rely on alternative energy sources might reduce emissions completely and avoid paying the tax. For example, when carbon tax is imposed, bio-ethanol becomes economically feasible for public vehicles. Though the alternative technology would have higher initial costs, implementing the new technology would be cheaper than paying environmental taxes, fees and charges over a period of a few years. As a result, we can say environmental taxes, fees and charges could also encourage innovation in new technology.

All previous research studies agreed that either imposing new environmental taxes, fees and charges or increasing existing environmental tax rates decrease the level of pollution generated as well as increase cleanup activities (improve environmental quality). For instance, the cleanup rate in China increased from 37.7 percent to 65.4 percent and the wastewater treatment slightly increased from 4.5 billion tons to 4.7 billion tons per day after increasing wastewater taxes. Also, the research studies in Germany, France, and New Zealand had the same results.

Hill (1998) found that tax on carbon dioxide emissions in Sweden reduced carbon dioxide emissions, yet the tax caused an increase in sulfur dioxide and nitrogen oxide emissions instead. Kumbaroglu (2003) declared that SO_2 tax decreased the SO_2 emissions while NO_2 tax had no significant effect on NO_2 emissions. However, all tax scenarios showed that the reduction in energy use was induced by the emission taxes. Memapan (1996) said that the indirect carbon tax in Thailand decreased carbon dioxide emissions from 350,000 million tons of CO_2 to 260,000 million tons CO_2 or about 25 percent reduction in Thailand.

However, Xie and Saltzman (2000) found that the environmental tax policies in China were not effective because they did not reach extensively to the polluting sectors. The current pollution levy systems in China were ineffective in reducing pollution emissions because of weak legal enforcement of pollution emission taxation. Moreover, Xie and Saltzman explained that increase environmental tax rate hurts non-polluting sectors but does not affect pollution-intensive sectors because all sectors are assumed to compete for capital resources under a tight capital supply constraint. When capital-intensive sectors, like energy and mining sectors, become more cost-benefit effective due to the decrease in their pollution abatement costs, they have the advantage of gaining more capital to increase their production.

3.5.2 <u>Effect on Production and Output</u>

In general, levying any taxes, fees and charges would decrease GDP and cause output levels to decrease. However, if revenues from the taxes were used to subsidy non-polluting industries, it should increase output levels of those sectors. In case of China, Xie and Saltzman (2000) found that the total output dropped from 41,806 hundred million yuan to 41,713 hundred million yuan because of their model given the limited capital resources available in the economy. Moreover, they stated that if government increased emission taxes, it would cause a steady decrease in production and output level of both polluting and non-polluting sectors such as agriculture, mining, light and heavy industries, construction and services. However, they found that increasing the rates caused an increase in production and output level of the energy sector, one of polluting sectors.

Hill (1998) and Bohringer & Rutherford (1997) agreed that imposing environmental taxes, fees and charges would reduce production and output level in Sweden and Germany because of higher cost of production even though it lowered labor costs. Hill found that there were large reductions in production of fossil fuel products and domestic output level in the mining sector and the steel sector. In addition, Scrimgeour, Oxley, Fatai (2004) proved that tax on petroleum product and on carbon emission reduced output level in mining & metal products and electricity & gas by an average of two percent.

On the other hand, Bosquet and Hoerner (2003) declared that outputs would increase after imposing environmental taxes, fees and charges on producers because they assumed that the revenue recycling will compensate to the cuts in social security contributions from employers. This increased the employment rate and output level which caused increasing in output level. Furthermore, Kumbaroglu (2003) declared that the taxes increased gross production of non-NO_x-intensive in Turkey by using substitute fuels which helped less cost of production.

In case of Thailand, the research results showed that the indirect carbon taxes increased output of beverage, cigarette, government service, chemicals, and infrastructure by 2 percent to 9 percent. Then the taxes decreased output of agriculture about 3 percent to 8 percent as well as decreased output of food and transportation industries for about less than 3 percent.

3.5.3 Effect on Gross Domestic Product (GDP)

Most researches found that imposing environmental taxes, fees and charges on either production or consumption caused an increase in price index. Likewise, the taxes reduced economic activity in high energy intensive industries, so there is a loss of efficiency in the economy as is evident via the reduction in real GDP. For example, Scrimgeour, Oxley, Fatai (2004) stated that levying any environmental taxes, charges, and fees affected the real GDP of New Zealand to decrease by 0.385 percent. Xie and

Saltzman (2000) and Kumbaroglu (2003) also agreed that imposing environmental taxes, fees and charges would decrease GDP in China from 17,272 hundred million yuan to 17,227 hundred million yuan and in Turkey increased GDP lying in the range 3.6 to 6.9 percent.

Moreover, Kumbaroglu did more research on the impacts of difference environmental tax policy scenarios and found more interesting results. Kumbaroglu (2003) assumed there were three tax scenarios which were tax on nitrogen oxide (NO_x) emissions only, tax on sulphurdioxide (SO_2) emissions only and tax on all emissions equally. The results as showed in all scenarios there were decreases in GDP. Additionally, all emission tax policy achieved more emission reductions with less GDP loss than nitrogen oxide emission tax and sulphur dioxide emission tax scenarios in short term.

The highest GDP loss caused by emission taxes was about 1.5 percent, but the GDP loss induced by sulphur emission taxes was much higher. Moreover, if policy makers introduced sulphur emission taxes instead of emission tax to reducing SO_2 emissions, the losses in GDP to be expected would roughly be four times higher.

Nonetheless, Bosquet and Hoerner (2003) argued that imposing environmental taxes, fees and charges could increase GDP by 2.5 percent. Furthermore, Kim (2002) addressed that more stringent environmental policy may boost economic growth in the long run. Memapan (1996) also found that the effect on GDP from imposing taxes was likely small in Thailand. GDP increased slightly up to 1 percent or increased from 2,730,947 to 2,733,763 million baht in case of imposing indirect environmental taxes compared to not imposing.

3.5.4 Effect on Consumption

Environmental taxes, fees and charges are usually used for controlling the negative externalities, so the taxes would cause people to reduce the consumption externalities. In New Zealand, Scrimgeour, Oxley, Fatai (2004) found that tax on energy use, tax on petroleum products and tax on CO2 emissions relatively decreased incomes and purchasing power. Hence, it affected reducing household consumption as a whole not only the consumption of polluting products. However, the most impact was on petroleum consumption sectors such as a transportation sector in which there was about 1.6 percent reduction. Also in Turkey, Kumbaroglu (2003) stated that emission taxes reduced the use of solids fuels faster than oil and gas.

On the other hand, Hill (1998) argued that tax on fossil fuel products benefited energy consumers in transport, fishing, and private consumers. In Sweden, since there was revenue recycling to subsidy labor taxes for workers caused relatively increasing workers' wages, the positive effects on consumption would occur. However, there was no effect on value of consumption in Thailand. The consumption was constant at 2,232,491 million baht either imposing taxes or not. However, the taxes caused an increase in consumption of chemical products, government services, beverage, cigarette, construction, infrastructure, mining and textile. Conversely, taxes decreased consumption of agricultural, fishing, food, plastic, and communication products. In addition, Memapan (1996) said that Thai people spent less on food, transportation, and leisure. They would spend more on beverage, housing, fuel, and health in case that government imposed taxes.

3.5.5 Effect on Investment

Theoretically, levying any taxes causes a decrease in investments because of a general shrinkage of the economy. From most previous research studies it was found that unlike other distortionary taxes, emission taxes could reduce investment in the short and medium term whereas they could cause a slight increase in investments in the long term. If government reinvested the revenue from the taxes into international, political, social programs and technology innovations, environmental tax would introduce a boost in clean technologies and create economic benefits. Consequently, investment could decline in the long term only because of the policies did not promote abatement technology installation for pollution emissions.

Xie and Saltzman (2000) and Kumbaroglu (2003) concurred that those environmental taxes, fees and charges would decrease investment in short term but increase investment in long term. They stated that environmental taxes, fees and charges decreased in cleanup price and decreased in pollution abatement costs of firms. Therefore, these stimulate investment in waste water treatment sectors in China and investment in green technology in Turkey. Moreover, Xie and Saltzman thought that the taxes provide a significant source for a special environmental protection fund, which mainly invest in industrial pollution control activities. However, Kumbaroglu found that sulphur emission taxes in Turkey reduced investments in both short and long terms because this scenario did not encourage abatement technology.

In short term, Xie found that the investment in China decreased by 2,000 million yuan after imposing the wastewater treatment charges. Also, Scrimgeour, Oxley, Fatai (2004) explained decreasing in investment by falling in capital stock in short term. They said that investment in New Zealand fell between 0.51 percent to 0.54 percent after imposing taxes on petroleum products and carbon emission.

3.5.6 Effect on Government Revenues and Government Expenditures

Normally, the environmental taxes, fees and charges increase government revenues. The revenues should be used for reducing other existing distortionary taxes. In other words, environmental tax revenue corrected pre-existing inefficiencies of non-environmental taxes. Moreover, the revenues from emission taxes provided a significant source for a special environmental protection fund which mainly invests in industrial pollution control activities.

From the previous researches, Memapan (1996) found that Thailand's government revenues increased to 118,402 million baht if environmental taxes, fees and charges were imposed. Also, Xie and Saltzman (2000) said the China's government revenues increased from 1.2 billion to 1.45 billion yuan.

3.5.7 Effect on Welfare

According to the economic theory, environmental taxes, fees and charges generated "double dividend". Most economists believe that environmental taxes, fees and charges are only taxes that could raise the government revenues together with reducing the existing distortion taxes (Pearce, 1991). Goulder (1995) defined that the double dividend existed when environmental taxes, fees and charges can finance a reduction of a distortionary tax in such a way that the cost of the environmental tax is lower relative the case of returning the tax revenue to taxpayers in lump sum fashion.

From the international experiences, they shown that Germany, Sweden, Turkey gained the double dividend from levying environmental taxes, fees or charges. Bohringer and Rutherford (1997) found that the welfare cost decreased for all tax scenarios in Germany because cutback of existing distortionary taxes. Kumnbaroglu (2003) commented that Turkey could also gain even when tax revenue recycling is not for reducing existing tax distortions because environmental policies improve economic performance.

Furthermore, Hill (1998) found more about welfare improvements in Sweden. He stated that welfare would be improved if valuation of CO_2 emission reductions exceeds 0.3 SEK per kilogram. Otherwise, CO_2 tax will decrease welfare. The revenue from tax was used for subsidizing the cost of production which increases welfare with 6 percent. Moreover, environmental taxes reduced the cost of tax reform up to 9 percent in the CO_2 reduction interval examined. In Sweden, welfare increased without increases in the CO_2 emissions and get larger gain if non-uniform CO_2 tax scheme is abandoned. Hill also identified that the maximum welfare improvements in Sweden would occur at a tax rate which equals 35 percent of the benchmark rate.

However, China and New Zealand faced losses from imposing environmental taxes, fees and charges. Scrimgeour, Oxley, and Fatai (2004) said that the total welfare were loss due to the suffering from loss of competitiveness by implement the environmental policies in the energy intensive industries in New Zealand. Moreover, Xie and Saltzman (2000) found the environmental tax policies in China were ineffective because of weak legal enforcement of pollution emission taxation.

CHAPTER IV

RESEARCH METHEDOLOGY

4.1 The Actors in the Model

This is a closed economy model, taking into account only households in Bangkok area. This paper concerns only wastewater from households. The model does not cover wastewater from industrial areas as Pollution Control Department is responsible for monitoring and enforcing industrial entities to observe the Department's regulations. The industrial entities are forced to install wastewater treatment facilities and they have to dilute pollutants to the standard level before they are discharged. Thus, the charge imposed on the industrial sector will be redundant with the responsibility of Pollution Control Department. There are, therefore, two main actors in the model which are households and Bangkok Metropolitan Administration (BMA).

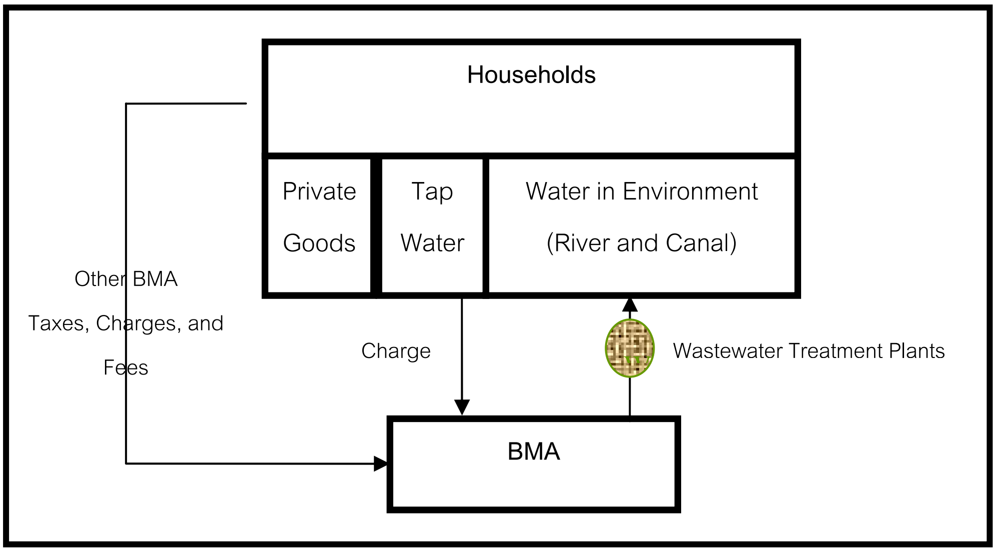


Figure 4.1: Diagram Shows Relationship between Actors in the Model

4.1.1 *Actor 1: Households*

Households directly and indirectly receive income and transfers from other actors. Households use their income to pay direct taxes, fees, charges and consumptions. Households consume private goods produced by private sector. The income that remains after taxes and transfers will be spent on private goods and water consumptions. Household's private goods consumptions are purchased at market prices. Then they decide their consumptions across different commodities. Household public goods consumptions are given by BMA. Households consume as many public goods as BMA produces.

Households' water consumptions create pollution to the environment and households respond to this by paying the cost of pollution abatement in the sense of treatment charge. In this case, households consume the water which is produced by Metropolitan Water Authority (MWA). Then they pay a wastewater treatment charge for cleaning up wastewater discharged to Bangkok Metropolitan Administration according to their tap water consumptions.

4.1.2 *Actor 2: Bangkok Metropolitan Administration (BMA)*

The BMA collects taxes such as local development tax, property tax and signboard tax; and other charges such as wastewater treatment charge. In addition, BMA receives subsidy from the national government which are exogenous to the BMA. The BMA uses these incomes to purchase commodities for its consumption and transfer to other actors in economy. BMA, moreover, contributes to investment in public services such as pollution clean up activities including wastewater treatment and solid waste collection, city cleaning and ordering, traffic control, public health, and education.

Indeed, BMA provides public goods to BMA's residents and it is responsible for cleaning up pollution which is wastewater treatment in this case. In this model, BMA is a producer and it spends its revenues on a wastewater treatment activity and other public services.

4.2 Modeling Framework

This analysis considers the partial equilibrium analysis in the water market and the wastewater abatement cost saving. In order to clarify the methodology, a diagram is important. First of all, the overall picture of the model will be presented before the mathematical models are discussed. The graphs in figure 4.2 and 4.3 show the relationship among water consumption, wastewater discharged, tax incidences and the abatement cost saving.

In tap water market, Metropolitan Water Authority (MWA) responds for producing tap water and infinitely supply to all Bangkok residents. Households face horizontal water supply. Since tap water is considered a necessity good, the demand of tap water is a steeply downward sloping curve. Households are the consumers and consume tap water according to their demands. Whenever households consume tap water, they generate wastewater to environment. Consuming tap water raises negative externality which creates an external cost to the society. In order to reduce water pollution, Bangkok Metropolitan Administration intends to impose a wastewater treatment charge on tap water uses of households. The policy has lowered tap water consumptions of households, which directly causes a reduction of wastewater discharged from households.

From figure 4.2, the author assumes that D_0 is a demand curve of tap water and S_0 is a supply curve of tap water before BMA imposes the wastewater treatment charge. The equilibrium before imposed the charge is at E_0. The price at the equilibrium point is Pw_0 and households consume tap water at Q_0. Consuming tap water creates wastewater equal WW_0 as shown in figure 4.3 which is approximately 80 percent of water consumption as regards to the Pollution Control Department information and Metcalf & Eddy (1991). These generate external costs to the household itself and other consumers. To reduce wastewater discharged from households, BMA then imposes the wastewater treatment charge on tap water on households at the rate f_w baht per m^3.

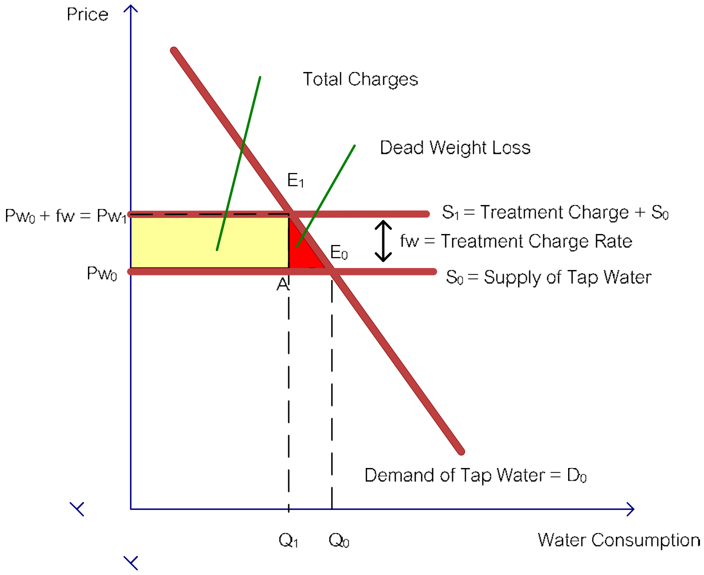


Figure 4.2: Water Consumption and Tax Incidence

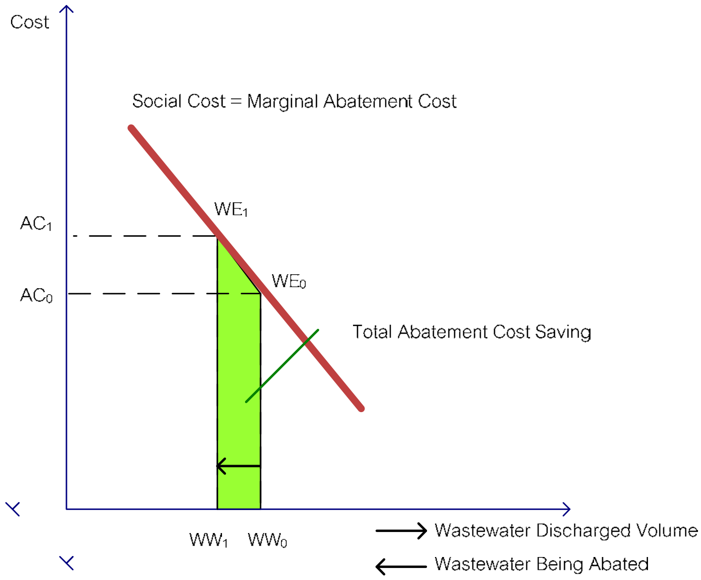


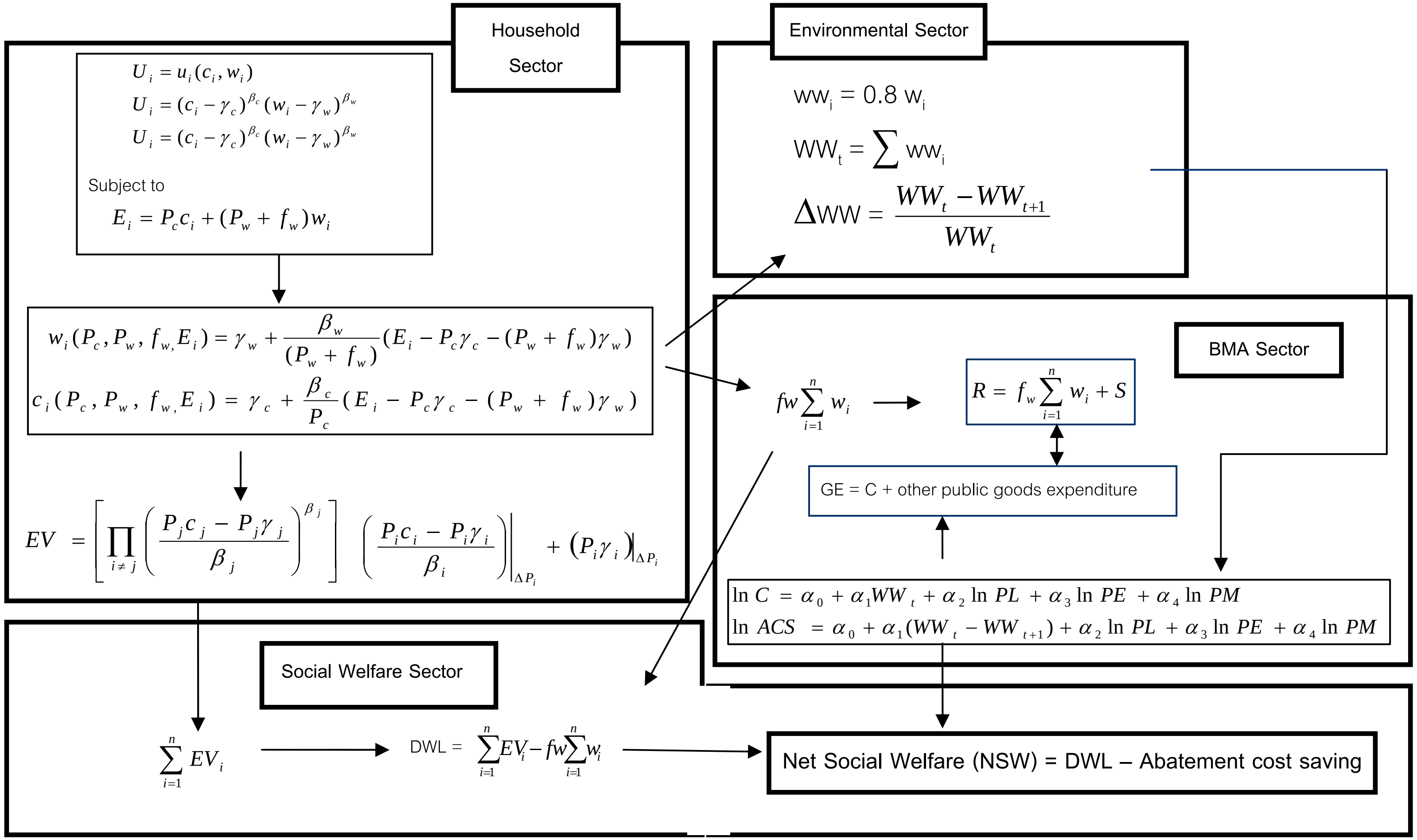
Figure 4.3: Wastewater Discharged and Abatement Cost Saving

The policy affects supply of water, S_0, to shift upward to S_1 and the distance between S_0 and S_1 equal to the charge rate, f_w. In order words, BMA should impose the charge at the rate which equals externality costs. S_1, therefore, reflects the real price which households face after levying the charge. The equilibrium point changes from E_0 to E_1. Additionally, the price at the new equilibrium point changes to Pw_1 and households decrease consuming tap water from Q_0 to Q_1. Households' consumer surplus is reduced or households bear the charge incidences equal area Pw_1E_1 E_0Pw_0. The total charge revenues, which BMA collects if tap water consuming level is at Q_1, equal to area $Pw_1E_1APw_0$. This amount of money will be transferred from household sector to BMA sector. They still have a certain amount of money lost in the process which called "Dead Weight Loss: DWL". The deadweight loss is occurred equaling to the triangle E_1E_0A. The reduction of tap water used from Q_0 to Q_1, however, drops wastewater discharged from households from WW_0 to WW_1.

Figure 4.3 presents the public marginal abatement cost (MAC). When households discharge wastewater, the external costs occur. They normally do not include the external costs into their consumption costs. Then the society pays the costs for the handling of such pollutions. To internalize the external costs, BMA then imposes the wastewater treatment charge on water consumptions at the rate f_w baht per m^3. It lowers wastewater from WW_0 to WW_1. This is an instant benefit from tap water consumption reduction. Regarding to these, the abatement cost saving is occurred equaling to area $WE_1WE_0WW_0WW_1$. To calculate the net social welfare, two main areas are estimated. First, the negative effect of the policy is the dead weight loss area in figure 4.2. Secondly, the positive effect of the policy is the total abatement cost saving area in figure 4.3. Nevertheless, the benefits causing by wastewater reduction are not only an abatement cost saving, there are some intangible benefits. However, this study does not include those benefits in order to point out the direct benefits from the policy.

The model consists of four parts which are household sector, environmental sector, BMA sector and social welfare sector as shown in figure 4.4. Figure 4.4 shows the relationship of the four sectors. To clarify the methodology, the paper presents the figure 4.4 along with the equations which are used for the estimations. Here the mathematics is applied.

Figure 4.4: Diagram Shows the Model Framework and Relation of Four Sectors



4.2.1 *Household Sector*

There are n households in the model. The utility function of household i defines upon private goods consumptions, c_i, and a water consumption, w_i. Household's private goods consumptions can be purchased at market prices and allocated across different commodities according to linear expenditure system demand function which derived from maximization of utility function subject to their budget constraint.

Maximize Utility $\quad U_i = \prod (c_i - \gamma_i)^{\beta_i} (w_i - \gamma_w)^{\beta_w}$ ---------- 4.1

Subject to $\quad E_i = \sum P_i c_i + (P_w + f_w) w_i$ ---------- 4.2

The Marshallian Demand Function of water consumption and other private goods consumptions are derived from equation 4.1 and 4.2. The demand functions are the function of private goods' prices, a tap water's price, a charge rate, and a total expenditure of household i. The demand functions are presented as follows.

$$w_i(P_c, P_w, f_{w,} E_i) = \gamma_w + \frac{\beta_w}{(P_w + f_w)} (E_i - P_c \gamma_c - (P_w + f_w)\gamma_w) \quad \text{--------- 4.3}$$

$$c_i(P_c, P_w, f_{w,} E_i) = \gamma_c + \frac{\beta_c}{P_c} (E_i - P_c \gamma_c - (P_w + f_w)\gamma_w) \quad \text{---------- 4.4}$$

The demand functions which are presented in equation 4.3 and 4.4 will be estimated in Chapter 5. This paper measures the change in the consumer surplus by using Equivalent Variation (EV). In order to determine EV, deriving Hicksian demand function is important. This function notify how quantity is affected by prices with utility held constant. It reflects only substitutional effects of changing prices. EV defines the welfare effects of price changes and the distortionary impact of the charge policy. This welfare measurement is based on initial equilibrium prices rather than new equilibrium prices. In other words, the EV is the difference between the post – change of total expenditure, $\mu(p^0; p^1, E^1)$, and the minimum expenditure required to achieve post – change utility at the pre – change prices, $\mu(p^0; p^0, E^0)$. It uses the current prices as the base and asks how much incomes or expenditures change at the current prices would be equivalent to the proposed the change in terms of its impact on utility. Hence,

$$EV_i = \mu(p^0; p^1, E^1) - \mu(p^0; p^0, E^0) \qquad \text{---------- 4.5}$$

$$EV_i = E^1 - \mu(p^0; p^0, E^0) \qquad \text{---------- 4.6}$$

$$EV_i = \left[\prod_{i \neq j} \left(\frac{P_j c_j - P_j \gamma_j}{\beta_j} \right)^{\beta_j} \right] \left. \left(\frac{P_i c_i - P_i \gamma_i}{\beta_i} \right) \right|_{\Delta P_i} + \left. \left(P_i \gamma_i \right) \right|_{\Delta P_i} \qquad \text{---------- 4.7}$$

4.2.2 Bangkok Metropolitan Administration Sector (Government Sector)

Next, the government sector is examined. Bangkok Metropolitan Administration (BMA) is the only actor in this sector. First of all, the calculation of BMA's revenue and expenditure are presented. The BMA's revenue, R, consists of the total charge revenue, TCR, which is the new source of revenue and other revenues, S, such as taxes, fees and other supplementary fund. Additionally, the BMA's expenditure, GE, consists of expenses on wastewater abatement, C, transfers and compensates, Tr, and other expenditures, OE, such as public education, public health, public transportation and traffic, cleanness, and its operation. The BMA's revenue and BMA's expenditure are presented in equation 4.8 and 4.9.

R = TCR + S --------------- 4.8

GE = C + Tr + OE --------------- 4.9

In BMA Sector, the total wastewater charge revenue, TCR, which is the BMA's new source of revenue, can be estimated from the summation of water consumptions, w_i, multiplied by the charge rate, f_w. The total charge revenue equals to area $Pw_1E_1APw_0$ in figure 4.2 and is presented as follow.

$$TCR = f_w \sum_{i=1}^{n} w_i \qquad \text{-------------- 4.10}$$

BMA directly responds the wastewater treatment in Bangkok area. The wastewater abatement expense is one of the public expenditure which is provided by BMA. Therefore, BMA is responsible for managing the abatement cost of all treatment plants. To estimation of the abatement cost, C, the stochastic cost function frontier analysis is applied. The abatement cost function is the function of the wastewater discharged, WW_t, and three input prices which are wage, electricity price, and material price defined as PL, PE, and PM, respectively. The estimation of stochastic cost frontier function is estimated in Chapter 6 as defined in equation 4.11.

$$\ln C = \alpha_0 + \alpha_1 \ln WW_t + \alpha_2 \ln PL + \alpha_3 \ln PE + \alpha_4 \ln PM + (V + U) \quad \text{------------------ } 4.11$$

Since the charge policy affects decreasing in water consumption, it directly affects reducing in wastewater discharged from households. With the purpose of estimation welfare gain in BMA sector, determining the abatement cost saving function, ACS, is necessity which is similar to equation 4.11. However, ACS is the function of input prices and difference between wastewater volume before and after imposed the charge, (WW_0 – WW_1). Otherwise, the abatement cost saving is the integration of marginal abatement cost. The ACS also presents the decreasing of externality cost which equals to area $WE_1WE_0WW_0WW_1$ in figure 4.3. The equation of abatement cost saving is presented as follow.

$$\ln ACS = \alpha_0 + \alpha_1 \ln(WW_t - WW_{t+1}) + \alpha_2 \ln PL + \alpha_3 \ln PE + \alpha_4 \ln PM + (V + U) \text{ -- } 4.12$$

4.2.3 Environmental Sector

Then from the water demand, the estimation of wastewater discharged from each household, ww_i, is shown in equation 4.13 in the environmental sector. The wastewater discharged rate equals 0.8 of water consumption. This rate is assured by Pollution Control Department.

$$ww_i = 0.8 w_i \quad \text{---------- } 4.13$$

After that the total wastewater discharged from households at time t, defined as WW_t, will be the summation of wastewater discharged, ww_i, from households in Bangkok area.

$$WW_t = \sum ww_i \qquad \text{---------- 4.14}$$

The wastewater treatment plants' duties are to reduce the impurities. Thus, the output of the plant is pollution reduction which is also shown in the environmental sector. Environmental also sector illustrates certain statistics about wastewater discharged. For instance, total wastewater discharged before and after imposed the treatment charge. The percent change of wastewater discharged from Bangkok's households is calculated as follow.

$$\Delta WW = \frac{WW_t - WW_{t+1}}{WW_t} \qquad \text{--------- 4.15}$$

4.2.4 <u>Social Welfare Sector</u>

The EV is considered as a welfare change in household sector. Then the total equivalent variation, TEV, which represents the total welfare change causing by policy reform in the household sector is the summation of EV_i, which equal to area Pw_0 $Pw_1E_0E_1$ in figure 4.2.

$$\text{TEV} = \sum_{i=1}^{n} EV_i \qquad \text{--------- 4.16}$$

Next, the Dead Weight Loss (DWL) estimation is considered. DWL equals to summation of EV in equation 4.16 deduces total revenue from treatment charges in equation 4.10 which defined as the part which is transferred from households sector to government sector. The DWL equals to area AE_0E_1 in figure 4.2 and is defined as follow.

$$DWL = TEV - TCR \quad \text{--------- 4.17}$$

Indeed, in order to estimate Net Social Welfare (NSW), the dead weight loss and abatement cost saving are estimated. As mentioned above, the dead weight loss (DWL) is the result form the household sector and has the negative effect to the social welfare function. The abatement cost saving (ACS) defined the benefits of decreasing in wastewater discharged from households which has the positive effects on social welfare. ACS occurs when households reduce their water consumption and is estimated from the stochastic cost frontier function. The ACS is the function of difference between the volumes of wastewater discharged before and after imposed the charge on households and the input prices. Then the NSW will be the additive of negative effects from household sector and positive effects from BMA sector.

$$NSW = \Delta \text{ Household Sector} + \Delta \text{ BMA Sector}$$

Or,

$$NSW = \overset{(-)}{(TEV - TCR)} + \overset{(+)}{ACS} = \overset{(-)}{(Pw_1E_0\,E_1Pw_0 - Pw_1E_1APw_0)} + \overset{(+)}{WE_1WE_0WW_0WW_1}$$

$$= \overset{(-)}{DWL} + \overset{(+)}{ACS} = \overset{(-)}{E_1E_0A} + \overset{(+)}{WE_1WE_0WW_0WW_1}$$

Or,

$$\text{Net Social Welfare} = \overset{(-)}{\text{Household loss}} + \overset{(+)}{\text{BMA gain}}$$

$$= \overset{(-)}{\text{Loss due to the treatment change on water consumption}}$$

$$+ \overset{(+)}{\text{Total charge revenues}} + \overset{(+)}{\text{Abatement cost saving}}$$

$$\text{Net social welfare} = \text{Dead Weight Loss} + \text{Abatement Cost Saving} \quad \text{--------------- 4.18}$$

As you can see, the net social welfare gain or loss depends on the size of dead weight loss and abatement cost saving. Indeed, the environmental policy, imposed wastewater treatment charge on households by BMA, affects welfare gain if the abatement cost saving is more than the dead weight loss which is occurred by imposing the policy. The welfare loses if the benefit is less than the dead weight loss. In other words, the policy affects net social welfare gain if the BMA's gains more than households' lose.

Endogenous Variables

U = households' utility

i = commodities and i = 1, 2, 3, . . ., n

c_i = consumption of private goods i

w = tap water consumption

EV_i = equivalent variation of household i

TEV = total equivalent variation

DWL = dead weight loss

TCR = total revenue from the charge

C = abatement cost frontier of treatment plants

ACS = abatement cost saving

R = BMA revenue

GE = BMA expenditure

NSW = net social welfare

ww_i = wastewater discharged from household i

WW_t = total wastewater discharged from households at time t

ΔWW= percent change of wastewater discharge (%)

μ = expenditure function; $\mu = f(P, V(P, E))$ is the function of price of commodity, P, and indirect utility, $V(P, E)$.

Exogenous Variables

Pc_i = price of commodity i

Pw = price of tap water

f_w = wastewater treatment charge rate

E_i = total consumption expenditure of household i

PL = wage

PE = electricity price

PM = material price

S = amount of supplementary fund and other BMA revenue

OE = other public goods expenditures

Unknown Parameters

γ_i = committed levels of expenditure of commodity i

β_i = consumption expenditure share of commodity i

α_i = unknown parameters of stochastic cost frontier function

CHAPTER V

DEMAND FUNCTION ESTIMATION

5.1 Introduction

This paper can classify demand function estimation into 2 main methods. First, it is direct method such as interviewing focus groups, samplings, survey on consumers, consumer clinic and market experiment. This method provides the primary data for estimation. Second is data analysis which known as indirect method. Normally, the study analysis time series data, cross section data and combination of both. This section aims to estimate the demand function by using households' perspective. There are several researches on data analysis of demand estimation.

Standard approaches to specifying and estimating demand systems that ignore the non – negativity constraints. Deaton (1986) found that the problem of dealing with zero expenditure is one of the most pressing in applied demand analysis. Then, Lee and Pitt (1987) and Lee (1993) have proposed methods for estimating demand with binding non – negativity constraints. The approach is based on the Kuhn – Tucker conditions associated with a stochastic direct utility function. The development of discrete choice model was presented by Mc Fadden (1989). Contrary to discrete choice model, simulated method of moments for consumer demands with non – negativity constraints require more than a simple generation of random numbers.

According to earlier literatures, Almost Ideal Demand System (AIDS) is also well-known approach developed by Deaton and Muellbaure (1980). The advantage of this system is giving a first-order approximation to any demand system. It also imposes neither separability nor homotheticity. The sample of the study which used AIDS in Thailand is Kardkarnklai (1992). She used partial equilibrium analysis to analyze the effects of carbon dioxide taxes on consumption expenditure. From demand estimation, she found that consumers mostly spend on their food and beverages, recreation and transportation, respectively. However, they reduced their consumption on food and beverages, transportation and recreation after imposing carbon dioxide taxes. She claimed that the proportion of private consumption to Gross Domestic Product (GDP) also decreased. Then Banks, Blundell and Lewbel (1997) said expenditures on some goods are non – linear in total expenditure or income while some are linear. Therefore, he decided to flexible functional form of consumer preferences, which could handle non – linear expenditure effect. This method is called the quadratic extension. Brannlund and Nordstrom (2004) use the Quadratic Almost Ideal Demand System (QAIDS) model to determine the differences in consumption patterns between different household categories in order to examine the affect of the government policy on households' consumption.

Extended Linear Expenditure System (ELES) and Linear Expenditure System (LES) are also widely used. These two methods assume that consumer households are risk – neutral and maximize their utility subject to a budget constraint. This system is attractive because of its linear structures in expenditure. In other words, the expenditure on each good is a linear function of all prices, although it is restrictive in that the implied Engel curve is linear. The LES estimation is much more sensitive compared to ELES. The peculiarity of LES is erratic behavior - parameters. Yet, the set of parameters are roughly the same in both model. Unlike LES, ELES attempts to use income instead of total expenditure to complete demand system, but it can also be decomposed into the LES. This study intends to use LES which is normally used to estimate the demand for consumer products. This approach was pioneered by Stone (1954). Stone's approach has been generally used in the literature on private goods market by using either primary data or secondary data to estimate the coefficients. Linear Expenditure System is also appropriate for simultaneously estimating several equations. Then, Pollak and Wales (1981) added demographic variables such as family size and age composition in the analysis of household budget data. Also, there are some researches using LES in Thailand such as Arunsmit (1997), Sarntisart (1999), and Chomtohsuwan (2004). Arunsmit used LES as a part of CAMGEM – H. She found that households decreased their consumptions on transportation, chemical, and entertainment while the expenses on luxury goods increased during the recession in

1997. Sarntisart (1999) researched on effects of value added tax (VAT) on households' consumption. He also used LES to estimate demand of Thai's households. He found that VAT was regressive because the ratio of tax incidences to the total expenditure of high income households was more than low income households. Moreover, this study can evaluate the incidence of taxes and welfare effects by estimating the consumption pattern of households. For instance, Sarntisart (1999) found that households loss their welfare about 104 baht or about 1,246 baht per month when government increased VAT rate from 7 percent to 10 percent. Moreover, there are other studies which examined the consequence of government policy; especially the tax policies, by estimating the consumption pattern such as Blundell (1993), Paris (2003) and West and Williams (2004).

This chapter is organized as follows. Section 1 briefly presented the background to the study and the literature review. Section 2 introduces the model framework and research methodology. Finally, section 3 specifies and estimates the econometric model of consumer demands. The section statistically summarizes of each commodity categorized; as well as, calculates elasticity of commodities.

5.2 Framework

This study simplifies the determination of households' behavior by considering on their expenditure and prices of goods. Also, the model assumes that other factors remain constant. In the model, households receive income and transfer from other factors. Households use their income to pay for direct taxes, charges, fees, and their consumptions. The model includes eight consumer product categories: food & beverage, personal appearance, housing, transportation, education, tobacco & alcohol beverage, medical care and tap water. The details of product lists in each category are presented in appendix A.

This study will estimate the demand function of Bangkok's households for private goods according to Linear Expenditure System which derived from utility maximization. This estimated system also assumes that expenditures are independent and do not depend on saving. The conditions which are necessary for Linear Expenditure System demand function are additive and homogeneity. Therefore, $\beta_i \geq 0$ and $\sum \beta_i = 1$. The model assumes that households maximized their utilities subject to their expenditure.

Maximize $\qquad U = \prod (c_i - \gamma_i)^{\beta_i}$ ---------------------------- 5.1

Subject to $\qquad E = \sum P_i c_i$ ---------------------------- 5.2

From equation 5.1 & 5.2, Marshallian demand for private goods can be derived accordingly.

$$c_i(P_i, E) = \gamma_i + \frac{\beta_i}{P_i}(E - \sum P_i \gamma_i) \qquad \text{-------------------------- 5.3}$$

where

U = households' utility

i = commodity; i = 1, 2, 3, . . ., n

c_i = consumption of private goods i

γ_i = committed levels of expenditure of commodity i

β_i = consumption expenditure share of commodity i

P_i = price of commodity i

E = total expenditure of household

The equation 5.3 reveals that the households' consumption level depends on three components. They are the price of the goods, the prices of other goods and the households' expenditures. The unknown parameters needed to be estimated, are the committed levels of expenditure (γ_i) and the consumption expenditure share of commodities (β_i). The results and estimation method will be shown in the next section. Households' expenses can be classified into 2 parts. First, the committed level of expenditure is the necessity of the consumption level of households. The households will spend until they reach the committed level to fulfill their basic needs. The second part is supernumerary expenditure. This part is not necessity and can more sensitive to prices.

To expand our analysis, elasticity is considered. Elasticity is a tool which is used to describe the relationship between variables. It is defined as the percentage change in a dependent variable caused by a percentage change in prices. This paper considers two types of elasticity. First, expenditure demand elasticity on commodities explains the responses of households' spending on each commodity when prices change. Additionally, price elasticity is the necessity for analysis of households' behaviors. Price elasticity measures of the percentage change in quantity demanded of a commodity caused by a percentage change in a price when other factors remain unchanged. According to Frisch (1959) and Llunch C. and Williams R (1975), own price elasticities, cross price elasticities and expenditure demand elasticities are calculated as follows:

$$-\Phi = 1-\left(\frac{1}{E}\sum_{i=1}^{n} P_i\gamma_i\right) \qquad \text{-------------------------- 5.4}$$

$$w_i = \frac{E_i}{E} \qquad \text{-------------------------- 5.5}$$

$$\eta_i = \frac{\beta_i}{w_i} \qquad \text{-------------------------- 5.6}$$

$$\varepsilon_{ij} = \phi\eta_i - \eta_i w_i(1+\phi\eta_i) \quad , i = j \qquad \text{-------------------------- 5.7a}$$

$$= -\eta_i w_j(1+\phi\eta_j) \quad , i \neq j \qquad \text{-------------------------- 5.7b}$$

$$\varepsilon_{ij}{*} = \eta_i(1-\beta_i)\phi \quad , i = j \qquad \text{-------------------------- 5.8a}$$

$$= -\eta_i\beta_j\phi \quad , i \neq j \qquad \text{-------------------------- 5.8b}$$

Also, the above inequalities hold $\varepsilon_{ii,}\varepsilon_{ii}{*} < 0,\ \varepsilon_{ij} < 0$ and $\varepsilon_{ij}{*} > 0$ for i $\neq$ j, where

$-\Phi$ = supernumerary ratio

w_i = expenditure share of commodity i

η_i = expenditure demand elasticity of commodity i

ε_{ij} = uncompensated price elasticity

$\varepsilon_{ij}{*}$ = compensated price elasticity

The expenditure demand elasticity is the tool to categorize goods into luxury and necessity while price elasticities are the tool to determine the relationship among variables. The calculation of elasticities and the analysis are presented in the next section.

5.3 Estimation and Results

5.3.1 <u>Data, variable derivation, and summary statistics</u>

According to the section above, to analyze households' expenditure behaviors in Bangkok area, prices and expenditures data are required. In this empirical study, the socio-economic survey (SES) of year 2002, 2004 and 2006 is used as a main component. The SES collected data from households in Bangkok area monthly. The data includes the total expenditures of each household in Bangkok area and amount of expenditures of each household on each good such as the expenditure of household$_s$ on consumption and non-consumption goods such as food & beverages, personal care, transportation, reading, insurance premiums, and interest. The data also includes a wide variety of household income measures such as income from pension payments, property and loans. However, the demand function estimation in this analysis focuses only on the expenditure of consumption goods of households.

This study uses the pooled data method which is the combination set of both a cross-sectional and a time-series component. The total numbers of Bangkok area observations were 6,778. The total consumption expenditure equals to the amount spent on food & beverage, personal appearance, housing, tap water, transportation, education, tobacco & alcohol beverage, and medical care. In order to clearly analyze the effects of the policy on households' behaviors, the paper also categorized households into three categories which are low income households, medium income households, and high income households.

From the literature, the low income level households are the households whose incomes lower than the poverty line. From the SES data, it shows that 99 percent of households' incomes in Bangkok area are above the poverty line. The households which are considered as low income households in this study have current monthly incomes lower than minimum income levels which have to pay income taxes. There are 2,069 observations in low income households. For the medium income households, this paper consider households whose monthly incomes range between minimum income levels which have to pay income taxes up to 50,000 baht per household per month. The observations of medium income households are 3,558. The high income households' incomes are equal to and higher than 50,001 baht per household per month which are 1,151 observations. As you can see, more than half of Bangkok households are classified in medium income level which accounted for 52.49 percent. 30.52 percent are low income households and the least are high income household which accounted for 16.98 percent of all.

In order to estimate the demand function, the prices of commodities are also needed. The price data of food & beverage, tobacco & alcohol, personal appearance, housing, medical care, transportation, and education are from the Consumer Price Index (CPI) provided by the Interior Commerce Department, Ministry of Commerce. The CPI of water is available at Investment Planning and Information Division, Metropolitan Water Authority.

Table 5.1 provides a summary of statistics for the Bangkok households' expenditures. The table shows that Bangkok's households average expenditures are 17476.76 baht per month. They spent mainly on food & beverages compared to other commodities. The average expenditure of this commodity is 29.09 percent of all , or equals to 4410.474 baht per month per household, followed by transportation, housing, education, personal appearance, medical care and tobacco & alcoholic beverages which are 4300.367, 3233.802, 1169.327, 922.145, 546.1262, and 302.8573 baht per household per month, respectively. For commodity weight, Interior Commerce Department judges according to the necessity and average expenditure of goods. The heaviest weight is on food & beverages followed by housing, transportation, education, medical care, personal appearance, tobacco & alcoholic beverages and water used, respectively. Tap water is normally a component of housing category while tap water expenditure is as another commodity category in this model. Consequently, the expenditure share of this commodity is the least proportion, equaling to 1.50 percent. Expenditure on food & beverages also gets the highest share which accounts for 29.09 percent.

Table 5.1: Statistical Summary of Each Commodity Categorized

Commodity Categories	Mean Expenditure of Each Income Level				Weight*	Expenditure Share of Each Income Level			
	Low	Medium	High	TOTAL		Low	Medium	High	TOTAL
Food & beverages	2664.4630	4799.2847	7367.1364	4410.474	5462.3	0.4071	0.3585	0.2064	0.2909
Tobacco Product & alcoholic beverages	245.7081	324.0579	349.4570	302.8573	473.75	0.0379	0.0243	0.0098	0.0193
Personal Appearances	305.9952	690.1563	2539.1529	922.145	509.97	0.0495	0.0537	0.0744	0.1911
Housing	1356.8304	2586.6900	7293.0686	3233.802	3557.56	0.2172	0.1813	0.2137	0.1279
Medical care	188.8376	464.7097	1221.9505	546.1262	824.58	0.0307	0.0360	0.0356	0.0323
Transportation	1018.6501	3172.8367	11961.4170	4300.367	2206.6	0.1926	0.2553	0.3592	0.2544
Education	277.9232	930.2662	3031.4613	1169.327	939.68	0.0441	0.0724	0.0891	0.0691
Tap water used	132.8014	242.8673	406.4596	236.8781	177.46	0.0211	0.0186	0.0117	0.0150
Total Consumption Expenditure	7026.0960	15767.6759	42313.7732	17476.76		1	1	1	1

Source: Calculated by the author

* Interior Commerce Department, Ministry of Commerce

The study also found that the first three consumption goods which households at each income level spent mainly are on the same categories which are food & beverages, transportation, and housing although they are at different order. Low income and medium income households spent on food & beverages in the highest proportion while high income households spent on transportation. However, the high income and the medium income households spent on housing in the third order while the low income households spent on transportation in the third order. Moreover, the last three consumption goods which Bangkok's households spent slightest are in the same categories which are medical care, tobacco product & alcoholic beverages, and tap water. The order also differs among each income level. Low income and medium income households spent smallest amount on tap water although high income households spent least on tobacco product & alcoholic beverages. High income and medium income households spent on medical care more than tobacco product & alcoholic beverages whereas low income households spent on tobacco product & alcoholic beverages more than medical care.

For the low income households, their average consumption expenditures are 7,026.096 baht per household per month. They spent a large amount on food & beverages and equals to 4,266.46 baht per household per month, accounted for 40.71 percent of all, followed by housing, transportation, personal appearance, education, tobacco & alcoholic beverages, medical care and tap water which are 1,356.83, 1,018.65, 305.995, 277.92, 245.70, 188.84, and 132.80 baht per household per month respectively.

Same as low income households, the medium income level spent mainly on food & beverages and equals to 4266.46 baht per household per month, accounted for 35.85 percent of all, followed by transportation, housing, education, personal appearance, medical care, tobacco & alcoholic beverages, and tap water which are 3,172.84, 2,586.69, 930.27, 690.16, 464.71, 324.06, 242.87 baht per household per month respectively. Their average consumption expenditures are 15,767.676 baht per household per month.

Finally, the high income households' average consumption expenditures are 42,313.773 baht per household per month. Unlike low income and medium income households, they spent most on transportation which equals to 11,961.417 baht per household per month, accounted for 35.92 percent of all, followed by food & beverages, housing, education, personal appearance, medical care, tap water and tobacco & alcoholic beverages which are 7,367.14, 7,293.07, 3,031.46, 2,539.15, 1,221.95, 406.46, and 349.46 baht per household per month respectively.

5.3.2 System Estimation and Results

Since the demand estimation contains a number of linear equations and they have the same parameter vector, it would be unrealistic to expect that the equation errors would be uncorrelated. Our estimation of each equation uses the same data set; therefore, there is a possibility that the errors may be correlated across the equations. Thus, the equations seem independent of each other, but the equations are related through the correlation in the errors. Seemingly Unrelated Regression (SUR) model estimation; consequently, is obtained in this study. It is a technique for analyzing a system of multiple equations with cross-equation parameter restrictions and correlated error terms. In other words, SUR is an extension of the **linear regression** model which allows correlated errors between equations. Thus, rather than estimating the system equations individually by **least squares**, the method of SUR is applied.

In this study, this paper separates private goods in our model into eight categories which are food & beverage, personal appearance, housing, tap water, transportation, education, tobacco & alcohol, and medical care. This study uses partial equilibrium analysis based on Linear Expenditure System to estimate the demand of private consumption. According to section 2, the demand functions of all categories can be written as follows:

$$fb(P_i, E) = \gamma_{fb} + \frac{\beta_{fb}}{P_{fh}}(E - \sum P_i\gamma_i) \text{ --- 5.9a}$$

$$pa(P_i, E) = \gamma_{pa} + \frac{\beta_{pa}}{P_{pa}}(E - \sum P_i\gamma_i) \text{--- 5.9b}$$

$$h(P_i, E) = \gamma_h + \frac{\beta_h}{P_h}(E - \sum P_i\gamma_i) \text{ ---------- } 5.9c$$

$$trn(P_i, E) = \gamma_{trn} + \frac{\beta_{trn}}{P_{trn}}(E - \sum P_i\gamma_i) \text{ ---------- } 5.9d$$

$$edu(P_i, E) = \gamma_{edu} + \frac{\beta_{edu}}{P_{edu}}(E - \sum P_i\gamma_i) \text{ ---------- } 5.9e$$

$$med(P_i, E) = \gamma_{med} + \frac{\beta_{med}}{P_{med}}(E - \sum P_i\gamma_i) \text{ ---------- } 5.9f$$

$$tal(P_i, E) = \gamma_{tal} + \frac{\beta_{tal}}{P_{tal}}(E - \sum P_i\gamma_i) \text{ ---------- } 5.9g$$

$$w(P_i, E) = \gamma_w + \frac{\beta_w}{P_w}(E - \sum P_i\gamma_i) \text{ ---------- } 5.9h$$

where

fb = food & beverage demand

pa = personal appearance demand

h = housing demand

trn = transportation & communication demand

edu = education, recreation & reading demand

med = medical care & personal care demand

tal = tobacco & alcohol beverage demand

w = water demand

E = total expenditure of household

i = fb, pa, h, trn, edu, med, tal, or w

The estimated coefficients, the committed levels of expenditure (γ_i) and the consumption expenditure share of commodities (β_i) are presented in table 5.2. The results show that coefficients have high level of statistical significance which is indicated by the value of the probabilities. Also, the study demonstrated that all key variables have the expected sign ($\beta_i \geq 0$ and $0 < \gamma_i < c_i$). First, committed consumption level (γ) is discussed. It means the minimum expenditure, which household spends on each category. The table 5.2 reveals that committed consumption levels are all positive.

Table 5.2: Coefficient Estimation of Bangkok Households' Demand Function

Household Categories	Goods Categories	β	Prob	γ	Prob
Average Households	Food & Beverage	0.1165	0.0000	2722.1795	0.5186
	Tobacco Product & Alcohol Beverage	0.0033	0.0000	249.9476	0.0000
	Personal Appearance	0.0389	0.0000	502.7559	0.0000
	Housing	0.2050	0.0000	943.7221	0.0000
	Medical Care	0.0271	0.0000	235.7066	0.0000
	Transportation	0.3401	0.0000	564.7852	0.0000
	Education	0.0575	0.0000	530.5887	0.0000
	Tap Water	0.0050	0.0000	165.0788	0.0000
Low Income Household	Food & Beverage	0.3844	0.0000	610.7906	0.0000
	Tobacco Product & Alcohol Beverage	0.025	0.0000	111.4608	0.0000
	Personal Appearance	0.0128	0.0000	246.2507	0.0000
	Housing	0.1069	0.0000	827.3539	0.0000
	Medical Care	0.0391	0.0000	0.2751	0.9440
	Transportation	0.2139	0.0000	138.2974	0.0000
	Education	0.0558	0.0000	2.7093	0.8196
	Tap Water	0.0068	0.0000	90.6218	0.0000
Medium Income Household	Food & Beverage	0.2232	0.0000	2120.7529	0.0000
	Tobacco Product & Alcohol Beverage	0.0095	0.0000	210.1851	0.0000
	Personal Appearance	0.0086	0.0000	608.5461	0.0000
	Housing	0.1438	0.0000	830.0886	0.0000
	Medical Care	0.0361	0.0000	83.664	0.0001
	Transportation	0.2736	0.0000	371.1243	0.0002
	Education	0.0487	0.0000	421.7977	0.0000
	Tap Water	0.0045	0.0000	180.0343	0.0000
High Income Household	Food & Beverage	0.0930	0.0000	4075.7285	0.0000
	Tobacco Product & Alcohol Beverage	0.0021	0.0021	270.4575	0.0000
	Personal Appearance	0.0298	0.0000	1701.0158	0.0000
	Housing	0.2157	0.0000	1131.1115	0.0144
	Medical Care	0.0197	0.0000	640.3594	0.0000
	Transportation	0.3279	0.0000	2562.2148	0.0000
	Education	0.0392	0.0000	1916.1523	0.0000
	Tap Water	0.0038	0.0000	270.3529	0.0000

Source: Estimated by the author

All Bangkok households' minimum expenditure on food & beverage, tobacco & alcohol, personal appearance, housing, medical care, transportation, education, and water consumption are 2722.1795, 249.9476, 502.7559, 943.7221, 235.7066, 564.7852, 530.5887, and 165.0788 baht per household per month, successively.

Considering by the households' types and minimum level of expenditures, there is an evidence that households, which have higher incomes, pay higher in minimum level of consumption in each category. For example, high income households pay for the minimum level of consumption on food & beverage equal to 4075.7285 baht per household per month which higher than medium income level households. Also, medium income level households pay for the minimum level of consumption on food & beverage equal to 2120.7529 baht per household per month which is higher than low income level households

Next, marginal budget shares (β) are all positive. The marginal budget share of on food & beverage, tobacco & alcohol, personal appearance, housing, medical care, transportation, education, and tap water are 0.1165, 0.0033, 0.0389, 0.2050, 0.0271, 0.3401, 0.0575, and 0.0050, respectively for overall households in Bangkok area.

The marginal budget share also means that every increase in expenditure of households will increase the spending on each product equal to β. For example, if Bangkok households increase their expenditure by one baht, they will increase their spending on food & beverage equal to 0.1165 baht and on housing equal to 0.2050 baht. Also, they spend on tobacco & alcohol, personal appearance, medical care, transportation, education, and tap water accordingly. Additionally, the author found that households will increase their spending most on transportation which equals to 0.3401, followed by housing, food & beverage, education, personal appearance, medical care, and tap water successively. They spend the least on tobacco product & alcohol beverage.

According to the table, the marginal budget shares on food & beverage of lower income households are more than higher income households. Like food & beverage, lower income households spend their money on tobacco product & alcohol beverage, medical care, education and tap water in the higher proportion than higher income households. However, the marginal budget shares on housing and transportation are different. The reason is higher income households have more extra money to spend or buy other goods than lower income households. Moreover, higher income households always choose to spend the money on more luxury houses and transportations compare to lower income households. Therefore, higher income households expend their money on both categories in higher proportion than lower income households.

Noticeably, the marginal budget share of personal appearance of high income households is higher than medium and low income households. As mentioned earlier, the high income households have more extra money to buy more expensive goods. They can buy brand name clothes, accessories, shoes and even luxury jewelry while low income households and medium income households just spend their money on normal personal appearance goods. However, the marginal budget share of this category of medium income households is lower than low income households. The pattern of consumptions of these 2 types of households are almost the same but the amount of money that low income households can allocate are more limited than medium income households. Therefore, based on the money in the pockets, low income households have to spend on personal appearance goods in higher proportion than medium income households.

5.3.3 Elasticity

The expenditure demand elasticity can identify the necessity and luxury goods. If the elasticity is greater than 1, it means that the good is a luxury good. However, if the elasticity is less than 1, it implies that the good is a necessity good. In economics, a luxury good is a **good** for which demand increases more than proportionally as income rises, in contrast to a necessity good for which demand increases less than proportionally as income rises. Luxury goods are said to have high income elasticity of demand. A good may become a **normal good**, a luxury good or even an **inferior good** at different income levels. From table 5.3, the results show that transportation and housing are luxury goods while other products are necessity for overall Bangkok households' perspectives in average household category. The expenditure demand elasticity for food & beverage, tobacco products & alcohol beverages, personal appearance, housing, medical care, transportation, education, and water are 0.4742, 0.1931, 0.7242, 1.1058, 0.8665, 1.3373, 0.8514, 0.3701, respectively.

Table 5.3: Expenditure Demand Elasticity

Category of Goods	Expenditure Demand Elasticity			
	Low Income Household	Medium Income Household	High Income Household	All Households
Food & Beverages	0.9444	0.6226	0.4504	0.4742
Tobacco Products & Alcohol Beverages	0.6596	0.3908	0.2140	0.1931
Personal Appearance	0.2590	0.1596	0.4008	0.7242
Housing	0.4922	0.7932	1.0094	1.1058
Medical Care	1.2760	1.0022	0.5523	0.8665
Transportation	1.1106	1.0717	0.9128	1.3373
Education	1.2651	0.6727	0.4402	0.8514
Water	0.3219	0.2391	0.3230	0.3701

Source: Estimated by the author

Noticeably, transportation is a luxury good because the expenditure data which provided by SES include expenditure on public and private transportation as well as expenditure on local transportation, travel expenses, domestic trip, out bound tours, souvenir during the out bound tour, vehicle purchase, fuel, maintenance costs and all vehicle operations. The expenditure on public transportation which is considered as a necessity good is a very small proportion compared to other kinds of transportation expenses which are considered as luxury goods. Transportation, moreover, includes communication expenses. The consumption of communication is more fashionable, so the communication products are sensitive to prices compare to other goods. Therefore, the results prove to support that transportation is the luxury good in Bangkok households' perspectives. Same as transportation, housing is considered luxury. The expenditure data includes rent, electricity, maintenance, local servant services, as well as major and minor equipments such as microwave, bed, sofa, refrigerators, linen, and curtains. Thus, the expenses on luxury equipment, furniture and facilities have more proportion than the necessity expend on housing. The lists of products in each category are presented in appendix A.

This section would like to intensely consider into each type of households. Normally, food & beverages, personal appearance, and tap water are necessary for basic living. According to the expenditure demand elasticity, they are reasonable necessity goods for all household types. Tobacco products & alcohol beverages are also necessity goods. Since whisky, beer and cigarettes are addicted products, households maintain the consumption in both regularity and frequency despite income changes. On the other hand, housing, medical care, transportation, and education are considered differently among each type of households. Medical care is considered as a luxury good for low income households and medium income households while it is necessity for high income households. From the data providing by SES, medical care includes public & private health services, public & private hospitals, traditional medical services, modern drugs, traditional drugs, and herbal drugs even spa and massage therapy. As you can see, the special medical care services and drugs are larger proportion than basic medical care services.

Additionally, since most of the households in these 2 types normally use the government medical care program. Also, most of them use the social security's medical care benefit. They do not pay the other special services. They often decide to pay the extra special medical care services which are more expensive even when their incomes increase. In contrast, medical care is the necessity goods for high income households because they habitually spend their money on special medical services, expensive drugs, spa and massage. High income households satisfy to pay for medical care in order to prevent from diseases and sickness unlike the lower income households. Lower income households will pay for the services only when they get seriously sick or some serious diseases. Otherwise, they may choose not to cure rather than spend their money on the services because they think they have other essential and more important things to spend on at the same amount of money.

Like medical care, transportation, is considered as a luxury good for low income households and medium income households while it is necessity for high income households. The explanations are the same as medical care service. The luxury transportation, travel products, vehicle purchases and vehicle operation such as taxi, private cars, ferry, domestic trip, out bound tour, and gasoline are larger proportion than basic public services such as bus and train. Low and medium income households normally use the pubic transportation, but they easily switch to more expensive transportation such as Bangkok Mass Transit System (BTS) and taxi in the beginning of the month. Moreover, the installment program and promotion, such as zero percent down payment, increase opportunity for medium income households to buy their own private cars. They have to keep a fixed amount of money to pay the installment monthly which affects demand on private car increasing more than proportionally as income rises. However, high income households use the luxury transportation as a part of their lives and works. They, additionally, spend on leisure such as travelling both domestic and outbound trip during the weekend while low and medium income households will travel only on the national holiday.

As housing is a basic necessity of life, it is considered as a necessity good for medium income households and low income households. Nevertheless, high income households usually spend on expensive and designed furniture and facilities, which they can express their luxury life styles. It is therefore considered a luxury good for high income households. Education is considered as a luxury good for low income households while it is necessity for high income households and medium income households. Since low income households concern more about the products that necessity for the living such as food & beverages, than they will spend their extra money to education. Moreover, most of low income households normally use the free public education provision which provides by BMA while medium and high income households regularly use the private educational institutions with high tuition fees. The low income households spend only on the accessories such as uniforms, books and stationery which are very small amount compared to tuition fee.

Table 5.4.1 shows uncompensated and compensated price elasticities. It presents both own prices and cross prices elasticities. The own price elasticity is the responsiveness of demand to its price changes. The results shows that all calculations have theoretically expected sign. The own price elasticities of uncompensated demand of all households in Bangkok of food & beverage, tobacco products & alcohol beverages, personal appearance, housing, medical care, transportation, education, and water are -0.1929, -0.1207, -0.4191,-0.4298, -0.5203, -0.3459, -0.4750 and -0.2316, respectively. It can also be used to forecast the effects of price changes on quantity. For example, the quantity demanded of housing will decrease by 42.98 percent if its price rises by 1 percent. Moreover, the table 5.4.1 shows the cross price elasticity that can estimate how consumption of other goods change when price of one change. As you can see, all cross price elasticities are negative. These imply that increasing on price of one good affects decreasing in consumption of other goods. In other words, whenever BMA imposes wastewater treatment charge on tap water which directly increases its price, Bangkok households' consumption will accordingly decrease.

Table 5.4.1: Uncompensated and Compensated Price Elasticities for Average Households

Categories of Goods	Uncompensated Demand Elasticity								Compensated Demand Elasticity							
	Food & Beverages	Tobacco Products & Alcohol Beverages	Personal Appearance	Housing	Medical Care	Transportation	Education	water	Food & Beverages	Tobacco Products & Alcohol Beverages	Personal Appearance	Housing	Medical Care	Transportation	Education	water
Food & Beverages	-0.1929	-0.0070	-0.0137	-0.0259	-0.0066	-0.0178	-0.0146	-0.0049	-0.2672	0.0010	0.0118	0.0620	0.0082	0.1028	0.0174	0.0015
Tobacco Products & Alcohol Beverages	-0.0331	-0.1207	-0.0056	-0.0106	-0.0027	-0.0072	-0.0060	-0.0020	0.0143	-0.1227	0.0048	0.0252	0.0033	0.0419	0.0071	0.0006
Personal Appearance	-0.1241	-0.0107	-0.4191	-0.0396	-0.0101	-0.0271	-0.0223	-0.0075	0.0538	0.0015	-0.4439	0.0947	0.0125	0.1570	0.0265	0.0023
Housing	-0.1895	-0.0164	-0.0319	-0.4298	-0.0155	-0.0414	-0.0341	-0.0115	0.0821	0.0023	0.0274	-0.5605	0.0191	0.2398	0.0405	0.0035
Medical Care	-0.1485	-0.0128	-0.0250	-0.0474	-0.5203	-0.0324	-0.0267	-0.0090	0.0644	0.0018	0.0215	0.1133	-0.5376	0.1879	0.0318	0.0028
Transportation	-0.2291	-0.0198	-0.0386	-0.0731	-0.0187	-0.3459	-0.0413	-0.0139	0.0993	0.0028	0.0331	0.1748	0.0231	-0.5628	0.0490	0.0043
Education	-0.1459	-0.0126	-0.0246	-0.0466	-0.0119	-0.0319	-0.4750	-0.0088	0.0632	0.0018	0.0211	0.1113	0.0147	0.1846	-0.5117	0.0027
Water	-0.0634	-0.0055	-0.0107	-0.0202	-0.0052	-0.0139	-0.0114	-0.2316	0.0275	0.0008	0.0092	0.0484	0.0064	0.0802	0.0136	-0.2348

Source: Estimated by the author

Table 5.4.1 also exhibits compensated price elasticities. The compensated price elasticities are calculated from Hecksian demand function which drops off all income effects. The own price elasticities of compensated demand are all negative sign. Since increasing in its own price affects decreasing in its consumption. The elasticities of compensated demand of food & beverage, tobacco products & alcohol beverages, personal appearance, housing, medical care, transportation, education, and water are -0.2672, -0.1227, -0.4439, -0.5605, -0.5376, -0.5628, -0.5117 and -0.2348, respectively. It also can be used to estimate the substitutional effects of price changes on quantity.

Theoretically, if households consume a bundle of goods and one's price increases, households will decrease consumption of the one but increase their consumptions on other goods in order to remain on the same level of utility. As you can see from the table, all cross price elasticities are positive. This means if one's price increases, households will increase their consumptions on other goods which are according to the theory.

Considering deeply into each household type, the results find that the both uncompensated and compensated demand elasticities of all types of households are according to the theory. From table 5.4.2, 5.4.3 and 5.4.4, own price and cross price elasticities of uncompensated demand are all negative. However, increasing in one's price affects on its demand more than other goods' demands.

The own price elasticities of uncompensated demand of low income households in Bangkok of food & beverage, tobacco products & alcohol beverages, personal appearance, housing, medical care, transportation, education, and water consumption are -0.137, -0.431, -0.169, -0.232, -0.828, -0.460, -0.795, and -0.218. Medium income households' own price elasticities of uncompensated demand of food & beverage, tobacco products & alcohol beverages, personal appearance, housing, medical care, transportation, education, and tap water consumption are -0.176, -0.255, -0.101, -0.362, -0.629, -0.341, -0.400, -0.158, respectively.

Table 5.4.2: Low Income Households’ Price Elasticity

Categories of Goods	Uncompensated Price Elasticity								Compensated Price Elasticity							
	Food & Beverages	Tobacco Products & Alcohol Beverages	Personal Appearance	Housing	Medical Care	Transportation	Education	water	Food & Beverages	Tobacco Products & Alcohol Beverages	Personal Appearance	Housing	Medical Care	Transportation	Education	water
Food & Beverages	-0.137	-0.019	-0.038	-0.135	-0.003	-0.041	-0.005	-0.015	-0.406	0.016	0.008	0.070	0.026	0.141	0.037	0.004
Tobacco Products & Alcohol Beverages	-0.092	-0.431	-0.027	-0.094	-0.002	-0.029	-0.003	-0.011	0.177	-0.449	0.006	0.049	0.018	0.098	0.026	0.003
Personal Appearance	-0.036	-0.005	-0.169	-0.037	-0.001	-0.011	-0.001	-0.004	0.069	0.005	-0.178	0.019	0.007	0.039	0.010	0.001
Housing	-0.068	-0.010	-0.020	-0.232	-0.002	-0.021	-0.003	-0.008	0.132	0.009	0.004	-0.307	0.013	0.073	0.019	0.002
Medical Care	-0.177	-0.026	-0.052	-0.182	-0.828	-0.055	-0.007	-0.021	0.342	0.022	0.011	0.095	-0.855	0.190	0.050	0.006
Transportation	-0.154	-0.023	-0.045	-0.158	-0.004	-0.460	-0.006	-0.018	0.298	0.019	0.010	0.083	0.030	-0.609	0.043	0.005
Education	-0.176	-0.026	-0.051	-0.180	-0.004	-0.055	-0.795	-0.021	0.339	0.022	0.011	0.094	0.035	0.189	-0.833	0.006
Water	-0.045	-0.007	-0.013	-0.046	-0.001	-0.014	-0.002	-0.218	0.086	0.006	0.003	0.024	0.009	0.048	0.013	-0.223

Source: Estimated by the author

Table 5.4.3: Medium Income Households' Price Elasticity

Categories of Goods	Uncompensated Price Elasticity								Compensated Price Elasticity							
	Food & Beverages	Tobacco Products & Alcohol Beverages	Personal Appearance	Housing	Medical Care	Transportation	Education	water	Food & Beverages	Tobacco Products & Alcohol Beverages	Personal Appearance	Housing	Medical Care	Transportation	Education	water
Food & Beverages	-0.176	-0.011	-0.030	-0.052	-0.007	-0.044	-0.025	-0.010	-0.327	0.004	0.004	0.061	0.015	0.115	0.020	0.002
Tobacco Products & Alcohol Beverages	-0.081	-0.255	-0.019	-0.033	-0.005	-0.028	-0.015	-0.006	0.059	-0.262	0.002	0.038	0.010	0.072	0.013	0.001
Personal Appearance	-0.033	-0.003	-0.101	-0.013	-0.002	-0.011	-0.006	-0.002	0.024	0.001	-0.107	0.016	0.004	0.030	0.005	0.000
Housing	-0.165	-0.014	-0.038	-0.362	-0.009	-0.056	-0.031	-0.012	0.120	0.005	0.005	-0.459	0.019	0.147	0.026	0.002
Medical Care	-0.208	-0.018	-0.048	-0.084	-0.629	-0.071	-0.040	-0.016	0.151	0.006	0.006	0.097	-0.653	0.185	0.033	0.003
Transportation	-0.223	-0.019	-0.051	-0.090	-0.012	-0.341	-0.042	-0.017	0.162	0.007	0.006	0.104	0.026	-0.526	0.035	0.003
Education	-0.140	-0.012	-0.032	-0.057	-0.008	-0.047	-0.400	-0.011	0.101	0.004	0.004	0.065	0.016	0.124	-0.432	0.002
Water	-0.050	-0.004	-0.011	-0.020	-0.003	-0.017	-0.009	-0.158	0.036	0.002	0.001	0.023	0.006	0.044	0.008	-0.161

Source: Estimated by the author

Table 5.4.4: High Income Households' Price Elasticity

Categories of Goods	Uncompensated Price Elasticity								Compensated Price Elasticity							
	Food & Beverages	Tobacco Products & Alcohol Beverages	Personal Appearance	Housing	Medical Care	Transportation	Education	water	Food & Beverages	Tobacco Products & Alcohol Beverages	Personal Appearance	Housing	Medical Care	Transportation	Education	water
Food & Beverages	-0.216	-0.004	-0.024	-0.030	-0.010	-0.061	-0.028	-0.004	-0.279	0.001	0.009	0.066	0.006	0.101	0.012	0.001
Tobacco Products & Alcohol Beverages	-0.031	-0.144	-0.012	-0.014	-0.005	-0.029	-0.013	-0.002	0.014	-0.146	0.004	0.032	0.003	0.048	0.006	0.001
Personal Appearance	-0.057	-0.003	-0.245	-0.027	-0.009	-0.054	-0.025	-0.004	0.025	0.001	-0.266	0.059	0.005	0.090	0.011	0.001
Housing	-0.144	-0.008	-0.055	-0.394	-0.022	-0.136	-0.063	-0.009	0.064	0.001	0.021	-0.541	0.014	0.226	0.027	0.003
Medical Care	-0.079	-0.005	-0.030	-0.037	-0.357	-0.075	-0.034	-0.005	0.035	0.001	0.011	0.081	-0.370	0.124	0.015	0.001
Transportation	-0.130	-0.008	-0.049	-0.061	-0.020	-0.195	-0.057	-0.008	0.058	0.001	0.019	0.135	0.012	-0.419	0.024	0.002
Education	-0.063	-0.004	-0.024	-0.029	-0.010	-0.059	-0.262	-0.004	0.028	0.001	0.009	0.065	0.006	0.099	-0.289	0.001
Water	-0.046	-0.003	-0.017	-0.021	-0.007	-0.044	-0.020	-0.217	0.021	0.000	0.007	0.048	0.004	0.072	0.009	-0.220

Source: Estimated by the author

The own price elasticiites of high income households are -0.216, -0.144, -0.245, -0.394, -0.357, -0.195, -0.262 and -0.217, accordingly. Also, own price elasticities of compensated demand of all type of households are negative while cross price elasticities are positive. The elasticities of compensated demand of food & beverage, tobacco products & alcohol beverages, personal appearance, housing, medical care, transportation, education, and water for the low income households are -0.406, -0.449, -0.178, -0.307, -0.855, -0.609, -0.833 and -0.223, respectively. Medium income households' own price elasticities of compensated demand of food & beverage, tobacco products & alcohol beverages, personal appearance, housing, medical care, transportation, education, and tap water are -0.327, -0.262, -0.107, -0.459, -0.653, -0.526, -0.432, and -0.161, respectively. The own price elasticities of high income households are -0.279, -0.146, -0.266, -0.541, -0.370, -0.419, -0.289, and -0.220, accordingly.

In general, most tax, fee and charge policies are regressive. Tax policies affect lower income households more than higher income households. In consideration of a tap water category, own price elasticity of uncompensated demand of low income, medium income, and high income households are -0.218, -0.158 and -0.217, successively. This implies that the wastewater treatment charge affects on low income households and high income households more than medium income households. Comparing between the low and medium income households' elasticities are according to the theory. Treatment charge affects on low income households more than medium income households while the policy affects least on high income households. However, the analysis of the tax system cannot be judged by only elasticities. Since, an important feature of tax systems is the percentage of the tax burden as it relates to income or consumption. The terms progressive, regressive, and proportional are used to describe the way the rate progresses from low to high, from high to low, or proportionally. The important indicator which identify the wastewater treatment charge policy whether it is a regressive charge rate, progressive charge rate or proportional charge rate is that the effective rates decreases, increases or fixes as the amount to which the rate is applied increases. More analysis of degree of the system is presented in chapter 7.

CHAPTER VI:

WASTEWATER TREATMENT STOCHASTIC COST FRONTIER FUNCTION ESTIMATION

6.1 Introduction

From the literatures, this paper categorizes the methods to estimate the cost function of wastewater treatment plants into 3 methods. First, the estimating of wastewater abatement cost was suggested by Israngkura (2000). It is known as average cost pricing approach. It is suitable for estimating cost of each plant separately. The research used a general formula outlines which use the common variables for calculating the charge. The specific values of the parameters used in the formula will vary according to the cost structure of each plant. There are three main variables in the model which are fixed cost, variable cost and administrative cost. The charge which calculated from this method is based on the average cost concept and not on the marginal cost concept. This average cost pricing technique will allow to break – even cost of wastewater treatment but it will not result in the allocation efficiency.

The next method which normally used for estimation is deriving water pollution abatement cost functions by using production function. This method was developed by Misra (1998) and Rossi, Young, and Epp (1979). The earlier studies commonly defined the production function of wastewater abatement associated with production factor such as labor, capital, and materials. Additionally, Hartman, Wheeler, and Singh (1994) added quality characteristics of effluent and influent stream in their function.

Based on Goldar, Misra, and Mukherji (2001), the wastewater abatement cost function was properly developed. The plant gets a given volume of polluted water in their model. The plant responds for reducing the impurities. Thus, the output of the plant is pollution reduction. Their model specify the final water quality as a function of wastewater generated, pollution level of influent water and amount of input used for abatement activity. The treatment plants minimized the cost of treatment, given the prices of input factors the volume of wastewater, the pollution level of influent wastewater stream, and the output of abatement activity measured in terms of reduction in pollution load. Although these two methods are well known and acceptable, these methods are introduced to estimated abatement cost of industrial estate or the firms' treatment plants.

The BMA's treatment plants consist of four different types. There are twelve community plants whose capacities are 40,000 m^3 per day. Two small scale plants are able to treat wastewater range between 30,000 to 60,000 m^3 per day. The capacities of three medium scale plants are between 60,001 to 160,000 m^3 per day. Lastly, two large scale plants are able to treat wastewater range between160,001 to 350,000 m^3 per day. As difference in an operation system, a purify system between private and public wastewater treatment plants, characters of influent stream of wastewater and some limitations, the estimation from the ordinary least square of the first two methods that mention above may not well explain all characters of all types of treatment plants. As a result, this study would like to introduce the frontier analysis. This method is also suitable for analyzing the cost of public provision of BMA in this case.

Prior to the introduction of the cost frontier analysis, the paper would like to discuss about production frontier development. First, Farrell (1957) considered the technical efficiency of firm in the sense of relative efficiency by using frontier estimation. Also, Aigner and Chu (1968), Afriat (1972), and Schmidt (1976) induced the estimation of deterministic frontier models whose values were defined to be greater than or equal to observed values of production for different levels of inputs in the production process. The concept of the technical efficiency of firms has been developed an application of econometric models of frontier function. During the last two decades, frontier analysis and technical efficiency measurements were developed. The frontier analysis is determining the shape and location of frontier rather than the fitted average function. The frontier approach developed along two competing paradigms, stochastic frontier analysis (SFA) and data envelopment analysis (DEA).

Data envelopment analysis (DEA), occasionally called frontier analysis, was first put forward by Charnes, Cooper and Rhodes in 1978. It is a performance measurement technique which can be used for evaluating the relative efficiency of decision-making units (DMU's) in organisations. Here a DMU is a distinct unit within an organization that has flexibility with respect to some of the decisions it makes, but not necessarily complete freedom with respect to these decisions.

The stochastic frontier analysis (SFA) was independently proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and Broeck (1977). This method specifies the output of each firm is bounded above by a frontier that is stochastic in the sense that its placement is allowed to vary randomly across firm. This allows firm to be technically inefficient relative to their own frontier rather than to some sample norm.

Two different techniques also differ in the assumptions imposed on the data. DEA assumes non – parametric linear programming techniques but SFA assumes the parametric stochastic frontier approach. Therefore, SFA allows observation to depart from the frontier due to both random error and inefficiency while DEA measure random error as a part of inefficiency. From these reasons, stochastic frontier analysis is more appropriated for cost frontier estimation of public wastewater treatment plants'.

This chapter is organized as follows. Section 2 introduces to the model framework for wastewater abatement cost and research methodology for stochastic frontier analysis. Section 3 specify and estimate a model of abatement cost.

6.2 Framework

Before explaining the cost frontier analysis, the understanding of the production frontier function is necessary. The stochastic frontier production function has been a significant contribution to the econometric modeling of production and the estimation of technical efficiency of firms. Based on Schmidt and Lovell (1979), the stochastic frontier involved two random components. The first component accounted for the presence of technical inefficiency and another being a traditional random error. The values were defined to be greater than or equal to observed values of production for different levels of inputs in the production process. The model can expressed as follow:

$$Y_{it} = x_{it}\alpha + (V_{it} - U_{it}) \quad \text{--------------------------- 6.1}$$

where

Y_{it} = Output of firm i at time t

x_{it} = Input factors associated with the production of firm i at time t

V_{it} = random variables which are assumed to be independent and identically distributed $N(0, \sigma_v^2)$

U_{it} = non negative random variables which are assumed to account for technical inefficiency in production and are assumed to be independent and identically distributed as truncations at zero of the $N(\mu, \sigma^2)$

All of above have been expressed in terms of production function, with the U_i interpreted as technical inefficiency effects, which cause the firm to operate below the stochastic production frontier. The firm seeks to minimize the cost of producing its desired rate of output subject to a stochastic production frontier constraint. If the firm is technically inefficient it operates beneath its stochastic production frontier, and if the firm is allocatively inefficient it operates off its least cost expansion path. Incorporating these features into the analysis leads to the derivation of a system of stochastic factor demand frontiers and then a stochastic cost frontier. To specify a stochastic frontier cost function, most literatures simplied alter the error term specification from $(V_{it} - U_{it})$ to $(V_{it} + U_{it})$. Consequently, the cost frontier function based on Schmidt and Lovell (1979) and Battese & Coelli (1992) can be written as follows:

$$C_{it} = x_{it}\alpha + (V_{it} + U_{it}) \quad \text{--------------------------- 6.2}$$

where

C_{it} = Cost of production firm i at time t

x_{it} = Input prices associated with the production of firm i at time t and output of firm i at time t

α = unknown parameters

V_{it} = random variables which are assumed to be independence and identically distributed $N(0,\sigma_v^2)$

U_{it} = non negative random variables which are assumed to account for technical inefficiency in production and are assumed to be independence and identically distributed as truncations at zero of the $N(\mu,\sigma^2)$

In the case of cost frontier function, the U_i defines how far the firm operates above the cost frontier. If allocation efficiency is assumed, the U_i is closely related to the cost of technical inefficiency. If this assumption is not made, the interpretation of the U_i in a cost function is less clear, with both technical and allocative inefficiencies possible involved. Thus the author refers to efficiencies measured relative to a cost frontier as cost efficiencies instead.

6.3 Estimation & Results

6.3.1 Data, variable derivation, and summary statistics

This paneled data method observes an over 36 time periods of five wastewater treatment plants. Since Bangkok where this research conducted, is located on a tropical zone where precipitation level contrasts significantly across the year, season has a profound effect in data collection. Therefore, panelled data method is suitable considered while many studies on abatement cost estimation used the pool data method. The data used for estimation cost function of wastewater treatment of Bangkok from year 1999 to 2007 are provided by Sewage & Draining Department, BMA. Due to incomplete reporting data, this paper uses the monthly data from year 2003 to year 2005. This study; moreover, uses the data of five wastewater treatment plants which represent all four types of BMA's plants. Si Phraya plant and Rattanakosin plant represent community plant and small scale plants. Tung Kru plant and Nong Khaem - Pasicharoen plant signify medium scale plants. Lastly, Chong Nonsi plant represents large scale plants. This study excludes Dindang plant, and Chatuchak plant.

Table 6.1: Summary Statistics for Variables for Wastewater Abatement of Bangkok Metropolitan Administration

Variables	Minimum	Maximum	Mean	Std. Deviation
Total abatement cost (baht / month)	741,156	8,885,750	3,338,044	2,360,899
Volume of water inflow (m^3)	401,250	5,331,690	1,803,723	1,240,138
Total material costs (baht/ month)	59,138	766,375	266,439	201,220
Total electricity costs (baht/ month)	266,577	3,374,270	1,211,861	908,394
Wage per worker (baht/ month)	3,580	48,522	16,177	12,119
Number of workers	38	46	43	3.568954
Bio Oxygen Demand (BOD) in influence stream (mg/ l)	22.97	190.70	53.04	27.51
Bio Oxygen Demand (BOD) in effluence stream (mg/ l)	1.36	15.96	6.10	3.21

Source: Calculated by the author

For estimating the cost function, prices of input are needs. Price of labor was computed as the wage bill of each plant divided by the number of workers of that plant. Price lists of electricity for the three years were available from the database of interior commerce department, the Ministry of Commercial. Prices of raw material were constructed by the budgets which were set by Bangkok Metropolitan Administrative for each plant each year divided by the number of kilograms of raw material used of that plant. Polymer, alum and sodium hypochloride are important materials for settling of suspended particles. Rattanakosin and Si Phraya treatment plants use only sodium hypochloride as its raw materials while other plants use polymer and sodium hypochloride with some other additives rather than alum. Also, other plants use sodium hypochloride in the most proportion compare to other materials. Consequently, this model sets sodium hypochloride as an only raw material because in both cost aspect and quantity aspect, other materials are the chemical addition and not significantly used.

Table 6.1 is the summary of the data on the variables in the cost frontier function. The table shows the mean and standard deviation of total cost, costs of material, electricity, and labor, wastewater volume, and BOD concentration in influent and effluent. It consists of 180 observations monthly collected from five wastewater treatment plants in Bangkok from year 2003 to 2005. As you can see in the table 5.1, total abatement cost of treatment plants is average 3,338,044 baht per month. An electricity cost has highest proportion of all costs followed by a material cost and a labor cost. On average, a material cost, an electricity cost, a labor cost of each plant is 266,439 baht, 1,211,861 baht, and 16,177 baht, successively. The volume of wastewater inflow ranges between 401,250 m^3 to 5,331,690 m^3 per plants per month which is averagely 1,803,723 m^3 per plant per month. Number of workers vary from 38 workers to 46 workers depend on the plant's size.

6.3.2 System Estimation and Results

In this study, the author estimates the Cobb – Douglas cost frontier. The stochastic cost frontier function for panel data on wastewater treatment plants in Bangkok which has been estimated in this paper is defined by:

$$\ln C_{it} = \alpha_0 + \alpha_1 \ln WW_{it} + \alpha_2 \ln PL_{it} + \alpha_3 \ln PE_{it} + \alpha_4 \ln PM_{it} + (V_{it} + U_{it}) \quad \text{------------ 6.3}$$

where C_{it}, WW_{it}, PL_{it}, PE_{it}, and PM_{it} are cost, wastewater inflow, wage, electricity price and material price, respectively, and V_{it} and U_{it} are assumed normal and half – normal distributed. Since the households respond for the operation and maintainance cost while BMA respond for investment in main facilities and infrastructure, this study does not include land cost, construction cost and capital cost. The coefficients estimations are presented in table 6.2.

Table 6.2: Maximum – Likelihood Estimates for Coefficients of Stochastic Frontier Cost Function for Wastewater Treatment Plants in Bangkok from Year 2003 to Year 2005

Variable	Parameter	Coefficient (OLS)	Coefficient (MLE)
Constant	α_0	2.3152 (4.1556)	1.9955 (3.9999)
$\ln(WW_i)$	α_1	0.4283 (11.3049)	0.5113 (15.4801)
$\ln(PL)$	α_2	0.5528 (15.9714)	0.4856 (16.3754)
$\ln(PE)$	α_3	0.5268 (1.5581)	0.1084 (0.3050)*
$\ln(PM)$	α_4	0.0695 (1.7798)	0.0761 (2.3256)
sigma-squared σ_S^2		0.0328	0.0784
μ		0	0
η		0	0
Log (likelihood) = 61.3785			
LR test of the one-sided error = 13.4772			
Mean Efficiency = 1.2550			

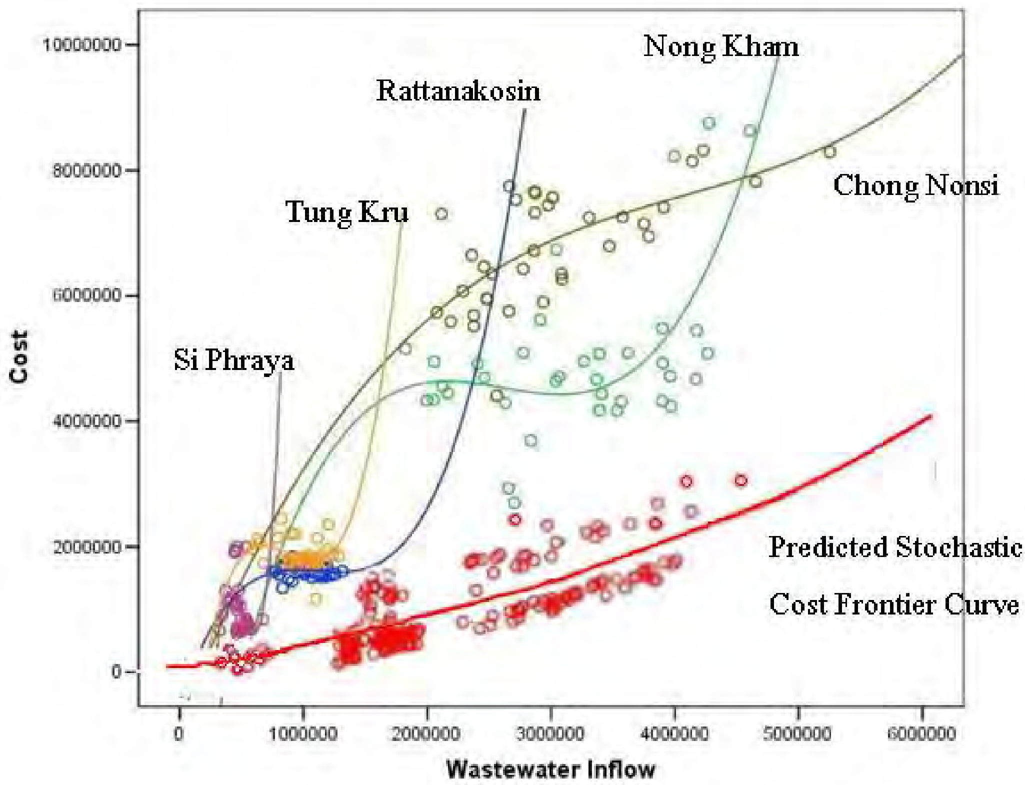
Source: Estimated by the author

t – ratios are in parentheses

The ordinary least square (OLS) and maximum likelihood estimates (MLE) of the parameters of the model are obtained by using computer program, FRONTIER Version 4.1c (Coelli, 1995). The estimated stochastic cost frontier function is presented in table 6.2. The results show that the variables have the expected sign in both OLS and MLE and the coefficients have high levels of statistical significance. The log – likelihood is 61.3785 which are considerably high. The likelihood ratio test is 13.4772. As you can see, from maximum likelihood estimation, volume of wastewater inflow (WW) is positive equaling to 0.5113 and is significant. This implies that the cost of abatement goes up if the volume of wastewater inflow increases. The elasticity of cost with respect to wastewater volume is found to be less than one. This shows that the economy of scale occurs. In other words, there are economies of scale in water pollution abatement. Next, the coefficient of wage (PL), price of electricity (PE), and price of material which is a sodium hypochloride (PM) are all positive which 0.4856, 0.1084, and 0.0761, respectively. These reflect the fact that increases in input prices will raise the cost of abatement. The treatment cost heavily depends on wage followed by price of electricity and price of materials.

Figure 6.1: Cost Curves and Predicted Stochastic Cost Frontier Curve

of Bangkok's Five Wastewater Treatment Plants



Source: Graphed by author

To clarify the patterns of treatment costs, the cost curves of five treatment plants and the predicted stochastic cost frontier curve are presented in figure 6.1. The predicted stochastic cost frontier curve is the line which drawn below all treatment cost curves and also drawn below all observations. From figure 6.1, there are noticeably some inefficiency occurred; especially, in the large scale plants such as Chong Nonsi Plant and Nong Kham Plant. These results relate to the statistic that we mention in previous chapter. According to Chapter 2, all treatment plants can averagely operate only 64.34 percent of their capacities. For example, Chong Nonsi Plant can operate only 58.77 percent. Indeed, BMA nowadays inefficiently operates the treatment plants.

6.3.3 Cost Efficiency Estimation

Table 6.3: Predicted Cost Efficiencies of Wastewater Treatment Plants from Year 2003 to Year 2005

(baht per m^3)

Plants	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03
1	1.158	1.109	1.112	1.422	1.082	1.158	1.084	1.077	1.773	1.130	1.151	1.127
2	1.106	1.129	1.130	1.128	1.116	1.178	1.187	1.201	1.299	1.180	1.172	1.199
3	1.105	1.069	1.154	1.214	1.289	1.527	1.391	1.343	1.343	1.195	1.181	1.170
4	1.552	1.521	1.278	1.371	1.346	1.618	1.580	1.477	1.353	1.137	1.201	1.149
5	1.198	1.458	1.358	1.436	1.398	1.528	1.378	1.416	1.524	1.320	1.489	1.427
Mean	1.224	1.257	1.206	1.314	1.246	1.402	1.324	1.303	1.458	1.192	1.239	1.214

Plants	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04
1	1.045	1.054	1.044	1.069	1.102	1.189	1.239	1.217	1.355	1.055	1.078	1.053
2	1.063	1.092	1.126	1.039	1.084	1.091	1.099	1.049	1.108	1.086	1.054	1.071
3	1.126	1.158	1.028	1.065	1.098	1.118	1.114	1.100	1.100	1.029	1.062	1.088
4	1.056	1.076	1.113	1.075	1.084	1.082	1.079	1.063	1.061	1.081	1.108	1.199
5	1.176	1.179	1.213	1.159	1.094	1.102	1.098	1.093	1.067	1.159	1.192	1.206
Mean	1.093	1.112	1.105	1.081	1.093	1.116	1.126	1.104	1.138	1.082	1.099	1.124

Source: Calculated by author

Table 6.3: Predicted Cost Efficiencies of Wastewater Treatment Plants from Year 2003 to Year 2005 (Continued)

(baht per m^3)

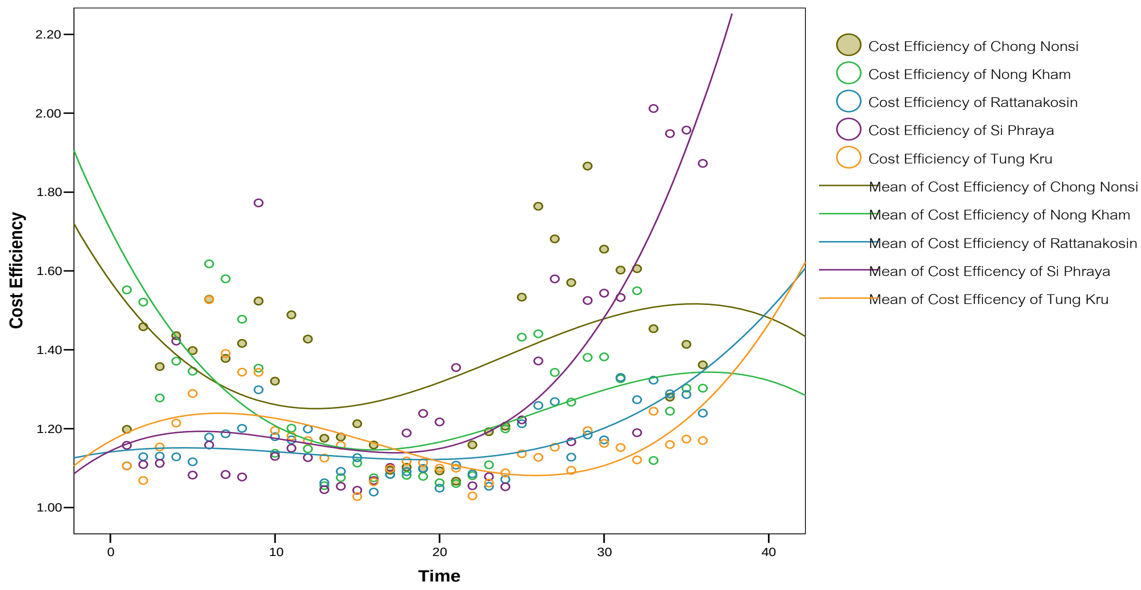
Plants	Jan-05	Feb-05	Mar-05	Apr-05	May-05	Jun-05	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05
1	1.222	1.371	1.580	1.167	1.525	1.544	1.533	1.190	2.012	1.948	1.957	1.873
2	1.212	1.259	1.269	1.128	1.184	1.172	1.330	1.273	1.323	1.289	1.287	1.239
3	1.136	1.127	1.153	1.094	1.195	1.163	1.152	1.121	1.244	1.160	1.174	1.170
4	1.432	1.441	1.343	1.267	1.381	1.382	1.327	1.550	1.119	1.244	1.303	1.303
5	1.533	1.764	1.681	1.570	1.866	1.655	1.602	1.606	1.453	1.280	1.414	1.362
Mean	1.307	1.392	1.405	1.245	1.429	1.383	1.389	1.348	1.430	1.384	1.427	1.389

Source: Calculated by author

This paper uses a translog cost frontier as the standard to measure cost efficiency. The predicted cost efficiencies of Bangkok's wastewater treatment plants from year 2003 to year 2005 are presented in Table 6.3. The cost efficiencies of five plants are range between 1.105 to 1.552 in January 2003 and 1.170 to 1.873 in December 2005. The mean of cost efficiencies in each period of time also show that cost efficiencies increase overtime. For example, the mean of cost efficiency in January 2003 was 1.224 baht per m^3 and it increases to 1.389 baht per m^3 in December 2005. However, the data indicated that the cost efficiencies are fluctuated during the year. There exist considerable variations in the efficiencies of the treatment plants were in year 2004. According to table 6.3, the author concludes that the cost efficiencies depend on season. The predicted cost efficiencies of the treatment plants in the beginning of the year and the end of the year were lower than the mid of the year. The highest cost efficiencies were in September which is the end of the rainy season and is the highest rainy volume of the year whereas the cost efficiencies are low in the summer. The graphs in figure 6.2 present the mean cost efficiencies of five plants over time.

Figure 6.2: Predicted Cost Efficiencies of Five Wastewater Treatment Plants

from Year 2003 to Year 2005



Source: Graphed by author

Noticeably, the mean curves of small scale plants, medium scale plants and large scale plants are difference. Si Phraya Plant, Tung Kru Plant, and Rattanakosin Plant's mean cost efficiency curves increase over time while Nong Kham Plant and Chong Nonsi Plant's mean cost efficiency curve eventually decrease. These can be explained as follows. Since the small scale plants have more limited capacities than the medium and large scale plants, the wastewater inflow is mostly constant while the operation and maintenance cost are higher over time. The cost efficiency of the less capacity plants; therefore, are lower in the long run compare to the large scale plants. In other words, the cost efficiencies of the plants, whose treatment capacities less than 150,000 m^3 per day, increase over time. While the cost efficiencies decrease over time for the plants whose capacities more than 150,000 m^3 per day. This implies that a large scale plant is more cost-effective than the small scale plant. However, this analysis does not include construction cost and pipe system construction cost into the model.

6.3.4 Marginal Abatement Cost (MAC) Estimation

Table 6.4: Marginal Cost Treatment

(baht per m^3)

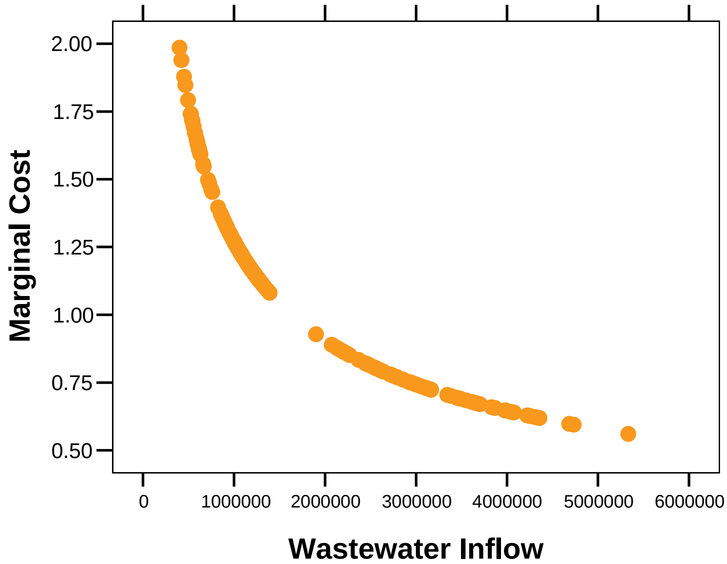
Treatment Plants (Capacity of Treatment)	Marginal Cost of Treatment Based on Capacity of Treatment	Marginal Cost Treatment Based on Wastewater Inflow
Si Phraya Plant ($30,000\ m^3$ per day)	1.337949314	1.602260849
Rattanakosin Plant ($40,000\ m^3$ per day)	1.162470929	1.231830242
Tung Kru Plant ($65,000\ m^3$ per day)	0.916933967	1.219893277
Nong Kham Plant ($157,000\ m^3$ per day)	0.595899002	0.744871732
Chong Nonsi Plant ($200,000m^3$ per day)	0.529414046	0.705249938

Source: Estimate by author

Consequently, BMA should be better investing in one large scale treatment plants than many small plants in the area to obtain more cost efficiency in the long run. However, this estimation does not include land cost, treatment plants' construction costs, and pipe system costs.

According to the stochastic cost frontier estimation, the marginal abatement cost of treatment plants can be computed as presented in Table 6.4. A marginal abatement cost of treatment plant is the cost a plant incurs in treatment one additional unit of the wastewater inflow. Marginal abatement cost usually initially falls as due to economy of scale. Thus the MAC of small plants should higher than medium and large scale treatment plants. Table 6.4 present the MAC calculated from capacity of treatment and MC estimated from volume of wastewater inflow per day. The marginal abatement costs estimated from treatment capacities of Si Phraya Plant, Rattanakosin Plant, Tung Kru Plant, Nong Kham Plant, and Chong Nonsi Plant, are 1.34, 1.16, 0.92, 0.60 and 0.53, successively. The MAC estimated from wastewater inflow to the plants, are 1.60, 1.23, 1.22, 0.74, and 0.70, respectively. From the results, the marginal abatement cost curve of the treatment plants can be estimated as follows.

Figure 6.3: Marginal Cost Curve



Source: Graphed by author

As you can see in table 6.4 and figure 6.3, marginal abatement costs of small scale plants such as Si Phraya Plant are the least. The marginal abatement costs of medium scale plants such as Tung Kru Plant are lower than small scale plants but higher than large scale plants such as Chong Nonsi Plant. It can be explained that treated the large amount of wastewater save more costs than treated just only the small amount. Therefore, BMA should invest in only one large scale treatment plant rather than invest in many small plants. Therefore, the BMA's wastewater treatment marginal cost curve should be the downward sloping as shown in Figure 6.3.

The marginal abatement cost (MAC) is required in this study to determine the abatement cost saving of all plants. It occurs when the wastewater has been treated. It is a relationship between volumes of wastewater being abated and the price of abatement. Morris, Paltsev, and Reilly (2008) claimed that the marginal abatement cost has been widely used as devices to illustrate simple economic concepts such as the benefits of emissions trading. The social abatement cost consists of two types of abatement cost which are the private and public abatement costs. The private cost of treatment is the cost that households concern and bear as it own costs such as costs of set up the septic tank, grease trap and wastewater treatment tank in their houses, town houses and condominiums. Since the households' private costs of treatment are fixed cost, the private marginal abatement cost is zero. It does not affect the slope of the social cost. Even though households have the treatment system, wastewater discharged from households still contaminated and creates other problems to the society. BMA responds for the abatement cost of the wastewater that occurs in the area which this paper considers as a public treatment cost. As the marginal private cost is zero and does not affect the social cost sloping, the marginal public abatement cost equal the social abatement cost.

The marginal public abatement cost in this study presents the social abatement cost or the marginal cost of wastewater reduction. MAC curve in this study is downward sloping presenting economy of scale. It means more wastewater inflow to the plants will decrease marginal abatement cost. Since the marginal abatement cost curves are simply the slope or the derivative of the total abatement cost curves, the area under the marginal abatement cost curve is given the height of the total cost. To estimate the total abatement cost, integration of the marginal abatement cost is considered. Otherwise, total abatement cost is simply the sum of the marginal costs. Then the abatement cost saving is the area under the marginal abatement cost curve between the wastewater inflow before imposing the charge and the wastewater inflow after imposing the charge.

CHAPTER VII

SOCIAL WELFARE ANALYSIS

7.1 Introduction

The net social welfare measurement in this paper takes into account the water market and the wastewater abatement cost saving which estimated from stochastic cost frontier analysis in chapter 5 and 6. According to the methodology described in Chapter 4, the author would like to refer to the net social welfare measurement in this study. The net social welfare (NSW) is the addition of positive and negative affects of all sectors which presented as follows:

NSW = Δ Household Sector + Δ BMA Sector

Or,

(-) (+) (-) (+)

NSW = (TEV – TCR) + ACS = (Pw_1E_0 E_1Pw_0 – $Pw_1E_1APw_0$) + $WE_1WE_0WW_0WW_1$

(-) (+) (-) (+)

= DWL + ACS = E_1E_0A + $WE_1WE_0WW_0WW_1$ (from figure 4.2 and 4.3)

Or,

(-) (+)

Net Social Welfare = Household loss + BMA gain

(-)

= Loss due to the treatment change on water consumption

(+) (+)

+ Total charge revenues + Abatement cost saving

Nevertheless, the benefits caused by wastewater reduction are not only abatement cost saving, but there are certain intangible benefits. Reduction in damage from water pollution and benefits from water quality improvement such as health benefits and recreation benefits are also the intangible benefits from water pollution reduction. However, this paper does not value those benefits in monetary form in order to illustrate the direct benefit from the policy.

7.2 Estimation & Results

Since the BMA will impose the wastewater treatment charges on households at 2 baht per m^3 on water consumptions, the calculations, which are made in this section, are based on this assumption. This section compares consumer surplus, expenses, wastewater discharge and other welfare measurements with and without the wastewater treatment charge.

7.2.1 Data

According to Chapter 4 and Chapter 5, prices and expenditure levels data for analyze households' behaviors in Bangkok area were from the Interior Commerce Department, Ministry of Commerce, and the socio-economic survey (SES) of the years 2002, 2004 and 2006. The total numbers of Bangkok area observations were 6,778, which consists of three categories: low income households, medium income households, and high income households. For cost of abatement estimation, this study used the paneled data method which observed over 36 time periods of five wastewater treatment plants: Si Phraya plant, Rattanakosin plant, Tung Kru plant, Nong Khaem - Pasicharoen plant and Chong Nonsi plant. The variable derivation and summary statistics were already discussed in Chapter 5 and Chapter 6.

There are 2 million households in Bangkok area which approximately consists of 610,505 households in the low income household category, 1,049,867 households in the medium income household category, and, 339,628 households in the high income household category. This chapter estimates the changes of average income household and each category of households.

7.2.2 System Estimation and Results

This section presents the estimation of net social welfare (NSW) change if BMA imposes the wastewater treatment charge on Bangkok households. It provides estimates of all indicators such as water consumption expenses, total expenses, wastewater discharged, equivalent variation, total charge revenues, dead weight loss, and the total abatement cost saving. Then this paper presents the revenue neutral method as the alternative scenarios. The revenue neutral is an underlying principle of tax reform has been that whatever changes are made in the system that results must be revenue – neutral. If BMA raises one tax, it should lower another tax in order to create revenue neutrality. The amount of revenues coming into the BMA should not be changed. In addition, the charge revenues are earmarking, so the revenues will be used for clean-up activities only. Indeed, there are four main scenarios which will be presented in this chapter as follows.

Benchmark Scenario : Without the wastewater treatment charge – the fundamental or certain circumstance

Scenario 1 : The BMA designed policy – imposed the wastewater treatment charge at 2 baht per m^3 on households' water consumptions

Scenario 2 : First alternative policy – with the treatment charge at 2 baht per m^3 on households' water consumptions and introducing a revenue neutral method by compensating lump sum amount to Bangkok households. BMA will transfer the same estimated amounts to all households equally.

Scenario 3 : Second alternative policy – with the charge at 2 baht per m^3 on households' water consumptions and introducing a revenue neutral method by reducing other taxes to the level that can achieve the assumption of the revenue neutral.

According to these four scenarios, this chapter; moreover, provides policy implications and recommendations which can be drawn from the analyses. Efficiency and equity are the topics that economists usually discuss when they mention policy implication. The study basically compares the effects on efficiency and equity of those four scenarios in order to give recommendations and some guidelines to the policy maker. The results can be used as the baselines for further policy development.

Table 7.1: Comparison of Average Income Households' Water Expenses, Other Goods Expenses and Total Expenses of the Four Scenarios

	Benchmark Scenario	Scenario 1	Scenario 2	Scenario 3
Water Expenses per Household (Baht)	236.16	235.990	236.2	236.2
Other Goods Expenses per Household (Baht)	14,926.33	14,898.94	14,931.99	14,932.08
Total Expenses per Household (Baht)	15,162.50	15,134.93	15,168.19	15,168.28
Water Expense Ratio= $\frac{\text{Water Expenses}}{\text{Total Expenses}}$	1.5576%	1.5592%	1.5572%	1.5572%
Other Expense Ratio = $\frac{\text{Other Expenses}}{\text{Total Expenses}}$	98.4424%	98.441%	98.443%	98.443%

Source: Calculated by the author

Table 7.1 shows the average income class of households in Bangkok area. First is the fundamental circumstance in existence before BMA reformed its environmental policy. In household sector, Bangkok's households averagely spend 15,162.50 baht per household per month on their consumption. They spend 236.17 baht per household per month on tap water while spending 14,926.34 baht per household per month on other goods.

Secondly, the scenario 1 occurred when BMA imposes the wastewater treatment charge at 2 baht per m^3 on households' water consumptions. This situation aims to raise the BMA's revenues. It introduces the policy reform according to the "Polluters Pay

Principle". Since households create water pollution, BMA imposes wastewater treatment charges on water consumptions. With the treatment charge, the average expenditure of all households in Bangkok is decreased to 15,134.93 per household per month. The water consumption expense of households after imposing the charge is averagely decreased to 235.99 baht per household per month. However, the proportion of water consumption expenses to the total expenses very slightly increased from 1.5575 percent to 1.5592 percent after the charge is imposed on households. Since the water is considered a necessity goods, households spend more on water consumption while the other expenses decrease from 98.4425 percent of all expenses to 98.4408 percent of all expenses. Indeed, the treatment charge affects decreasing in amount of all expenses and water consumption. However, the ratio of water consumption expenses to total expenses is increased while the ratio of other goods expenses to total expenses is slightly decreased.

However, the total water consumption expenses in revenue neutral scenarios (scenario 2 and scenario 3) are increased as you can see in table 7.1. Then the results define that revenue neutral policy encourages an increase in all expenses. The total expense of scenario 2 and scenario 3 are 15,168.19 and 15,168.28 baht per household. The scenario 1, imposed the charge at 2 baht per m^3, influences higher ratio of water expenses to total expenses of average income households while the other scenarios are lower the ratio. The ratios of water expenses to total expenses are 1.5592, 1.5572, and 1.5572 percent for the scenario 1, scenario 2 and scenario 3, successively. Additionally, the revenue neutral scenarios affect increasing in the other goods ratios, which is the percent of other goods expenses to the total expenses. The percentage of other goods expenses of households in scenario 2 and scenario 3 are equal at 98.443%.

Table 7.2: Comparison of Bangkok Households Expenditures Classified by Income Class

	Benchmark Scenario			Scenario 1			Scenario 2			Scenario 3		
Income Classes	Low Income	Medium Income	High Income	Low Income	Medium Income	High Income	Low Income	Medium Income	High Income	Low Income	Medium Income	High Income
Water Expenses (Baht)	131.99	243.60	403.73	131.86	243.43	403.52	132.15	243.62	403.68	131.86	243.49	404.30
Other Goods Expenses (Baht)	6,132.76	12,837.4	34,136.3	6,116.77	12,809.2	34,095.0	6,152.0	12,840.4	34,125.5	6,116.77	12,819	34,245.5
Total Expenses (Baht)	6,264.75	13,080.97	34,540.16	6,248.63	13,052.6	34,498.6	6,284.05	13,084	34,529.2	6,248.63	13,062.5	34,649.8
% of Water Expenses	2.107%	1.862%	1.169%	2.110%	1.865%	1.170%	2.103%	1.862%	1.169%	2.110%	1.864%	1.167%
% of Other Goods Expenses	97.893%	98.138%	98.831%	97.890%	98.135%	98.830%	97.899%	98.138%	98.831%	97.890%	98.136%	98.833%

Source: Calculattions by the author

Table 7.2 shows the results of water consumption expenses, other goods consumption expenses and total expenses of each household category in Bangkok with and without the treatment charge. The water expenses ratios of households without the treatment charge are 2.1069, 1.8623, and 1.1689 percent for low, medium, and high income households. This means that lower income households spend more on water consumption compare to higher income households. The average expenditure of low, medium, and high income households are 6,264.75, 13,080.97, and 34,540.16 baht per household per month. While with the treatment charge in scenario 1, the average expenditure of low, medium, and high income households are decreased to 6,248.63, 13,052.62, and 34,498.55 baht per household per month. The water consumption expense of each household after imposing the charge are slightly decreased to 131.86, 243.43, and 403.52 baht per month for low, medium, and high income households. Although the water consumption decreases, the price of tap water increases. These affect the proportion of water consumption expenses to total expenses of households very slightly increases.

Like the average income households' water expenses ratio, the ratios of low, medium, and high income households are very slightly increased to 2.110, 1.865, and 1.170 percent. The water expense ratio is higher in lower income households followed by medium income and high income households. The other expense ratios in all categories of households are decreased because households have to decide to spend more on the more necessity goods. Indeed, the treatment charge affects decreasing in all expenses except the water consumption expenses of all categories of households.

Although scenario 1 decreases total expenditures of all household categories, the scenario 2 increases total expenditures of low and medium income households and decreases total expenditure of high income households. It also increases total expenditures in low income households more than medium income households. The expenditure of low, medium, and high income households are changed to 6.284.05, 12,840.4, and 34,125.5 baht per household per month.

Lastly, the scenario 3 decreases total expenditures of low and medium income households to 6,248.63 and 13,062.5 baht per households per month but it increases the expenditures of high income households from 34,540.16 baht per households per month to 34,649.8 baht per households per month. As a result, scenario 2, imposed the treatment charge with revenue recycling by transferring lump sum amount to all households equally, creates better income distribution compare to other scenarios. The results can also be concluded that the scenario 3 affects worst income distribution compare to other scenarios because it increases high income households' expenditures while decreases low and medium income households' expenditures. Additionally, this scenario affects decreasing in expenditures of low income households more than medium income households.

Table 7.3: Welfare Analysis of Household Sector of Average Income Households

	Benchmark Scenario	Scenario 1	Scenario 2	Scenario 3
Equivalent Variation / Household / Month (Baht)	0	42.579	42.609	42.609
Total EV / Month (Million Baht)	0	85.159	85.218	85.218
Charge / Household / Month (Baht)	0	41.935	41.996	41.996
Total Charge / Month (Million Baht)	0	83.870	83.993	83.993
Dead Weight Loss / Household / Month (Baht)	0	0.644	0.612	0.612
Total DWL / Month (Million Baht)	0	1.288	1.225	1.225
Charge Ratio (%) = $\frac{\text{Total Charge per HH}}{\text{Total Expenses}}$	0	0.2771%	0.2769%	0.2769%
EV Ratio (%) = $\frac{\text{E V per Household}}{\text{Total Expenses}}$	0	0.2813%	0.2809%	0.2809%
DWL Ratio (%) = $\frac{\text{DWL per Household}}{\text{EV}}$	0	1.5128%	1.437%	1.437%

Source: Calculated by the author

Equivalent Variation (EV) is also an important indicator with which to measure the welfare changes or consumer surplus change. EV reflects surplus loss in term of money in this case. According to table 7.3, households averagely lose 42.579 baht per household per month and the total consumer surplus change is 85.159 million baht per month for scenario 1. Additionally, the results show that both policies of revenue neutral scenarios have the same outcomes. Households lose their surplus 42.609 baht per household per month. Total welfare changes in household sector are 85.218 baht per month in scenario 2 and scenario 3. As you can see, the welfare or surplus losses in household sector in both of revenue neutral scenarios are slightly more than scenario 1. If considered the ratio of equivalent variation to total expenses, the result indicates that the consumer surplus change 0.2813 percent of total expenses for average income households in scenario 1 and 0.2809 percent for scenario 2 and scenario 3. The ratio shows the proportion of households' welfare changes (loss) to their total expenses. From these result, the both scenario of revenue neutral are more efficiency in the sense of welfare measurement because the scenarios create percent of losses less than scenario 1.

In the perspective of BMA, a wastewater treatment charge is a new source of revenue for them. At the rate of 2 baht per m^3, BMA can gain 83.87 million baht per month. In other words, households pay for the treatment charge averagely 41.935 baht per household per month for the scenario 1. BMA gains 83.993 million baht per month, or households are charged 41.996 baht per household per month for revenue neutral scenarios. Noticeably, the amounts of money that households pay to BMA are slightly different to the EV or consumer surplus that the households lose. This implies that there are some amounts of money lost into the economy which called Dead Weight Loss. According to table 7.3, the charge ratios are 0.2771 percent, 0.2769 percent and 0.2769 percent for scenario 1, scenario 2 and scenario 3. The ratio shows the percentage of the treatment charge is paid by households to their total expenses. It shows the charge burden on each household. The results show that households bear the charge burden less percentage in both of revenue neutral scenarios, but BMA can gain more on these scenarios compare to scenario 1.

Next, Dead Weight Loss (DWL) reflects the excess burden which occurs when the charge is imposed to the households. In this study, DWL can be calculated in monetary term in order to simply illustrate the effects of the policy. With the treatment charge in scenario 1, DWL is averagely 0.644 baht per household per month or 1.288 million baht per month. Also, the DWL are 0.612 baht per household per month or 1.225 million baht per month for both of revenue neutral scenarios. Then the author considers the ratio of dead weight loss to equivalent variation. This ratio presents how much percent of excess burden occurring compare to the total consumer surplus loss. The ratio is 1.5128 percent and 1.437 percent for scenario 1 and both of revenue neutral scenarios, respectively. The ratios show that the percentage of excess burden in revenue neutral scenarios is less that scenario 1. These can confirm that both scenarios of revenue neutral are more efficient compared to scenario 1.

Next, the determining of welfare analysis in household sector classified by income classes are applied which presented in table 7.4. As you can see, the benchmark scenario occurs before BMA imposes the charge, so there is no change in welfare of households in Bangkok. The EV and DWL in all household categories are zero. Even the treatment charge that households have to pay to BMA is also zero. With the treatment charge, the equivalent variations of household categories in each scenario are different. Thus, all categories of households lose their surpluses, but in different amounts in different scenarios.

For scenario 1, low, medium, high income households lose their surplus equal to 23.995, 44.116, and 70.948 baht per household per month, respectively. If BMA compensates households by transferring lump sum amount, households lose 24.037, 44.141, and 70.969 baht per household per month for low, medium and high income households, successively. Then the equivalent variation are 23.995, 44.124, 71.049 baht per household per month, respectively, if BMA decides to decrease other tax rates in scenario 3. In the sense of amount of money, the policy impacts on higher income household categories more than lower income household categories.

Table 7.4: Comparison of Welfare Analysis of the Four Scenarios Classified by Income

	Benchmark Scenario	Scenario 1			Scenario 2			Scenario 3		
Income Classes	All categories of Households	Low Income	Medium Income	High Income	Low Income	Medium Income	High Income	Low Income	Medium Income	High Income
EV / Household / Month (Baht)	0	23.995	44.110	70.939	24.037	44.141	70.968	23.995	44.124	71.049
Total EV / Month (Million Baht)	0	14.649	46.316	24.096	14.675	46.342	24.103	14.649	46.324	24.130
Charge / Household / Month (Baht)	0	23.588	43.600	69.782	23.673	43.653	69.877	23.588	43.614	70.002
Total Charge / Month (Million Baht)	0	14.401	45.774	23.700	14.453	45.830	23.715	14.401	45.792	23.775
DWL / Household / Month (Baht)	0	0.407	0.516	1.165	0.365	0.488	1.141	0.407	0.507	1.047
Total DWL / Month (Million Baht)	0	0.249	0.541	0.396	0.223	0.512	0.388	0.249	0.532	0.356
Charge Ratio (%)	0	0.3775%	0.3340%	0.2023%	0.3767%	0.3336%	0.2024%	0.3775%	0.3339%	0.2020%
EV Ratio (%)	0	0.384%	0.338%	0.206%	0.383%	0.337%	0.206%	0.384%	0.338%	0.205%
DWL Ratio (%)	0	1.697%	1.169%	1.642%	1.517%	1.104%	1.608%	1.697%	1.149%	1.474%

Source: Calculated by the author

Nonetheless, regarding to the ratio of EV to total expenses, it shows different results. The ratio shows the proportion of households' consumer surplus changes in term of amount of money to their expenditure. Consequently, the more of the proportion, the more relatively affects of policy incidences on the households. The ratios are 0.384, 0.338, and 0.2057 percent in scenario 1 for low, medium, and high income households, successively. Additionally, EV in the scenario 2 and scenario 3 are almost the same. The ratios are 0.383, 0.337, and 0.206 percent if BMA decides to compensate the lump sum amount to all households equally. They are 0.384, 0.338, and 0.205 percent, successively, for low, medium and high income households if BMA decide to lower other tax rates. As you can see, all scenarios are regressive. All scenarios influence high income household relatively losing their surplus the least because the percentage of losing the surplus to the total expenses is the least of all. Also, all policy scenarios affect the lower income household categories more than the higher income household categories.

At the rate of 2 baht per m^3 in scenario 1, households have to pay treatment charge to BMA 23.588, 43.600, 69.783 baht per household per month from low, medium, and high income households. In other words, BMA receives revenues from low, medium, and high income households about 14.401, 45.774, and 23.700 million baht per month. Households pay the charge to BMA 23.673, 43.653 and 69.877 baht per household per month for low, medium, and high income households in scenario 2 and pay 23.588, 43.614 and 70.002 baht per household per month in scenario 3. According to the charge ratio, high income households bear the charge burden at the lowest percentage of 0.2023 percent and low income households bear the highest percentage of 0.3775 percent to the total expenses in scenario 1. The results are also the same in scenario 2 and scenario 3. Then the author concludes that policies affect lower income households to bear more charge burden than the higher income households. According to the charge ratios, the policies are all regressive.

Dead Weight Loss (DWL) also can be considered as an inefficiency caused by the treatment charge policy. The author also finds the same conclusion for all scenarios. All categories of households lose their surpluses, but in different amounts in different cases. The DWL which occurs in scenario 1 for low, medium, high income households equal to 0.407, 0.516, and 1.165 baht per household per month, respectively, or about 249,000 baht, 541,000 baht and 396,000 baht per month, successively. The DWL are 0.365, 0.488, 1.141 baht per household per month for the scenario 2. Lastly, the DWL are 0.407, 0.507, 1.047 baht per household per month for low, medium, and high income households, respectively, for the scenario 3. If the analysis considers only the amount of money, the policy impacts on higher income household categories is greater than those on lower income household categories in all policy scenarios.

Nonetheless, according to the ratio of DWL to EV, the results are different. This ratio presents the proportion of excess burden to the total consumer surplus loss. In other words, this ratio shows the percentage of economy loss to the total consumer surplus loss. The ratios are 1.6967, 1.1690, and 1.6424 percent in scenario 1 for low, medium, and high income households, successively. From these ratios, the policy mostly creates the excess burden to low income households compare to other household categories. However, high income household bears the excess burden more than medium income households. The ratios are 1.517, 1.107, and 1.608 percent if BMA compensated the lump sum amount to households. Lastly, they are 1.697, 1.149 and 1.474 percent for the scenario 3.

According to the ratios, the author finds that the scenario 1, charging 2 baht per m^3 without any compensated and scenario 3, reducing other taxes, have the same results. The scenarios affect low income household most followed by high income households and medium income households, respectively. However, the scenario 2, affect high income households most followed by low income households and medium income households. Indeed, all policies have the same character. They are regressive if the income level is lower than the minimum level that households have to pay income taxes, but the policy is progressive when the income level is higher than the minimum level that households have to pay income taxes.

Next, the paper analyzes the consumption behaviors of households. The results of estimation are presented in Table 7.5. The table presents water consumptions and wastewater discharged of households in Bangkok area in different scenarios. First, the water consumptions of households are discussed.

Table 7.5: Water Consumptions and Wastewater Discharged of Households With and Without the Wastewater Treatment Charge of Average Income Households

	Benchmark Scenario	Scenario 1	Scenario 2	Scenario 3
Water Consumption / Household / Month (Unit)	206.071	199.192	199.483	199.484
Total Water Consumption / Month (Unit)	412.142	398.384	398.96	398.968
Wastewater / Household / Month (Unit)	164.857	159.354	159.5866	159.5872
Total Wastewater / Month (Million Unit)	329.713	318.707	319.173	319.175
Change of Wastewater (%)	-	-3.338%	-3.197%	-3.196%

Source: Calculated by the author

Without the treatment charge (benchmark scenario), households consume water 206.071 units. Then with the charge, households decrease their water consumptions to 199.192 units, 199.483 units, and 199.484 units for scenario 1, scenario 2 and scenario 3, respectively. These results directly impact wastewater discharged from households to decrease accordingly. Moreover, both of revenue neutral scenario influents households decreased the total wastewater discharged from 329.713 to 319.173 and 319.175 million units per month whereas the scenario 1 decreased the discharged to 318.707 million units per month. Therefore, imposing the charge without any compensation scenario affects decreasing in wastewater discharged from households more than revenue neutral scenario. From these results, both of revenue neutral scenarios are more efficiency in the sense of welfare measurement; these two scenarios are less effective in the sense of environmental effects compare to the scenario 1. The treatment charge decreased water consumptions and wastewater discharged of all Bangkok's households categories at the same proportion. Wastewater discharged also decreases about 3.338, 3.197 and 3.196 percent for the scenario 1, scenario 2 and scenario 3.

Table 7.6: Wastewater Discharged of Bangkok Households Classified by Income Classes With and Without the Wastewater Treatment Charge

	Benchmark Scenario			Scenario 1			Scenario 2			Scenario 3		
Income Classes	Low Income	Medium Income	High Income	Low Income	Medium Income	High Income	Low Income	Medium Income	High Income	Low Income	Medium Income	High Income
Water Consumption / Household / Month (Unit)	116.40	212.60	343.62	112.05	207.10	331.47	112.45	207.35	331.68	112.05	207.18	332.51
Total Water Consumption / Month (Million Unit)	71.06	223.20	116.70	68.40	217.43	112.58	68.65	217.69	112.65	68.40	217.51	112.93
Wastewater / Household / Month (Unit)	93.12	170.08	274.90	89.64	165.68	265.18	89.96	165.88	265.34	89.64	165.74	266.01
Total Wastewater / Month (Million Unit)	56.85	178.56	93.36	54.72	173.94	90.06	54.92	174.15	90.12	54.72	174.01	90.34
% Change of Wastewater	-	-	-	-3.74%	-2.59%	-3.54%	-3.40%	-2.47%	-3.48%	-3.74%	-2.55%	-3.23%

Source: Calculated by the author

From Table 7.6, the results show that scenario 1 affects households' behaviors, decreasing water consumption and wastewater discharged most compared to the other two scenarios. Therefore, the author concludes that the scenario 1 is the most effective scenario among all policy scenarios which presented in this paper.

In scenario 1, low income households reduce water consumption by 3.744 percent per month while medium income households reduce their discharged by 2.587 percent per month. High income households decrease wastewater the most compare to other categories of households which is 3.536 percent per month. The wastewater averagely reduced from 93.122 units to 89.635 units per household per month in low income households. Medium income households averagely reduce their wastewater discharged from 170.081 units to 165.681 units per household per month. Lastly, high income households averagely reduce from 274.895 units to 265.175 units per household per month.

In scenario 2, low income households reduce water consumption 3.4 percent per month while medium income households reduce their discharged 2.47 percent per month. High income households decrease wastewater the most compare to other categories of households which is 3.48 percent per month. The wastewater averagely reduced from 93.122 units to 89.96 units per household per month in low income households. Medium income households averagely reduce their wastewater discharged from 170.081 units to 165.88 units per household per month. Lastly, high income households averagely reduce from 274.895 units to 265.34 units per household per month. In scenario 3, low income households reduce water consumption 3.74 percent per month followed by high income households and medium income households which are 3.23 percent and 2.55 percent. The wastewater averagely reduced to 89.64 units per household per month, 165.74 units per household per month and 266.01 units per household per month, for low income households, medium income households and high income households, successively.

Table 7.7: Bangkok Metropolitan Administration's Revenue and Expenditure

With and Without the Wastewater Treatment Charge

Comparison of BMA Budgeting and Expenditure of the Three Scenarios

	Benchmark Scenario	Scenario 1	Scenario 2	Scenario 3
BMA's Total Revenues / Year (Million Baht)	43,687.422 *	44,693.87	43,687.42	43,687.42
BMA's Total Expenditure / Year (Million Baht)	30,934.153 *	31,643.26	30,934.15	30,934.15
Percentage of Expenditure of Total Revenue (%)	70.80%	70.80%	70.80%	70.80%
Expenditure on Wastewater Treatment / Year (Million Baht)	524.088 **	1,006.44	1,007.77	1,007.92
Expenditure on Others / Year (Million Baht)	30,410.07	30,636.81	29,926.24	29,926.23
Percentage of Expenditure on Wastewater Treatment of Total Expenditure (%)	1.69%	3.180%	3.258%	3.258%

Source: Calculated by the author

*Information from revenue division and expenses division of BMA (year 2007)

** Information from water management department of BMA (Year 2007)

The assumption held in this analysis is that BMA still maintain its budgeting policy. According to the information of revenues and expenses division of BMA in year 2007, BMA uses surplus budgeting and spends only 70.8 percent of its revenues on its public provisions and administrations. From table 7.7, the policy in scenario 1 raises Bangkok Metropolitan Administration's revenues from 43,687.42 million baht to 44,693.87 million baht per year. Revenue neutral scenarios are maintaining the level of revenues per year at 43,687.42 baht. Regarding to public spending, reducing other taxes scenario encourages wastewater treatment expenses the most compare to others but it decreases other expenditures on public provision. This scenario increases wastewater treatment expenses from 524.088 million baht per year to 1,007.92 million baht per year. It accounts for 3.258 percent of total BMA's expenditures.

According to the calculation, BMA also increase its expenditure from 30,934.15 million baht to 31,643.26 million baht per year. Wastewater treatment expenditures also increase from 524.09 million baht to 1,006.44 million baht per year. In other words, the policy affects wastewater treatment expenditures to increase 92 percent. The proportion of wastewater treatment expenses to the total expenses increases from 1.69 percent to 3.18 percent. Expenditures on other public provisions additionally increase from 30,410 million baht to 30,636.81 million baht per year. The study concludes that the charge increases BMA's revenues and its expenditure on wastewater treatment and other public provisions.

Table 7.8: Net Social Welfare Analysis of the Wastewater Treatment Charge Policy

(Million Baht per Month)

	Benchmark Scenario	Scenario 1	Scenario 2	Scenario 3
1. Change in Household Sector (Δ Household Sector)				
Change in Consumer Surplus (EV)	0	- 85.159	- 85.2178	- 85.2180
2. Change in BMA Sector (Δ BMA Sector)				
Total Charge Revenues	0	+ 83.870	+ 83.9930	+ 83.9933
Abatement Cost Saving	0	+ 5.865	+ 5.7369	+ 5.7366
3. Environmental Sector				
Change in Wastewater Discharged (%)	0	- 3.338%	- 3.197%	- 3196%
4. Welfare Analysis (Δ Household Sector + Δ BMA Sector)				
Net Social Welfare (NSW)	0	+ 4.577	+ 4.5121	+ 4.5119

Source: Calculated by the author

Lastly, the discussion about the net social welfare analysis and abatement cost saving are presented in this section. The net social welfare (NSW) is the adding up of welfare change in both household sector and BMA sector. Table 7.8 presents the net social welfare analysis of wastewater treatment charge policy in different scenarios. If the treatment charge policy is applied, the policy affects changing of water consumptions and wastewater discharged of Bangkok's households. As you can see, all scenarios affect loss in household sector and gain in government sector (BMA sector). They also impact gain in environmental sector by reducing the wastewater discharged. Next, the paper estimates the net social welfare scenario by scenario. In scenario 1, households lose their surplus equal to 85.159 million baht per month. Households in Bangkok averagely decrease wastewater discharged by 3.338 percent. Decrease in wastewater discharged from households automatically reduces costs of wastewater treatment of the Bangkok's treatment plants. BMA consequently gains from the abatement cost saving which is 5.865 million baht per month for scenario 1. It also gains 83.870 million baht per month by collecting the charge from households. Therefore, the net social welfare in scenario 1 is positive at 4.577 million baht per month.

Like scenario 1, there are losses in household sector in scenario 2 about 85.2178 million baht per month while they have some gain in BMA sector. BMA sector gains from increasing the total revenue by 83.993 million baht per month. In addition, the cost saving is considered as a welfare gain in the BMA sector occurs when households reduce the wastewater discharged by 3.197 percent. The gain from abatement cost saving is 5.7369 million baht per month. Consequently, the treatment charge policy affects net social welfare gain equal to 4.5121 million baht per month in scenario 2. Lastly, households lose their surplus 85.218 million baht per month while gain from the charge revenues and abatement cost saving in BMA sector of 83.9933 million baht per month and 5.7366 million baht per month. These affects net social welfare gain in scenario 3 about 4.5119 million baht per month. Comparing these 3 scenarios, the study shows that Bangkok gains most in scenario 1 followed by scenario 2 and scenario 3.

Certainly, these results answer the questions in the beginning of the study. The wastewater treatment charge policy solves water pollution in Bangkok area because the policy affects Bangkok households' behaviors. It decreases water consumption in all categories of households, so it directly reduces wastewater discharged from households. Although households loss their surplus to an extent and the dead weight loss occurs, the public sector which BMA responds for all activities gains the welfare from the charge revenues and the abatement cost saving of faintly decreasing wastewater discharged of households. In conclusion, the policy affects the net social welfare gain to the Bangkok as a whole in all scenarios.

7.3 Policy Implication

Efficiency and equity are the topics that economists usually discuss when they mention about policy implication. The study basically compares the effects on efficiency and equity of the three following scenarios in order to give recommendations and some guidelines to the policy maker. The results can be used as the baselines for further policy development.

7.3.1 Efficiency

The efficiency is achieved when the policy can minimize welfare lose or maximum welfare gain. Since equivalent variation and total dead weight loss are the indicators to measure the welfare of households, the paper compares the total equivalent variation and total dead weight loss of each scenario to examine the efficiency. The most efficient scenario is the scenario which minimizes welfare loss or maximizes welfare gain.

Since the price of water is increased, the total water consumption expenses in all scenarios will be increased. Then the study finds that the scenario 1, imposing the charge at 2 baht per m^3, influences higher ratio of water expenses to total expenses of average households while the other scenarios are lower the ratio compare to the scenario 1. This means that scenario 1 encourages increase in water consumption expenses compared to other goods expenses. However, this scenario reduces total expenses more than other scenarios.

According to the equivalent variation, the study additionally discovers that households losses their surpluses more if the revenue neutral scenarios are applied. However, if considered on the ratio of EV to total expenses, the ratio in the both cases of revenue neutral scenarios are the same and it is slightly less than the first scenario. The revenue neutral scenarios; therefore, are more efficient since the proportion of losing the surplus is less than first scenario. Moreover, EV and dead weight loss of revenue neutral are less than the scenario 1. Indeed, the revenue neutral scenario is more efficiency than imposing the charge at 2 baht per m^3 without any compensation. However, the society gains most if BMA chooses the scenario 1 regarding to the net social welfare estimation. Consider on DWL ratio, the least proportion of excess burden to the surplus change is the scenario 3, and it is the most in scenario 1. From these numbers, the scenario 3 is the most efficient scenario because this scenario affects welfare change and the excess burden in the least proportion compared to other scenario while the scenario 1 is the least efficient.

Even if the both of revenue neutral scenarios are more efficiency in the sense of welfare measurement, these two scenarios are less effective in the sense of environmental effects. Regarding public spending, reducing other taxes scenario, scenario 3, encourages wastewater treatment expenses the most compare to others but it decreases other expenditures on public provision.

7.3.2 Equity

The equity occurs when the policy affects welfare in each category of households equally. In this case, the author also justifies the equity by using equivalent variation and total dead weight loss to indicate the welfare of households. However, the study compares the total equivalent variation and dead weight loss by a household group. The most equity scenario is the scenario which affects welfare loss or gain on each household group, equally. Otherwise, the apportionment of the resources among household categories is considered fair. On other words, at least it has to encourage better income distribution.

The study discovers that the scenario 1 decreases total expenditures of all household categories, but scenario 2 increases total expenditure of low and medium income households and decrease total expenditure of high income households. It also increases total expenditures in low income households more than medium income households. The scenario 3 decreases total expenditure of low and medium income households but increases the expenditure of high income households. As a result, compensating by transferring lump sum amount to households creates better income distribution compare to other scenarios. Indeed, the scenario 3 affects best income distribution by encouraging total expenses of lower income households more than higher income households.

However, equity also means that who creates pollution should be responsible for paying the cost of abatement according to "Polluter Pay Principle". Therefore, the wastewater treatment charge policy is the tool to force the polluters to bear their costs. Basically, the equity can not be occurred without wastewater treatment charge. It also generates the better environmental qualities to society. These conclude that the equity will be achieved when BMA imposes the treatment charge. In other words, the charge policy creates equity in the society.

CHAPTER 8

CONCLUSION AND DISCUSSION

8.1 Conclusion of the Study

This paper aims to present a basic conceptual framework to analyze consequences of the wastewater treatment charge policy whether it solves water pollution and affects net social welfare gains. It also provides a substantive contribution and can be developed to an environmental general equilibrium model for local and nationwide. This research presents the linkage between environment and development in the sense of effects of the wastewater treatment charge on social welfare, households' behaviors, and public service expenditures.

The model consists of four main parts which are a household sector, a government sector (BMA), an environmental sector and a net social welfare analysis. This study consists of three different estimation sections which are household's demand estimation, stochastic treatment cost frontier estimation and social welfare estimation. The paper analyses the effects of wastewater treatment charge on social welfare which considering only the wastewater discharged from the household area.

According to the LES demand estimation, the results show that coefficients have high level of statistical significance which is indicated by the value of the probabilities. Also, all key variables have the expected sign. Considering by the households' types and minimum level of expenditures, the author finds that households, which have higher incomes, pay higher in minimum level of consumption in each category. Additionally, according to the budget share, households spend most on transportation followed by housing, food & beverage, education, personal appearance, medical care, and tap water successively. They spend the least on tobacco product & alcohol beverage.

All calculations of elasticities have theoretically expected sign. The own price elasticities of compensated demand are all negative sign. Since increasing in its own price affects decreasing in its consumption. However, if considered on the elasticities of each household type, the treatment charge affects on low income households more than medium income households while the policy affects least on high income households.

According to the stochastic treatment cost frontier estimation, the study finds that the variables have the expected sign in both OLS and MLE and the coefficients have high levels of statistical significance. The log – likelihood is 61.3785 which are considerably high. The elasticity of cost with respect to wastewater volume is found to be less than one. This shows that the economy of scale occurs. The volume of wastewater inflow has positive effects on the cost of abatement. The coefficients of input prices are also all positive. These reflect the fact that increases in input prices will raise the cost of abatement. The treatment cost heavily depends on wage followed by price of electricity and price of materials. Then marginal abatement cost initially falls as due to economy of scale. Thus the MAC of small plants should be higher than medium and large scale treatment plants. Consequently, the marginal abatement cost curve of the BMA's treatment plants is the downward slopping curve.

All treatment plants can averagely operate only 64.34 percent of their capacities, so BMA nowadays inefficiently operates the treatment plants; especially, in the large scale plants such as Chong Nonsi Plant and Nong Kham Plant. The study; moreover, finds that BMA should invest in one large scale treatment plants better than many small plants in the area to obtain more cost efficiency in the long run with the assumptions of excluding land cost, treatment plants' construction costs, and pipe system costs.

Lastly, the estimation of the net social welfare is considered. The net social welfare (NSW) is the adding up of welfare change in both household sector, BMA sector and environmental sector. However, this paper does not value the intangible benefits in environmental sector in monetary form in order to point out the direct benefit from the policy such as reduction in damage from water pollution and benefits from water quality improvement, health benefits and recreation benefits. There are four main scenarios which are presented as follow.

Benchmark Scenario : Without the wastewater treatment

Scenario 1 : The BMA designed policy – imposed the wastewater treatment charge at 2 baht per m^3 on households' water consumptions

Scenario 2 : First alternative policy – with the treatment charge at 2 baht per m^3 on households' water consumptions and introducing a revenue neutral method by compensating lump sum amount to Bangkok households.

Scenario 3 : Second alternative policy – with the charge at 2 baht per m^3 on households' water consumptions and introducing a revenue neutral method by reducing other taxes.

The study finds that the wastewater treatment charge policy solves water pollution in Bangkok area because the policy affects Bangkok households' behaviors. It decreases water consumption in all type of households, so it directly reduces wastewater discharged from households. Although households somewhat loss their surplus and the dead weight loss occurs, the public sector which BMA responds for all activities gains the welfare from the charge revenues and the abatement cost saving of faintly decreasing wastewater discharged of households. In conclusion, the policy affects the net social welfare gain to the Bangkok as a whole in all scenarios.

Next, the study examines the efficiency and equity of all policies. According to the EV ratios and the charge ratios, the author finds that the revenue neutral scenario (scenario 2 and scenario 3) are more efficient than imposing the charge at 2 baht per m^3 without any compensation. However, the society gains most if BMA chooses the scenario 1 regarding to the net social welfare estimation. Consider on DWL ratio, the least proportion of excess burden to the surplus change occurs in scenario 3, and the most in scenario 1. From the estimations, the scenario 3 is the most efficient scenario because this scenario affects welfare change and the excess burden in the least proportion compare to other scenario. The study discovers that the scenario 2, which compensating by transferring lump sum amount to households, encourages total expenses of lower income households more than higher income households. Even if the both of revenue neutral scenarios have more efficiency in the sense of welfare measurement, these two scenarios are less effective in the sense of environmental effects compare to scenario 1.

Moreover, the equity can be translated into who creates pollution should response by paying the cost of abatement according to “Polluter Pay Principle”. Therefore, the wastewater treatment charge policy is the tool to reinforce the polluters to bear their costs. It also generates the better environmental qualities to society. These can conclude the charge policy creates equity to the society.

8.2 Discussion and Future Study

8.2.1 Demand function

This study uses Linear Expenditure System (LES) to estimation demand patterns of Bangkok households. Therefore, it is useful to briefly describe the process of calculation of equivalent variation which is necessary for determination of the welfare effects. Since non – linear patterns exist in reality, some hesitations on the linear function occurred. Although, the simulation results of the literatures show that the linear model can approximate the non – linear model well, they are always attached with some conditions and assumptions. For instances, Moschini (1995) indicated that the linear model can approximate the non – linear well only by providing a proper price index. Consequently, the development of non – linear expenditure system methodology would also be beneficial in terms of improvements of the results.

8.2.2 *<u>Cost Function</u>*

For the abatement cost estimation in BMA sector, this study applies the stochastic cost frontier analysis (SFA) to explain the abatement cost of public treatment plants. Since, the frontier curve is well presented the cost curve in different levels of the technology in different scales of treatment plants; it also reflects the feasibility of the technology and treatment activities. This curve also reflects the long run cost curve which exterminates the influences of construction costs and land costs. The SFA; moreover, applied the envelop theorem which provides greater flexibility in determining the charge rate.

Although the abatement costs of the public treatment plants can be presented as a cumulative function, this methodology is not practical for determining the unanimously charge rate. If the cumulative function is applied, the different charge rates in different areas will be considered. However, the cumulative abatement cost function can be examined if the paper objects to reflect the actual responsibilities of the resident in the area. Moreover, this study does not include land cost, construction cost and capital cost. Consequently, adding the land cost, construction cost and capital cost in the cost function are useful for estimating the marginal abatement cost in order to determine the optimal charge rate in future works.

8.2.3 *<u>Social Welfare measurement</u>*

The net social welfare in this study determine the welfare changes in household sector and BMA sector in money term, but does not value the indirect effects in environmental sector. The estimation of net social welfare will be more completed if cost – benefit analysis of the intangible benefits in environmental sector such as health benefits and recreation benefits are taken into account. Also, results did not include the institutional cost, the administration and management costs of collecting the charge, which can be considered as a negative effect to net social welfare. Thus, if the cost is too high, it may not worth to impose the charge.

Another discussion of social welfare measurement is the utility function. Since the utility measures the preference of individuals, the development of utility function would be more clarified on households' satisfactions. If wastewater is one of the variables in utility function, how results are changed. Wastewater can be publicly bad and has negative effects to the utility function. Therefore, decreasing in volume of wastewater would be increasing utility of the Bangkok's households. Imposing the treatment charge on water consumptions decreases volume of wastewater in two ways. First is increasing clean up activities by investing on treatment facilities. Second, the policy directly reduces wastewater discharged from households. As a result, the charge policy would be a double increase in the utility function.

8.2.4 Charge rate determining

In order to determine the charge rate, sensitivity analysis may be applied. The further study in sensitivity can suggest the range of the proper charge rates in different circumstances instead of suggest optimal charge rate. Additionally, the sensitivity can use for estimating the welfare sizes which will occurs in different scenarios. Although this study did some kinds of sensitivity analysis by introducing the three different scenarios, other sensitivity cases can be considered for the improvement of the results.

Even though this study introduces the basic framework to examine the effects of the charge rate on net social welfare, it does not conclude or suggest the optimal charge rate. By using the model framework, the study can define that the charge rate which affects net social welfare equals zero is 19.90 percent or about 1.89 baht per m^3. Accordingly, if the charge rate is less than 1.89 baht per m^3, the policy affects net social welfare loss. In contrast, if BMA imposes the charge at rate more than 1.89 baht per m^3, the policy affects net social welfare gain. As you can see, the charge rate at 2 baht per m^3 can be considered as a minimum rate that BMA should impose on households' water consumptions. At this rate, households' behaviors can be affected the least. However, the determining of the optimal charge rate would be beneficial for the future study.

REFERENCES

Afriat, S.N. 1972. Efficiency estimation of production function. **International Economic Review** 13: 568 – 598.

Aigner, D.J. and Chu, S.F. 1968. On estimating the industry production function. **American Economic Review** 58: 826 – 839.

Aigner, D.J, Lovell, C.A.K. and Schmidt, P.J. 1977. Formulation and estimation of stochastic frontier production function models. **Journal Econometrics** 6: 21 – 37.

Arunsmit, K. 1997. **CAMGEM – H Model Development for Long Run Forecast: Analysis of Thai Economy.** Bangkok: Research Fund Committee, Faculty of Economics, Chulalongkorn University.

Bangkok Metropolitan Administration. 2007. **Annual Report 2006.** Bangkok: Bangkok Metropolitan Administration

Bangkok Metropolitan Administration, Budgeting Department. 2008. **Budgeting Department: Annual Report 2007**. Bangkok: Bangkok Metropolitan Administration

Bangkok Metropolitan Administrative, Sewage & Draining Department, Water Quality Management Division. 2005. **Analysis Results of Water Quality from Bangkok Wastewater Treatment Plants.** Bangkok: Bangkok Metropolitan Administrative.

Bangkok Metropolitan Administrative, Sewage & Draining Department, Water Quality Management Division. 2006. **Annual Report 2005**. Bangkok: Bangkok Metropolitan Administrative.

Bangkok Metropolitan Administrative, Sewage & Draining Department, Water Quality Management Division. 2008. **Sewage & Draining Department: Annual Report 2007.** Bangkok: Bangkok Metropolitan Administrative.

Bangkok Metropolitan Administrative, Sewage & Draining Department, Water Quality Management Division. 2005. **Executive Summary for Bangkok Governor**. Bangkok: Bangkok Metropolitan Administrative.

Banks, J., Blundell, R. and Lewbel, A. 1997. Quadratic engel curves and consumer demand. **The Review of Economics and Statistics** 79, No. 4: 527 – 539.

Battese, G. E. and Coelli, T. J. 1992. Frontier production functions, technical efficiency and panel data: With application to paddy farmers in India. **The Journal of Productivity Analysis** 3: 153 – 169.

Blundell, R. 1993. What do we learn about consumer demand patterns from micro data? **The American Economic Review** 83: 570 – 597.

Bohringer, C. and Rutherford, T. F. 1997. Carbon taxes with exemptions in an open economy: A general equilibrium analysis of the German tax initiative. **Journal of Environmental Economics and Management** 32: 189 – 203.

Bosquet, B. and Hoerner, J.A. 2003. **Environmental Tax Reform: The European Experience** [Online]. Available from: http://www.rprogress.org/newprograms/sustEcon/euro-execsumm.htm [6 January 2005].

Brannlund, R. and Nordstrom, J. 2004. Carbon tax simulation using a household demand model. **European Economic Review** 48: 211 – 233.

Charnes, A., Cooper, W. W. and Rhodes, E. 1978. Measuring the efficiency of decision making units. **European Journal of Operational Research** 2, 4: 429 – 444.

Chomtosuwan, T. 2004. **Effectiveness of pricing and tax policies on water demand of households and the tap water deficient problem in Thailand**. Master's Thesis. Economics, Faculty of Economics, Chulalongkorn University.

Coelli, T.J. 1995. **A guide to FRONTIER Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation**. Armidale: Centre for Efficiency and Productivity Analysis (CEPA).

Corlett, W.J. and Hague, D.C. 1953. Complementarity and the excess burden of taxation. **Review of Economic Studies** 21: 21-30.

Creedy, J. and Cornwell, A. 1997. Measuring the welfare effects of tax changes using the LES: An application to a carbon tax. **Empirical Economics** 22: 589 – 613.

Deaton, A. and Muellbaure, J. 1980. An almost ideal demand system. **American Journal of Agricultural Economics** 80: 208 – 220

Deaton, A. 1986. Demand analysis. in Griliches, Z, **Handbook of Economics**, 1768 – 1838. Intriligator: North – Holland.

Deroubaix, J. F. and Leveque, F. 2004. The rise and fall of French ecological tax reform: Social acceptability versus political feasibility in the energy tax implementation process. **Energy Policy**. [Online]. Available from: http://www.elsevier.com/locate/envsoft [3 December, 2008]

Diamond, P. and Mirlees, J.A. 1971. Optimal taxation and public production I: Production efficiency, **American Economic Review** 61: 8 – 27.

Dresner, S., Jackson, T. and Gilbert, N. 2004. History and social responses to environmental tax reform in the UK, **Energy Policy**. [Online]. Available from: http://www.elsevier.com/locate/envsoft [3 December, 2008]

Farlex and Sinclair. 2006. [Online]. Available from: http://www.thefreedictionary.com/externality [27 January 2006]

Farrel, M.J. 1957. The measurement of a productive efficiency. **Journal of the Royal Statistical Society**, Series A. General 120. No. 3: 253 – 281.

Fisher, I. 1937. Income in theory and income taxation practice. **Econometrica** 5: 1 – 55.

Frisch, R. 1959. A complete scheme for computing all direct and cross demand elasticities in a model with many sectors. **Econometrica** 27: 177 – 196.

Golder, B., Misra, S. and Mukherji, B. 2001. Water pollution abatement cost function: methodological issues and an application to small – scale factories in an industrial estate in India. **Journal of Environment and Development Economics** 6: 103 – 122

Goulder, L. H. 1995. Environmental taxation and the double dividend: A reader's guide. **International Tax and Public Finance** 2 (August 1995): 157 – 183.

Goulder, L. H. 1996. Optimal Environmental taxation in the presence of other taxes: General Equilibrium Analyses. **American Economic Review** 86: 985 – 1000.

Harberger, A.C. 1964. Taxation, resource allocation, and welfare. **The Role of Direct and Indirect Taxes in the Federal Revenue System.** J. Due Edition. Princeton University Press. New Jersey: Princeton.

Hartman, R.S., Wheeler, D., and Singh, M. 1994. The cost of air pollution abatement. **Policy Research Working Paper No. 1398**. Washington, DC.: The World Bank

Hicks, J. R. 1956. **A revision of demand theory**. Oxford University. Oxford: Oxford University Press.

Hill, M. 1998. **Green Tax Reform in Sweden: The Second Dividend and the Cost of Tax Exemptions.** Stockholm: Economics Department, Stockholm School of Economics and the Beijer Institute.

Israngkura, A. 2002. Asia case studies: Thai industrial estate water treatment fee. **Economic Instruments for Environmental Management**, 86 – 98. London: Earthscan.

Jorgenson, D. W. and Wilcoxen, P. J. 1993. Reducing U.S. carbon dioxide emission: an assessment of different instruments. **Journal of Policy Modeling** 15: 491 – 520.

Kardkarnkai, Y. 1992. **Tax policy for pollution control and its impacts on Thai industries.** Master's Thesis. Environmental Economics, Faculty of Economics, Chulalongkorn University.

Kim, S.R. 2002. Optimal environmental regulation in the presence of other taxes: A generalized second – best rule. **Contribution to Economic Analysis and Policy** 1, No.1, Article 4. [Online]. Available from: http://econpapers.hhs.se/paper/wpawuwppe/0201004.htm [30 December, 2005]

Kumbaroglu, G. S. 2003. Environmental taxation and economic effects: computable general equilibrium analysis for Turkey. **Journal of Policy Modeling** 25: 795 – 810.

Lee, L. F. 1993. Multivariate tobit models in econometrics. in Maddala, G.S. and Rao, C. R. Edition. **Handbook of Statistics** 11, 145 – 175. Massachusetts: North – Holland.

Lee, L. F. and Pitt, M. M. 1987. Microeconometric models of rationing, imperfect markets, and non – negativity constraints. **Journal of Econometrics** 36: 89 – 110.

Llunch, C. and Williams, R. 1975. Consumer demand systems and aggregate consumption in the USA: An application of the extended linear expenditure system. **The Canadian Journal of Economics** 8, No. 1 (February 1975): 49 – 66

McFadden, D.1989. A method of simulated moments for estimation of discrete response models without numerical integration. **Econometrica** 57: 995 – 1026.

Meade, J. E. 1973. **The Theory of Economic Externalities: The Control of Environmental Pollution and Similar Social Costs.** International Economics Series. Geneva: Institute Universitaire de Hautes Etudes Internatinales.

Meeusen, W. and Broeck, J. 1977. Efficiency estimation from Cobb-Douglas production functions with composed error. **International Economic Review** 18, 2: 435 – 444.

Memapan, R. 1996. **Modelling for Analyzing Carbon Dioxide Tax: In Case of Green House Gas Emission Control in Thailand**. Master Degree. Environmental Economics, Faculty of Economics, Chulalongkorn University.

Metcalf & Eddy, Inc. 1991. **Wastewater Engineering Treatment, Disposal , and Reuse**. in Revised by Tchobanogious, G. and Burton, F.L. 1991. 3rd edition, McGraw – Hill Series in Water Resources and Environmental Engineering. Singapore: McGRAW – Hill International.

Metcalf & Eddy International, Inc and Progress Technology Consultant, Co., Ltd. 1998. **Final Report: BMA Wastewater User Charge Study**. Bangkok: Bangkok Metropolitan Administration.

Misra, S. 1998. Economies of scale in water pollution abatement: a case of small – scale factories in an industrial estate in India. **Working Paper No. 57**. Centre for Development Economics, Delhi School of Economics, University of Delhi: Delhi.

Moschini, G. 1995. Units of measurement and the Stone index in demand system estimation. **American Journal of Agricultural Economics** 77, No.1 (February 1995): 63 – 68.

Nakamura, S. and Kondo, Y. 2002. Input – output analysis of waste management. **Journal of Industrial Ecology** 6, 1: 39 – 64.

National Statistical Office, Office of the Prime Minister. 2002. **Report of the 2002 Household Socio – Economic Survey**. Bangkok: Office of the Prime Minister

National Statistical Office, Office of the Prime Minister. 2004. **Report of the 2004 Household Socio – Economic Survey**. Bangkok: Office of the Prime Minister

National Statistical Office, Office of the Prime Minister. 2006. **Report of the 2006 Household Socio – Economic Survey**. Bangkok: Office of the Prime Minister

Paris, Q. 2003. Extimation of consumer demand function when the observed prices are the same for all sample units. **Working Paper**. (September 2003) Davis: Department of Agricultural and Resource Economics, University of California.

Pearce, D. 1991. The role of carbon taxes in adjusting to global worming. **Economic Journal** 101, 407: 938 – 948.

Pigou, A.C. 1947. **A Study in Public Finance**, 3rd edition, London: Macmillan.

Pollak and Wales. 1981. Demographic variables in demand analsysis. **Econometrica** 49, 6: 1533 – 1551.

Ramsey, F.P.1927. A contribution to the theory of taxation. **Economic Journal** 37: 47 – 61.

Roomratanapun, W. 2002. **Introducing centralized wastewater treatment in Bangkok: a study of factors determining its acceptabilit**y. Bangkok: Department of Social Administration Thammasat University.

Rossi, D., Young C.E., and Epp D.J. 1979. The cost impact of joint treatment of domestic and poultry processing wastewaters. **Land Economics**, 55 (4): 444 – 459.

Rubio, S. J. and Escriche L. 2001. Strategic pigouvian taxation, stock externalities and polluting non-renewable resources. **Journal of Public Economics** 79, 2 (February 2001): 297 – 313.

Sarntisart, I. 1999. Income distribution causing by changing of value added tax rate. **Academic Journal for Celebrating His Majesty King Bhumibol Adulyadej 72nd Birthday**. Bangkok: Economic Research Center, Faculty of Economic, Chulalongkorn University. [Thai version]

Schmidt, P. 1976. **Econometrics.** New York: Marccll Dekker.

Schmidt P. and Lovell C.A.K. 1979. Estimating technical and allocative inefficiency relative to stochastic production and cost frontiers, **Journal of Econometrics** 9: 343 – 366.

Scrimgeour, F., Oxley, L. and Fatai, K. 2004. Reducing carbon emission? The relative effectiveness of different types of environmental tax: The case of New Zealand. **Journal of Environmental Modeling and Software** [Online]. Available from: http://www.elsevier.com/locate/envsoft [3 December, 2008]

Stone, R. 1954. Linear Expenditure Systems and Demand Analysis: An Application to the Pattern of British Demand. **Economic Journal** 64: 511 – 527.

Tapvong, C. and Kruavan, J. 2003. Water Quality Improvements: A continent valuation study of the Chao Phraya River. **Research Report.** Economy and Environment Program for Southeast Asia [Online]. Available from: http://203.116.43.777/publications/research1/ACF23D.html [5 January 2006]

Tuntoolavest, M. and Yolthantham, T. 2006. Industry vs Community: Who's the culprit? **The Proceeding of 5th National Environmental Conference.** Bangkok: Environmental Engineering Association of Thailand.

Tyler, C. 1976. **Public Good and Externalities.** in the 2nd Edition. London: McGraw-Hill.

Water Management for Community Division, Pollution Control Department, Ministry of Environment and Natural Resources. 1999. **Calculation of Wastewater Treatment Charges of Sakonnakorn: Stabilization Pond (SP) Wastewater Treatment Plant.** Bangkok: Ministry of Environment and Natural Resources.

Water Management for Community Division, Pollution Control Department, Ministry of Environment and Natural Resources. 1999. **Calculation of Wastewater Treatment Charges of Sriracha: Open Detonation Unit (OD) Wastewater Treatment Plant.** Bangkok: Ministry of Environment and Natural Resources.

Water Management for Community Division, Pollution Control Department, Ministry of Environment and Natural Resources. 1999. **Calculation of Wastewater Treatment Charges of Pichit: Aerated Lagoon (AL) Wastewater Treatment Plant.** Bangkok: Ministry of Environment and Natural Resources.

West, S. E. and Williams, R. C. 2004. Estimates from a consumer demand system: Implications for the incidence of environmental taxes, **Journal of Environmental economics and Management** 47: 535 – 558.

Whitcomb, D. K. 1972. **Externalities and Welfare**. Series Columbia studies in economic 6. New York: Columbia University Press.

Xie, J. and Saltman, S. 2000. Environmental Policy Analysis: an environmental computable General-Equilibrium approach for Developing countries. **Journal of Policy Modeling** 22, 4: 453 – 489.

Zhang, Z. X. 1996. Macroeconomic Effects of CO2 Emission Limits: A Computable General Equilibrium Analysis for China. **Journal of Policy Modeling** 20, 2: 213 – 250.

BIBLIOGRAPHY

Bachrach, M. and Vaughan, W.J. 1994. Household water demand estimation. **Inter – American Development Bank Working paper ENP106.** Washington, D.C. : American Development Bank.

Ballard, C. L. and Medema, S. G. 1993. The marginal efficiency effects of taxes and subsidies in the presence of externalities: A computational general equilibrium approach. **Journal of Public Economics** 52 : 199 – 216.

Ban, K. 1999. Application of CGE modeling to analysis of environmental measures in APEC. **1999 Conference on Towards APEC's Second Decade: Challenges, Opportunities and Priorities.** Auckland : APEC Study Centre Consortium.

Bangkok Metropolitan Administration, Budgeting Department. 2005. **Budget Allocation Strategy Fiscal Year 2005.** Bangkok : Bangkok Metropolitan Administration

Bangkok Metropolitan Administration, Sewage & Draining Department, Water Quality Management Division. **Bangkok Wastewater Treatment Project.** [Online]. Available from http://www.bma.go.th/bmaeng/body_project21.html. [13 June 2005]

Bangkok Metropolitan Administrative, Sewage & Draining Department, Water Quality Management Division. 2006. Bangkok state of the environment. **Environmental Quality in Bangkok Report 2006.** Bangkok : Bangkok Metropolitan Administrative.

Besley, T. J. and Rosen, H. S. 1998. Vertical externalities in tax setting: evidence form gasoline and cigarettes. **Journal of Public Economics** 70 : 383 – 398.

Berntsen, J., Peterson, B. M., Jacobsen, B. H., Olesen, J. E. and Hutchings, N. J. 2003. Evaluating nitrogen taxation scenarios using the dynamic whole farm simulation model FASSET. **Agricultural Systems** 76 : 817 – 839.

Borge, L. E. and Rattso, J. 1993. Dynamic responses to changing demand: a model of the reallocation process in small and large municipalities in Norway. **Applied Economics** 25 : 589 – 598.

Bovenberg, A. L. and Heijdra, B. J. 1998. Environmental tax policy and intergenerational distribution. **Journal of Public Economics** 67 : 1 – 24.

Bovenberg, A. L. and Mooij, R. A. (1997). Environmental tax reform and endogenous growth. **Journal of Public Economics** 63 : 207 – 237.

Bradford, D.F. 1981. The incidence and allocation effects of a tax on corporation distributions. **Journal of Public Economics** 15 : 1 – 22.

Clinch, J. P. and Dunne, L. 2004. Environmental tax reform: an assessment of social responses in Ireland. **Energy Policy**. [Online]. Available from: http://www.elsevier.com/locate/envsoft [3 December, 2008]

Coelli, T.J. 1995. Estimators and hypothesis tests for a stochastic frontier function: a Monte Carlo analysis. **Journal of Productivity Analysis** 6 : 247 – 268.

Cremer, H. and Gahvari, F. 2001. Second – best taxation of emissions and polluting goods. **Journal of Public Economics** 80: 169 – 197.

COWI Consulting Engineers and Planners AS. 1999. **Economic instruments in environmental protection in Denmark.** Copenhagen: Ministry of Environment and Energy and Danish Environmental Protection Agency.

Dasgupta, S., Huq, M., Wheeler, D.and Zhang, C.1996. Water Pollution Abatement by Chinese Industry: Cost Estimates and Policy Implications. **Policy Research Working Paper No. 1630**. Washington, D.C.: The World Bank.

Dixit, A. K. and Munk J. J. 1977. Welfare effects of tax and price changes: a correction. **Journal of Public Economics** 8: 103-107.

Downing, P. B. and Watson Jr., W. D. 1974. The Economics of enforcing air pollution controls. **Journal of Environmental Economics and Management** 1: 219 – 236.

Drezgic, S. 2008. Measuring the distributional effects of inflation in Croatia by using the LES approach. **Review of Doctoral Dissertation**, 239 – 256. Zagreb : Faculty of Economics, University of Rijeka.

European Environment Agency. 2005. **Market Based Instruments for Environmental Policy in Europe**. Luxembourg : Office for Official Publications of the European Communities.

Feldstein, M. 1978. The Welfare cost of capital income taxation. **Journal of Political Economy** 86: 29 – 51.

Feldstein, M. 1999. Tax avoidance and the deadweight loss of the income tax. **Review of Economics and Statistics** 81, 4 (November 1999): 674-680.

Forsund, F. R. 1973. Externalities, environmental pollution and allocation in space: A general equilibrium approach. **Regional and Urban Economics** 3, 1: 3 – 32.

Glover, D. 1997. **Research issues in environmental tax reform**. Ottawa: International Development Research Centre. [online]. Available from: http://www.idrc.ca/uploads/user-S/10305684330acf2a4.html [11 January, 2006]

Goulder, L. H. 1994. Effects of carbon taxes in an economy with prior tax distortions: an intertemporal general equilibrium analysis, **Journal of environmental economics management** 29: 271 – 297

Goulder, L.H. 1998. Environmental policy making in a second – best setting. **Journal of Applied Economics** 1: 279 – 328

Guang, H.W. 1998. Linear estimation of the non linear almost ideal demand system: a Monte Carlo study. **Applied Economics Letters** 5: 181 - 186

Harberger, A.C. 1962. The incidence of the corporation income tax. **Journal of Political Economy** 70: 215 – 250.

Harberger, A.C. 1966. **Efficiency Effects of Taxes on Income from Capital.** in Krzyaniak, M., Edition Effects of Corporate Income Taxes, Detroit: Wayne State University Press.

Hicks, J.R. 1946. **Value and Capital**, 2nd Edition. Oxford University. Oxford: Oxford University Press.

Hoerner, J. A. 2000. **Burdens and benefits of environmental tax reform: an analysis of distribution by industry.** Redefining progress. Washington, DC.: Center for a Sustainable Economy.

Israngkura, A. 1998. Environmental valuation what, how and for whom. **Thammasat Economic Journal** 16, 4: 55 – 88.

Kao, C., Lee, L.F., Pitt, M. M. and Mark M. 2001. Simulated maximum likelihood estimation of the linear expenditure system with binding non – negativity constraints, **Annals of Economics and Finance** 2: 203 – 223

King, M.A. 1977. **Public Policy and the Corporation**. London: Chapman and Hall.

Koottatep, T. and Chaosakul, T. 2006. Appraisals of environmental sustainability indicators on the conventional centralized and proposed decentralized swerage and domestic wastewater treatment systems in Bangkok. **The Proceeding of 5th National Environmental Conference.** Bangkok: Environmental Engineering Association of Thailand.

Kwon, O. S. and Yun, W. C. 1999. Estimation of the marginal abatement costs of airporne pollutants in Korea's power generation sector. **Energy Economics** 21: 547 – 560.

Lee, H. and Roland – Holst, D. 1997. The environment and welfare implications of trade and tax policy. **Journal of Development Economics** 52: 65 – 82.

Leone, R. A. 1978. Some complications in the measurement of environmental control impacts: A case study of water pollution controls. **Socio – Economics Plan** 12: 103 – 111.

Mirrlees, J.A. 1971. An exploration in the theory of optimum income taxation. **Review of Economic Studies** 38: 175 – 208.

Mishan, E. J. 1981. **Economic Efficiency and Social Welfare: Selected Essays on Fundamental Aspects of the Economic Theory of Social Welfare.** London: George Allen & Unwin.

Musgrave, R.A. 1959. **The Theory of Public Finance.** New York: McGraw-Hill.

Nava, M. Schroyen, F. and Marchand, M. 1996. Optimal fiscal and public expenditure policy in a two – class economy. **Journal of Public Economics** 61: 119 – 137.

Pelloni, A. and Waldmann, R. 2000. Can waste improve welfare? **Journal of Public Economics** 77: 45 – 79.

Pendakur, K. and Sperlich, S. Semiparametric estimation of consumer demand systems in real expenditure. **Working Paper No. V5A 1S6.** Burnaby: Institutional of Statistik and Okonometrie, Canada.

Puig – Junoy, J. and Aggiles, J. M. 2000. **Measuring and explaining farm inefficiency in a panel data set of mixed farms.** Barcelona: Department of Economics and Business, Pompeu Fabra University. [Online]. Available from Email: jaume.puig@econ.upf.es.

Rezek, J. P. and Campbell, R. C. 2007. Cost estimates for multiple pollutants: A maximum entropy approach. **Energy Economics** 29: 503 – 519.

Rongen, G. 1993. Efficiency in the provision of local public goods in Norway. **Journal of Public Economics** 11: 253 – 264.

Rose, M. 1976. A note on cost sharing of municipal wastewater pollution abatement projects. **Land Economics** 52, 4: 554 – 558.

Ruffle, B. 2005. Tax and subsidy incidence equivalence theories: experimental evidence from competitive markets. **Journal of Public Economics** 89: 1519 – 1542.

Sarntisart, I. 1995. An estimation of consumer demand. **Chulalongkorn Journal of Economics** 7, No. 3 (September 1995): 361 – 398.

Sierra West Consulting Group Inc. and Huisingh Environmental Consultants Inc. 1999. **Strengthening National Financing and Cost Recovery Policies for the Wastewater Management Sector TA No. 2499 – THA.** Bangkok: Pollution Control Department, Ministry of Science, Technology and Environment, Kingdom of Thailand.

Simachaya, W. 2003. Environmental financing strategies: User charges in the wastewater sector in Thailand. **Paper for the Workshop on Financing Urban Water Supply and Sanitation in Asia.** Port Dickison: OECD Emerging Asian Economies Program.

Sukharomana, R. 1998. Using Surveys to value non – marketable goods: Contingent valuation method. **Thammasat Economic Journal** 16, 4: 90 – 117.

Sussangkarn, C. and Kumar, R. 1997. **A Computable General Equilibrium (CGE) Model for Thailand Incorporating Natural Water Use and Forest Resource Accounting.** Bangkok: Thailand Development Research Institute Foundation.

Tyler, W. G. 1976. The Stochastic Frontier Production Function and Average Efficiency: An Empirical Analysis. **Journal of Econometrics** 7, 2: 385 – 389

APPENDICES

APPENDIX A: Lists of Goods Included in Each Category

1. Food & Beverage Category

<u>Grains and cereal products</u>

01 Rice (include half – milled rice)

02 Glutinous rice

03 Rice and wheat flour and oats

04 Cassava flour and corn flour

05 Noodles

06 Macaroni and spaketti

07 Bread and cake

08 Pastries

09 Bean curd

10 Other cereal products such as malt , sago , malt flour etc.

<u>Meat and poultry</u>

01 Pork, lean

02 Spare ribs and other pork

03 Beef , goat and mutton

04 Other ▯ resh beef

05 Rabbit and other wild animals (game)

06 Chicken

07 Duck

08 Goose and turkey

09 Bird, snake and other reptile

10 Other fresh meat and insect

11 Roast pork and salted pork

12 Minced pork, ham, sausage and etc.

13 Salted beef

14 Prepared fowl

15 Other prepared meat and poultry

<u>Fresh and seafood</u>

01 Fresh water fish

02 Sea water fish

03 Prawns

04 Squid

05 Shell fish

06 Crabs

07 Sea crabs

08 Other fresh fish and seafood

09 Steamed fish

10 Dried and salted fish

11 Dried shrimp and squid

12 Fish balls

13 Fermented fish or shrimp

14 Salted crab

15 Other preserved fish and seafood

<u>Milk products and eggs</u>

01 Milk, fresh (include pasteurize and sterilize)

02 Milk, condensed

03 Milk, powdered

04 Non – diary cream

05 Beverage and milk product

06 Cheese

APPENDIX A: Lists of Goods Included in Each Category (continued)

07 Hen's eggs
08 Duck's eggs
09 Salted eggs
10 Sour milk and yoghurt
11 Other milk and egg products

Fruits

01 Bananas
02 Coconut, ground
03 Oranges
04 Papaya (ripe)
05 Pineapple
06 Rambutan
07 Mangoes
08 Melons
09 Durians
10 Other fresh fruits
11 Dried and preserved fruits
12 Tinned fruits
13 Ground nut
14 Mung beans
15 Other beans and seeds
09 Bean sprouts
10 Pumpkins
11 Sweet potatoes and potatoes
12 Green onions
13 Chillies
14 Coriander (Chinese parsley)
15 Garden peas, and Gourds
16 Lemon
17 Papaya (green)
18 Sting bean (Yard long bean)
19 Squash
20 Ivy gourd
21 Convulvulus
22 Chinese leek
23 Chinese radish and carrot
24 Chinese celery
25 Ginger, galingale, lemongrass and other herbs
26 Other fresh vegetables
27 Pickled mustard
28 Other pickled vegetables
29 Dried onions and red onion
30 Chinese flower and dried mushrooms
31 Seaweed
32 Other dried vegetables

Vegetables

01 Cabbage
02 Cucumber
03 Chinese white cabbage, mustard greens and lettuce
04 Chinese kale
05 Mushrooms
06 Bamboo shoots
07 Egg plant
08 Tomatoes

APPENDIX A: Lists of Goods Included in Each Category (continued)

Oils and fats

01 Lard oil

02 Vegetable oil

03 Butter and ghee , margarine

04 Other oils and fats

Sugar and sweets

01 White sugar

02 Brown sugar

03 Palm sugar

04 Candy, chocolate, jelly and jam

05 Confection

06 Other sugar and sweets

Spices, coffee, etc.

01 Salt

02 Fish sauce

03 Vinegar

04 Soy sauce

05 Oyster sauce

06 Chilli sauce

07 Tomato paste

08 Sodium glutamate

09 Shrimp paste

10 Dried chillies, pepper and garlic

11 Spices and other condiments

12 Coffee

13 Tea leaves

14 Cocoa etc.

15 Others

Prepared food eaten at home

01 Curry

02 Noodles

03 Fried rice

04 Meals

05 Instant noodles

06 Can prepared food

07 Other prepared food

Beverages, non - alcoholic

01 Soda water

02 Coke, etc.

03 Fresh water

04 Fruit /vegetable juices

05 Ice

06 Can prepared coffee

07 Can prepared tea

08 Lipovitum - D, etc.

09 Other beverages

Meal eaten away from home

01 Breakfast

02 Lunch - Prepared food as American / European style

03 Lunch - Other prepared food

04 Dinner - prepared food as American / European style

05 Dinner - Other prepared food

06 Snacks

APPENDIX A: Lists of Goods Included in Each Category (continued)

2. Tobacco Products & Alcohol Beverages

Alcoholic beverages

01 Beer

02 Wine

03 Whiskey

04 Other alcoholic drinks

Tobacco products

01 Cigarettes, Cigars and tobacco

02 Betelnut, etc.

Alcoholic beverages eaten away from home

3. Personal Appearance & Foot Wear

Men's clothing

01 Cloth, cotton

02 " nylon

03 " other

04 Uniforms, school

05 " other

06 Raincoats, light jackets

07 Jackets, Sweaters

08 Trousers, shorts

09 Dressing shirts

10 Shirts, polo

11 Sport shirts, T-shirt

12 Singlet

13 Suit and shirts, other

(continued)

14 Chinese trousers

15 Sleepwear

16 Robes

17 Panung, Sarong

18 Briefs

19 Socks

20 Ties

21 Handkerchiefs

22 Gloves made of cloth

23 Crash helmets

24 Belts

25 Swimming suits

26 PA-KAO-MA

APPENDIX A: Lists of Goods Included in Each Category (continued)

Women's clothing

01 Cloth, cotton
02 " nylon
03 " other
04 Uniforms, school
05 " other
06 Raincoats, light jackets
07 Jackets, Sweaters
08 Trousers, shorts
09 Dressing shirts
10 Shirts, polo
11 Sport shirts, T-shirts
12 Undershirts
13 Suit and shirts, other
14 Chinese trousers
15 Sleepwear, women's
16 Robes
18 Dresses suits, Maternal dresses
19 Blouses
20 Skirts
21 Panung, Sarong
22 Slipss
23 Brassieres
24 Briefs and underpants
25 Socks
26 Panties
27 Ties
28 Handkerchiefs

(continued)

29 Gloves
30 Crash helmets
31 Belts
32 Swimming Suits
34 Other women's clothing

Clothing for boys and girls

01 Cloth, cotton
02 " nylon
03 " other
04 Uniforms, school
06 Raincoats, light jackets
07 Jackets, Sweaters
08 Trousers, shorts
09 Dressing shirts
10 Shirts, polo
11 Sport shirts, T-shirts
12 Singlet
13 Shirts, others
14 Chinese trousers
15 Sleepwear
16 Robes
17 Baby's Suit
18 Baby's dresses
19 Blouses
20 Skirts
21 Panung, Sarong
22 Slips

APPENDIX A: Lists of Goods Included in Each Category (continued)

23	Brassieres
24	Briefs or panties
25	Socks
28	Handkerchiefs
29	Gloves
30	Crash helmets
31	Belts
32	Swimming suits
33	PA-KAO-MA
34	Other boys' and girls' clothing

Sewing Services

01	For men
02	For women
03	For boys and girls
04	Accessories
05	Repair and altering of garments
06	Hire of garments
07	Launder and dry cleaning
08	Other related services

Men's footwear

01	Shoes, Dress leather
02	" other leather
03	" sport
04	Sneakers
05	Slippers, leather
06	" rubber
07	Other men's footwear

Women's footwear

01	Shoes, Dress leather
02	" other leather
03	" sport
04	Sneakers
05	Slippers, leather
06	" rubber

Boys' and girls' footwear

01	Shoes, Dress leather
02	" other leather
03	" sport
04	Sneakers
05	Slippers, leather
06	Slippers, rubber
07	Other boys' and girls' footwear

Repair and hire of footwear etc.

01	For men
02	For women
03	For boys and girls
04	Hire of foot wear and shoes cleaning services

APPENDIX A: Lists of Goods Included in Each Category (continued)

4. Housing

Housing (shelter)

01 House rent
02 Land rent
03 Land tax
04 Lumber
05 Cement
06 Bricks
07 Roof tiles
08 Roof tin
09 Other materials for repair
10 Painting
11 Fitting /repair of plumbing & bathroom appliances
12 Fixtures and fitting for lighting
13 Other labor costs
14 Tools for maintenance
21 Rent including electricity
22 Rent and other utilities

Fuel and light

01 Electricity
02 Gas for cooking
03 Gas for other purposes
04 Charcoal
05 Wood
06 Kerosene
07 Batteries
08 Matches
09 Candles

(continued)

10 Light bulbs, Fluorescences
11 Lamps
12 Other fuel and light

Minor equipment

01 Glassware
02 Pottery
03 Cutlery
04 Pots and pans
05 Dishes
06 Small kitchen utensils
07 Basins
08 Buckets & jars
09 Vacuum flasks
10 Charcoal stove
11 Other minor equipments

APPENDIX A: Lists of Goods Included in Each Category (continued)

Textile housefurnishings

01 Mosquito net

02 Sheets

03 Pillow cases

04 Blankets

05 Bed spreads

06 Curtains

07 Towels

08 Table covers

09 Table and Kitchen linen

10 Floor mats

11 Door mats

12 Other household textiles

Cleaning supplies

01 Detergent, Soap, Flake

02 Liquid detergents

03 Softener and starch

04 Household polishes

05 Mops and brooms

06 Deodorizer

07 Insecticides, Disinfectants

08 Rubbish services

09 Others

Domestic servants

01 Maids

02 Cooks

03 Guards

04 Gardeners

05 Drivers

(continued)

06 Laundress

07 Baby sisters

08 Other servants

Major equipment

01 Beds

02 Chairs, tables

03 Sofas

04 Other furnitures

05 Carpets

06 Mattress, pillows

07 Cook stove, gas or electric

08 Microwave ovens

09 Electric pots

10 Water filter

11 Electric iron

12 Electric fan

13 Sewing machine

14 Vacuum cleanner

15 Refrigerators

16 Lawn mower

17 Household water pump

18 Washing machine

19 Blenders, Mixers

20 Rice cookers

21 Air conditioners

22 Water boiler

23 Maintenance and repair

24 Other major equipments

APPENDIX A: Lists of Goods Included in Each Category (continued)

5. Medical Care (included medical care and personal care)

Medical supplies

01 Cough remedies
02 Antipyretics and Analgesics
03 Cold remedies
04 Anti-inflammatory Analgesics, muscle relaxants
05 Antimicrobials
06 Antivenim
07 Antifungals-dermatologic preperation
08 Antiseptics
09 Laxatives, Purgatives
10 Anthelmintics
11 Antacids, Digestives, Carminatives
12 Antidiarrheals
13 Contraceptives
14 Inhalant
15 Vitamins
16 Other modern drugs
17 Traditional drugs, Herbal drugs
18 Condom
19 1st aid kits and other medical equipments

Medical services

For outpatients

01 Traditional healer / sed herb medical services
02 Public health centre
03 Public hospital within amphoe

(continued)

04 Provincial public hospital
05 Private hospital
06 Private clinic
07 Private dental clinic
08 Others

For inpatients and optometries

09 Public hospital within amphoe
10 Provincial public hospital
11 Public hospital in the other provinces
12 Private hospital within province
13 Private hospital in the other provinces
14 Other medical services
15 Optometry services , include corrective eye - qlasses, contact lenses etc.

Personal care supplies

01 Toilet soaps
02 Tooth paste
03 Tooth brush, Electric tooth brush
04 Shampoo, Conditioner
05 Hair tonic, Hair lotion
06 Perfume and cologne
07 Face powder and powder

APPENDIX A: Lists of Goods Included in Each Category (continued)

08 Lipstick

09 Other cosmetics

10 Brushes, Electric brushes

11 Razor and blades, Electric shaver

12 Hand – bags, purses, suitcases

13 Watches

14 Sun – glasses

15 Toilet paper, Tissue paper

16 Sanitary napkins

17 Other supplies

18 Maintenance and repair

Personal services

01 Haircut

02 Haircurl

03 Hairset

04 Hairdye

05 Manicure

06 Face and body massage

07 Traditional massage

08 Turkish bath, Massage

09 Other Personal services

6. Transportation (included transportation and communication)

Local Transportation

01 Bus

02 Taxi, Samlor

03 Tricycle

04 Motorcycle

05 Mini bus, Van

06 School bus

07 Bus for clerks only

08 Boat and ferry

09 Trains

10 Other local transport

Travel out of area and tours

01 Travel to visit home / relatives, denation activity and other business

02 Personal domestic trip

03 Personal out – bound tour

04 Package of domestic trip

05 Expenses on goods / souvenir during the domestic trip

06 Package of out – bound tour

07 Expenses on goods / souvenir during the out – bound tour

APPENDIX A: Lists of Goods Included in Each Category (continued)

Vehicle operation

01 Unleaded gasoline (Octane no. 87)

02 Unleaded gasoline (Octane no. 91, 92)

03 Unleaded gasoline (Octane no. 95)

04 High speed diesel

05 Low speed diesel

06 Liquified petroleum gas

07 Grease & lubricating oil

08 Lubrication

09 Washing

10 Tyre repair

11 Overhaul

12 Repairs, Spare parts

13 Driving lessons

14 Parking rate

15 Toll fees

16 Other maintenance costs

Vehicle purchase

01 Automobile, Van, Pick up

02 Motorcycle

03 Bicycle

04 Other vehicles

05 Tyres

06 Batteries

07 License fees

08 Registration fees

09 Other purchases

Communications services

01 Telephone rate

02 Packlink, Phonelink etc. (Service rate)

03 Membership and Internet services

04 Telegraph

05 Postage

06 Writing pad and envelope

07 Ink, pens and other stationery

08 Other communications

Communication equipment

01 Telephone handset

02 Mobile phone

03 Facsimile

04 Packlink, Phonelink etc.

05 Installation fees

06 Other equipments

APPENDIX A: Lists of Goods Included in Each Category (continued)

7. Education (included recreation, reading, and education)

<u>Admissions</u>

01 Cinema

02 Theatre, cultural / traditional arts

03 Sport stadiums

04 Fairs

05 Amusement parks

06 Museums

07 Gardens, zoo, historical sites, natural park

08 Sightseeing

09 Swimming rate

10 Sport fees

11 Horse racing rate

12 Memberships

13 Others

<u>Recreation equipment</u>

01 Toys

02 Tricycles, etc.

03 Tennis, Golf, sport equipments

04 Body fitness equipments

05 Lottery ticket

06 Numbers game

07 Other gamblings

08 Film, developed and contact printing

(continued)

10 Renting records,disk, tapes, VDO tape

11 Cable TV membership fees

12 Souvenir and collecting (coins, stamps, etc.)

13 Pets and pet equipments

14 Pet food' Pet care and grooming products

15 Natural and artificial flowers

16 Trees, shrubs, fertilizer, sprays, and garden equipments

17 Others

<u>Reading materials</u>

01 Newspapers

02 Magazines

03 Books

04 Library fees

05 Other reading materials

<u>Religious activities</u>

01 Flowers

02 Joss sticks

03 Gift to wats

04 Other religious expenses

APPENDIX A: Lists of Goods Included in Each Category (continued)

09 Purchasing records, disk, tapes, VDO tape

Musical equipment

01 Radio
02 Tape recorders
03 Receiver-tape players
04 Disc players, stereo
05 Musical instruments
06 TV sets
07 Video
08 Camcorders
09 Cameras
10 Movie slide projector
11 Home computer equipments
12 Cable TV installment fees or satellite discs
13 Maintenance and repair
14 Others

Education expenses

01 School fees - Private school
02 School fees - Government school
03 Tuition, Private vocational
04 Tuition, Government vocational
05 Tuition, Private University
06 Tuition, Government University
07 School fees - Adult education
08 Text books
09 School equipment
10 Special lessons
11 Students' lunch (Semester or month)
12 Pocket money for children to school (daily)
13 Other education expenses

8. Water

01 Water
02 Underground water

APPENDIX A: Lists of Goods Included in Each Category (continued)

Other Non - Consumption Goods

Ceremonies

01 Weddings

02 Monkhood

03 Cremations

04 Birthdays

05 Other ceremonies

Miscellaneous expenses

01 Legal fees

02 Lawyer fees

03 Financial services

04 Advertising rate

05 Copy printing rate

06 Child care services (outside dwelling)

07 Outside dwelling guards fees

08 Other miscellaneous

Other expenses

01 Interest

02 Shares

03 Lost money

04 Compensation

05 Money to servants

06 Packing, grating moving services

07 Commission to domestic servant services

Taxes

01 Income tax

02 House and land tax

03 Fine rate

04 Other taxes

Contributions

01 Religious institutions

02 Educational "

03 Charitable "

04 Political "

05 To persons

06 Other contributions

Occupational expenses

01 Labour union dues

02 Agricultural associations

03 Merchant associations

04 Other occupational expenses

Insurance premiums

01 Property insurance

02 Life insurance

03 Cremation fees

04 Auto insurance

05 Third Party insurance

06 Other insurance

APPENDIX B: Classify of Households Income Level of Year 2002, 2004 and 2006

baht per household per month

Income Level	Year 2002	Year 2004	Year 2006
Low Income Households*	0 – 12,500	0 – 13,500	0 – 15,000
Middle Income Households**	12,501 – 50,000	13,501 – 50,000	15,501 – 50,000
High Income Households***	50,001 up	50,001 up	50,001 up

Source: Revenue Department, Ministry of Finance

*Low income households have income per month range between zeros to the income level which does not have to pay income tax.

**Middle income households have income per month range between the income levels which have to pay income tax to 50,000 baht.

***High income households have income per month more than 50,000 baht.

APPENDIX C1: Results from Demand Coefficient Estimation of Low Income Households

Estimation Method: Seemingly Unrelated Regression

Sample: 1 2069

Included observations: 2069

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	24.7142	3.0727	8.0432	0.0000
C(9)	0.3844	0.0086	44.6614	0.0000
C(2)	-10.5575	0.8797	-12.0010	0.0000
C(3)	15.6924	0.4994	31.4243	0.0000
C(4)	-28.7638	1.3167	-21.8452	0.0000
C(5)	0.5245	7.4719	0.0702	0.9440
C(6)	-11.7600	2.1950	-5.3577	0.0000
C(7)	1.6460	7.2193	0.2280	0.8196
C(8)	-9.5196	0.2084	-45.6803	0.0000
C(10)	0.0250	0.0025	9.8175	0.0000
C(11)	0.0128	0.0025	5.1619	0.0000
C(12)	0.1069	0.0072	14.9520	0.0000
C(13)	0.0391	0.0035	11.2496	0.0000
C(14)	0.2139	0.0087	24.6940	0.0000
C(15)	0.0558	0.0038	14.5052	0.0000
C(16)	0.0068	0.0005	12.8061	0.0000

Determinant residual covariance 5.60000E+44

Equation: FB=((C(1)^2)*PFB) +(C(9)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.43726	Mean dependent var	2664.463
Adjusted R-squared	0.435074	S.D. dependent var	2185.846
S.E. of regression	1642.916	Sum squared resid	5.56E+09
Durbin-Watson stat	1.280144		

APPENDIX C1: Results from Demand Coefficient Estimation of Low Income Households (Continued)

Equation: AT=((C(2)^2)*PAT)+(C(10)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.031569	Mean dependent var	245.7081
Adjusted R-squared	0.027808	S.D. dependent var	488.5314
S.E. of regression	481.6908	Sum squared resid	4.78E+08
Durbin-Watson stat	1.851471		

Equation: AF=((C(3)^2)*PAF) +(C(11)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.017695	Mean dependent var	305.9952
Adjusted R-squared	0.01388	S.D. dependent var	463.3603
S.E. of regression	460.1334	Sum squared resid	4.36E+08
Durbin-Watson stat	1.455215		

Equation: H=((C(4)^2)*PH) +(C(12)*(CONEXP-(((C(1)^2)*PFB) +((C(2)^2)
*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)+((C(6)^2)
*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.107721	Mean dependent var	1356.83
Adjusted R-squared	0.104256	S.D. dependent var	1400.195
S.E. of regression	1325.197	Sum squared resid	3.62E+09
Durbin-Watson stat	0.92771		

Equation: MED=((C(5)^2)*PMED) +(C(13)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.059085	Mean dependent var	188.8376
Adjusted R-squared	0.055431	S.D. dependent var	668.452
S.E. of regression	649.6615	Sum squared resid	8.69E+08
Durbin-Watson stat	1.844243		

APPENDIX C1: Results from Demand Coefficient Estimation of Low Income Households (Continued)

Equation: TRAN=((C(6)^2)*PTRAN) +(C(14)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.22573	Mean dependent var	1018.65
Adjusted R-squared	0.222723	S.D. dependent var	1972.857
S.E. of regression	1739.335	Sum squared resid	6.23E+09
Durbin-Watson stat	1.53718		

Equation: EDU=((C(7)^2)*PEDU) +(C(15)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.098099	Mean dependent var	277.9232
Adjusted R-squared	0.094597	S.D. dependent var	747.8979
S.E. of regression	711.6448	Sum squared resid	1.04E+09
Durbin-Watson stat	1.708812		

Equation: W=((C(8)^2)*PW) +(C(16)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.086265	Mean dependent var	132.8014
Adjusted R-squared	0.082717	S.D. dependent var	101.0461
S.E. of regression	96.77679	Sum squared resid	19293437
Durbin-Watson stat	1.688502		

APPENDIX C2: Results from Demand Coefficient Estimation of Medium Income Households

Estimation Method: Iterative Seemingly Unrelated Regression

Sample: 1 3558

Included observations: 3558

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	47.7322	1.3494	35.3726	0.0000
C(2)	14.7396	0.5580	26.4140	0.0000
C(3)	24.8100	0.4322	57.4067	0.0000
C(4)	33.7667	2.0630	16.3682	0.0000
C(5)	10.5065	1.9716	5.3290	0.0000
C(6)	23.3452	4.1740	5.5930	0.0000
C(7)	21.4306	1.2333	17.3769	0.0000
C(8)	13.5273	0.1551	87.2088	0.0000
C(9)	0.2232	0.0052	43.0503	0.0000
C(10)	0.0095	0.0011	8.6239	0.0000
C(11)	0.0085	0.0014	6.0011	0.0000
C(12)	0.1478	0.0053	27.6531	0.0000
C(13)	0.0361	0.0023	15.8415	0.0000
C(14)	0.2745	0.0072	38.2318	0.0000
C(15)	0.0486	0.0025	19.2825	0.0000
C(16)	0.0045	0.0003	16.8153	0.0000

Determinant residual covariance 7.85E+49

Equation: FB=((C(1)^2)*PFB) +(C(9)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.277445	Mean dependent var	4799.285
Adjusted R-squared	0.275816	S.D. dependent var	3885.792
S.E. of regression	3306.771	Sum squared resid	3.88E+10
Durbin-Watson stat	1.166012		

APPENDIX C2: Results from Demand Coefficient Estimation of Medium Income Households (Continued)

Equation: AT=((C(2)^2)*PAT)+(C(10)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.009623	Mean dependent var	324.0579
Adjusted R-squared	0.007391	S.D. dependent var	700.9656
S.E. of regression	698.3704	Sum squared resid	1.73E+09
Durbin-Watson stat	1.77081		

Equation: AF=((C(3)^2)*PAF) +(C(11)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.014196	Mean dependent var	690.1563
Adjusted R-squared	0.011974	S.D. dependent var	891.8042
S.E. of regression	886.4488	Sum squared resid	2.79E+09
Durbin-Watson stat	1.399735		

Equation: H=((C(4)^2)*PH) +(C(12)*(CONEXP-(((C(1)^2)*PFB) +((C(2)^2)
*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)+((C(6)^2)
*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.181267	Mean dependent var	2586.69
Adjusted R-squared	0.179421	S.D. dependent var	3687.515
S.E. of regression	3340.364	Sum squared resid	3.96E+10
Durbin-Watson stat	1.249349		

Equation: MED=((C(5)^2)*PMED) +(C(13)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.067149	Mean dependent var	464.7097
Adjusted R-squared	0.065046	S.D. dependent var	1479.081
S.E. of regression	1430.168	Sum squared resid	7.26E+09
Durbin-Watson stat	1.799029		

APPENDIX C2: Results from Demand Coefficient Estimation of Medium Income Households (Continued)

Equation: TRAN=((C(6)^2)*PTRAN) +(C(14)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.293986	Mean dependent var	3172.837
Adjusted R-squared	0.292394	S.D. dependent var	5620.784
S.E. of regression	4728.165	Sum squared resid	7.93E+10
Durbin-Watson stat	1.34278		

Equation: EDU=((C(7)^2)*PEDU) +(C(15)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.101515	Mean dependent var	930.2662
Adjusted R-squared	0.09949	S.D. dependent var	1656.755
S.E. of regression	1572.181	Sum squared resid	8.77E+09
Durbin-Watson stat	1.578894		

Equation: W=((C(8)^2)*PW) +(C(16)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.080629	Mean dependent var	242.8673
Adjusted R-squared	0.078557	S.D. dependent var	175.893
S.E. of regression	168.8429	Sum squared resid	1.01E+08
Durbin-Watson stat	1.821762		

APPENDIX C3: Results from Demand Coefficient Estimation of High Income Households

Estimation Method: Iterative Seemingly Unrelated Regression

Sample: 1 1151

Included observations: 1151

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	63.8414	2.0222	31.5710	0.0000
C(2)	16.4456	0.9392	17.5104	0.0000
C(3)	41.2434	1.7268	23.8847	0.0000
C(4)	33.6320	13.7451	2.4468	0.0144
C(5)	25.3053	2.5599	9.8854	0.0000
C(6)	50.6183	11.3327	4.4666	0.0000
C(7)	43.7739	2.5526	17.1488	0.0000
C(8)	16.4424	0.4124	39.8683	0.0000
C(9)	0.0930	0.0047	19.9103	0.0000
C(10)	0.0021	0.0007	3.0764	0.0021
C(11)	0.0298	0.0025	11.9421	0.0000
C(12)	0.2157	0.0102	21.0524	0.0000
C(13)	0.0197	0.0023	8.4781	0.0000
C(14)	0.3279	0.0128	25.6063	0.0000
C(15)	0.0392	0.0033	11.7473	0.0000
C(16)	0.0038	0.0003	14.8335	0.0000

Determinant residual covariance 7.88E+55

Equation: FB=((C(1)^2)*PFB) +(C(9)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.188376	Mean dependent var	7367.136
Adjusted R-squared	0.182691	S.D. dependent var	6581.979
S.E. of regression	5950.448	Sum squared resid	4.04E+10
Durbin-Watson stat	1.036877		

APPENDIX C3: Results from Demand Coefficient Estimation of High Income Households (Continued)

Equation: AT=((C(2)^2)*PAT)+(C(10)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.000061	Mean dependent var	349.457
Adjusted R-squared	-0.006944	S.D. dependent var	864.1647
S.E. of regression	867.1598	Sum squared resid	8.59E+08
Durbin-Watson stat	1.829514		

Equation: AF=((C(3)^2)*PAF) +(C(11)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.114656	Mean dependent var	2539.153
Adjusted R-squared	0.108454	S.D. dependent var	3322.632
S.E. of regression	3137.286	Sum squared resid	1.12E+10
Durbin-Watson stat	1.573403		

Equation: H=((C(4)^2)*PH) +(C(12)*(CONEXP-(((C(1)^2)*PFB) +((C(2)^2)
*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)+((C(6)^2)
*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.280417	Mean dependent var	7293.069
Adjusted R-squared	0.275376	S.D. dependent var	15118.73
S.E. of regression	12869.8	Sum squared resid	1.89E+11
Durbin-Watson stat	1.362444		

Equation: MED=((C(5)^2)*PMED) +(C(13)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.059947	Mean dependent var	1221.95
Adjusted R-squared	0.053362	S.D. dependent var	3006.906
S.E. of regression	2925.579	Sum squared resid	9.77E+09
Durbin-Watson stat	1.820928		

APPENDIX C3: Results from Demand Coefficient Estimation of High Income Households (Continued)

Equation: TRAN=((C(6)^2)*PTRAN) +(C(14)*(CONEXP-(((C(1)^2)*PFB)

+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)

+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.363237	Mean dependent var	11961.42
Adjusted R-squared	0.358776	S.D. dependent var	20803.46
S.E. of regression	16658.68	Sum squared resid	3.17E+11
Durbin-Watson stat	1.410895		

Equation: EDU=((C(7)^2)*PEDU) +(C(15)*(CONEXP-(((C(1)^2)*PFB)

+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)

+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.114518	Mean dependent var	3031.461
Adjusted R-squared	0.108315	S.D. dependent var	4440.652
S.E. of regression	4193.266	Sum squared resid	2.01E+10
Durbin-Watson stat	1.526942		

Equation: W=((C(8)^2)*PW) +(C(16)*(CONEXP-(((C(1)^2)*PFB)

+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)

+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.152985	Mean dependent var	406.4596
Adjusted R-squared	0.147051	S.D. dependent var	350.7786
S.E. of regression	323.9624	Sum squared resid	1.20E+08
Durbin-Watson stat	1.918665		

APPENDIX C4: Results from Demand Coefficient Estimation of Average Income Households

Estimation Method: Iterative Seemingly Unrelated Regression

Sample: 6270

Included observations: 6270

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	52.1745	0.7182	72.6422	0.0000
C(2)	15.8097	0.2944	53.7023	0.0000
C(3)	22.4222	0.7249	30.9322	0.0000
C(4)	30.7201	2.9561	10.3922	0.0000
C(5)	15.3527	1.0205	15.0450	0.0000
C(6)	23.7652	5.1316	4.6312	0.0000
C(7)	23.0345	1.1944	19.2852	0.0000
C(8)	12.8483	0.1434	89.5722	0.0000
C(9)	0.1165	0.0022	53.1865	0.0000
C(10)	0.0033	0.0004	8.1845	0.0000
C(11)	0.0389	0.0009	41.8589	0.0000
C(12)	0.2050	0.0036	57.2403	0.0000
C(13)	0.0271	0.0010	26.7974	0.0000
C(14)	0.3401	0.0046	74.3707	0.0000
C(15)	0.0575	0.0013	44.0885	0.0000
C(16)	0.0050	0.0001	43.1925	0.0000

Determinant residual covariance 7.65E+51

Equation: FB=((C(1)^2)*PFB) +(C(9)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.262651	Mean dependent var	4410.474
Adjusted R-squared	0.261709	S.D. dependent var	4259.877
S.E. of regression	3660.25	Sum squared resid	8.39E+10
Durbin-Watson stat	1.025235		

APPENDIX C4: Results from Demand Coefficient Estimation of Average Income Households (Continued)

Equation: AT=((C(2)^2)*PAT)+(C(10)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	-0.000972	Mean dependent var	302.8573
Adjusted R-squared	-0.002251	S.D. dependent var	663.6041
S.E. of regression	664.3507	Sum squared resid	2.76E+09
Durbin-Watson stat	1.720846		

Equation: AF=((C(3)^2)*PAF) +(C(11)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.222073	Mean dependent var	922.145
Adjusted R-squared	0.221079	S.D. dependent var	1748.222
S.E. of regression	1542.92	Sum squared resid	1.49E+10
Durbin-Watson stat	1.556113		

Equation: H=((C(4)^2)*PH) +(C(12)*(CONEXP-(((C(1)^2)*PFB) +((C(2)^2)
*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)+((C(6)^2)
*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.343376	Mean dependent var	3233.802
Adjusted R-squared	0.342537	S.D. dependent var	7339.042
S.E. of regression	5950.798	Sum squared resid	2.22E+11
Durbin-Watson stat	1.542185		

Equation: MED=((C(5)^2)*PMED) +(C(13)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.102638	Mean dependent var	546.1262
Adjusted R-squared	0.101492	S.D. dependent var	1773.686
S.E. of regression	1681.271	Sum squared resid	1.77E+10
Durbin-Watson stat	1.878304		

APPENDIX C4: Results from Demand Coefficient Estimation of Average Income Households (Continued)

Equation: TRAN=((C(6)^2)*PTRAN) +(C(14)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.466401	Mean dependent var	4300.367
Adjusted R-squared	0.46572	S.D. dependent var	10570.33
S.E. of regression	7726.33	Sum squared resid	3.74E+11
Durbin-Watson stat	1.570946		

Equation: EDU=((C(7)^2)*PEDU) +(C(15)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.23933	Mean dependent var	1169.327
Adjusted R-squared	0.238358	S.D. dependent var	2479.514
S.E. of regression	2163.924	Sum squared resid	2.93E+10
Durbin-Watson stat	1.633058		

Equation: W=((C(8)^2)*PW) +(C(16)*(CONEXP-(((C(1)^2)*PFB)
+((C(2)^2)*PAT)+((C(3)^2)*PAF)+((C(4)^2)*PH)+((C(5)^2)*PMED)
+((C(6)^2)*PTRAN)+((C(7)^2)*PEDU)+((C(8)^2)*PW))))

R-squared	0.232314	Mean dependent var	236.8781
Adjusted R-squared	0.231333	S.D. dependent var	222.0665
S.E. of regression	194.6938	Sum squared resid	2.37E+08
Durbin-Watson stat	1.847289		

where

C(1) = Square root of committed levels of expenditure of food & beverage (γ_{fb})

C(2) = Square root of committed levels of expenditure of tobacco & alcohol beverage (γ_{ta})

C(3) = Square root of committed levels of expenditure of appearance & footwear (γ_{aw})

C(4) = Square root of committed levels of expenditure of housing (γ_{h})

C(5) = Square root of committed levels of expenditure of medical care & personal care (γ_{med})

C(6) = Square root of committed levels of expenditure of transportation & communication (γ_{tc})

C(7) = Square root of committed levels of expenditure of recreation, reading & education (γ_{edu})

C(8) = Square root of committed levels of expenditure of water used (γ_{w})

C(9) = consumption expenditure share of food & beverage (β_{fb})

C(10) = consumption expenditure share of tobacco & alcohol beverage (β_{ta})

C(11) = consumption expenditure share of appearance & footwear (β_{aw})

C(12) = consumption expenditure share of housing (β_{h})

C(13) = consumption expenditure share of medical care & personal care (β_{med})

C(14) = consumption expenditure share of transportation & communication (β_{tc})

C(15) = consumption expenditure share of recreation, reading & education (β_{edu})

C(16) = consumption expenditure share of water used (β_{w})

APPENDIX D: Results from Stochastic Cost Frontier Coefficient Estimation

Output from the program FRONTIER (Version 4.1c)

The model is a cost function

The dependent variable is logged

The Ordinary Least Square Estimations

	Coefficient	Standard Error	t-ratio
Constant	2.31522	0.55714	4.15556
$\ln(WW_i)$	0.42825	0.03788	11.30485
$\ln(PL)$	0.55278	0.03461	15.97137
$\ln(PE)$	0.52683	0.33812	1.55809
$\ln(PM)$	0.06947	0.03903	1.77982
sigma-squared	0.03282		
log likelihood function	54.63986		

The Estimations after Grid Search

	Coefficient
Constant	2.12125
$\ln(WW_i)$	0.42825
$\ln(PL)$	0.55278
$\ln(PE)$	0.52683
$\ln(PM)$	0.06947
sigma-squared	0.06953
gamma	0.85000

APPENDIX D: Results from Stochastic Cost Frontier Coefficient Estimation (Continued)

The Final Maximum Likelihood Estimations

	Coefficient	Standard Error	t-ratio
Constant	1.99549	0.49889	3.99991
$\ln(WW_i)$	0.51131	0.03303	15.48014
$\ln(PL)$	0.48564	0.02966	16.37536
$\ln(PE)$	0.10838	0.35538	0.30498
$\ln(PM)$	0.07610	0.03272	2.32560
sigma-squared	0.07843	0.01150	6.82220
gamma	0.91831	0.03588	25.59234
log likelihood function	61.37846		

LR test of the one – sided error = 13.47721

With number of restriction = 1

(Note: This statistic has a mixed chi – square distribution)

Number of iterations = 13

Number of cross – sections = 5

Number of time periods = 36

Total number of observations = 180

Thus, there are 0 observations not in the panel.

APPENDIX E: Results of Net Social Welfare Estimation

	Benchmark Scenario (Without Charge)				Senario 1 (With Charge at 2 Baht per m3)				Revenue Neutral							
									Scenario 2 (Compensated in Lump Sum)				Scenario 3 (Reduce Other Tax Rates)			
	Low Income	Medium Income	High Income	Average Household	Low Income	Medium Income	High Income	Average Household	Low Income	Medium Income	High Income	Average Household	Low Income	Medium Income	High Income	Average Household
1. Number of Households	610,505	1,049,867	339,628	2,000,000	610,505	1,049,867	339,628	2,000,000	610,505	1,049,867	339,628	2,000,000	610,505	1,049,867	339,628	2,000,000
2. Other Goods Expenses (Baht)	6,132.76	12,837.37	34,136.43	14,926.33	6,116.77	12,809.19	34,095.03	14,898.94	6,151.90	12,840.36	34,125.53	14,931.99	6,116.77	12,818.98	34,245.49	14,932.08
(Ratio = 2 / 4)	97.8931%	98.1377%	98.8311%	98.4424%	97.8898%	98.1350%	98.8303%	98.4408%	97.8971%	98.1380%	98.8309%	98.4428%	97.8898%	98.1360%	98.8332%	98.4428%
3. Water Expenses(฿)	131.9896	243.6008	403.7345	236.1648	131.8602	243.4321	403.5197	235.9899	132.1446	243.6188	403.6780	236.2009	131.8602	243.4907	404.3006	236.2015
(Ratio = 3 / 4)	2.1069%	1.8623%	1.1689%	1.5576%	2.1102%	1.8650%	1.1697%	1.5592%	2.1029%	1.8620%	1.1691%	1.5572%	2.1102%	1.8640%	1.1668%	1.5572%
4. Total Expenses (Baht) 2 + 3	6264.7455	13080.9707	34540.1632	15162.4955	6248.6301	13052.6247	34498.5466	15134.9314	6284.0484	13083.9832	34529.2053	15168.1916	6248.6301	13062.4757	34649.7932	15168.2793
5. EV per Household (฿)	-	-	-	-	23.9954	44.1159	70.9481	42.5794	24.0378	44.1406	70.9685	42.6089	23.9954	44.1237	71.0489	42.6090
(Ratio = 5 / 4)					0.0038	0.0034	0.0021	0.0028	0.0038	0.0034	0.0021	0.0028	0.0038	0.0034	0.0021	0.0028
6. Total EV / Month (Million Baht) 5 x 1	-	-	-	-	14.6493	46.3159	24.0959	85.1587	14.6752	46.3417	24.1029	85.2178	14.6493	46.3240	24.1302	85.2180
7. Charge /Household (฿)	-	-	-	-	23.5882	43.6002	69.7828	41.9352	23.6732	43.6531	69.8272	41.9965	23.5882	43.6168	70.0017	41.9966
8. Total Charge / Month (Million Baht) 7 x 1	-	-	-	-	14.4007	45.7745	23.7002	83.8704	14.4526	45.8299	23.7153	83.9930	14.4007	45.7919	23.7745	83.9933

APPENDIX E: Results of Net Social Welfare Estimation (Continued)

	Benchmark Scenario (Without Charge)				Senario 1 (With Charge at 2 Baht per m3)				Revenue Neutral							
									Scenario 2 (Compensated in Lump Sum)				Scenario 3 (Reduce Other Tax Rates)			
	Low Income	Medium Income	High Income	Average Household	Low Income	Medium Income	High Income	Average Household	Low Income	Medium Income	High Income	Average Household	Low Income	Medium Income	High Income	Average Household
9. DWL / HH (฿) 5 – 7	-	-	-	-	0.4071	0.5157	1.1653	0.6441	0.3646	0.4875	1.1413	0.6124	0.4071	0.5068	1.0472	0.6123
(Ratio = DWL / EV)					1.6967%	1.1690%	1.6424%	1.5128%	1.5168%	1.1044%	1.6082%	1.4373%	1.6967%	1.1487%	1.4739%	1.4371%
10. Total DWL / Month (Million Baht) 6 - 8	-	-	-	-	0.24856	0.54141	0.39575	1.28830	0.22259	0.51182	0.38762	1.22485	0.24856	0.53211	0.35565	1.22468
11. Water Consumption / Household (Unit)	116.40254	212.60181	343.61879	206.07077	112.04414	207.10113	331.46837	199.19221	112.44769	207.35212	331.67916	199.48330	112.04414	207.17997	332.50824	199.48407
12. Total Water Cons. / Month (Unit)	71.06433	223.20363	116.70256	412.14155	68.40351	217.42864	112.57594	398.38441	68.64988	217.69215	112.64753	398.96659	68.40351	217.51142	112.92911	398.96813
13. Wastewater / HH (Unit) 11 x 0.8	93.12203	170.08145	274.89503	164.85662	89.63531	165.68090	265.17469	159.35376	89.95815	165.88169	265.34333	159.58664	89.63531	165.74398	266.00659	159.58725
14. Total Wastewater / HH / Month (Million Unit)	56.85147	178.56290	93.36205	329.71324	54.72281	173.94291	90.06075	318.70753	54.91990	174.15372	90.11802	319.17328	54.72281	174.00913	90.34329	319.17450
15. Change of Wastewater (%)	-	-	-	-	-3.744%	-2.587%	-3.536%	-3.338%	-3.398%	-2.469%	-3.475%	-3.197%	-3.744%	-2.550%	-3.233%	-3.196%
16. Abatement Cost Saving / Month (Million Baht)	-	-	-	-	-	-	-	5.8652	-	-	-	5.7369	-	-	-	5.7366
17. NSW (Million Baht) 16 - 10	-	-	-	-	-	-	-	4.5769				4.5121				4.5119

APPENDIX E: Results of Net Social Welfare Estimation (Continued)

	Benchmark Scenario (Without Charge)	Senario 1 (With Charge at 2 Baht per m3)	Revenue Neutral	
			Scenario 2 (Compensated in Lump Sum)	Scenario 3 (Reduce Other Tax Rates)
	Average Household	Average Household	Average Household	Average Household
18. BMA's Total Revenues (Million Baht / Year)	43,687.42	44,693.87	43,687.42	43,687.42
19. BMA's Total Expenditure (Million Baht / Year)	30,934.15	31,643.26	30,934.15	30,934.15
20. Expenditure on Others (Million Baht / Year)	30,410.07	30,636.81	29,926.24	29,926.23
21. Exp on Wastewater Treatment (Million Baht/ Year)	524.088	1,006.44	1,007.92	1,007.92

Source: Calculated by the author

BIOGRAPHY

Miss Nantarat Tangvitoontham, the eldest child of Mr. Suphot and Mrs. Sumana Tangvitoontham, was born on April 11, 1977 in Bangkok, Thailand. She attended Saint Joseph Convent School for her earlier years of schooling and high-school years. She received her Bachelor of Economics from the Faculty of Economics, Thammasat University, Thailand in April 1994. In May 2001, she received her Master of Arts in Economics from the School of Arts and Sciences, American University, Washington, D.C., USA. She additionally received her Master of Business Administration from Kogod School of Business American University, Washington, D.C., USA, in May 2002. During her studying in the USA, she interned as a Marketing Analyst for Welfare to Work Partnership Company, Washington DC. Then she joined the Doctor of Philosophy Program in Economics, Chulalongkorn University in June 2004.