FACULTY OF AGRICULTURAL SCIENCES

Institute of Farm Management

University of Hohenheim

Computer Applications and Business Management in Agriculture

Prof. Dr. Reiner Doluschitz

Behavioral economic impact on animal health surveillance system in Thailand

Dissertation

Submitted in fulfillment of the requirements for the degree

“Doktor der Agrarwissenschaften”

(Dr.sc.agr./Ph.D. in Agricultural Sciences)

to the

Faculty of Agricultural Sciences

presented by

Tossapond Kewprasopsak

Stuttgart, Germany, 2021

(Correct version)

This thesis was accepted as a doctoral thesis (dissertation) in fulfillment of the requirements for the degree “Doktor der Agrarwissenschaften” (Dr.sc.agr./Ph.D. in Agricultural Sciences) by the Faculty of Agricultural Sciences at the University of Hohenheim, Stuttgart, Germany, on February 16, 2021.

Date of the oral examination: March 17, 2021

Examination Committee

Chairperson of the oral examination:	Prof. Dr. Andrea Knierim
Supervisor and reviewer:	Prof. Dr. Reiner Doluschitz
Co-Reviewer:	Prof. Dr. Arief Anshory Yusuf
Additional Examiner:	Prof. Dr. Ludwig E. Hölzle

Acknowledgements

A dissertation is not successfully created by a single student. It takes a lot of kind support from many people. Thus, I would like to extend my gratitude to everyone who supported me along the way in writing my dissertation.

Firstly, I would like to express my thankfulness to Prof. Dr. Reiner Doluschitz for accepting me as his PhD student and giving me the opportunity to make a dissertation following my passion for behavioral economics. For all of his support, comments, advice, and patience during my PhD period: I am really grateful. Moreover, every field trip was very valuable memory for me and my family. I am very honored and proud to have received the opportunity to be his PhD student. He always demonstrated the professional way to handle all situations wisely and carefully, even in urgent and pressing situations. I will never forget this. In the institute 410c, I would like to thank all of my colleagues for the relaxing coffee breaks and enjoyable lunches. Especially Dr. Heinrich Hagel, who was my colleague and my friend, I really thank for the support he has given me since the beginning of my German life until the final stage of my PhD dissertation and for the numerous wonderful dinners with his wife and lovely daughters. Thanks also to all the former and present institute secretaries, Renate Bayer, Yvonne Riekert, and Andrea Ellesser, and thanks to Prof. Dr. Ludwig Hölzle as the co-examiner.

I would like to thank Assist. Prof. Dr. Charuk Singhapreecha for supporting me in making the PhD application and giving me an opportunity to participate in the PODD project. The topics and ideas of this dissertation could not have been found without the experience in this project. I also thank him for his generosity in letting me select a topic I was passionate about and for his advice during my PhD period. In this context I would also like to thank all of the PODD officers and the PODD reporters for their supporting data. In addition, I would like to thank Assist. Prof. Terdsak Yano for supporting me with animal disease information and giving me advice for the veterinary journal.

For funding of my PhD program, I would like to thank the Food Security Center (FSC) of the University of Hohenheim. And I would like to thank also my FSC friends for special times in the Food and Security class and the intensive German classes.

I would like to express my gratitude to my parents Kavee Kewprasopsak and Pikul Kewprasopsak for giving me such wonderful support my whole life, from birth until now. I would also like to thank them for taking the time to video call with me every Sunday since I have been in Germany. This encouraged me when I was feeling down. I would like to dedicate this dissertation to my grandmother Jin Sailhor and my grandfather Keaw Kewprasopsak.

Last but not least, I would further like to thank Assoc. Prof. Dr. Arriya Mungsanti for supporting me during my Master's degree and PhD period and treating like their own son. Without their financial and mental support for my Master's degree, it would not have been possible for me to apply to be a PhD candidate. I would also like to thank them for their encouragement in the hardest times and helpful recommendations. They helped me so much in getting through difficult situations during my PhD period.

It is difficult to describe my gratefulness in words to my lovely wife Tanwadee Kewprasopsak. Tanwadee, who always supported me at every moment. Thank you for your encouragement, for being patient, for taking care of me, especially when I had an accident and couldn't walk for six months, and for being by my side me until now. I also would like to thank my Thai student friends in the University of Hohenheim for supporting me from the beginning of my PhD period, for the wonderful parties with nice Thai food. I would like to thank my friends in Thailand Thanakorn Chonlathan and Weera Weerasing for always spending their time with me when I went to Thailand, and for wonderful discussions over our Thai-style hotpot dinners.

Table of contents

List of tables

List of figures

List of abbreviations

ANOVA	Analysis of variance
AR	Authority ranking
CMU	Chiang Mai University
CNM	National Center for Parasitology, Entomology and Malaria Control
COVID-19	Corona virus disease 2019
CS	Communal sharing
EM	Equality matching
ERMH	Emergency risk management for health
EUR	Euro currency
FAO	Food and Agriculture Organization of the United Nations
FMD	Foot-and-mouth disease
GDP	Gross Domestic Product
GPHIN	Global Public Health Intelligence Network
GPS	Global positioning system
HC	Health center staff
HPAI	Highly pathogenic avian influenza
IT	information technology
MC	Malaria Consortium
MERS	Middle East Respiratory Syndrome
MoPoTsyo	Mobile Reminder System for Cambodia Diabetics
MP	Market pricing
OIE	Office International des Epizooties
PIP	Pandemic Influenza Preparedness
PODD	Participatory One Health Disease Detection project
ProMED	Program for Monitoring Emerging Diseases
PRRS	Porcine reproductive and respiratory syndrome
SARS	Severe acute respiratory distress syndrome
SMS	Short Message Service
SWOT	Strengths Weaknesses Opportunities and Threats

THB	Thai baht
TVC	Total variable cost
USD	U.S. Dollar
VMWs	Village malaria workers
WHO	World Health Organization

Chapter 1 General Introduction

1.1 Problem statement

Zoonotic diseases continues to be the main threat to global health (causing millions of deaths every year). It can be transmitted between humans and animals. For example, 60,000 people pass away from rabies every year. Zoonotic diseases are not only a threat to human health, but also animal health and welfare. They cause decreased productivity (egg and milk quality and safety), and have an impact on farmers' income and countries' economies. Moreover, they are of increasing global importance because of increased travel and global trade (OIE, 2019).

Zoonotic diseases are a global threat and the global demand for livestock product is increasing. The growing world population and rising incomes increase the global demand for livestock and crop products (Steinfeld, et al., 2006 : Tilman, Balzer, Jason, & Befort, 2011). Global meat consumption is forecast to increase from 287.4 million tons in 2010 to 475.8 million tons in 2050 (Revell, 2015). And global crop demand is expected to double (around 100-110%) from 2005-2050 (Tilman, Balzer, Jason, & Befort, 2011).

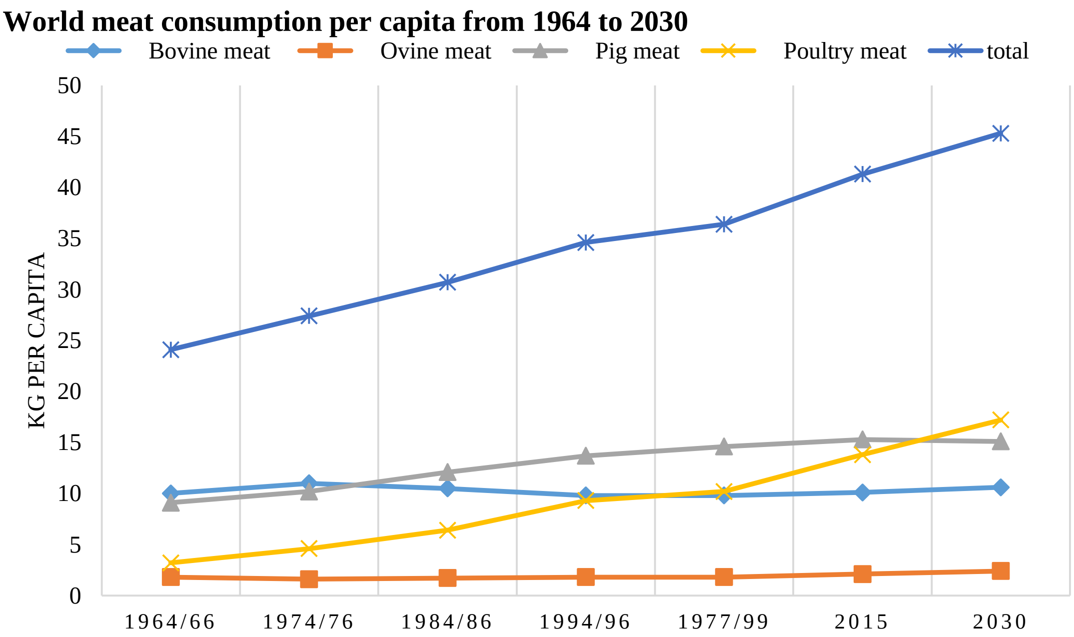

Figure 1: Meat consumption and GDP per capita from 1964 to 2030
Source: Bruinsma, 2003

Figure 1 demonstrates the projection of world meat consumption. The global trend for meat consumption has increased since 1946 and this increase is expected to continue to 2030. When considering in the different kinds of meat product (table 1), the trend of poultry meat consumption has been increasing since 1964. And its consumption rate per capita will be the highest in the projection for 2030. While pork consumption also will increase from 9.1 kg in 1964 to 15.1 kg in 2030. However, the trend for global bovine and ovine meat slightly increased. The increasing trend of bovine meat has been driven by developing countries, especially the high growth of beef production and consumption in Brazil. In the developing countries, China and Brazil have influenced

Table 1: Meat Consumption by type (kg per capita, carcass weight equivalent)

	1964/66	**1974/76**	**1984/86**	**1994/96**	**1977/99**	**2015**	**2030**
World							
Bovine meat	10.0	11	10.5	9.8	9.8	10.1	10.6
Ovine meat	1.8	1.6	1.7	1.8	1.8	2.1	2.4
Pig meat	9.1	10.2	12.1	13.7	14.6	15.3	15.1
Excl. China	9.7	10.8	11.3	10.4	10.3	9.9	9.7
Poultry meat	3.2	4.6	6.4	9.3	10.2	13.8	17.2
Developing countries							
Bovine meat	4.2	4.3	4.8	5.7	6.1	7.1	8.1
Ovine meat	1.2	1.1	1.3	1.6	1.7	2.0	2.4
Pig meat	3.6	4.1	6.4	9.6	10.8	12.0	12.2
Excl. China	2.1	2.4	2.8	3.3	3.4	4.0	4.7
Poultry meat	1.2	1.8	2.9	5.8	6.9	10.5	14.0
Excl. China & Brazil	1.2	1.9	3.2	4.8	5.2	8.1	11.6

Source: Bruinsma, 2003

the meat consumption trend (Bruinsma, 2003).

The reasons behind increasing global meat demand are urbanization through population growth, changes in the pattern of animal product consumption and income elasticity; the demand for meat and other livestock products is at a high level. Moreover, as country incomes rise, country livestock product consumption rises immediately (Rae, 1998 : Delgado, Rosegrant, Steinfeld, Ehui, & Courbois, 1999). Figure 2 and table 2 demonstrate the trend of meat consumption and GDP per capita on a global scale in 2013 (FAO, Food Balance Sheets: Meat - Food supply quantity, 2017 : World Bank, GDP (current US$) - Thailand, Singapore, Indonesia, Philippines, Vietnam, 2019 : Our world in data, Meat consumption vs. GDP per capita, 2019) Countries with high GDP per capita consume meat products at high levels (table 2), for example, Germany (GDP per capita 42,914.48$, consumption rate 85.94 kilograms per capita) and United Kingdom (GDP per capita 37,398.8 USD, consumption rate 81.48 kilograms per capita). The highest meat consumer is Australia at 116.23 kilograms per capita (GDP per capita 43,118.09 USD). Countries with the middle level of GDP per capita are in the middle level of global meat consumption, for example, the meat consumption rate of China is at 60.91 kilograms per capita (GDP per capita 11,951.25 USD,), the meat consumption rate of Mexico is at 62.23 kilograms per capita (GDP per capita 16,385.06 USD), and the meat consumption rate of Thailand is at 28.94 kilograms per capita (GDP per capita 14,771.47 USD). Finally, Countries with a low GDP per capita consume meat products at low levels, for example, the meat consumption rate of Afghanistan is at 12.33 kilograms per capita (GDP per capita 1,848.7 USD), the meat consumption rate of Bangladesh is at 4.11 kilograms per capita (GDP per capita 2,835.77 USD), and the meat consumption rate of Ethiopia is at 7.06 kilograms per capita (GDP per capita 1,325.76 USD).

Table 2: Meat consumption and GDP per capita in 2013 in selected countries

Countries	Meat consumption per capita (kilograms per year)	GDP per capita (USD)	Total population
Afghanistan	12.33	1,848.700	3,4499,915
Australia	116.23	43,118.086	23,213,944
Bangladesh	4.11	2,835.767	154,393,847
China	61.82	11,951.248	1,359,368,470
Ethiopia	7.06	1,325.755	88,356,373
Germany	85.94	42,914.476	81,804,228
Mexico	62.23	16,385.060	117,478,371
Thailand	29.33	14,771.467	70,243,267
United Kingdom	81.48	37,398.797	63,177,406
United States	115.13	51,003.686	318,497,630

Source: FAO, 2017; World Bank,2019; Our world in data, 2019

Meat consumption and GDP per capita in 2013

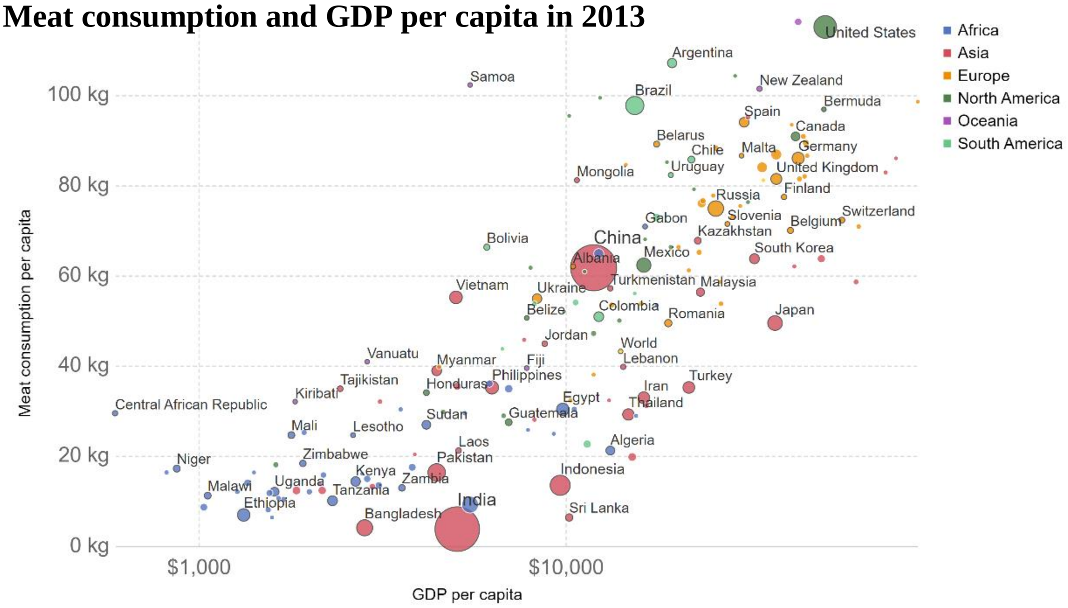

Figure 2: Meat consumption and GDP per capita in 2013
Source: FAO, 2017; World Bank, 2019; Our world in data, 2019

When considering the trend of income growth and the meat consumption rate from 1990 to 2013 in table 3, the relationship between these two factors is positive, especially in Asian countries. In 1990, China’s meat consumption rate increased from 24.84 to 61.82 kilograms per capita (249% increase) and income rates also increased from 1,526.41$ to 11,951.25$ per capita (783% increase). Vietnam’s meat consumption rate increased from 15.39 to 55.22 kilograms per capita (359% increase) and the income rate also increased from 1,452.88$ to 5,024.44$ per capita (346% increasing). In Myanmar, the meat consumption rate increased from 4.8 to 39.03 kilograms per capita (813% increasing) and the income rate also increased from 742.97$ to 4,457.9$ per capita (600% increasing). Finally, in Thailand, the meat consumption rate increased from 23.56 to 29.33 kilograms per capita (124% increasing) and the income rate also increased from 6,650.44$ to 14,771.47$ per capita (222% increase) (FAO, Food Balance Sheets: Meat - Food supply quantity, 2017 : World Bank, GDP (current US$) - Thailand, Singapore, Indonesia, Philippines, Vietnam, 2019 : Our world in data, Meat consumption vs. GDP per capita, 2019).

Table 3: Meat consumption and GDP per capita from 1990 - 2013 in selected countries

Countries	1990		2000		2013	
	Meat consumption *(kilograms per year)	GDP* (USD)	Meat consumption *(kilograms per year)	GDP* (USD)	Meat consumption * (kilograms per year)	GDP* (USD)
China	24.84	1,526.41	45.06	3,700.74	61.82	11,951.25
Vietnam	15.39	1,452.88	23.6	2,562.1	55.22	5,024.44
Myanmar	4.8	749.97	9.6	1,306.44	39.03	4,457.9
Thailand	23.56	6,650.44	26.65	9,189.06	29.33	14,771.47

*per capita
Source: FAO, 2017; World Bank,2019; Our world in data, 2019

Considering the meat supply side in particular, figure 3 demonstrates that from 1961-2013, the development of meat supply per capita over time increased 182% (from 23.08 to 42.22 kg.), in Africa it increased 141% (from 13.4 to 19.01 kg.), in America it increased 146% (from 59.62 to 86.94 kg.), in Europe it increased 163% (from 47.37 to 77.34 kg.), in Oceania it increased 109% (from 99.95 to 108.49 kg.), in Asia it increased 611% (from 5.33 to 32.55 kg.) (FAO, Food Balance Sheets: Meat - Food supply quantity, 2017): (Our World In Data, 2019). Figure 1 shows that Asia had the lowest amount of meat supply per capita in 1961, but the increasing trend is the highest compared to the other regions. In Europe, the trend has been decreasing since 1990 because of ethical and environmental awareness, which is increasing the vegetarian population over time (Santini, Ronzon, Dominguez, Enciso, & Proietti, 2017). However, Africa shows the lowest amount of meat supply per person in 2013. Oceania has the lowest increasing trend, but the amount of meat supply per person has been highest since 1961. The reason is that Australia and New Zealand are major world meat producers and have a high level of meat consumers (figure 2).

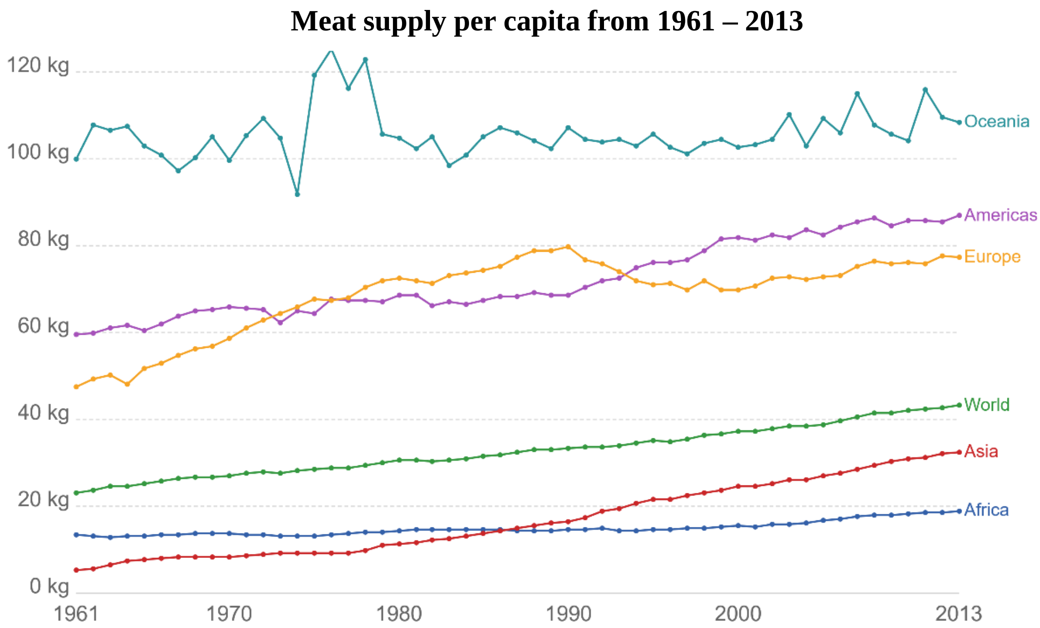

Figure 3: Meat supply per capita from 1961 – 2013 in different continents of the world
Source: FAO, 2017; Our world in data, 2019

In 2018, as a result of productivity improvements, good management practices, streamlined production processes and new technology, there was an increase in meat output quantities in all major regions in the world, the estimated world meat output was 336.4 million tons, 1.2 percent higher than in 2017. The main region for global meat production is Asia. Comparing the various meat sectors, bovine meat output has the highest growth (+2.1 percent), followed by poultry meat (+1.3 percent), and pig meat (+0.6 percent). The estimated world meat exports in 2018 were 3.8 million tons, which is an increase of 2.9 percent from 2017. This expansion generally came from increased shipments from the Unites States of America, Australia, Argentina and the European Union. (FAO, Meat Market Review , 2019).

Global meat consumption and the product safety requirements of societies has increased in contrast with escalating instability of the global meat market due to animal disease outbreaks and human health concerns. Animal disease outbreaks become more easily widespread because of increased animal densities and changes in production and slaughtering systems (Morgan & Prakash, 2006). For example, in figure 4, since 1961, there was a 50% increase in the global average of livestock units per agricultural land area, compared to the present (120% in Africa, 40% in Americas, 35% in Asia, and 20% in Oceania) (FAO, FAO Agri-Environmental Indicators Update: Livestock Patterns, 2019). Since 2001, the magnitude and the impact of animal disease outbreaks have increased. Animal disease outbreaks cause market disturbances and affect meat consumption, trading patterns, meat price instability and livestock industries (Morgan & Prakash, 2006).

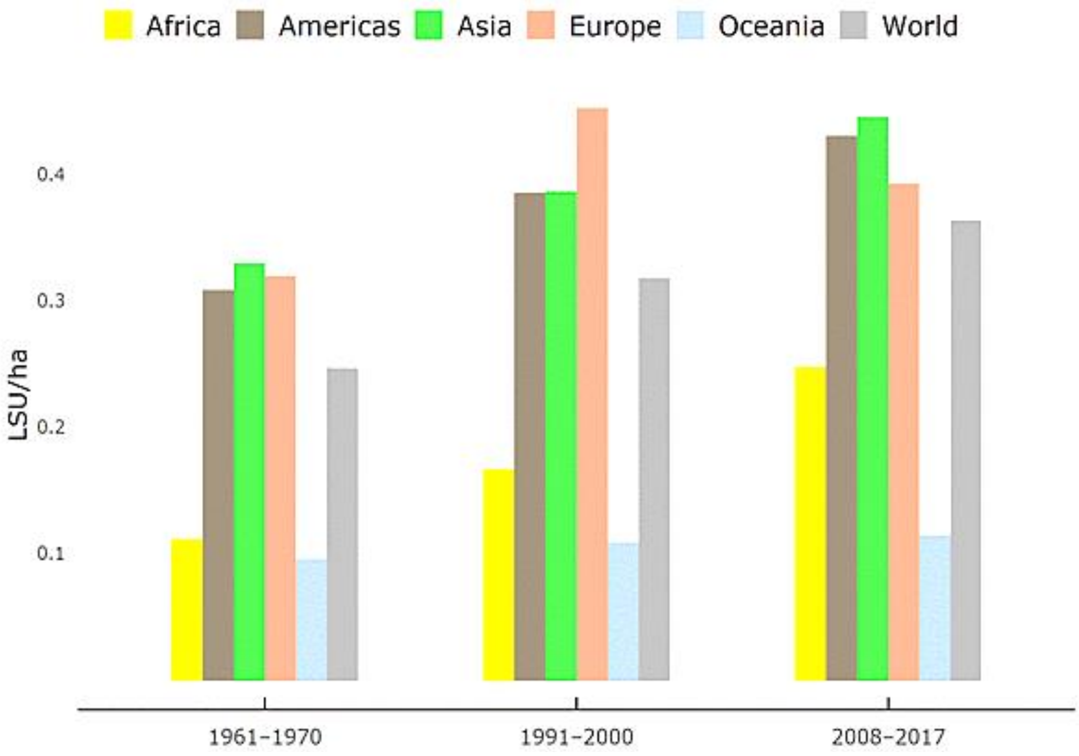

Figure 4: Livestock unit per agricultural land area in different continents of the world
Source: FAO, 2019

This study focuses on the disease surveillance system in Thailand, on one hand as an important meat exporter, and on the other as a rather fragile location where animal/ zoonotic diseases are concerned. The country is located at the center of Southeast Asia and covers an area of 513,000 square kilometers. The population of Thailand is about 69.2 million. The population growth rate is about 0.2 percent per year over the past decade. The trend of expected population growth rates has decreased in 2020. In 2050, the total population is expected to be about 65 million. Bangkok is the capital and largest city of Thailand. There are 77 provinces which are divided into the four regions; Northern Thailand, Northeastern Thailand, Central Thailand and Southern Thailand (Country Report: Thailand, 2019). Compared with the other countries in Southeast

Asia, Thailand’s GPD in 2018 is the second highest in Southeast Asia (504.99 Billion USD) (table 4). The highest is Indonesia (1.04 Trillion USD) (World Bank, GDP (current US$) - Thailand, Singapore, Indonesia, Philippines, Vietnam, 2019).

Table 4: GDP (USD) of selected South east Asia countries from (2008-2018)

	GDP (Billion USD)				
	Indonesia	Philippines	Singapore	Thailand	Vietnam
2008	510.23	174.20	193.61	291.38	99.13
2009	539.58	168.33	194.15	281.71	106.01
2010	755.09	199.59	239.81	341.11	115.93
2011	892.97	224.14	279.35	370.82	135.54
2012	917.87	250.09	295.09	397.56	155.82
2013	912.52	271.84	307.58	420.33	171.22
2014	890.81	284.58	314.85	407.34	186.20
2015	860.85	292.77	308.00	401.30	193.24
2016	931.88	304.90	318.07	412.35	205.28
2017	1015.42	313.62	338.41	455.28	223.78
2018	1042.17	330.91	364.16	504.99	244.95

Source: World Bank, 2019

Thailand is a global meat exporter. A world market demand for value-added ready-to-eat products, especially in Japan, is driving Thailand's poultry meat export to expand (FAO, Meat Market Review, 2018). In 2018 Thailand’s meat exports were 1.2 million

Percentage of Export products of Thailand to EU in 2018

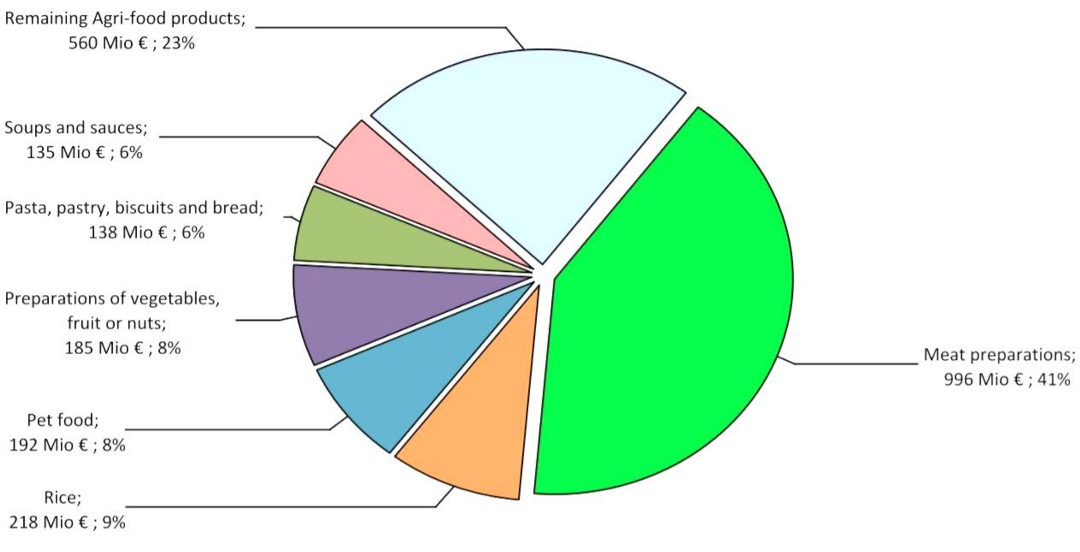

Figure 5: Thai export products to EU in 2018

Source: European Commission, 2019

tons, 9.3 percent higher than in 2017 (FAO, Meat Market Review , 2019). Thailand is an important agri-food exporter to the EU. In 2018, the main export agri-food products from Thailand to EU are meat preparations (41%, 1,101.85 million USD or 996 million EUR) (Figure 5) (European Commission, 2019). It means that the disease surveillance system is very important to Thailand because the effect of animal disease outbreaks has a high impact on Thai meat export and the Thai economy.

In 2005, zoonoses such as avian influenza or bird flu affected people in Southeast Asia and the mortality rate of this disease was around 60% (Cheng , 2017). Many countries in Asia, including Thailand, suffered economic damages from avian influenza and the estimated disease impact on demand and supply in Thailand was 10.3 billion USD

Table 5: Cost of animal disease outbreaks in selected countries (US$ million)

Cost	BSE United Kingdom 1996/1997	CSF Netherlands 1997/1998	Foot and mouth disease Uruguay 2000 /2001	United Kingdom 2001	Republic of Korea 2000	Japan 2000	Taipei China 1997
Direct costs							
Compensation	2,433	1,183	n.a.	2,223	377	0.5	188
Control measures	n.a.	138	20	1,335	66	14.5	66
Sub-total	2,433	1,321	20	3,558	433	15	254
Indirect costs							
Agricultural sector	n.a.	423	n.a.	489	n.a.	n.a.	2,202
Related industries	n.a.	596	60	267	n.a.	n.a.	3,212
Other	n.a.	n.a.	n.a.	4,890	n.a.	n.a.	949
Sub-total	1,395	1,019	60	5,646	n.a.	n.a.	6,363
Total costs	3,828	2,340	80	9,204	433	15	6,617
Impact on GDP	– 0.4%(a)	– 0.75%	n.a.	– 0.2%(b)	n.a.	n.a.	–0.64%
Cost to public sector	63.5%	43.5%	25.0%	38.6%	n.a.	n.a.	3.8%
Cost to private sector	36.5%	56.5%	75.0%	61.4%	n.a.	n.a.	96.2%

a) – 0.1% to – 0.2% if the cost of compensation, which accounts for 64% of total costs, is excluded
b) the impact on United Kingdom (UK) gross domestic product (GDP) is relatively low because the cancellation of tourism and leisure to the countryside (53% of total costs), was largely offset by increased consumer spending in other sectors of the UK economy
BSE: bovine spongiform encephalopathy
CSF: classical swine fever
n.a.: not available
Source: FAO, 2002 : Morgan & Prakash, 2006

(Bloom, de Wit, & Carangal San—Jose, 2005). Modeling research forecasts have predicted that between 2 to 7.4 million people worldwide could be infected and die in the next pandemic (Cheng , 2017). These forecasts have many implications for societies, including economic losses, human and animal health problems, and food insecurity.

The future continues to be uncertain in regard to such pandemics, because vaccines for humans, such as those for influenza or avian influenza, are still under development (WHO, Influenza, 2017).

The incidents of animal diseases in the agricultural sector relate to prevention and control costs. In table 5, foot and mouth disease cost 80 million US$ for Uruguay in 2000 and 2001, 9,204 million US$ for the UK in 2001, 433 million US$ for Korea in 2000, 15 million US$ for Japan in 2000, and 6,617 million US$ for Taipei in 1997 (FAO, Animal diseases: implications for international meat trade, 2002). The animal disease outbreaks can also have an effect on Thai's meat exports and food security.

In 2004, there were official reports of the highly pathogenic avian influenza (HPAI) spreading widely across Indonesia, Thailand, and Vietnam. The effects of the disease were multi-dimensional. First, the mortality rate of the infected flock was higher than 50%. Second, in Asia, there were 41 deaths and 67 confirmed human cases. Finally, the infection affected other livestock species, such as ducks and geese. Especially in Thailand, 93% of farms were infected in the central and northern region of the country. Ang Thong, Kanchanaburi and Uthaithani were the most highly impacted provinces (table 6) (Rushton, Viscarra, Guerna Bleich, & Mcleod, 2005).

At a farm level, animal diseases can contribute to an increase in the farm's vulnerability. Hence, we not only need better vaccines against viruses, but also a rapid alert system for early detection, so that the spread of the pathogen can be controlled before it causes a pandemic. In 2019, FAO, WHO, and OIE have launched a guide for countries to prevent and control zoonotic diseases, and a surveillance system is one of focal points. There are six elements in the guide: 1) strategic planning and emergency preparedness, 2) surveillance and information sharing, 3) coordinated investigation and response, 4) joint risk assessment for zoonotic disease threats, 5) risk reduction, risk communication, and community engagement, and 6) workforce development (OIE, 2019). The objective of surveillance and information sharing is for multi-coordinators to organize a national surveillance system for early and timely zoonotic disease detection and to make data sharing routine among all coordinators. The results of the surveillance system and early warning system can be used to understand zoonotic diseases and monitor trends (FAO, OIE, & WHO, 2019). Therefore, the disease surveillance system is an important part of diseases controlling. It includes reporting the disease or events, analyzing the data, responding to those events, and implementing measures aimed at prevention and control.

Table 6: Regions and provinces affected in the epidemiological week ending January 30, 2004 in Thailand.

Region	Province	Farms		Farms depopulated	
		Affected	% of national total	Total	% of farms affected
Central	Ang Thong	1,313	19.3	287	21.9
Central	Bangkok	73	1.1		0.0
Central	Chainat	2	0.0	2	100.0
Central	Kanchaburi	2,863	42.1	1,892	66.1
Central	Ratchburi	15	0.2	9	60.0
Central	Singburi	45	0.7	7	15.6
Central	Suphanburi		0.0	850	
Central		4,311	63.4	3,047	70.7
North	Kampaengphet		0.0		
North	Phichit	36	0.5		0.0
North	Phitsanuloke		0.0		
North	Sukhothai		0.0	2	
North	Uthaithani	1,524	22.4	536	35.2
North	Uttadit	477	7.0	59	12.4
North		2,037	30.0	597	
North East	Kalasin	7	0.1	81	1,157.1
North East	Nakhonpathom	242	3.6	10	4.1
North East	Sakonakhon	203	3.0	203	100.0
North East		452	6.6	294	
Total		6,800	100.0	3,938	57.9

Source: Rushton, Viscarra, Guerna Bleich, & Mcleod, 2005

1.2 Digital disease surveillance systems and human behavior

The internet is now a part of daily life that many people and organizations would find it unthinkable to work and live without it (Graham & Dutton, 2014). In the case of disease surveillance systems, the internet and digital technology have been used for data collection and management during the present epidemic situation. These make for a more convenient and faster service system. This section demonstrates and compares two types of disease surveillance systems (passive and active disease surveillance systems), including digital disease surveillance systems.

Passive surveillance is the system by which veterinary authorities obtain the data on animal diseases. The role of veterinary authorities in passive surveillance systems is as a data receiver. They do not establish the specific objective and data collection system in a systematic way. They only select the relevant data to apply in the animal disease surveillance system from their routine work and the reports from farmers or other sources rather randomly. For this reason, passive surveillance is inexpensive and is commonly used by the veterinary authorities. On the other hand, the role of veterinary authorities in active surveillance systems is as a designer and conductor. The active surveillance systems need to be designed and conducted by the veterinary authorities with the specific objective of acting as a disease surveillance system. The system involves spending a great deal of time, labor, and budgetary resources (World Organization for Animal Health, 2018 : FAO, 1999). The main difference between these two systems is data collection. Active surveillance is needed for more systematic data collection, while passive surveillance collects data rather randomly.

Comparison between passive and active surveillance system by using Strengths Weaknesses Opportunities and Threats analysis or SWOT analysis (table 7). There are many weaknesses in active surveillance systems compared to passive surveillance systems. The main weakness is higher budget consumption because of the specific data collection system and veterinary authority supervision. It means that many surveillance systems may not be ready because of the budget restriction. However, comparisons between resource consumption and the benefits of an active surveillance systems show they are worth it. Because presently, there are many threats from faster and wider outbreaks, including the mutation of diseases.

Table 7: SWOT analysis of passive and active surveillance system

Strengths	Weaknesses	Opportunities	Threats
Passive			
• Inexpensive • Commonly used • Independent of data collection and management	• No specific data • No specific data collection system • Lack of linkage between partners in the system	• Increasing global disease awareness • Convenient data collection through digitalization	• Faster outbreak and wider spread • Mutation of diseases
Active			
• Specific data • Conduct by veterinary authorities • Specific data collection system • Linkage between partners in the system	• Expensive • Not commonly use • Time consuming • Labor need	• Increasing global diseases awareness • Convenient data collection by digitalization	• Many partners may not ready • Faster outbreak and wider spread • Mutation of diseases

Source: Own analysis of relevant literature sources

Participatory disease surveillance systems are a type of active disease surveillance system that involve public health practitioners providing health and disease data together. However, the participatory disease surveillance system is less expensive and more flexible than other types of active surveillance systems (World Organization for Animal Health, 2018), because it is a very sensitive method which can collect a lot of data information in a short time from good collaboration between farmers and animal health agencies (Lore, 2009). Moreover, it can also be conducted on a large scale, allowing for animal population-based monitoring at a low cost. For the participatory disease surveillance system, the key stakeholders are the community who are willing to respond rapidly in sharing health data and who are able to provide insight data about health behavior (Smolinski, Crawley, Olsen, Jayaraman, & Libel, 2017). In addition, digital technology, particularly smartphones allows them to share the data faster (Smolinski, et al., 2015).

Disease reporting is the first stage in disease surveillance systems and subsequently induces other processes. It can lead to a major early detection and rapid response activity. Therefore, the World Organization for Animal Health (OIE) formally indicated that the OIE country members must report their country's animal disease situation in order to guarantee transparency and to improve knowledge of world animal health (Animal Health in the World – Overview, 2019). To confront animal disease outbreaks, many related sectors need to collaborate, coordinate, concern, and communicate together (OIE, 2019). In 2014, the Participatory One Health Disease Detection project, or PODD was set up by the veterinary inspection authorities to test animal epidemic control systems using smartphone applications in the Chiang Mai province in Northern Thailand (Figure 6). The PODD project, in collaboration with Chiang Mai University (CMU), the Skoll Global Threats Fund, and the Chiang Mai Provincial Livestock Office, was a pilot project which involved various parties, i.e. digital technology, local government agencies, and community volunteers. A total of 296 volunteers from 74 local government agencies were involved in the project (Yano, et al., 2018). These volunteers play an important role in the PODD system by reporting abnormal animal sicknesses and deaths, animal diseases, animal bites, food safety issues, human diseases, and environmental problems via smartphones. However, to sustain the viability of the project, the volunteers need to be motivated in order to fulfil their commitments.

Figure 6: Study Area and Sample area in the Chiang Mai Province of Northern Thailand. Source: Own figure after Google map, (2017)

1.3 Objectives of the study

Animal disease surveillance systems are complex systems due to multiple and numerous participants in the system; governments, veterinarians, reporters, information technology (IT) developers, and farmers. To operate a functional and sustainable system, it needs not only the impact evaluation, but also an understanding of the behavior of participants. Understanding the behavior of participants is important to manage the required long-term motivation and to produce a precise animal disease detection and control system by avoiding the human bias in the process. Heterogeneous participant behavior can influence the performance of the surveillance system. Therefore, this study investigates behavioral differences as its focus. The main objectives of this study are (i) to demonstrate an overall picture of the economics and behavior issues of the system, (ii) to evaluate the economic impact of the system on farmers, and (iii) to better understand the behavior of participants in the system, i.e. between animal disease reporters and farmers, by using the concepts of behavioral economics.

The specific objectives are identified as follows;

- To evaluate the economic impact of the digital animal diseases surveillance system on farmers.
- To demonstrate the impact of different motivations on animal disease reporters with monetary and non-monetary incentives by using the data from the PODD project to design the experiment.
- To present the effect of the socioeconomic factors and farmer bias on animal disease reporting behavior by using an indirect measurement to calculate farmer bias.

1.4 Thesis structure

This thesis is divided into six chapters. The first Chapter provides the introduction of the problems, the importance of animal disease surveillance systems, the overview and SWOT analysis of passive and active surveillance system. It also includes an introduction to the study area and the importance of meat export for Thailand. Finally, this chapter indicates and demonstrates the three objectives of this study and a summary of the thesis structure.

Chapter Two provides more details of digital animal diseases surveillance systems and a comparison between modern and traditional surveillance systems to clarify the advantages and disadvantages of each system. In addition, this chapter provides literature reviews of the socioeconomic impact to calculate the impact of the PODD digital animal disease surveillance system on framers. Furthermore, this chapter also focuses on the motivations of PODD reporters in the digital animal disease surveillance system regarding monetary and non-monetary incentives. The behavior of farmers on the livestock's health report is also a focal point. Finally, this chapter provides an overview of animal disease control in Thailand. In general, this chapter investigates previous knowledge regarding the focus topic and, as a conclusion, demonstrates the research gaps. This study attempts to expand knowledge and fill the research gaps.

Following the literature reviews in the Chapter Two, Chapter Three first demonstrates the conceptual framework of this study, including the methods and experimental design in this study, plus an introduction of the study area and the PODD project. This chapter also provides the challenges of doing research on the study area and strategies for dealing with the challenges. Statistic methods are also demonstrated and compared and their suitability is demonstrated in this chapter to clarify the methodology in this study.

Chapter Four presents the results over the three parts, which are (i) changes after the PODD project focusing on farmers' cost for grassland dependent and independent livestock, (ii) the report effort of the PODD reporter based on the different motivations, and (iii) the optimistic bias of farmers on the livestock's health report. All of these results answer the objectives in this study by using methodologies and statistical analyses from Chapter Three.

Chapter Five provides the conclusion and discussion based on the results in Chapter Four. The impact of the PODD digital animal diseases surveillance system on farmers, the effect of the motivations on report behavior, and the influence of farmer's optimistic bias on the livestock's health report are concluded and discussed. The impact of the PODD system on farmer, the best motivation for animal disease reporters, and the effect of optimistic bias of farmers are clarified in this chapter. Moreover, the final chapter also presents the policy implications, the contribution of this study, the study's limitations, and the direction for future research. The structure of this study is also demonstrated in figure 8. Finally, all figures, tables and appendixes, and referenced are listed in the annex.

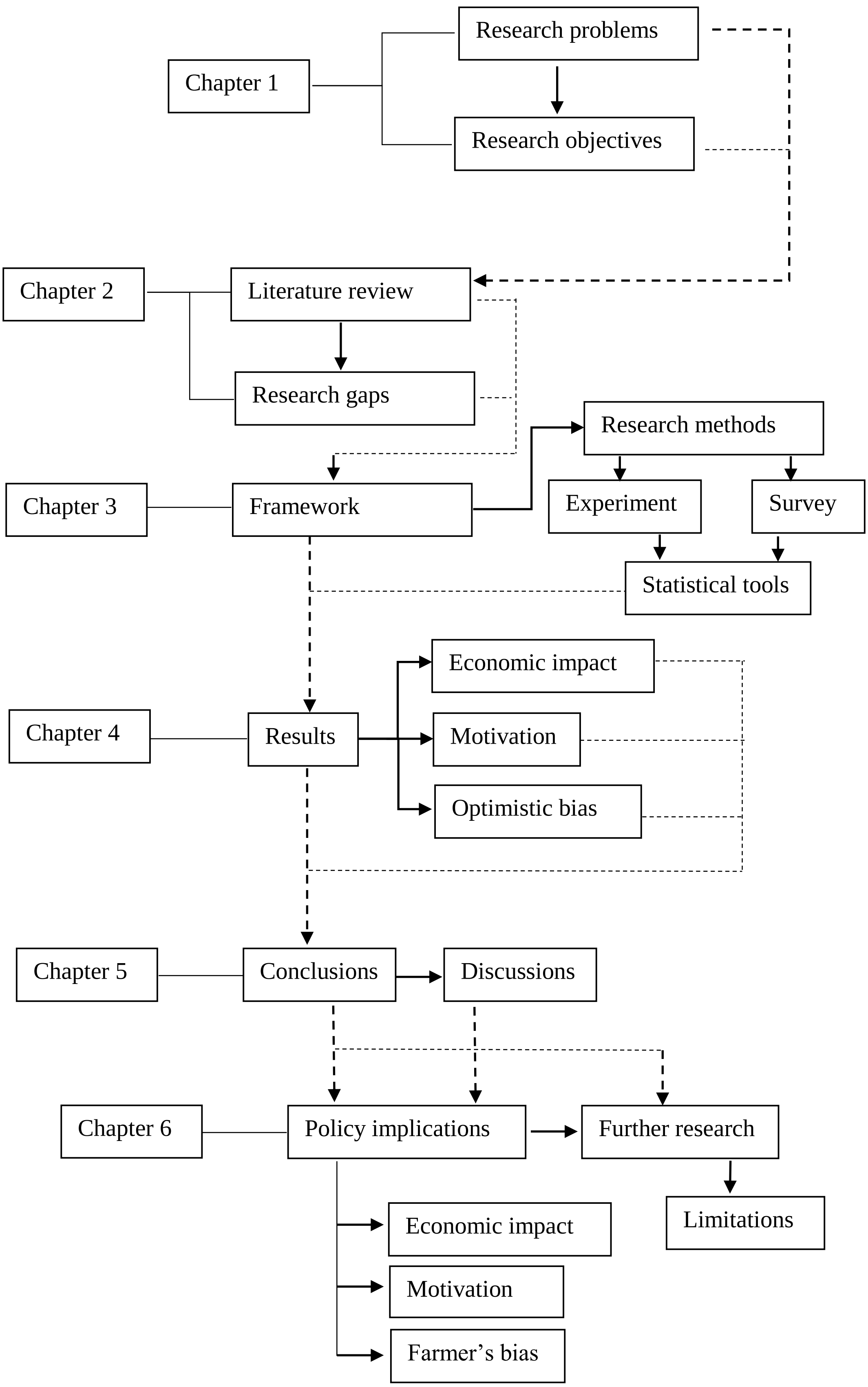

Figure 7: Schematic demonstration of the structure of thesis

Chapter 2 Literature review

The contents of this chapter give an overview of disease surveillance systems in the past and present, the differentiation of human and animal disease surveillance systems with the first priority on human diseases. The content also includes theories and articles, which were used to study the impact of cost reduction on farmers after adoption of digital animal disease surveillance systems following the expectation of the PODD project. The theoretical concepts of motivation and human bias, which may effect on the efficiency of the system, are also described in this chapter. And finally, the content also explains the urgent need for awareness and management to tackle animal diseases at a global level and regional level, as well as in Thailand.

2.1 Digital disease surveillance system

To reduce the confusion of the word of surveillance, the content in this part describes definitions of surveillance to give a clear understanding of meaning, coverage, and differentiation between each definition. The first definition of surveillance is the "ongoing systematic and timely collection, analysis, interpretation, and dissemination of information about the occurrence, distribution, and determinants of diseases" (Smolinski, Crawley, Olsen, Jayaraman, & Libel, 2017). Following the definition of surveillance, continuity and precision are important elements of surveillance systems. The World Health Organization (WHO) has defined the definition of public health surveillance as the "continuous, systematic collection, analysis and interpretation of health-related data needed for the planning, implementation, and evaluation of public health practice. Such surveillance can serve as an early warning system for impending public health emergencies; document the impact of an intervention, or track progress towards specified goals; and monitor and clarify the epidemiology of health problems, to allow priorities to be set and to inform public health policy and strategies." (WHO, Public health surveillance, 2019). According to the definition of WHO, it is not only continuous and systematic data collection, but also the presence of a rapid alert system and the impact of disease documenting. So, the meaning of WHO is wider and it covers the activities after the end of the outbreaks. In this study, the definition of WHO is used to study, analyze, and discuss the issue of surveillance systems.

Following the two definitions above, the elements of success of surveillance systems, whether in human or animal diseases, are continuity, precision, and speed. These three elements can lead to an effective early warning and timely response system to reduce the impact of the outbreaks. Fortunately, the rapid advances in digitalization in this modern day can improve both elements in surveillance systems. Internet signals and smartphones are widely used around the globe. The growth rate of smartphone users is high compared to the traditional feature phone and the speed of the internet is improving. It is not only smartphones or computers but also the other electronic products such as lamps, air conditioning, and security cameras which can connect to the internet and communicate between one another. Speed, precision, and easy accessibility of these technologies can be used to increase efficiency in surveillance systems. To provide a clear understanding and the advantages and disadvantages of past-present surveillance systems, the next section provides a comparison of traditional surveillance systems and advanced surveillance systems in the present day.

2.1.1 Traditional surveillance systems

In traditional surveillance systems such as the number of confirmed cases by the health department or government agencies; becoming ill, seeking care, having proper diagnostic testing, and being reported, were monitored and used in official reports. The problem with traditional surveillance systems is the slow pace of receiving reports and breaches in each stage within surveillance system, which can affect official reports. For example, illness recognition and reports of ill patients and/or health care providers can impact heavily on official reports. The existing surveillance systems can miss a case if the patient cannot access public health services or the health care provider makes the wrong diagnosis or improperly submits a report. Moreover, the case can be missed due to failed laboratory tests or result confirmation. For these reasons, official reports may under-report cases in the traditional surveillance system. (Madoff & Li, 2014)

Disease surveillance before 1994 commonly used the traditional surveillance system because of the low cost of data collection and lack of modern digital devices and processes; there was no requirement for advanced technology and qualified labor. Traditional surveillance systems are a type of passive surveillance system. The data in the surveillance systems is collected without any specific requirement of the disease data. The collected data is based on routine official routine work and other sources. The weaknesses of the traditional surveillance system, which are the slow pace of reporting and missing cases, lead to inefficiency in early warning and timely response. Therefore, the capability of the surveillance system to reduce the impact of the outbreaks is not as good as it should be. The impact of outbreaks in the past was high due to the slow pace of the surveillance system. For these reasons, the capability of the traditional surveillance system cannot successfully complete the objective of an up to date surveillance system following the WHO definition. This led to the improvement of surveillance systems by using advanced information technology.

2.1.2 Advanced surveillance systems

The development and switch from traditional surveillance systems to advanced surveillance systems began in 1994, which is the period when internet communication became more widely used by individuals. A larger amount of information can be transferred more quickly, compared to the past. For example, if the public health authority needs to send the official outbreak report to the central government for an emergency plan announcement, it might take 1-2 days by surface mail, depending the geographical distance. Under other conditions, in the same situation, the public health authority can send the report by email, which might take 2-3 seconds. Furthermore, when considering the cost of information transfer, the cost via the internet is lower because there is no need for the mailman, fuel energy, and travelling time. These are the reasons why internet technology and electronic information were widely adopted to improve the surveillance systems. On a global scale, the global health of disease reporting was changed from the traditional public health infrastructure because data about diseases and outbreaks is announced through many online channels by government agencies, press reports, blogs, and chat rooms (Brownstein J. S., Freifeld , Reis , & Mandl , 2008).

Attempts to apply internet technology and electronic information in surveillance systems increased because it can reduce the weaknesses of traditional surveillance systems such as slowness, error, and missing cases. Since 1994, public health surveillance has used internet technology and electronic information to reduce outbreak detection time and to conveniently prevent and respond to outbreaks. Public health agencies, Global Outbreak Alert, and the Response Network of the World Health Organization (WHO) use web-based source data which is not captured by traditional government communication channels as sources for daily surveillance activities (Brownstein, Freifeld, & Madoff, 2009).

The capability extension of surveillance systems via internet technology and electronic information does not only occur at a national level, but also at a global level. In 1994, the Program for Monitoring Emerging Diseases, or ProMED-mail was founded, with more than 45,000 subscribers in 188 countries (Madoff, 2004). The ProMED readers receive outbreak e-mails and post case reports and expert commentary (Brownstein, Freifeld, & Madoff, 2009). These were the first efforts to create a publicly available reporting system by the International Society for Infectious Diseases (Madoff, 2004). The cooperation of 188 countries in ProMED demonstrated that internet technology and electronic information can increase the speed and expand the connectivity of public health authorities in many countries, instead of individuals work separately. Moreover, it reduces the problem of information non-continuity and increases the global surveillance system capability to control trans-border outbreaks. The ProMED Flowchart is shown in figure 8 and the number of reports in ProMED from 1994-2003 is shown table 8.

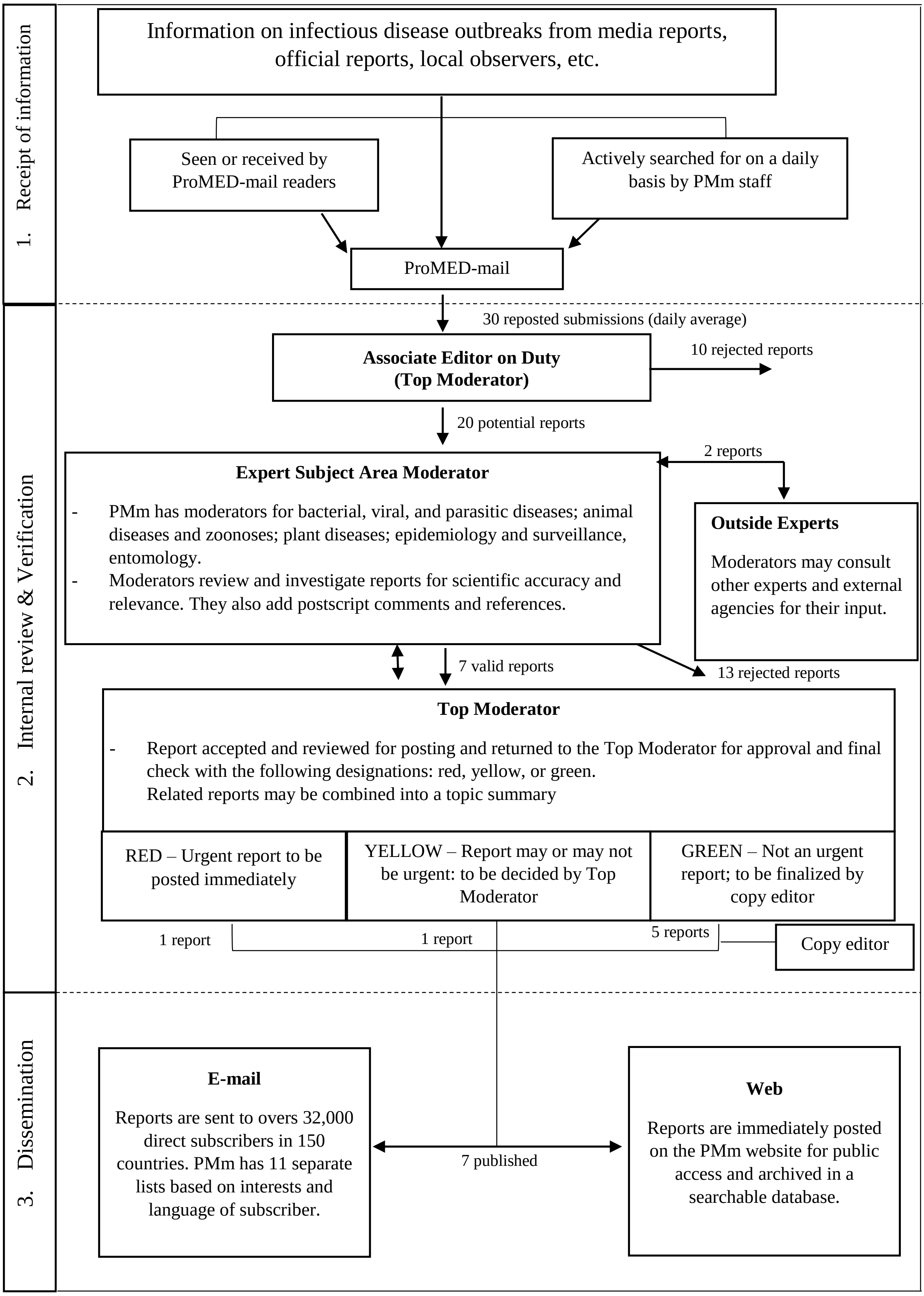

Figure 8: The ProMED Flowchart
Source: (Madoff L. C., 2004)

Table 8: Number of Reports in ProMED from 1994-2003

Disease	Number of reports
Dengue	749
West Nile virus infection	728
Foot-and-mouth disease	597
Cholera	578
Bovine spongiform encephalopathy	578
Rabies	557
Anthrax	474
Ebola virus infection	424
Escherichia coli O 157 infection	422
Hantavirus infection	340
Creutzfeldt-Jakob disease	332
Influenza	329
Salmonella	308
Malaria	279
Yellow Fever	265
Unknown illness	209

Source: (Madoff, 2004).

Another example of advanced surveillance systems is the Global Public Health Intelligence Network (GPHIN). It was established in 1997 by the Public Health Agency of Canada, in collaboration with the WHO Relevant articles from the news are retrieved every 15 minutes with extensive search queries by the software. ProMED and GPHIN became an important tool for providing information about a severe acute respiratory distress syndrome (SARS) outbreak or severe acute respiratory syndrome in China on November 2002 to public health officials by analyzing informal reports on website and chatroom discussions.

However, advanced information technology in the present is involved in many dimensions of everyday life, especially smartphone technology. Many smartphone applications are ready to be downloaded and to be used to make a more secure and convenient life. Compared to the feature phone, there are many advanced improvements on smartphones such as built-in global positioning system (GPS) to locate the phone position, built-in cameras to capture images and record videos, high-speed internet access to the website and mapping, and a built-in touch screen instead of a joystick and hardware keyboards (Anokwa, Hartung, Brunette, Borriello, & Lerer, 2009). Mobile and wireless technologies can be used to contribute and reform health services worldwide. These are new opportunities for integration between the growth of mobile phone networks and health services to create eHealth service (Vital Wave Consulting, 2009). Moreover, in the developing world, many organizations operating need effective data collection to successfully reach their goals. Smartphone growth and technical progress are chances to improve the weakness of the current health data collection method by using wireless technology. (Anokwa, Hartung, Brunette, Borriello, & Lerer, 2009).

2.2 Digital animal disease surveillance system in Southeast Asia

The birthplace of emerging diseases such as severe acute respiratory syndrome, or SARS, and highly pathogenic avian influenza (H1N1) in 2003 was Southeast Asia (Horby, Pfeiffer, & Oshitani, 2013 ; Paul, et al., 2010). This region has high potential to be the zoonotic origin because of the high diversity of wildlife and microbial life in subtropical and tropical climates (Morse, et al, 2012). On the other hand, in Southeast Asia, it is easy to find smartphone users who are accessing social media such as Facebook or YouTube because more than 600 million people in this region watch online videos on YouTube and the number of social media users is growing (Venkiteswaran , 2019) while the estimated number of global YouTube users is 1.78 billion in 2020 (Clement, 2018). There are few projects in Southeast Asia which apply the smartphone and communication technology to improve the animal disease surveillances in their country. However, most of this technology is in human health rather than in animal health.

For example, in Cambodia in 2004, a Mobile Reminder System for Cambodia Diabetics or MoPoTsyo Patient Information Center was established by Maurits van Pelt and Cambodian collaborators. The system provides information and health care for the patients suffering from hypertension and diabetes. The objective of the system is to provide reliable information to the patients. The patients are volunteers and received automatic voice messages (15-20 sec.) daily from Monday to Saturday and a special massage for subgroup. Voice messages were used in this system because text message did not support Khmer (formal language of Cambodia) fonts and the letters are too small on the phone. After receiving the message, patients could reply or end the call (Integrating Mobile E-Health into Diabetes Management and Hypertension in Cambodia, n.d.).

Another example in Cambodia is the malaria day zero alert system, which was established in 2011. The system was funded by the Malaria Consortium (MC) in collaboration with The National Center for Parasitology, Entomology and Malaria Control (CNM), CamGSM Co. Ltd. This system uses web-based applications to

Figure 9: SMS report training of the malaria day zero alert system
Source: (Cambodia Malaria Surveillance System, n.d.)

integrate a working system between health center staff (HC) and village malaria workers (VMWs). VMWs were trained to use a cell phone and report malaria cases. It is the duty of VMWs to report malaria cases in provincial villages by Short Message Service (SMS) text to alert the system center. After the center receives the report, the center forwards the report to the local, which confirms the malaria case. At the same time, if it's necessary, the report will be forwarded to a national level, such as Cambodia ministry of health for emergency disease control (Cambodia Malaria Surveillance System, n.d.).

In Thailand, the smartphone application DocterMe was launched in the IOS and Android stores in 2001, in collaboration with the Folk Doctor Foundation, Opendream, with financial support from the Thai Health Promotion Foundation (figure 10). It is a free of charge and accessible application, which is the most popular application in the health and fitness applications category in Thailand. The aim of DoctorMe is to increase the participation of Thai people in the disease surveillance system and also collect health data because of the increasing of technology capacity in Thailand and the disease outbreak hotspots in Southeast Asia. This application has been downloaded by 400,000 users in two years. The number of active users per month is 35,000, mostly in Thailand. The application also provides the location of more than 1,000 hospital and clinic locations with GPS technology. After an update, the function of user health data collection was removed and the application only demonstrates the user searching trends of symptom. However, the issue of a user incentive, such as a monetary or social incentive for engaging, is very important for the application (Susumpow, Pansuwan, Sajda, & Crawley, 2014).

Figure 10: The DoctorMe application on a smartphone
Source: (Susumpow, Pansuwan, Sajda, & Crawley, 2014)

Given the success in applying advanced technology to disease surveillance, such as the DoctorMe and GeoChat apps, Thailand expanded from human health to animal disease surveillance systems. In 2014, The Participatory One Health Diseases Detection or PODD was established in collaboration with Chiang Mai University (CMU), Skoll Global Threats Fund, and the Chiang Mai Livestock Office. The pilot project was started with 74 local governments in the Chiang Mai province. The project aims to create an effective animal disease detection system by using advanced technology in Thailand. As reporters, the village volunteers had to report the animal disease situation in their area via the smartphone application "PODD" on an android system. They were trained in how to use the application and the basic knowledge of animal disease from the veterinarian in the project. The application has a list of short but important question for the volunteers to answer before submitting. The process only takes a few minutes. They could also attach photos and a location (GPS) with their report. After the report is submitted, the PODD Epicenter receives it and a specialist makes a decision to respond to the situation. If the report of an animal disease is confirmed, the alert will be sent to the local government and the livestock authorities (figure 11). This project has won international and national level awards for health innovations because of the holistic approach, community-ownership, and effective response surveillance system (Venkiteswaran , 2019 ; Yano, et al., 2018).

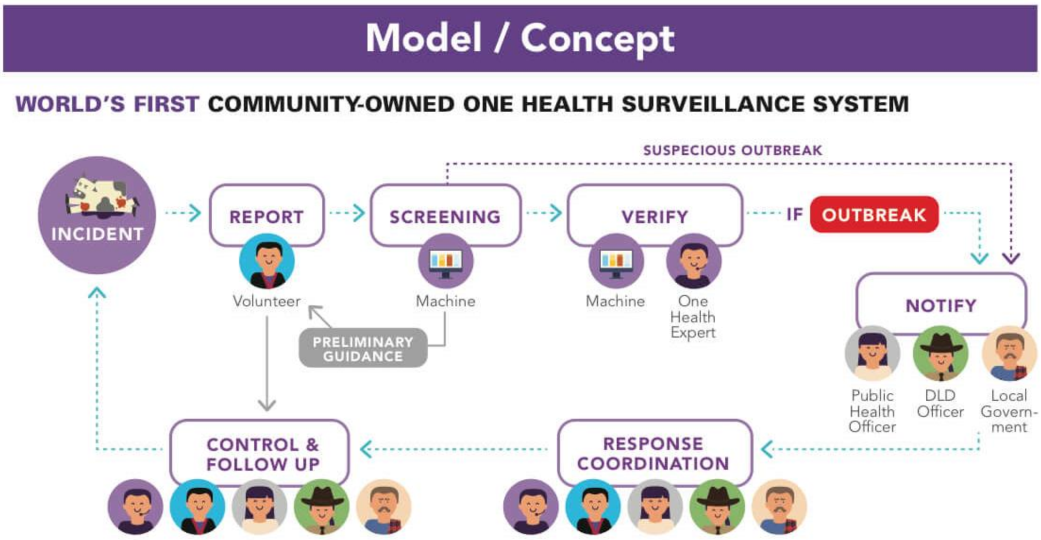

Figure 11: PODD model
Source: (PODD, n.d.)

Table 9: Comparison of Traditional, Advanced, and Further Advanced Surveillance Systems

Surveillance systems Key facts	Traditional (Paper) 1532 - present	Advanced (Email, Web) 1994 - present	Further Advanced (Mobile phone, Smartphone) 2004 - present
Ongoing data collection	√	√	√
Low operation cost	√		
Rapidity		√	√
Accuracy		√	√
Precision			√
High performance labor need		√	√
High technology need		√	√
Internet accessibility need		√	√
Global scale system		√	√

Source: Own analysis of relevant literature sources

2.3 The economic impact of digital animal disease surveillance systems on framers

This study focuses on the impact of animal diseases on farmers, which is one of the objectives of this study. The overall picture of the impact of animal diseases can foster a clear understanding about the way to consider the dimension of the impact. The FAO (2004) states that it can be complex to evaluate the economic impact of animal diseases because, in some cases, the effect only appears in the long-term and indirectly to farmers. It is hard to precisely evaluate the economic impact, as this depends on variables such as the type and damage of animal disease. Considering the type of economic impacts of animal diseases, there are six impact types; production, price and market, trade, food security and nutrition, health and environment, and the financial cost (figure 12).

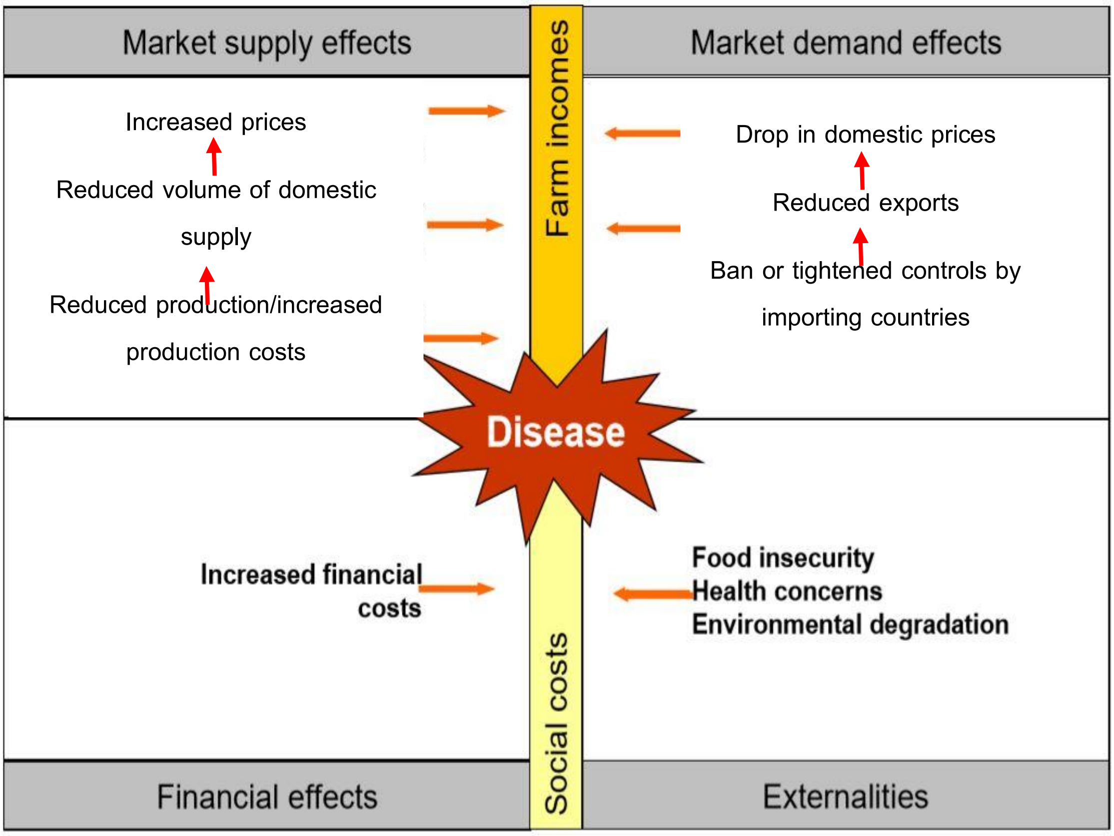

Figure 12: Types of disease impacts
Source: (FAO, Transboundary Animal Diseases. Assessment of socioeconomic impacts and institutional responses. Livestock policy, 2004)

1. **The impact on production**

In figure 12, Farm income is reduced by losing or reducing productivity, which is the direct economic impact of animal diseases. The magnitude of this impact will depend on many factors, such as the variety of farm income and the number of producers in the market. In some cases, there can be a long-lasting impact on a reduction in animal productivity or a delay in livestock output/reproduction (hidden number). The evaluation of economic impact cannot be calculated easily by multiplying lost output by the market price. It should be the same with the economic impact of the damage. Adaptation of frames, farm community responses, and market adjustments should be considered in the actual economic impact. For these reasons, the lost output may be higher than the welfare loss. However, the lost output may less than the welfare loss if the farmer or community response is limited and the economy only depends on the affected product.

2. The impact on price and market effects

The market supply and demand effects in figure 12 demonstrate that price variations can be an economic impact as a result of animal diseases because of demand and supply shocks. Wage variations can occur on the farm and process by market effects. Moreover, it can affect on upstream and downstream businesses. The elasticity of demand and supply are an imprint role to reduce or increase the economic impact of the disease. In some cases, health concerns of consumers can lead to a reduction in demand and induce lower price.

3. The impact on trade

As number 3 in figure 12 shows, the economic impact of animal diseases on trade can be higher than the impact on production because in countries which are not infected, the disease will seriously control the import of livestock products from infected countries, to protect their livestock production. Importation may be very strict or cancelled. It demonstrates that farmers or export countries have to be aware of the implication of consumer or import countries concerning their animal diseases.

4. The impact on food security and nutrition

Figure 12 in the externalities part demonstrates that food security and nutrition in developing countries can be significantly affected by animal diseases. Growing international trade creates more food variety and reduces the impact of animal diseases. However, in low income communities, animal diseases can still have an effect on food security because of a lack of food substitution. In developing countries, national policy-makers are seriously concerned about the food security impact and the need for international support for animal disease control.

5. The impact on health and the environment

From the externalities part in figure 12, zoonotic diseases increase concerns for human health. However, the concern is not only for human health, but also the environment. Animal disease can have an effect on domestic wildlife. Moreover, the environment can be affected by the animal disease control process.

6. **The impact on financial costs**

As shown in the financial effects part of figure 12, controlling animal diseases normally requires a budget. Many necessary processes incur a cost, such as inspection, monitoring, preventing, and responding. Governments have to spend the budget on these animal disease control processes. In some cases, the level of the animal disease control costs is equal to the size of the agricultural sector. The benefit part of animal disease control is not obvious, especially in the case of prevention and emergency preparedness

2.4 Reporter motivation in the digital animal disease surveillance system

Motivation is important for the performance and success of a participatory disease surveillance system. There are many explanations of motivation involved in this study. Maslow's theory is the famous theory of human motivation. He separated human needs into five levels that motivate individuals to achieve: physiological needs, safety needs, belongingness and love needs, esteem needs, and self-actualization needs (Maslow, 1943).

However, it is undeniable that today's utilization of money as a motivation is widespread. That is because we live in the age of market triumphalism, in which money can buy most of our desires (Sandel , 2012). For instance, in the standard labor model of economics, human beings as laborers will offer their effort and time in exchange for compensation (Snyder & Nicholson, 2016).

According to the standard labor model of economics, people work more for higher wages and work less for lower wages. In other words, if there is no payment, there is no effort. However, the overarching question is how should we do this if we want to motivate participants in the participatory disease surveillance system? Is money the only effective motivation, or is non-monetary motivation even more effective and sustainable in the long run? As the participatory system of disease surveillance has developed, the outbreak situation of diseases currently has a quite high impact. For example, in 2005, zoonoses such as avian influenza affected populations in Southeast Asia. Modeling research forecasts have predicted that between 2 to 7.4 million people worldwide could be infected and die in the next pandemic (Cheng, WHO Handbook for

Journalists: Influenza Pandemic, 2005). These forecasts have many implications for societies, including economic losses, human and animal health problems, and food security. Regarding such pandemics, the future continues to be uncertain because vaccines for humans, such as those for influenza or avian influenza, are not yet ready for widespread use. That is because the candidate vaccines are still under development (WHO, Influenza, 2011). Therefore, we not only need better vaccines against viruses, but also access to a rapid alert system for early detection. So that these issues can be dealt with by controlling the spread of the pathogen before it causes a pandemic. However, development and application of surveillance systems is an on-going activity that must be sustainable and permanently available, so the PODD project encountered the issue of how to motivate volunteers, especially in the long-term.

In this study, we attempt to use the theory of monetary and non-monetary incentives to explain the short-term and long-term responses of participants. Monetary and non-monetary incentives are called monetary markets and social markets respectively (Heyman & Ariely, 2004), which is the theoretical framework of this study. This concept was derived from the Fiske's relational models theory (1992). Fiske analyzed human relationships by reviewing studies from various communities. The model categorizes human relationships into four models; communal sharing (CS), authority ranking (AR), equality matching (EM), and market pricing (MP). These four types of relationships not only represent relationships in society as a whole, but also represent it in a social group or between individuals (Fiske , 1992).

Fiske compared all of the relationships to a statistical scale for easy comprehension. First, CS fits into a nominal scale. People in this relationship are as important as the others in the group. People treat each other or a group of people equally and without distinction. People think that they have certain characteristics that are related to other members in the group and have sympathy for others. Moreover, they can access group resources, for example, family relationships. Second, AR fits into an ordinal scale. Under this relationship, people in the group are ranked. The lower ranked people must listen to the orders of the higher ranked people. AR is a perfect linear ranking relationship. Higher ranking people can manage group resources and can give orders to lower ranking people, for example, military relationships. Third, EM fits into an interval scale. In this relationship, everyone is under the same rules, for example, sports games or elections. EM is a balanced equilibrium relationship. To stimulate others to do something, we must do something in return, but not necessarily the same thing and the same amount of effort. And finally, MP fits into a ratio scale. Under this relationship, people calculate their costs and benefits for every activity. People reduce the variety of everything to the form of value and utility. If it is worthwhile, they do it. If it is not, they do the other thing. MP is a market relationship involving money, rent, wages, or interest rates. To make others do something, we have to do the same thing and put in the same effort in return or pay the money back. People in MP relationships are highly entrepreneurial and have benefits or profits as key drivers (Fiske , 1992). This relationship is what economists use as an assumption for predicting human behavior in economic models, which is called rationality.

Fiske (1992) explained that the characteristic of society affects the relationships of social members, for example, in Asia, CS and AR relationships were combined together, which Carl Marx called the Asiatic mode of production, and in societies that believe in monotheistic religions, there is an AR relationship between God and votary, however, modern societies which use the division of labor system demonstrate an MP relationship. There were obviously different relationships between societies in the past. However, the extension of the market relationship and spread of a market-centric-idea has changed relationships in each dimension of life to a market relationship (Sandel , 2012). It makes the different relationships between societies unclear.

The four types of relationship do not only demonstrate relationships in an overall picture of society, but also in a social group or between individuals. Heyman & Ariely (2004) reorganized Fiske's relationship by combining CS, AR, and EM, and called the merge social markets. MP alone was called a monetary market. Under social markets, people live in a warm human relationship and focus on altruism. When people have to do something, they do not expect anything in return. If, eventually, there is some type of return, it does not have to be done immediately, nor does it have to be to the same extent. For example, volunteer caregivers work to take care of the elderly without expecting them to do anything in return. Many times, volunteers only receive gratefulness in return, but it is not equivalent to what they have done. The social market is unclear and indirect in contrast to monetary markets. In monetary markets, people calculate the cost and benefits of every action. The return must be straightforward and clear without any ambiguity. For example, if somebody needs a caregiver, they have to pay hourly compensation. When they stop paying, elderly care is over. Consequently, it can be stated that there are two types of markets, not just monetary markets as economic theory assumes.

2.4.1 Monetary incentives

People calculate the cost and benefits of every action, even the opportunity costs, which is the other option loss after one option is chosen. The return must be straightforward and clear without any ambiguity and should be dominant over cost. For instance, if an elderly person requires attention, hourly compensation must be paid. When the compensation stops, the provision of care ceases (Heyman & Ariely, 2004).

2.4.2 Non-monetary incentives

Under the social markets, people live in a well-balanced human relationship and focus on altruism. People give out their time and energy without expectation of return. If eventually there is some type of returns, it does not have to be immediate, nor does it have to be equal to the input of time or effort. For example, volunteer careers commit to care for the elderly without expecting anything in return. They frequently receive only gratitude instead. The social market is unclear and indirect, which is in contrast to the monetary market (Heyman & Ariely, 2004).

Table 10: Monetary and non-monetary incentives

	Monetary incentive	Non-monetary incentive
Norm type	Market norm	Social norm
Fiske's human relationships	MP	CS, AR, and EM
Focus of interest	Self-interest	Altruism
Mode of thought	Cost and benefits	Well-balanced human relationship
Expectation of return	Yes	No / maybe
Quantity of return	Straightforward, clear, and dominates over cost	Gratitude, not have to equal to the effort
Duration of return	Immediately	None / not specified
Example of societies/institutions	Business relationship	Asiatic mode of production, Military relationship, sport competition

Source: (Heyman & Ariely, 2004)

2.4.3 The effect of monetary and non-monetary incentives on reporters

Previous researches demonstrated that in cases where social and monetary incentives interact with each other, monetary incentives are more influential. This means that social incentives will disappear for a long time, and it is difficult to return to social incentives after money incentives are used (Sandel , 2012 : Gneezy & Rustichini, 1970 : Ariely, 2010).Therefore, when using monetary incentives, we must be careful of the consequences, especially in the case of social activities that require volunteer groups. It makes them compare their compensation to the normal wage rate and their expectation of an equal amount of compensation (Frey & Gallus, 2016). Moreover, monetary incentives can reduce effort after the compensation is terminated (Ariely, 2016 : Lieberman, 2002). In addition, pushing people towards monetary incentives can be done easily by making them think about money even though there are no real payment (Vohs, Mead, & Goode, 2008). Therefore, compensation payment is enough to shift volunteers from the social incentive to the monetary incentive. In some cases, the exchange of effort instead of the money can maintain the relationship between social markets and monetary markets, but the relationship is more similar to social markets (Ariely, 2010).

2.5 Farmer's opinion and behavior on livestock health report

With respect to the economic perspective, people respond to an incentive and make a decision based on rational behavior. In the situation of adverse selection in farmers' reports, if farmers are economically rational beings, they must calculate the expected cost of the report and respond to the lowest cost option (Wolf, 2013). Focusing on the cost of the report, large scale farmers will report lower than small scale farmers because their fixed costs are higher (Wolf, 2006). From a rational behavior perspective, this means that every farmer has the same way of thinking, which is economic rationality. In an uncertain situation, they estimate the animal disease risk in their farms as neutral, without bias, neither optimistic nor pessimistic. Following unbiased estimation, their decisions to prevent animal disease and report are rational. It seems to be easy to understand farmers' behavior. However, our experience in a study area in which we interviewed farmers in Chiang Mai, Thailand showed different behavior.

In the study of area, we found that farmers' understanding of the situation is different from the real situation. In some cases, we found that farmers are less aware of an animal outbreak and have confidence that their farms are safe, even if other farms surrounding their farm are infected. This situation reflects the fact that some factors affect the surveillance and response to the animal epidemic among farmers. Even if the bad situation such as an outbreak in their farm or abnormal livestock death appears in front of them and the veterinarian gives the warning and information they need, they still choose to believe that they can control the situation and that the misfortune will not happen to them.

2.5.1 Optimistic bias

Against the background of the above mentioned reasons, we found that farmers have a clearly optimistic bias. The optimistic bias is the estimation error about the risk of a negative event and the probability of positive event. Persons who have an optimistic bias believe that their risk of a negative event is lower than for others and their probability of positive event is higher than for others (Harris & Hahn, 2011). The optimistic bias is widely discovered in psychology and behavioral economics documents and about 80% of people have an optimistic bias and its effect spans gender, nationality, age and race (Sharot, 2011). Weinstein (1980) was the first person to demonstrate optimistic bias, he called it unrealistic optimism. He explained that optimistic bias is an estimation error about the risk of a negative event, so that persons believe that their risk of negative event is lower than for others, and their probability of positive event is higher than for others. The optimistic bias has been demonstrated in many circumstances. For example, people believe that their probability of getting a serious illness (O'Sullivan, 2015), being a victim of crime (Perloff & Fetzer, 1986), and getting into a car accident (McKenna, 1993) is lower than for others. Moreover, this bias affects the reception of information. Optimistic people react to future positive information more than future negative information such as when people know that their estimate is better than the received information, they don't update their estimate, but when receiving information, which is better than their estimate, they update their estimate permanently (Sharot, 2011).

2.5.2 Confusion between overconfident and optimistic bias

There is some confusion between overconfidence and optimistic bias because they are related to each other. They are often use synonymously. The differences between these two biases are that the overconfidence bias is overconfident about their performance, believing that they are above average (Chaudhary, 2013), while optimistic bias focuses on the event, that they have a lower risk of negative events and higher chance of positive events. In this study, we used the case of optimistic bias to demonstrate farmers' preventative behavior in their farms, which also indicates their risk estimation.

2.5.3 Direct and indirect measurements of the optimistic bias

There are a variety of methods to study the optimistic bias, the most basic method is that the sample estimates their probability to experience with an event and this is compared to the others, or the average under the same conditions, such as the same sex or age. There are two methods to study the optimistic bias: the direct and indirect method (Helweg-Larsen & Shepperd, 2001).

The *direct method* was often used in the past. In this method, participants have to estimate their probability or likelihood to experience a situation anchored on a single scale. For example, compared to the average person of the same age and sex, how much higher or lower is your probability to experience a situation. The midpoint of the scale was labelled by researchers using the direct method to be the same as the average person. In the case of negative events, the optimistic bias mean scale is below the midpoint, which means that their opportunity to experience the negative event is lower than the average. On the other hand, in case of positive events, the optimistic bias mean scale is above the midpoint, which means that their proximity to experience the positive event is higher than the average person. For example, when participants have to answer the question "how probable is it that you will experience (some event) in your life, compared to the other people your sex and age? Nominally their answers are anchored by -3 = lower probability than average people and +3 = higher probability that average people (Helweg-Larsen & Shepperd, 2001).

The *indirect method* is in contrast to the direct method. In the case of indirect method, participants have to estimate their probability to experience an event in the first question and then they have to estimate the probability of the other people their sex and age of experiencing the same even on a second question. Normally, the answer for each question is set on a 0 to 100 scale or from 1 (very unlikely) to 7 (very likely). When parson participants are asked to estimate a negative outcome, the score is calculated by deducting the other estimated possibility from their estimated possibility. The amount of the difference in the score demonstrates the size of optimistic bias. It is difficult to define whether each participant is optimistic, realistic, or pessimistic with these two methods. Moreover, some studies show that the bias of the direct method is higher than the indirect method because of the few response options (Helweg-Larsen & Shepperd, 2001).

The comparison between actual risk and estimated risk has been used in this study. This method seems to demonstrate the accuracy of people's optimistic bias because people tend to overestimate other people's risk more than underestimate their own risk (Burger & Burns, 1988). Comparisons between actual and estimated risk might be the solution to define the optimistic bias, but there are few studies with this approach (Helweg-

Larsen & Shepperd, 2001). However, in this study, the estimated risk is not asked directly. Many studies demonstrate that optimistic bias might be associated with preventative behavior. For example, there is low contraception use (Burger & Burns, 1988) or influenza vaccination (Larwood, 1978), among optimistic people and they have sex with high risk (Sheer & Cline, 1994).

2.6 International animal disease control policies

Global pandemics such as Severe Acute Respiratory Syndrome or SARS, in 2002, Avian influenza (H5N1) in 2003, Influenza A or Swine flu (H1N1) in 2009, Ebola in 2014, Middle East Respiratory Syndrome or MERS in 2012, Corona virus disease 2019 or COVID-19 in 2020 have reflected the importance of the global health issues. Global health organizations such as the WHO have prepared the guidelines and protocols to manage and control the impact of pandemics in the future.

With the pandemic Influenza risk management guidance of WHO (2017), the phases of a pandemic are separated into four phases (Figure 13). The first phase is the interpandemic phase. This phase is the time between pandemics. The second phase is alert phase. In this phase, the infection has been identified and confirmed in human cases. Local, national, and global risk assessment is increased to predict whether the new virus will develop into a pandemic stage or not. The third phase is the pandemic phase. In this phase, the new virus is spreading on a global scale. The global risk assessment is important to prepare the fast or slow movement between the first, second, and third phase. Virological, epidemical, and clinical data are used to calculate the global risk assessment. The last phase is a transition phase. In this phase, the global risk reduces. Response and recovery activities are reduced based on the risk assessment of each country.

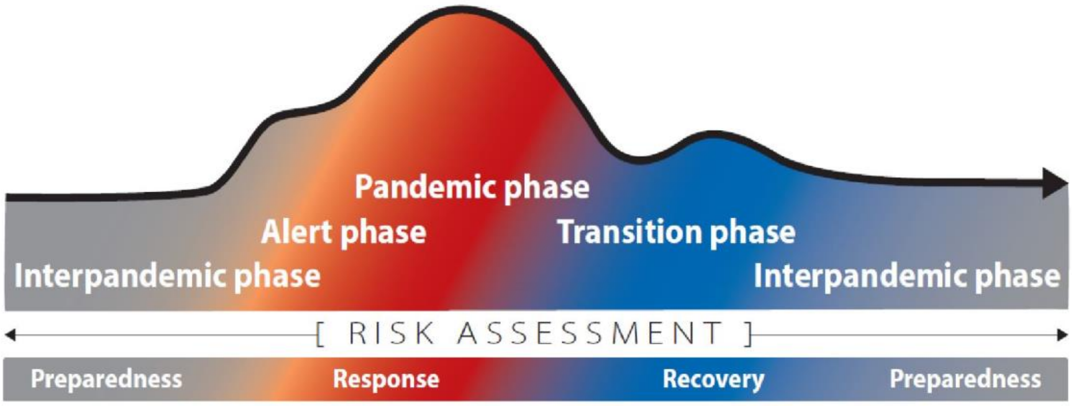

Figure 13: The continuum of pandemic phases*
Source: (WHO, Pandemic Influenza Risk Management: A WHO guide to inform and harmonize national and international pandemic preparedness and response, 2017)

*This continuum is according to a "global average" of cases, over time, based on continued risk assessment and consistent with the broader emergency risk management continuum.

In the case of the influenza virus, the Pandemic Influenza Preparedness Framework or PIP framework was established in 2011 to share the virus, vaccine, and useful information between WHO, member countries, and industries (WHO, Pandemic Influenza Preparedness Framework for the sharing of influenza viruses and access to vaccines and other benefits, 2013). The objectives of the framework are the improvement of virus sharing and vaccines and medicine assessments for countries which require this during the present and future pandemics. The PIP framework was adopted at the 64th world health assembly. To maintain ongoing global monitoring and risk assessment, the member countries need to share PIP biological materials. The surveillance capacity building is also included in the benefit sharing between members. WHO have been taking care of the vaccine candidate review since 2004 and making public announcements immediately on the WHO website (WHO, Pandemic Influenza Risk Management: A WHO guide to inform and harmonize national and international pandemic preparedness and response, 2017).

In the case of emergency risk, there is the system of emergency risk management for health or ERMH to prepare and respond to hazards, such as an influenza pandemic. There are four objectives of ERMH. First, country and community capacities should be strengthened to manage their own health risk. Second, the emergency risk management is ensured as a part in the health sector. Third, health system, multisector management system, and other relevant parts of society are linked and integrated. Fourth, national and international policies on emergency risk management are strengthened and supported. The ERMH explains the periods of preventing, mitigating, responding, and recovering from emergencies. The principles behind ERMH are comprehensive risk management (assessment and management), an all-hazards approach (developing and strengthening of all elements and systems), multisector approach (integrating government and society), multidisciplinary approach, community resilience (utilization of community capacities), sustainable development, and ethical basis. There are six categories of ERMH: policy and resource management, planning and coordination, information and knowledge management, health infrastructure and logistics, health and related services, and community ERMH capacity. More details about the components of each of the categories are summarized in table 7. The member countries of ERMH have received guidance and technical support from WHO based on World Health Assembly resolution (WHO, Pandemic Influenza Risk Management: A WHO guide to inform and harmonize national and international pandemic preparedness and response, 2017).

Table 11: Essential components in each category

Categories	Essential components
Policy and Resource Management	• Policies and legislation • Capacity development strategies • Monitoring, evaluation and reporting • Financing • Human resources
Planning and Coordination	• Coordination mechanisms • ERMH units in Ministries of Health • Prevention and mitigation planning and coordination • Preparedness and response planning and coordination • Recovery planning and coordination • Business continuity management • Exercise management
Information and Knowledge Management	• Risk assessments • Early warning and surveillance • Research for ERMH • Knowledge management • Information management • Public communications
Health Infrastructure and Logistics	• Logistics and supplies • Safer, prepared, and resilient health facilities
Health and Related Services	• Health care services • Public health measures • Specialized services for specific hazards
Community ERMH Capacities	• Local health workforce capacities and community-centered planning and action

Source: (WHO, Pandemic Influenza Risk Management: A WHO guide to inform and harmonize national and international pandemic preparedness and response, 2017)

Considering the section policy and resource management, the effective governance of ERHM based on appropriate policies and legislation. The all-hazard approach should be used for policies and legislation. For example, specific-hazard risk management measures have common components and the ERHM continuum should be covered by preventing, mitigating, preparing, responding, and recovering. National legislation should be aligned with international agreement and convention. It should define clear procedures of emergency management structures, including the duty of government authorities and other organizations, based on national risk management. The elements of ERHM should be considered by public health policy maker and should be part of the legislation. The member countries should develop a human resources plan and should define the requirement for health emergency staff. The role and responsibility of each authority and responder should be written for each specific function in the plan. WHO provides technical support to record the disease and economic impact (in cases of seasonal influenza) and national vaccine development policy, including support and guidance to improve health care staff through training. Moreover, WHO also provides information on the priority needs identification, prevention, mitigation, and response strategies to member countries (WHO, Pandemic Influenza Risk Management: A WHO guide to inform and harmonize national and international pandemic preparedness and response, 2017).

Policy-makers are facing challenges in dealing with animal disease outbreaks at present and the future because of the increase of livestock product trading and markets, in many cases the regional concentration of livestock, and the impact of animal diseases on the international livestock market. This makes it clear that national livestock product strategies need to adopt the international policies and guidelines for controlling animal diseases. A good understanding of the impact of animal diseases on the whole market is a requirement for policy-makers to manage the economic cost in many sectors and also the whole economy. Moreover, they have to realize the power of policy intervention and the socioeconomic implication, which can change the livestock industrial structure. The whole economy can be affected by animal disease outbreaks, which policy-makers have to realize. In addition, policy-makers have to understand the connections between local livestock market, other related sectors, and international livestock markets (Morgan & Prakash, 2006).

Chapter 3 Materials and methods

This chapter includes the conceptual framework of this study to explain the methodologies and concept which are used to find the answer to the three research questions. The content in this chapter is divided into four parts. The first part is the conceptual framework of this study. The second part is the study design and methodology of the economic impact of the animal disease surveillance systems on farmers. The third part is the experimental design of incentives for animal disease reporters. And, the final part is the study design and statistical model of the impact of optimistic bias and others socio-economic factors on farmers' reporting behavior.

3.1 Conceptual framework

The conceptual framework is separated into three parts to find the answers to each research question. The main topic of this study focuses on a digital animal disease surveillance system (the PODD project). The PODD project was a pilot project which was implemented in Chiang Mai. The conceptual framework demonstrates the relationship between concept and methodology in each question:

- First, the impact assessment approach is used to find the economic impact of the PODD project on farmers in 74 local governments of Chiang Mai (Yano, et al., 2018). This part represents the impact on farmers, to demonstrate the economic change of backyard chicken farmers, which was the main focus of the PODD project.
- Second, the experimental approach is used to find the influence of motivation on PODD reporting behavior via the PODD application on smartphones (Yano, et al., 2018). This part represents the impact on reporters or mobile application users. It demonstrates an efficient way to motivate reporters to be active reporters in the long-term. Moreover, it demonstrates the relationship with social activity when the monetary incentive was involved.
- Finally, the logit model of reporting behavior is used to find the effect of socio-economic factors and farmer bias in reporting behavior. Following the concept of optimistic bias, which is when

people believe that their risk of a negative event is lower than that of others and their probability of positive event is higher than that of others (Harris & Hahn, 2011), we assume this bias can also have an effect on farmer reports. This part represents the farmers' side in the role of animal disease reporting. It demonstrates the independent factors which impact on the farmers' reports. And it proves the correction in a real situation of the neoclassic economic assumption following adverse selection in farmers' reporting behavior (Wolf, 2013).

In this study, the three research questions were used to represent the whole picture of the impact of the systems. The full methodology and approach to finding the answers are demonstrated in Figure 14.

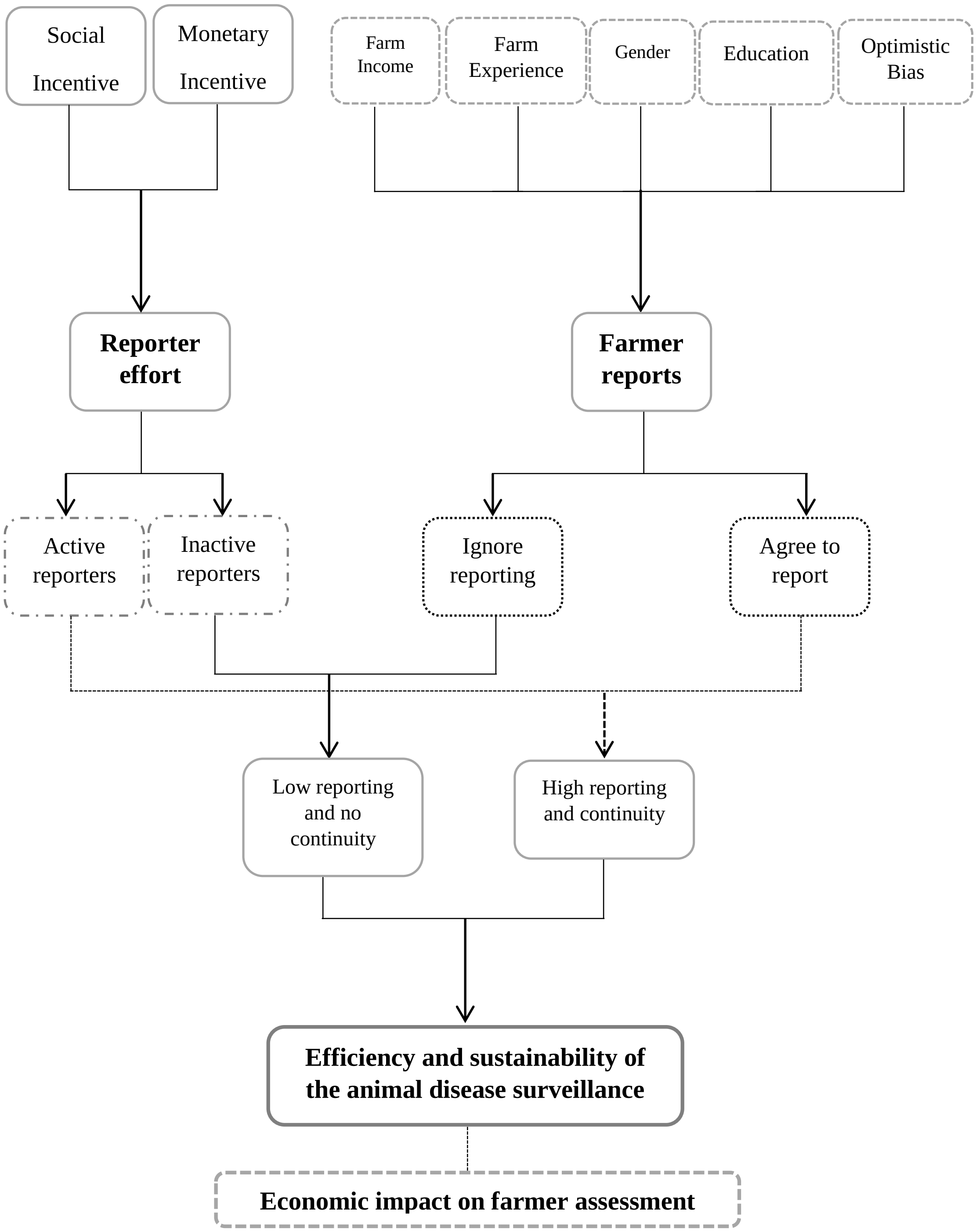

Figure 14: Conceptual framework

3.2 Economic impact of animal diseases on farmers

This part explains the method of economic impact assessment. To analyze the economic impact of the PODD project, this study focuses on a comparison of farmers' variable costs, especially the cost of preventing animal diseases. The impact assessment was design on the basis of the PODD data available. In this study, the data was available at two points in time, before and after the PODD project intervention in the area.

3.2.1 Study design

This study is based on information from the PODD project, conducted in the Chiang Mai province, the province where the pilot was conducted. Seventy-four local governments participated in the project. The local governments selected the areas for which they were responsible to participate in the project. There was at least one PODD volunteer in each village.

One of the expected outcomes of the project was to reduce the impact of animal diseases to farmers, especially to back yard chicken farmers. The project collected the data of variable farming costs in two periods. The base line data (before project intervention) was in 2015, and one year after the project intervention in 2016. The data of PODD project was not only collected in the areas of the project intervention but also in the non-project intervention areas.

3.2.2 Procedures of the economic impact analysis

For this study, the backyard chicken farmers in Chiang Mai area were selected to compare the impact of the project on farmers' costs. The chicken farmers were divided into two groups. The first group was with a PODD group. The second group was without a PODD group. Then, each main group was divided into two periods of time based on the period of the PODD project intervention. The numbers of farmers in the group with a PODD were 82 (51 farmers - before PODD intervention, 31 farmers - after PODD intervention). The numbers of farmers in the group without a PODD were 95 (56 farmers - before PODD intervention, 39 farmers - after PODD intervention) (table 12).

In the PODD intervention group, there was at least one PODD volunteer in their village. While, in the non-PODD intervention group, there was no PODD volunteer in their village. The volunteers would report the abnormal situation concerning the animals to the PODD center. It means that the group of PODD interventions would be more secure against animal diseases and the impact of animal diseases on farmers would be lower than in the non-PODD group, in cases where the PODD system was effective it followed the project expectation.

Table 12: The numbers of participants in PODD and non-PODD project interventions (n=177).

Groups \ Time periods	2015 Before PODD intervention (baseline)	2016 After PODD intervention	Total
With PODD	51	31	82
Without PODD	56	39	95

Source: Data from PODD project

3.2.3 Instruments of the economic impact analysis

For the instruments of this topic, the variable costs of farmers from both groups were collected by PODD projects in 2015 and 2016. In this study, the project was allowed to access and use the economic data. Based on the focus of the project, which was chicken farmers, the variable cost of chicken farming was calculated and compared between two periods of time. The livestock unit of chicken was referenced by the European Commission, which set the coefficient of broilers at 0.007 (table 13) (Eurostat, 2020). It related to the kind of livestock in the impact assessment. We found that the kind of chicken in the area of study is not different and backyard chickens are the only kind of animal of this assessment. It means that it is not necessary to divide the total variable cost by the livestock unit to reduce the variance. In this section, the total variable costs from the PODD project were used for the analysis by two-way ANOVA.

Table 13: Livestock unit coefficients

Kind of animals	Detail	Livestock unit
Bovine animals	Under 1 year old	0,400
	1 but less than 2 years old	0,700
	Male, 2 years old and over	1,000
	Heifers, 2 years old and over	0,800
	Dairy cows	1,000
	Other cows, 2 years old and over	0,800
Sheep and goats		0,100
Equidae		0,800
Pigs	Piglets having a live weight of under 20 kg	0,027
	Breeding sows weighing 50 kg and over	0,500
	Other pigs	0,300
Poultry	Broilers	0,007
	Laying hens	0,014
	Ostriches	0,350
	Other poultry	0,030
Rabbits, breeding females		0,020

Source: Eurostat, 2020

3.2.4 Statistical analysis

For the data analysis of this study, the outcome variable in this topic is the total variable cost (TVC) per month, which was reported as the mean, using two-way ANOVA to test the significant interaction of treatment and time. The *p*-value was set at 0.05. The TVC per month from each group was separated into two periods of time; Period 1 (2015: before PODD intervention), Period 2 (2016: after PODD intervention). The values at each single point of time were compared by t-test (paired analyses). The *p*-value was set at 0.05 to demonstrate the significant differences.

3.3 Reporting behavior of the PODD reporter

3.3.1 Study design

This study is based on information from the Participatory One Health Disease Detection project, or the PODD project, conducted in the Chiang Mai province, the province where the pilot was conducted. Population in this study is 296 PODD volunteers, who participated in the project since 2015. The limiting condition of this study is the geographical structure where the province is mostly mountainous (Fig 15). This limitation has an effect on the quality of the Internet signal. Moreover, there was a variety of livestock and population densities in different areas of the province. We could not use systematic sampling from all of the volunteers in the PODD project because of the limiting condition.

In this study, we recruited 67 volunteers from 17 areas of the study (3 to 5 volunteers per area). All volunteers were residing in the central part of Chiang Mai province to reduce the impact of other difference factors, i.e. the variety of livestock, population densities, and the internet signal, which is our limiting condition.

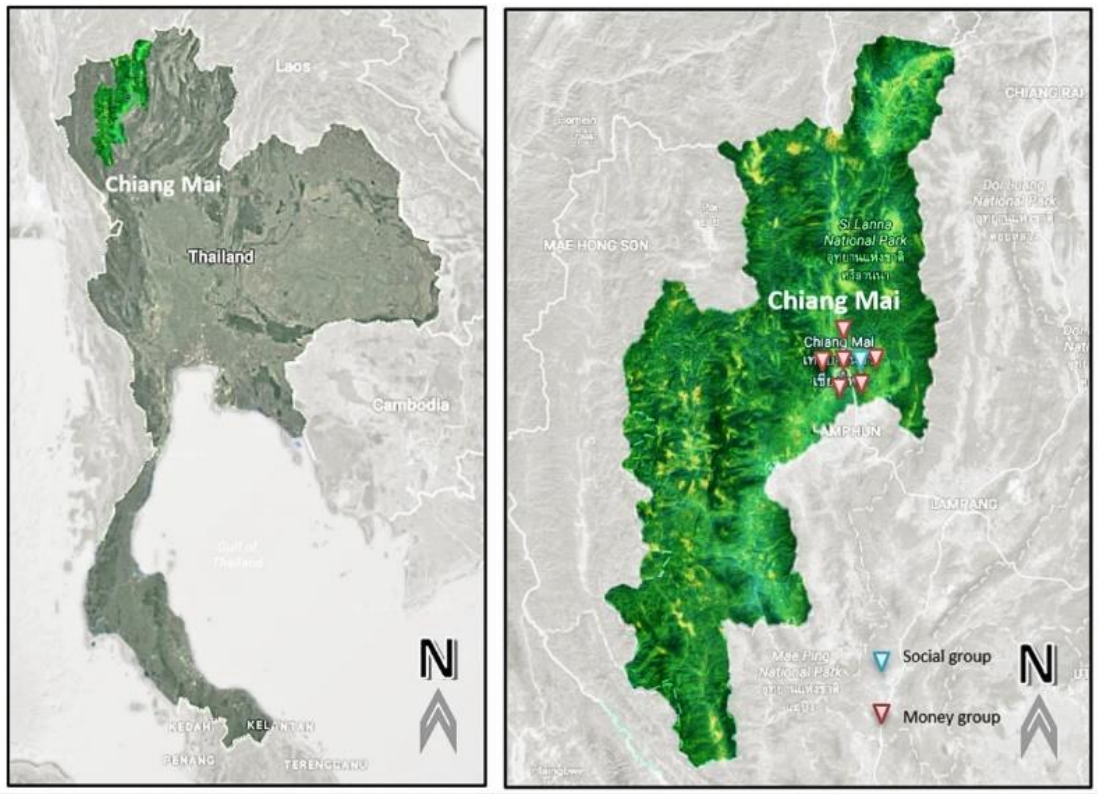

Figure 15: Geography of Chiang Mai. Source: Own figure after Google map, (2017)

3.3.2 Procedures of the Incentives experiment

For this study, participants were divided into two groups (Table 14). The first group was the experimental group, with 49 volunteers from 12 areas, who received a monthly transfer of 400 Baht[1] (11.5 USD). The transfer included payment for covering cost of a smartphone (54.5 USD) and compensation for monthly calls and internet charges. Whether they reported or not, this group of volunteers was still paid every month until the end of the payment period. The volunteers in this group were drawn to this study by monetary incentive and were reminded of the monthly compensation and other benefits they received.

The second group was the control group, with 18 volunteers from 5 areas, who received no compensation (no monthly salary, smartphone, or compensation for calls and internet charges). The volunteers in this group were drawn to this study without any

[1] 1 Bath equal to 0.028 USD or 0.026 EUR

monetary incentive. They were motivated to participate in this study by the social incentive and used their own smartphone and internet package to install the PODD application and report.

Both groups were informed about the benefits to society and trained by the PODD project with the same explanations regarding animal epidemics, the importance of reporting, and how to install and submit their report via smartphone applications. Their duty was to report both usual and unusual animal-related events in the communities for which they were responsible. Reports included taking photographs, sharing the location, and observing via the smartphone application. The type of the data on animal health abnormalities in this project was based on four categories of livestock; backyard chickens, pigs, dairy cattle, and beef cattle. They were trained by the project about how to observe the basic symptoms of important epidemic diseases such as Newcastle disease in poultry, porcine reproductive and respiratory syndrome (PRRS) in pigs, and foot-and-mouth disease (FMD) in cattle. They also had to report any normal events to confirm that there were no unusual animal-related events in the area. For this reason, they had to report whether they had noticed any sign of animal diseases every day (Yano, et al., 2018).

Table 14: Number of Reports per Month according to Group of Volunteers

Group of volunteers	Number of volunteers	Reports per month			
		Period 1[a]	Period 2[b]	Period 3[c]	Period 4[d]
Experimental group: (Monetary Group)					
1	5	17	14	0	9
2	4	19	13	17	2
3	4	21	23	9	9
4	4	23	13	16	5
5	4	25	20	15	6
6	4	22	10	5	6
7	4	24	26	25	19
8	4	28	25	24	8
9	4	30	29	27	6
10	4	24	17	0	0
11	4	31	28	23	0
12	4	27	31	24	8
Control group: (Social Group)					
1	4	12	21	18	10
2	4	30	12	11	8
3	4	13	26	26	17
4	3	11	19	9	18
5	3	20	20	10	18

Sources: Computation and analysis from PODD volunteers report database

Note: a Period 1 refers to the period of 5 months before the end of compensation
b Period 2 refers to the period of 1 month after the end of compensation
c Period 3 refers to the period of 5 months after the end of compensation
d Period 4 refers to the period of 10 months after the end of compensation

The only differences between the groups were the compensation in the form of a monthly salary payment, and with the provision of a smartphone with free calls and internet for the period of the study. We designed this study to answer three study sub-questions based on our objectives. It could be identified as follows;

- Question 1 : During the period when compensation is paid, are the efforts of the volunteers in the monetary market group higher than those in the social market group?

- Question 2 : Do the volunteers' efforts in the monetary market group decrease at the end of the payment period, whereas the efforts of the volunteers in the social market group do not decrease over the same period of time?

- Question 3 : Do the volunteers in the monetary market group perform less well compared to the social market group in the long-term after the compensation was terminated?

From question 1, which demonstrates the effect of monetary incentives (compensation and smartphone with internet) on volunteers in the monetary incentive group, we assume that the effort of the monetary group is higher than that of the social group.

Question 2 demonstrates the comparison of the efforts of both groups for all periods of time. Our assumption concerning this question is that the effort of the social group does not change over time, whereas the monetary group's effort decreases once the compensation has terminated.

Finally, question 3 reflects the effect of monetary incentives in the long-term. Our assumption concerning this question is that there is a negative effect from the monetary incentive in the long-term, which reduces the efforts of the monetary group. Moreover, this question demonstrates that when the monetary incentive is terminated, the volunteers will maintain their behavior based on the monetary incentive or return to the social incentive.

3.3.3 Instruments of the incentives experiment

For the instruments of this study, the reporting data from both groups on the PODD application were recorded by the PODD automatic system, which was linked to the Department of Livestock and the local government. Each volunteer in both groups received their own ID to sign in on the PODD application. Their reports were measured by the number of reports per month based on the areas for which they were responsible (Table 14).

Moreover, as our study concerned the rate of occurrences, we calculated average reports per month by counting only whether a report was received, meaning that the variation of occurrences had no effect on the average reports per month. The maximum number of reports per month was 30-31, and the lowest number of reports was zero. The available data that was collected from the project covered a period of two years from 2015-2016. As the social and monetary groups did not start participating in the project at the same time, this study used data collected after July 2015.

3.3.4 Statistical analysis

To analyze the data of this study, the outcome variable in this study is the number of reports per month. The number of reports per month was reported as the mean, using repeated measurement ANOVA to test the significant interaction of treatment and time. The *p*-value was set at 0.05. The number of reports per month from each group were separated into four periods of time; Period 1 (five months before the end of the compensation), Period 2 (one month after the end of the compensation), Period 3 (five months after the end of the compensation), and Period 4 (10 months after the end of the compensation). The values at each single point of time were compared by t-test (paired analyses). The *p*-value was set at 0.05 to demonstrate the significant differences.

A number of questions were raised in relation to these study results. Question 1 was tested using a t-test to compare the average report between the two groups in Period 1 (five months before the end of compensation). If the average report of the monetary group is higher than in the social group, our assumption that the effort of the monetary group is higher than the social group is correct. Question 2 was tested using repeated measurement ANOVA. Our assumption is that the effort of the social group does not change over time, while that of the monetary group decreases after the end of the compensation. Finally, Question 3 was tested using a t-test to compare the average report between the two groups in Period 4 (10 months after the end of compensation). If the result shows that there is a statistical significance, we can conclude that it is correct to say that the effort of the monetary group is lower than the social group.

3.4 Farmers' aspect on animal health reports

3.4.1 Study design

In this study, we developed a logit model to test farmers' optimistic bias and the other socio- economic factors. In the previous study, farmers' reporting behavior was described by many factors; information accessibility, opportunity and transaction cost, gender, farm size, economic and educational status, social capital, risk perception (Brugere, Onuigbo, & Morgan, 2017). However, we found that many factors were interrelated.

First, opportunity and transaction costs can relate to farm size. As an example, if the farm size is large scale, the opportunity and transaction costs are also higher than small scale farmers. In this case, we use livestock income as an explanation instead of farm size, because we have four kinds of animal. Livestock income is easier to represent in a logit model than farm size and we would like to prove the assumption of neoclassic economics. Second, information accessibility, social capital, and risk perception relate to each other because when farmers have a strong social connection, they can access the animal outbreak information from their neighbors and the effect on their risk perception. In this case, we focus on risk perception, which is represented by optimistic bias.

Gender is an unclear variable in terms of its effect on the framers' reporting behavior. In many cases, men are less in contact with zoonotic diseases than women and women are more concerned about livestock health than men (Kristjanson, et al., 2010). While in some studies it is demonstrated that gender has no effect on risk situations (Cueva, et al., 2016), in the case of animal disease risk, there is a knowledge gap about the effect of gender on farmers, which we discovered in our model. Moreover, education is significant for farmers' adoption and decision-making, while farming experience is not significant (Adeogun, Ajana, Ayinla, Yarhere, & Adeogun, 2008). We also added these two variables to our model to test their effect of the farmers' reporting decisions.

3.4.2 Procedures and instruments of analysis

The sample of this study was 467 animal farmers in the Chiang Mai Province. We used the data from PODD project. The questionnaire was divided into three parts. The first part concerned questions about animal disease. Farmers were asked about their reports to the livestock officer when there was an animal outbreak or illness in their farm. The answer to this question was binomial choice between reporting and not reporting. Another question was their experience with animal disease outbreaks on their farm. The second part concerned questions about their prevention of animal outbreaks, it was separated into four questions: animal outbreak news updates, vaccinations, animal health checks, and farm cleaning (Table 15). The answers to these questions were scored between 0 - 4: zero means that the farmer took no or very limited prevention measures and four means a high level of prevention measures. The last part concerned socio-economic questions: livestock income per month, experience of the farmer with livestock, gender, and years of education.

Table 15: Preventive behavior of famers regarding animal outbreaks

Preventive behavior	Answers
Animal outbreak news updates	(Never) 0 – 4 (diary)
Vaccination for livestock on the farm	(Never) 0 – 4 (all necessary vaccines)
Livestock health checks	(Never) 0 – 4 (diary)
Farm cleaning	(Never) 0 – 4 (diary)

Sources: Own study design and data of PODD

To calculate optimistic bias variable, the accurate way to estimate people's risk is comparing estimated risk and actual risk (Helweg-Larsen & Shepperd, 2001). In this study, we compared actual risks and expected risk of disease outbreak with farmers (Figure 16). For the actual risk part, we separated our observations according to the kind of animal: dairy cow, swine, chicken, and beef cow because the impact of animal disease in each kind of animal is different. We calculated actual risk from each kind of animal by the proportion of farmers who experienced an animal outbreak on their farm and transformed it into a percentage.

In the estimated risk part, we calculated according to preventative behavior, because it can demonstrate the personal disease perception (Cummings, Becker, & Maile, 1980). Farmers' expected risk variable was calculated by using the second part of the PODD questionnaire, through summation of the score from four actual preventive questions (maximum is 16, minimum is 0) and transformation into a percentage (Figure 16).

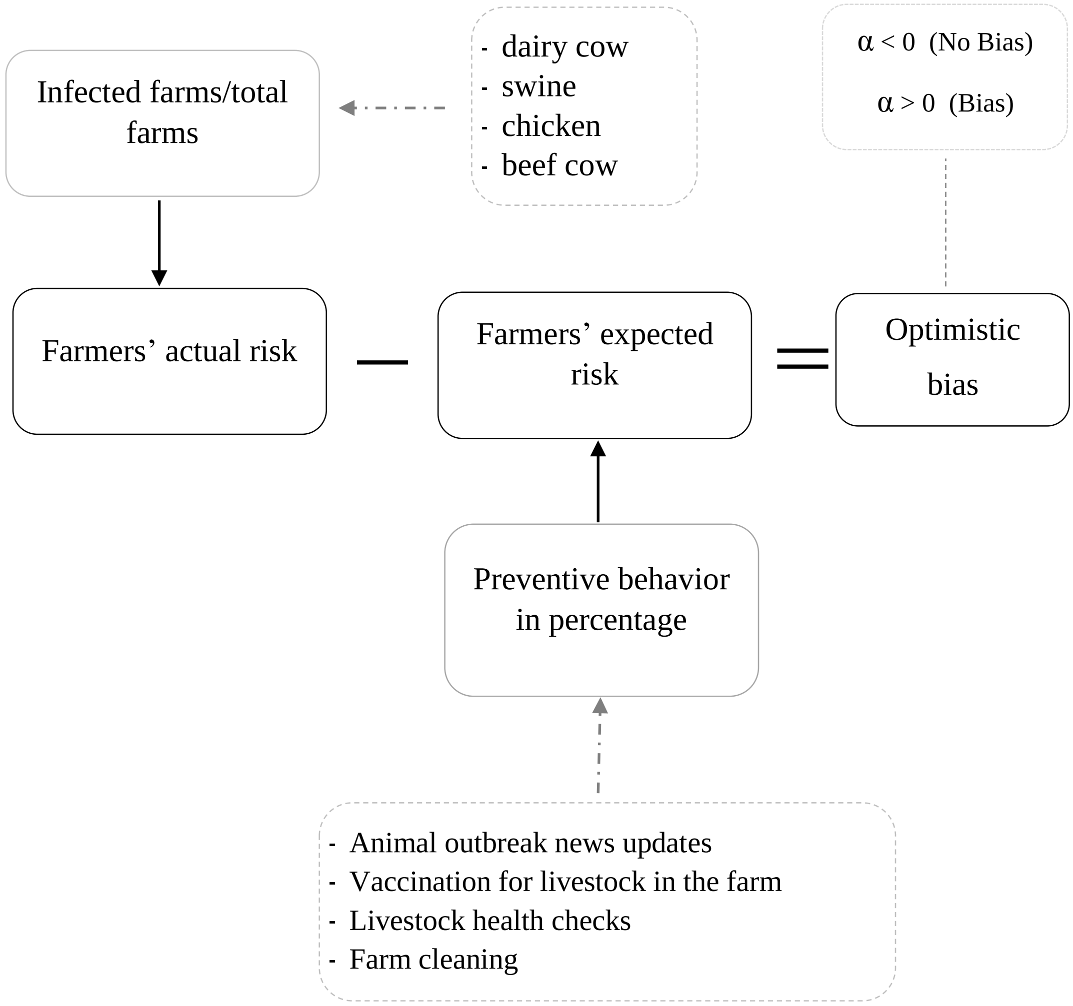

Figure 16: Optimistic bias calculation map

In pre-final calculation part, we used farmer's actual preventative behavior from four actual preventing questions instead of awareness of animal disease, because their awareness is not necessary to reflect their actual behavior (Crociata, Agovino, & Sacco, 2015). For example, in some cases, farmers can be aware of animal diseases on their farm, but this does not mean that the farmer practices animal diseases prevention in their farm. In other words: farmers can be aware of animal diseases without practicing prevention. Finally, the optimistic bias variable was calculated by actual risk minus farmers' expected risk. We define the optimistic bias of farmers by α (with $-1 < \alpha < 1$). If α is higher than 0, it means farmer has optimistic bias. If α is equal or lower than 0 it means optimistic no bias (Figure 16).

We developed the logit model from all of the independent variable explanations to test the impact of these variables.

$$Farmers\ report = Livestock\ income + Optimistic\ bias + Farm\ experience + Gender + Years\ of\ Education$$

In this study, our assumption is that the optimistic bias affects farmers' decisions more than the other socio-economic variables that we know. The definitions of all variables can be found in table 16.

Table 16: Definitions of variables in the model

Dependent variable	
Y_i	Farmer animal health reporting decision which takes the value of 1 for reports and 0 otherwise
Independent variable	
LINC (X_1)	Livestock income (USD)
OB (X_2)	Optimistic bias, measured by farmer's expected risk minus by actual risk (if the value is higher than 0, farmer has optimistic bias)
Farm_Exp (X_3)	Years of farming experience (in years)
Gender (X_4)	Farmer's gender, which takes the value of 1 if the farmer is a man and 0 otherwise
Edu_year (X_5)	Years of farmer's education (in years)

Sources: Own study design

Chapter 4 Results

There are three major objectives of this study. First, this study aims to estimate the economic impact of the PODD project on farmers, especially backyard chicken farmers. Second, this study aims to find the impact of social and monetary incentives on the effort of PODD reporters to report the animal health situation via the smartphone application. Third, this study aims to describe and determine the influential factors, which impact on farmers' animal disease reporting behavior. The research questions corresponding to these major objectives are:

1. What should the differences be between the areas with and without the PODD project intervention in the duration of one year? If there are differences, how great is the economic impact of the PODD project on backyard chicken farmers in Chiang Mai?
2. How effective are social and monetary incentives for motivating PODD reporters in the long-term??
3. What are the factors which impact on the farmer's reporting behavior of animal diseases and how great is the impact of optimistic bias on farmers?

This chapter includes the statistical analysis of each research question represented. The results are divided into two sections for each research question. The first section demonstrates descriptive analyses of all variables. The second section describes the statistic models which are selected for analysis in each research question. The results of this chapter are used for the discussion and conclusion in the chapter 5.

4.1 Economic impact of the PODD project on farmers

This section describes an analysis of the economic impact of the PODD project on farmers. The data of livestock total variable cost from the PODD project was used to analyze the impact. The unit of livestock total variable cost is USD per month. Farmers in the data are backyard chicken farmers, which is the most important group of the PODD project. The farmers were divided into two groups, which are a without PODD group (control group) and a with PODD group (experimental group). The data of these two groups was collected by the PODD project in two periods, which were in 2015 (before the PODD project intervention) and in 2016 (one year after the PODD project intervention). The results in this section are divided into two subsections. The first subsection is descriptive statistics and the second subsection is a two-way ANOVA analysis.

4.1.1 Descriptive statistical analysis of the economic impact of the PODD project on farmers

This subsection demonstrates the descriptive statistical analysis of the livestock total variable cost from two groups (without the PODD intervention group and with the PODD intervention group) between two periods of time (before and after the PODD intervention). This data is used to analyze two-way ANOVA analysis in the latter subsection.

Table 17: Mean and standard deviation of the livestock total variable cost (USD) per month of backyard chicken farmers in each group between the period of before and after PODD intervention (n = 177)

	Before PODD intervention			After PODD intervention		
Group	Mean	SD	n	Mean	SD	n
Without PODD	25.680	37.909	56	42.343	46.717	39
With PODD	26.122	28.965	51	157.852	336.530	31

Sources: Calculation

The descriptive result in table 17 demonstrates that the livestock total variable cost per month of backyard chicken farmers before the PODD project intervention between the without PODD and the with PODD groups is not so different. The average total variable cost of the with PODD group is 25.68 USD per month (n = 56), while the total variable cost in the without PODD group is 26.122 USD per month (n = 51). However, the SD in both groups is very high (37.909 in the group without PODD, 28.965 in the group with PODD). In the period of after PODD intervention, the average livestock total variable cost between the with and without PODD groups is very different. The result indicates that the average total variable cost in the group with PODD is higher than the group without PODD. The average total variable cost is 42.343 USD per month (n = 39) in the group without PODD and 157.852 USD per month (n = 31) in the group with PODD. However, in the same way as with the period before PODD intervention, the SD of both groups is very high (46.717 in the group without PODD, 157.852 in the group with PODD)

Table 18: Frequency and percentage of the duration variable and group variable

Variable		Frequency	Percent	Cumulative Percent
Duration	Before	107	60.5	60.5
	After	70	39.5	100.0
	total	177	100.0	
Group	Without PODD	95	53.7	53.7
	With PODD	82	46.3	100.0
	total	177	100.0	

Sources: Calculation

The descriptive results in table 18 demonstrate that, for the duration variable, there are 107 farmers or 60.5 percent in the period before the PODD intervention and 70 farmers or 39.5 percent in the period after the PODD intervention. The total number is 177. In the group variable, there are 95 farmers or 53.7 percent, which are in the area with the PODD project, and 82 farmers or 46.3 percent, which are not in the area. The total number is 177. The preliminary interpretation of the results is that, in this study, the number of farmers in the group with and without the PODD intervention is almost equal (54:46) and in the period between before and after the PODD intervention it is also almost equal (60:40).

4.1.2 The economic impact analysis of the PODD project on farmers by two-way ANOVA

The statistical analysis of this topic is two-way ANOVA. There are two dependent variables. The first factor is the duration. There are two values in this variable, which are before (collected in 2015 - before the PODD intervention) and after (collected in 2016 - one year after the PODD intervention). The second factor is the group. There are two values in this variable, which are the group “with PODD” intervention (experimental group) and the group “without PODD” intervention (control group). And there is one dependent variable in the analysis, which is livestock total variable cost per month.

Before the two-way ANOVA analysis, the data was tested on three assumptions of the two-way ANOVA. The test demonstrates that there is no outlier in the data, which is the first assumption. However, the data does not have normal distribution, which is the second assumption. Moreover, when the data was tested by Levene’s test, the result shows a problem with homogeneity, which is the third assumption. This means that the data violates the assumptions of the two-way ANOVA.

Due to the data violation of the two-way ANOVA assumptions, it is necessary to transform the data before using it in the two-way ANOVA analysis. The log 10 transformation is used to transform the data. The result of data transformation by log 10 demonstrates that that transformed data has normal distribution, which does not violate the assumptions. Table 19 demonstrates the normality test of the data between two independent variables. All normality tests show values significantly higher than 0.05, which means that the data has normal distribution. Moreover, the Levene’s test result demonstrates the significant value is more than 0.05, which means that there is no problem of homogeneity (Table 19). After data transformation by log 10, the transformed data does not violate the assumptions of the two-way ANOVA.

Table 19: Normality and homogeneity tests of transformed economic impact data by log10 (N = 177)

Model	Normality test Shapiro-Wilk		Homogeneity test Levene's Test	
	df	sig	F	sig
Before*Without PODD	56	.871	2.252	.084
Before*With PODD	51	.293		
After*Without PODD	39	.412		
After*with PODD	31	.976		

Sources: Calculation

In table 20, the result of the two-way ANOVA demonstrates that the independent variables are statistically significant in explaining the dependent value. The *p*-value of the duration variable is 0.000, which is lower than 0.01. This means that the period between before and after the PODD intervention is different. The livestock total variable cost of backyard chicken farmers one year after the PODD intervention is higher than before the intervention (table 17 and figure 17).

Moreover, the p-value of the group variable is 0.014, which is lower than 0.05 (table 20). This means that the group between without and with the PODD intervention is different. The livestock total variable cost of farmers in the group with the PODD intervention is higher than the group without the PODD (table 17 and figure 17).

It is important here that the result shows that the effect of duration and group is not statistically significant. The *p*-value of duration and group is 0.141, which is higher than 0.05 (table 20). This means that the effect between duration and group cannot explain the livestock total variable cost of farmers. In other words, the intervention of the PODD project in the one year period has no impact on the livestock total variable cost of farmers.

Based on these results, the preliminary interpretation is that there is no impact from the PODD project on backyard chicken farmers in the period of one year. The project could not reduce the variable cost of farmers, which includes the cost of animal disease prevention and economic lost from animal diseases. The farmers did not receive the benefit of the project by cost reduction. It also demonstrates that, in the period of one year, the digital animal disease surveillance system might be not enough to have an impact on farmers, because the system needs more than one year to increase the impact. Moreover, some success factors might be disregarded such as farmers' reporting behavior or the motivation of reporters, which are analyzed in the latter section.

Table 20: Results of the economic impact analysis by two-way ANOVA (n = 177)

Source	Sum of Squares	df	Mean Square	F	p-value
Duration	5.724	1	5.724	22.445	.000**
Group	1.582	1	1.582	6.203	.014*
Duration* Group	.559	1	.559	2.192	.141

R Squared = .139, Adjusted R Squared = .124
** ($p < 0.01$), * ($p < 0.05$)
Sources: Calculation

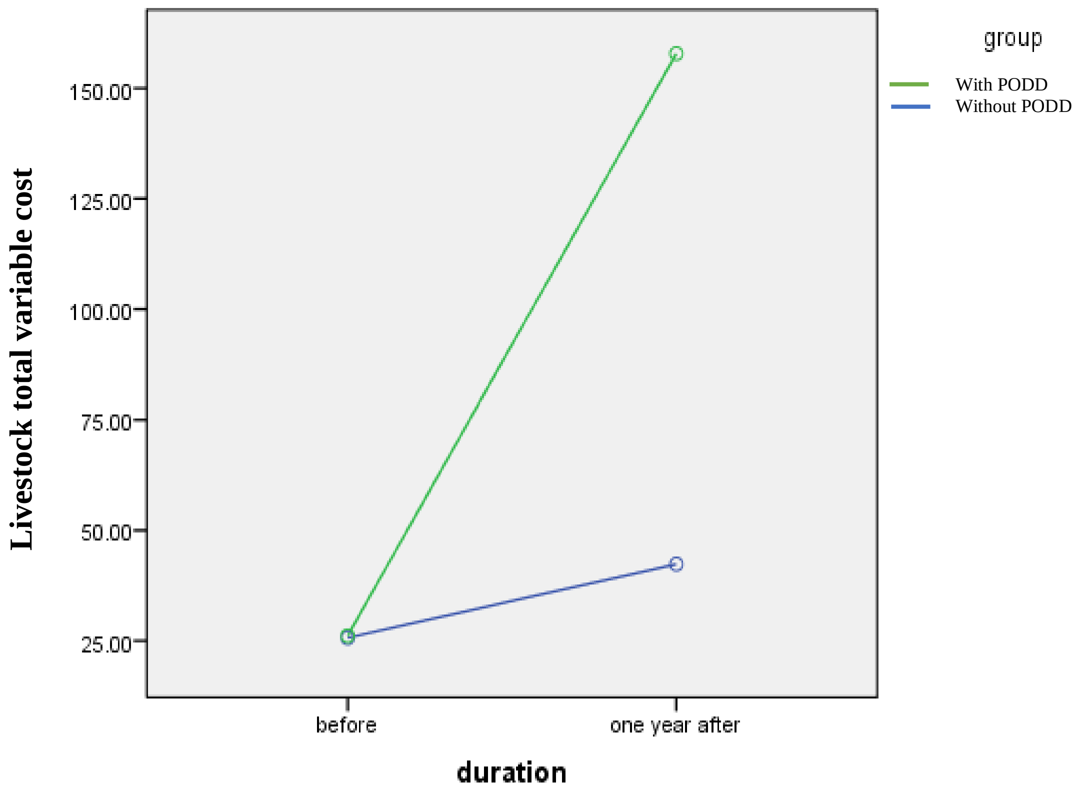

Figure 17: Livestock total variable cost of farmers in each group between before and after PODD intervention

4.2 Reporting behavior of the PODD reporters

This section contains an analysis of the PODD reporters' efforts to report the animal health situation using the PODD application. The report statistics of the PODD reporters from the PODD project were used to analyze the impact. The unit of the report variable is the number of reports per month (min = 0, max = 30). The PODD reporters were divided into two groups, the (I) social incentive group (control group) and the (II) monetary incentive group (experimental group). The data from these two groups was collected by the PODD project in four periods of time, which were 5 months before the end of compensation (period 1), 1 month after the end of compensation (period 2), 5 months after the end of compensation (period 3), and 10 months after the end of compensation (period 4). The results in this section are divided into two subsections. The first subsection is descriptive statistics and the second subsection is the RM-ANOVA or repeated measurement ANOVA. The statistical analysis in this section relates to three sub-research questions which were described in chapter 3. These are identified as follows;

- Question 1 : During the period when compensation is paid, are the efforts of the volunteers in the monetary market group higher than those of the volunteers in the social market group?

- Question 2 : Do the volunteers' efforts in the monetary market group decrease at the end of the payment period, but the efforts of the volunteers in the social market group do not decrease over the same period of time?

- Question 3 : Do the volunteers in the monetary market group perform less well compared to the social market group in the long-term after the compensation has been terminated?

4.2.1 Descriptive statistical analysis of the PODD reporters' behavior

This section concerns the descriptive statistical analysis of the PODD reporters' behavior. The dependent variable in this analysis is the monthly reports. The independent variables are the groups (social and monetary incentive groups) and the time periods (four periods). The dependent variable is separated and analyzed on the basis of two independent variables. Thereafter, the data is used to analyze the RM-ANOVA in the latter subsection.

The descriptive results in table 21 demonstrate that the number of reports per month of the PODD reporters in period 1 is different between two groups. The average reports per month of the social incentive group is 17.32 reports per month (SD = 7.88, n = 5), while in the monetary incentive group it is 24.15 reports per month (SD = 4.23, n = 12). In period 2, the average reports per month of both groups are no different. The average reports per month of the social incentive group is 19.70 reports per month (SD = 4.94, n = 5), while in the monetary incentive group it is 20.7 USD per month (SD = 7.09, n = 12). In period 3, the average reports per month of both groups are no different. The average reports per month of the social incentive group is 14.75 reports per month (SD = 7.03, n = 5), while in the monetary incentive group it is 15.36 reports per month (SD = 9.81, n = 12). And, in the last period, the average reports per month of both groups are different again. The average reports per month of the social incentive group is 14.05 reports per month (SD = 4.78, n = 5), while in the monetary incentive group it is 6.46 reports per month (SD = 4.92, n = 12). This means that the reports per month of the monetary group are higher than the social group in period 1. In periods 2 and 3, the reports per month of both groups are no different. And, in period 4, the reports per month of the social group are higher than the monetary group. The preliminary interpretation of these results is that the social incentive group can maintain the effort of the reporters in the long-term, while the monetary incentive group can increase the effort of the reporters in the period of payment. However, after the payment was terminated, the reporters cannot change their motivation from the monetary incentive to the social incentive in the long-term.

Considering the number of reports per month in each group, the average reports per month of the social incentive group in 4 periods is not so different (period 1 = 17.32, period 2 = 19.70, period 3 = 14.75, period 4 = 14.05), while the average reports per month of the monetary incentive group in 4 periods is different (period 1 = 24.15, period 2 = 2.07, period 3 = 15.36, period 4 = 6.46). In other words, the number of reports per month of the social incentive group is stable overtime, while the reports per month of the monetary incentive group decreases over time. However, the results at this stage needs to be confirmed by statistical significance in the next section.

Table 21: Descriptive results comparing social and monetary groups in periods 1 to 4

	Social group n = 5		Monetary group n = 12	
	Mean	SD	Mean	SD
Period 1	17.32	7.88	24.15	4.23
Period 2	19.70	4.94	20.7	7.09
Period 3	14.75	7.03	15.36	9.81
Period 4	14.05	4.78	6.46	4.92

Source: Calculation

4.2.2 The PODD reporters' behavior analysis by repeated-measures ANOVA

To obtain the result of this study, we tested the normality, correlated error, and homogeneity using the dependent variable (monthly report) between the four periods of time, the duration of each of which was a five-month interval. This data did not violate the assumption before analysis of repeated-measures ANOVA (table 22). The normality test in four periods of time was tested by the Shapior-Wilk test. The result demonstrates that the value of α of four periods of time is higher than 0.05, which means that there is no violation of normality assumption. There is normal distribution in the four periods. The homogeneity test in four periods of time was done using Levene's Test. The result demonstrates that the value of α of four periods of time is higher than 0.05, which means that there is no violation of the homogeneity assumption. There is no homogeneity in the four periods. The multicollinearity test result demonstrates that the value of VIF of four periods of time is lower than 3, which means that there is no violation of multicollinearity assumption. There is no multicollinearity in the four periods.

Table 22: Normality, correlated error, and homogeneity tests of four periods of time

Model	Normality test		Homogeneity test		Multicollinearity test							
	Shapiro-Wilk		Levene's Test		Period 1		Period 2		Period 3		Period 4	
	df	α	F	α	TL[e]	VIF[f]	TL	VIF	TL	VIF	TL	VIF
Period 1[a]	17	.497	3.448	.083			.631	1.584	.642	1.558	.919	1.089
Period 2[b]	17	.593	2.513	.134	.459	2.177			.823	1.215	.472	2.119
Period 3[c]	17	.195	.892	.360	.472	2.121	.831	1.204			.457	2.190
Period 4[d]	17	.077	.231	.638	.960	1.042	.677	1.476	.649	1.540		

Sources: Calculation

Note:
- a Period 1 refers to the period of 5 months before the end of compensation
- b Period 2 refers to the period of 1 month after the end of compensation
- c Period 3 refers to the period of 5 months after the end of compensation
- d Period 4 refers to the period of 10 months after the end of compensation
- e TL refers to tolerance
- f VIF is the variance inflation factor

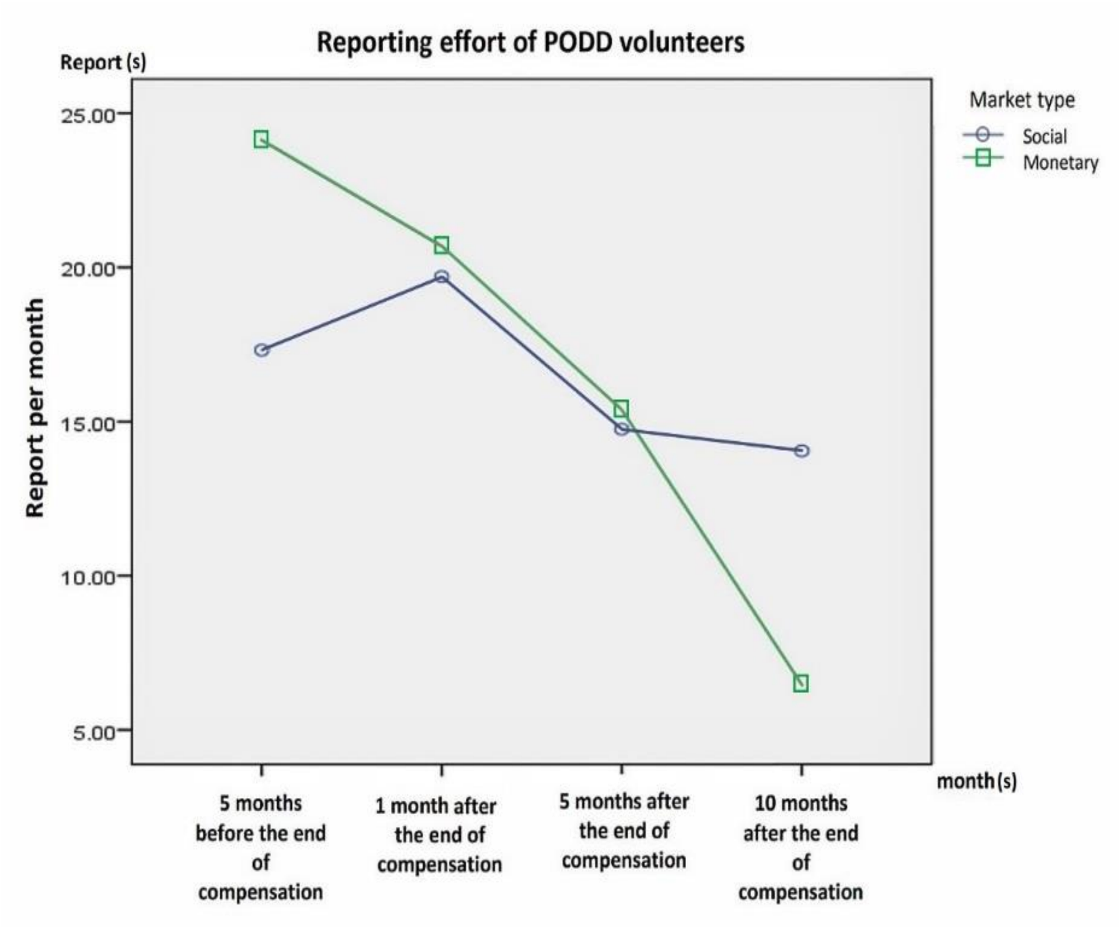

Figure 18 : Reporting effort of PODD volunteers in social and monetary groups

As shown in Figure 18, sub question 1, which is "during the period when compensation is paid, are the efforts of the volunteers in the monetary market group higher than those of the volunteers in the social market group?" was tested using a t-test to compare the reports of the two groups in Period 1. The results indicate that the average number of reports of the monetary group were 24.146 reports per month, while that of the social group was 17.32 reports per month (Table 23). During the time in which volunteers in the monetary group were paid, the monetary group's effort was significantly higher than that of the social group, the *p*-value, $p = 0.032$ (Table 23). Therefore, the first assumption was confirmed by these results**.** It means that during the period when compensation is paid, the efforts of the volunteers in the monetary market group is higher than those in the social market group due to the impact of the monetary incentive.

Then sub question 2, which is "do the volunteers' efforts in the monetary market group decrease at the end of the payment period, but the efforts of the volunteers in the social market group do not decrease over the same period of time?" was tested using the RM ANOVA. The results indicated that the reports of the monetary group were found to have a statistically significant decreasing trend, $F_{3,13} = 25.512$, $p < 0.001$ (Table 24). The descriptive statistics in Table 23 indicated the decreasing trend of the monetary group's reports. Moreover, the results indicated that there were no significant differences of reporting effort in the social group throughout the experimental period, $F_{3,13} = 2.001$, the *p*-value, $p = 0.164$ (Table 24). The second assumption was therefore confirmed by these results**.** This means that the volunteers' efforts in the monetary market group decreased at the end of the payment period, whereas the efforts of the volunteers in the social market group did not decrease over the same period of time.

Table 23: Comparing social and monetary groups in periods 1 to 4 by *t*-test

	Social group n = 5		Monetary group n = 12		*t*- test		
	Mean	SD	Mean	SD	t	df	p-value
Period 1	17.32	7.88	24.15	4.23	-2.36	15	.032*
Period 2	19.70	4.94	20.7	7.09	-.285	15	.779
Period 3	14.75	7.03	15.36	9.81	-.128	15	.900
Period 4	14.05	4.78	6.46	4.92	2.92	15	.011*

Source: Calculation

* ($p < 0.05$)

Table 24: The result of the repeated measurement ANOVA test between social and monetary groups

Group		Value	F	p-value
Social group	Pillai's trace	.316	2.001	.164
	Wilks' lambda	.684	2.001	.164
	Hotelling's trace	.462	2.001	.164
	Roy's largest root	.462	2.001	.164
Monetary group	Pillai's trace	.855	25.512	.000**
	Wilks' lambda	.145	25.512	.000**
	Hotelling's trace	5.887	25.512	.000**
	Roy's largest root	5.887	25.512	.000**

Source: Calculation
** ($p < 0.001$)

Finally, sub question 3, which is “do the volunteers in the monetary market group perform less well compared to the social market group in the long-term after the compensation has been terminated?” was tested using the t-test to compare the reporting of the two groups in Period 4. The results indicated that after the compensation was terminated for 10 months, the monetary group demonstrated significantly lower reporting effort than the social group, the *p*-value, $p < 0.05$ (Table 23). The average reporting effort of monetary group was 6.458 times per month, while the result of the social group was 14.05 times per month (Table 23). Thus, the third assumption was also confirmed by these results. This means that the volunteers in the monetary market group perform less well compared to the social market group in the long-term after the compensation has been terminated.

The following can be stated as a brief preliminary summary concerning this section of the PODD reporters’ behavior:

(I) The monetary market can increase the effort of the reporter until the monetary incentive is terminated. During the payment period, the monetary market has a higher impact on the reporter’s effort than the social market.

(II) After the payment was terminated, the effort of the reporters in monetary market decreased over time. This means that the monetary market has no power to keep the effort at a high level when there is no monetary incentive in exchange. On the other hand, the social market can keep the effort of the reporters at the same level. This means that the social market is more effective than the monetary market in the long-term without a monetary incentive.

(III) In the long-term, the reporters in the monetary market could not return to the social market. This means that when the reporters were put into the monetary market, it took longer than 10 months to bring them back to the social market. When social markets and monetary markets confront each other, social markets will disappear for a long time.

(IV) The standard labor model of economics cannot be used as an explanation in this study, because the effort of the reporters did not immediately decrease to zero after the payment was terminated, which means that the reporters spent their effort even though they no longer received payment. This study found that monetary markets have a negative impact in the long-term after 10 months of the terminated payment. However, the behavior of the reporters in the monetary market cannot be fully explained by the standard labor model of economics or the monetary market. It seems to be in between the monetary market and social market because the effort after the terminated payment was not zero and not at the same level as the social market in the long-term.

4.3 Farmers' behavior on animal health reports

This section is an analysis of the variables which impact on the farmers' reporting behavior of animal health. There are 5 variables in the logit model: livestock income, optimistic bias, farming experience, education, and gender. However, the optimistic bias in this study is indirectly calculated by the preventative behavior, actual risk, and expected risk. The data in the model was collected by the PODD project in 2015. The results in this section are divided into two subsections. The first subsection is descriptive statistics and the second subsection is the logit model.

4.3.1 Descriptive statistics of farmers’ report behavior

The descriptive result in table 25 demonstrates four preventative behavior variables. First, the animal diseases update mean value is 3.081 (SD = 1.49). Second, the use of required vaccines mean value is 2.739 (SD = 1.718). Third, the livestock health check mean value is 3.421 (SD = 1.344). Finally, the farm cleaning mean value is 3.439 (SD = 1.258). The maximum and minimum values of these four variables are 4 and 0 in order. The average values of these four variables are presented in percentage of the farmers’ expected risk of animal diseases. The mean value of the farmers’ expected risk of animal diseases is .792 (SD = .256). The data from the PODD project demonstrates that the mean value of actual risk of animal diseases is .217 (SD = .157). The optimistic bias variable is calculated from the actual risk of animal diseases minus the farmers’ expected risk of animal diseases. The mean value of the optimistic bias is -.575 (SD = .372).

The preliminary interpretation following these results is that the preventive behavior of farmers is at a high level (80%). Usually, they update the information about animal diseases, use the required vaccines on their farms, check animal health, and clean their farms. The result of high levels of preventive behavior refers to the high expected probability of animal disease infection on their farms. On the other hand, the actual probability of animal disease infection on their farms is lower than their expectation. That is the reason why most of farmers have no optimistic bias (the mean values is negative).

Table 25: Mean and standard deviation of the variables in the calculation of farmers' expected risk and the optimistic bias (n = 467)

Variable	Mean value	Standard deviation
Animal diseases update	3.081	1.49
Use of required vaccines	2.739	1.718
Livestock health check	3.421	1.344
Farm cleaning	3.439	1.258
Farmers' expected risk of animal diseases	.792	.256
Actual risk of animal diseases	.217	.157
Optimistic bias	-.575	.372

Source: Calculation

Table 26: Mean and standard deviation of independent variables (livestock income, optimistic bias, farming experience, and farmer's education) in logit model

Variable	Mean value	Standard deviation
Livestock income (LINC)	43.54	75.091
Optimistic Bias (OB)	-.575	.372
Farming experience (Farm_Exp)	12.588	10.711
Farmers' education (Edu_years)	7.212	3.393

Source: Calculation

Table 26 shows the descriptive statistics of the quantitative variables in the model. The First quantitative variable is livestock income. The mean value of livestock income is 43.54 $ per day and the standard deviation is 75.09. The second quantitative variable is the calculated optimistic bias of farmers and the value is between -1 to 1. If the value is positive, this demonstrates optimistic bias on the part of the farmers. On the other hand, the negative value demonstrates no optimistic bias on the part of the farmers. In case of zero value, this means that the actual risk of farmers is equal to expected risk of the farmers. The negative mean value demonstrates that most of farmers have no optimistic bias. It shows the perfect risk evaluation of farmers and also no optimistic bias in this case.

For example, in the event that a farmer has an optimistic bias, he will have low preventive behavior, because he believes that the probability of animal disease infection on his farm is lower than for other farmers. In this case, the expected risk of the farmer decreases because of the impact of optimistic bias. When we calculate the optimistic value in this case, it will be a positive value, because the actual risk is higher than their expected risk. On the other hand, in the case of a farmer who has no optimistic bias, he will have a high level of preventive behavior, because he believes that the probability of animal disease infection in his farm is equal or higher than for other farmers. In this case, the expected risk of the farmer does not decrease by the optimistic bias. When we calculate the optimistic value in this case, it will be an equal or negative value because the actual risk is equal or lower than their expected risk.

The third quantitative variable is the farming experience of farmers. The unit for this variable is years of work on the farm. The result shows the average farming experience is 12.59 years. The last quantitative variable is the number of years of farmers' education. The average of years of education is 7.21 years.

Table 27: Frequency and percentage of the gender variables in the logit model

Variable	Value	Frequency	Percent
Gender	male	200	42.8
	female	267	57.2
	total	467	100.0

Source: Calculation

Table 27 shows the descriptive statistics of a qualitative variable in the model. In this model, there are two values for the gender variable (male and female). The frequency of males is 200, which is 42.8 percent of the sample size. On the other hand, the frequency of females is 267, which is 57.2 percent of the sample size. The gender variable is one of the independent variables in the logit model.

The preliminary interpretation following the results is that most of the farmers have high livestock income (43.54 USD) compared to the minimum wage per day (12 USD). The standard deviation of the livestock income is very high because there are income variations for each kind of animal such as, dairy cow, backyard chicken, swine, and beef cow. In this study, most of farmers have no optimistic bias, which means than they demonstrate a high level of preventative behavior. Primary school is the largest education level of farmers, which means that they can read and write the Thai language to receive the animal disease information. Most of the farmers have been working for 7 years on the farm, which means that they are not new farmers. Moreover, in this study the number of males and females is almost equal (43:57).

4.3.2 Farmers' reporting behavior analysis by logit model

Table 28 is the multicollinearity test of the independent variables: livestock income (LINC), optimistic bias (OB), farming experience (Farm_Exp), and farmers' education (Edu_years). The result demonstrates that the tolerance values are around .672 - .884 and the VIF (Variance inflation factor) is around 1.131 – 1.488, which is lower than 3. This means that all of the independent variables in the model have no correlation to each other. There is no multicollinearity in the logit model.

Table 28: The result of multicollinearity test of independent variables (livestock income, optimistic bias, farming experience, and farmers' education)

Variable	Collinearity Statistics	
	Tolerance	VIF
LINC	.884	1.131
OB	.867	1.142
Farm_Exp	.674	1.485
Edu_years	.672	1.488

Source: Calculation

Table 29: Result of farmers' reporting behavior analysis by logit model

Variable	Coefficient	S.E.	Wald	df	Sig.	Exp(B)
LINC	.000	.000	.432	1	.511	1.000
OB	-3.388	.418	65.798	1	.000**	.034
Farm_Exp	.031	.011	7.569	1	.008**	1.031
Edu_years	.072	.037	1.897	1	.048*	1.075
Gender	-0.013	.227	.002	1	.955	.987
Constant	-2.364	.397	35.510	1	.000	.094
N =467, Nagelkerke R Square . =326, Overall percentage =71.3						

* $p < .05$, ** $p < .01$
Source: Calculation

In table 29, there are two variables which are not significant ($p > .05$): livestock income (LINC) and gender. This means that these two variables have no impact on farmers' reporting behavior. Only three variables in this model are significant at $p < .01$: optimistic bias (OB), education (Edu_years), and the years of farming experience (Farm_Exp). The value of the optimistic bias coefficient is -3.388. This means that the optimistic bias has a negative relationship with farmers' reporting behavior. The expected probability of animal disease reports of farmers with the optimistic bias is lower compared to farmers without the optimistic bias. In another word, farmers without the optimistic bias have a higher expected probability to report animal diseases. The EXP(B) value is .034, which means that when farmers have optimistic bias, the expected probability of animal disease reports decreases by 96%. In addition, the variable of farming experience has a positive relationship with farmers' reporting behavior (coefficient = .031). The Exp(B) value of the years of farming experience is 1.031. This means that when the years of farming experience increase, farmers' reporting behavior increases 3.1%. Another variable in this model is significant at $p < .05$: Education (Edu_years). The Exp(B) value of the years of farming experience is 1.075. This means that when the years of farming experience increase, farmers' reporting behavior increases 7.5%

We can write the following logit equation from this result:

$$Y = -2.364 + (-3.388)OB + 0.031Farm_{Exp} + .072Edu\_years$$

Table 30: Percentage of the accuracy of the prediction in the logit model

Observed	Predicted		Percentage correct
	No	Yes	
No	107	83	56.3
Yes	50	223	81.7
	total		71.3

Source: Calculation

Table 30 is the percentage of the accuracy of prediction in the logit model. The model can predict the probability of non-reporting at 56.3% and it can also predict the probability of reporting at 81.7%. In total, the model can predict the probability of non-reporting and reporting at 71.3. The apparent error rate is 28.7%.

The preliminary interpretation of these results is that there are three variables which can explain the animal disease reporting behavior of farmers. The first variable is the optimistic bias. It has a strong negative relationship with the farmers' reporting. If farmers have optimistic bias, their probability to report decreased by 96%. Moreover, the second variable is farming experience, which has a weakly positive relation to the farmers' reporting. If the number of years of farming experience increases, the probability of reporting increased by 3%. The last variable is the number of education years, which also has a weakly positive relation to the farmer's report. If the number of education years increases, the probability of reporting increases by 7.5%. On the other hand, the livestock income, which should be the main variable to explain, has no relation to the farmer's report. It is the very interring result and will be discussed in the next chapter. Finally, the gender variable also has no relation to the farmer's report.

In summary, there are three main results in this study. Firstly, that there is no impact of the PODD project on backyard chicken farmers in the period of one year. The project could not reduce the variable cost of farmers, which includes the cost of animal disease prevention and economic loss from animal diseases. It also demonstrates that, in the period of one year, the digital animal diseases surveillance system might not be enough to have an impact on farmers, because the system needs more than one year to increase the impact.

Secondly, the monetary market can increase the effort of the reporter until the monetary incentive is terminated. The monetary market has no power to keep the effort at a high level after there is no monetary incentive in exchange. On the other hand, the social market is more effective than the monetary market in the long-term, without a monetary incentive. In the long-term, the reporters in the monetary market could not return to the social market because monetary markets have a negative impact on the reporters. However, the result demonstrates that the behavior of the reporters in the monetary market cannot be fully explained by the standard labor model of economics or the monetary market. It seems to be in between the monetary market and social market, because the effort after the terminated payment was not zero and not at the same level as the social market in the long-term.

Thirdly, the animal disease reporting behavior of farmers can be explained by three factors. The first factor is optimistic bias, which has a strong negative relationship with the farmers' reporting. The second factor is farming experience, which has a weakly positive relation to the farmers' reporting. The last variable is the number of education years, which has also weakly positive relation to the farmers' reporting. On the other hand, the livestock income and gender factor have no relation to the farmers' reporting.

In general, the zero impact of the PODD project on backyard chicken farmers in the period of one year might be explained by the time period of the impact evaluation and the other two topics in this study. First, the PODD reporters were mostly motivated by monetary incentives, and the result demonstrates that their effort decreases over time. This can have an impact on the effectiveness of the system to control animal diseases in the area. When the reporter has low effort, the chance of no reporting of animal diseases increases. Second, most farmers have no optimistic bias. However, the one or two farmers who do have optimistic bias can be spreaders in their area because they have low preventative behavior and do not report the animal diseases on their farm. The PODD system cannot detect the animal outbreaks in the initial period so it cannot reduce the economic loss of the animal outbreak's impact. That is the reason why this study found that there is no the impact of the project on farmers' cost on the part of the reporter and farmer.

Chapter 5 Discussion and Conclusion

This chapter covers the discussions and conclusions from the statistical analysis and the results from the previous chapter. The discussions and conclusions are divided into three parts according to the research purposes. The first part is the discussions and conclusions of the economic impact of the PODD project on backyard chicken farmers. The second part is the discussions and conclusions of the motivation of the PODD reporters in the digital animal diseases surveillance system. Finally, the last part is the discussions and conclusions of the influential factors on farmers' reporting behavior of animal diseases. An overall and comprehensive discussion, including all relevant aspects is provided in the final subchapter.

5.1 Economic impact of the PODD project on farmers

1) Discussion

The assumption of the economic impact assessment of the PODD project on farmers is that the PODD system could reduce the impact of animal diseases on backyard chicken farmers by reducing the total variable costs. However, the results in the previous chapter demonstrate that there was no impact of the PODD project on backyard chicken farmers over the period of one year. This means that the variable costs for farmers, including the cost of animal disease prevention and economic loss from animal diseases, could not be reduced by the PODD system, contrary to the assumption. This is the reason why farmers could not perceive the benefit from the project in the reduction of their variable costs.

Compared to the traditional surveillance system, which is based on official reports from the health department or government agencies, the slowness of report receiving and reacting in each stage within the surveillance system is the problem with the traditional surveillance system, which can effect on official reports. The existing surveillance system can miss a case if the patient cannot seek out public health services or the health care providers make the wrong diagnosis or improperly submit a report. Moreover, the case can be lost through the failure of laboratory testing or if results are not confirmed. For these reasons, official reports can demonstrate underreporting of cases in the traditional surveillance system (Madoff & Li, 2014).

The PODD project used advanced technologies in the surveillance system. For example, GPS technology, smartphones, and internet were united and used jointly in the system to detect and share the information about animal diseases to the related partners. These advanced technologies can obviously improve the problem of slowness in the traditional surveillance systems. Moreover, the report receiving and reacting in each stage could be done on time. Therefore, the capability of the PODD surveillance system to reduce the impact of outbreaks should be better than with the traditional surveillance systems. Moreover, the PODD surveillance system should successfully complete the objective of an up to date surveillance system following the WHO definition, which is the "continuous, systematic collection, analysis and interpretation of health-related data needed for the planning, implementation, and evaluation of public health practice. Such surveillance can serve as an early warning system for impending public health emergencies; document the impact of an intervention, or track progress towards specified goals; and monitor and clarify the epidemiology of health problems, to allow priorities to be set and to inform public health policy and strategies." (WHO, Public health surveillance, 2019).

The objective of this study is to demonstrate that there are many positive ways in which advanced technologies can improve surveillance systems, such as new opportunities for integration between the growth of mobile phone networks and health services to create eHealth services (Vital Wave Consulting, 2009). Moreover, in the developing world, many organizations need effective data collecting to successfully meet their goals, such as economic development, food security improvement, and public health accessibility. Smartphone growth and technological progress are opportunities to improve the weaknesses in the current method of health data collection by using wireless technology (Anokwa, Hartung, Brunette, Borriello, & Lerer, 2009). However, the results in this study demonstrate that even though the PODD system has used advanced technologies to reduce the problem of slowness in the traditional surveillance system, this is not enough to reduce the impact of animal diseases on farmers over a period of one year. Following the WHO definition, the PODD system cannot successfully improve the efficiency of early warning. The PODD system still cannot successfully complete the objective of an up to date surveillance system following the WHO definition.

The weaknesses in this study are the limitations of livestock and economic data. There is only one kind of livestock in this study, which is backyard chickens. Other livestock might show a difference result. And, the total variable cost is only one economic variable in this economic impact assessment. Other economic variables might be used provide more detail, such as farm revenues or fixed costs (in case of renovation for animal diseases prevention). This should be improved in the follow up research.

2) Conclusion

In conclusion, the reason why there is no impact from the PODD system on farmers might be the short period of time of the impact assessment. In comparison with similar technology for human health in Thailand, due to the increase of technological capacity in Thailand and the disease outbreak hotspots in Southeast Asia, the smartphone application DoctorMe was launched in IOS and Android stores in 2001, which aimed to increase the participation of Thai people in disease surveillance systems and also collect health data. This application has been downloaded by 400,000 users over two years and the number of active users per month is 35,000, mostly in Thailand. (Susumpow, Pansuwan, Sajda, & Crawley, 2014). The population in Thailand is 64.55 million in 2003 (World Bank, Population, total - Thailand, 2020). In other words, the Doctorme app took two years to access 0.006 percent of the population. Thus, it can be concluded from this that the adoption rate of new technology for health in Thailand is very low. It is possible that in the period of one year, the digital animal disease surveillance systems might be not enough to have an impact on farmers, because the system needs more than one year for the technology to be adopted and the impact increased.

In this study, the results demonstrate that the opportunity for animal disease infections in the study area is 22%. Following this percentage, it is possible that in the period of one year, which was estimated to show the economic impact, there were no animal diseases or very few. In the results from farmer interviews in the study area, the farmers also reported that they are not affected by animal diseases every year, which correlates with the result of this study. This reason supports that the idea that a period of one year might be not enough to estimate the impact. So, the short time frame is another weakness in this study. Moreover, it is possible that some success factors might be disregarded, such as farmer's reporting behavior or the motivation of reporters, which are discussed in the latter section.

5.2. Motivation of reporters in digital animal disease surveillance systems

1) Discussion

In this study, we found that on-farm infectious animal diseases should be regarded as a major risk. They can cause financial losses and even insolvencies and they can spread to other farms and whole regions. With this background, this study focuses on the topic of motivation on animal health reporting in relation to the difference between monetary and social incentives (non-money). Data from the PODD project was used in this study. The initial results indicate that monetary incentive reduced the effort of the volunteers in the monetary group after the end of the payment period and in the long-term. On the other hand, the social incentive can maintain the effort of the volunteers in the social group throughout all periods of time in this study.

Monetary incentives are a successful means to increase effort as long as the payment is still in progress. The results from this study demonstrate that the monetary group had higher reporting efforts than the social groups during the payment period ($p < 0.05$). The level of reporting effort of the volunteers in the monetary market responded to the compensation they received. However, it was found that after the compensation was terminated, the reporting effort of the monetary group showed a decreasing trend ($p < 0.001$), whereas the social groups reported steadier efforts over time ($p = 0.164$). For all the periods, the effort of the monetary group tended to decline consistently.

At the 10-month interval after the end of payment, the effort of the monetary group had dropped by 73% compared with the payment period ($p < 0.001$), which was 54% lower than in the social group ($p < 0.05$). This means that when volunteers were forced to enter the monetary market, they could no longer return to the social market, even if our time frame was 10 months, while the social incentive was able to motivate the social group to produce reports during all periods of time without any compensation. Monetary incentives not only reduced the effort of the monetary group in the long term, but also became an obstacle for their return to a subsequent social market relationship.

Overall, it can be concluded that the long-term negative impact of the monetary market was that, even if we want the volunteers to return to the social market, it is not easy to do so.

In monetary markets, people lose their motivation when the compensation is not as high as their expectation. Using Fiske's 1992 theory, this is equivalent to the changes in social relationships, whether CS, AR, or EM, into the MP relationship (Fiske , 1992).

At the end of the compensation period, it was notable that the efforts of the monetary group did not vanish, which is the opposite of the economic standards prediction. The atmosphere of social activity may reduce the decline of efforts for a while, but eventually it was reduced by the impact of the monetary market. Moreover, after 10 months of compensation, the social groups had a higher reporting rate than the monetary groups. This does not align with the standard economics of the labor model (Sandel , 2012). Therefore, it can be concluded that the social activity in this study makes the result differ from the other study about social market and monetary market. In this study, the reporting effort of the PODD reporter did not lead to individual benefit but led to social benefit. For example, in the study of the fine in nurseries, the monetary market was used by nurseries to fine the parents who pick up their child later than the regulation. In this case, the benefit of payment was directly to the parents, which is individual benefit. Parents could pick up their child late as they wanted, because they paid for it. That is why later picking up behavior increased after the fines were introduced. Eventually, the nurseries stopped fining parents, but the parents' behavior did not change back to the social market in the long-term (Gneezy & Rustichini, 1970). However, in the case of the PODD reporter, their reporting effort does not directly benefit one person; it benefits the village or society. Their effort was increasing animal disease security not only for farmers in the area, but also the whole society, including their families. The differences between individual and social benefit might explain the PODD reporter's behavior, and why their effort did not disappear immediately after the payment was terminated. In other words, the efforts of the PODD reporters were in between the social and monetary incentive.

The exchange of effort instead of money can maintain the relationship in between social markets and monetary markets, but the relationship is more similar to social markets (Ariely, 2010). However, in this study, the PODD reporters were directly paid monetary incentives for their efforts. This is similar to the payment for animal disease reporting services. The efforts of the PODD reporters in this study demonstrate the dynamics of effort changing. Even though the behavior of the PODD reporters was more similar to social markets in periods 2 and 3, the behavior of the PODD reporters was more similar to monetary markets in the long-term.

The standard labor model of economics cannot be used to explain the behavior of the PODD reporters in this study, because the efforts of the reporters did not immediately decrease to zero after the payment was terminated, which means that the PODD reporters in the monetary group still spent put in effort, even though they received no further payment. Moreover, the standard labor model of economics cannot explain that why the efforts of the PODD reporters in the social incentive group (no wage) was higher than in the monetary group in the long-term. According to the model, when the payment or wage is zero, the effort should be zero as well. This study found that monetary markets have a negative impact in the long-term (10 months after the terminated payment). However, the behavior of the reporters in the monetary market cannot be fully explained by the standard labor model of economics or the monetary market.

The results from this study show a different dimension for understanding human motivation which is different from the rationality of economic assumption. On the other hand, the results confirm that monetary incentives are more influential than social incentives. Social incentives cannot be used for a long time after money incentives are used (Sandel , 2012 : Gneezy & Rustichini, 1970 : Ariely, 2010). However, there are two weaknesses in this study. The first is that the area of study in only in the center of Chiang Mai because of the technical limitations. The second is that the number of reports per month can represent the quantity of reports but it cannot represent the quality of reports. The result cannot demonstrate that the low or high number of reports equates to the report quality.

2) Conclusion

From the results, it can be concluded that the monetary markets are useful for motivating people in the short-term. Using monetary incentives has the positive effect of increasing effort as long as there is still compensation. At the same time, it drives people to consider the costs and benefits of their effort, forcing them to think more about self-interest rather than social benefits, while the volunteers in the social group work for their community without expecting any compensation in return. Moreover, from the results of this study, it can be concluded that the behavior of the PODD reporters seems to be in between the monetary market and social market because the effort after the terminated payment was not zero and not the same level as the social market in the long-term.

In conclusion, it can be expected that over time, volunteers were more motivated to work without payment compared with the situation when they receive money at the beginning and the payment is terminated later. It has been found that social incentives are more efficient than monetary incentives, at least in a sustainability sense. It's not only that they can motivate long-term efforts but also that they remain at a lower cost.

Nonetheless, the social market is very sensitive and can easily be challenged by the monetary market. Likewise, the volunteers' motivation is quite steady in the long term. It is driven by using the social markets rather than the monetary markets in the participatory surveillance system. This allows the participatory surveillance system developer to understand the whole picture better, especially the part played by the incentives for participants and stakeholders.

5.3 Farmers' optimistic bias on animal health reporting

1) Discussion

Of the five factors in the model, there are two factors that have no impact on farmers' decisions: farm income and gender. Farm income as an economic incentive and representation of opportunity and transaction cost has no impact on famers' reporting behavior. Whether farm income is high or low does not make a difference in the farmers' reporting behavior. It proves that the decisions of farmers are beyond the economic factors.

The economics prediction about adverse selection (asymmetric information) on farmers' reporting did not appear in this study. The prediction of farmers' behavior, that higher fixed cost farmers report less than lower fixed cost farmers (Wolf, 2006) cannot be used as an explanation in this study. In other words, the large scale farmers with high fixed costs and income did not report less or more than the small scale farmers. The farmers do not always calculate their expected cost of reporting or their fixed costs. This shows that farmers in Thailand are less rational than the economics assumption. Using this assumption to predict Thai farmers' behavior can lead to misunderstandings about their behavior and unsuitable policy making.

In addition, the gender factor does not affect the reporting decisions of the farmers. This means that whether they are a man or woman, there is no difference in reporting behavior. Gender is not a barrier for farmers' reporting, which positively relates with the result of Cueva, et al (2016). However, the results of the logit model contrast with the results of Kristjanson (2010), which report that women are more concerned about livestock health than men. And lastly, the number of education years has an effect on the reporting decision of the farmer. This means that more educated farmers report about animal diseases on their farm more than less educated farmers. Education systems may be the solution for this reporting problem. Moreover, the results demonstrate the low impact of farming experience on farmers' reporting decisions. The result contract with Adeogun, et al (2008).

The results demonstrate that the preventive behavior of farmers is at a high level (80%). The results of high preventative behavior refer to the high expected probability of animal disease infection on their farm. On the other hand, the actual probability of animal disease infection on their farm is lower than their expectation. That is the reason why most of the farmers have no optimistic bias. In this case, it can be concluded that the expected risk of the farmer decreases because of the impact of optimistic bias. When we calculate the optimistic value in this case, it will be a positive value because the actual risk is higher than their expected risk. On the other hand, in the case of a farmer who has no optimistic bias, he will have high preventative behaviors because he believes that the probability of animal disease infection in his farm equals or is higher than for other farmers. In this case, the expected risk of farmers does not decrease by the optimistic bias. When we calculate the optimistic value in this case, it will be an equal or negative value because the actual risk is equal or lower than their expected risk. This indirect method of optimistic bias moderation is the strength of this study. However, there are two weaknesses in this study. The first is the limited preventative behavior. It is possible that another factor might increase the precision of optimistic bias such as the level farm or hygienic standard. The second is the limited information of the actual animal disease risk because the official report of animal diseases did not represent the actual risk due to lots of lost cases or no reporting to the livestock department.

2) Conclusion

With an optimistic view, farmers may predict that they can handle the disease or it will quickly disappear from their farm they think that they will get more positive events than others; they believe that they are luckier farmers than the others. The average value of farmers' optimistic bias is -.58, from which it can be concluded that most of farmers have no optimistic bias on their farm about animal diseases.

From the results of the logit model, it can be concluded that only three variables have the impact on famers' reporting behavior: optimistic bias, education, and farming experience**.** This clearly shows that the optimistic bias has a high effect on farmers' reporting behavior. Just a one percent increase of this bias can reduce the probability of reporting by 96 percent. This is a higher impact than the other factor that was significant in this model. If farmers think that they have a lower risk than others, they do not report animal disease on their farm. Moreover, the second variable is farming experience, which has a weekly positive relation to farmers' reporting. If the number of years of farming experience increases, the probability of reporting is increased by 3%. The last variable is the number of education years, which also has a weakly positive correlation to farmers' reporting. It can be concluded that if the number of education years increases, the probability of reporting increases by 7.5%. On the other hand, the livestock income, which should be the main variable for an explanation, has no relation to farmers' reporting. Finally, the gender variable also has no relation to farmers' reporting.

5.4 General conclusion

Advanced technology can improve animal disease surveillance systems, which is a global threat, by focusing on human behavior as an important success factor for the systems. The digital animal disease surveillance system is a powerful instrument for reducing the impact of animal diseases and increasing food safety and security. However, the advanced technology still needs time to demonstrate the impact and to be adopted by users. Moreover, suitable motivation for the reports and awareness of farmers' animal disease reporting behavior cannot be neglected. The impact of the system might take longer than one year to appear. In terms of motivation, the monetary incentive can increase the effort of report but it comes at a high cost and has a negative impact in the long-term. While the social incentive costs less and is more effective in the long-term. Where farmers' animal disease reporting behavior is concerned, the optimistic bias is the highest influential factor on the farmers' reporting decisions, in an inverse correlation. An effective digital animal disease surveillance system can save not only human but also animal life. Moreover, it can reduce the time taken to control the disease and the economic losses. Further research should improve the digital animal disease surveillance system, developing a strong instrument for coping with animal disease outbreaks in the future.

Chapter 6 Policy recommendation and directions for further research

This chapter indicates a policy recommendation and directions for further research. The content of this chapter is divided into two parts. The first part contains the policy recommendation and benefits of this study, which is the explanation of how to adapt the knowledge discovered in this study to make policies, and the benefit of the study on the food security issue and the theory of decision making. The second part reflects on the limitations and directions for further research, which is the explanation of the limitation in each of the main study results and the suggestion for further research to fulfill the research gap and limitations of this study.

6.1 Policy recommendations and benefits of this study

6.1.1 Policy recommendations

According to the discussions and conclusions in this study, it is very important for the policy makers, government agencies, and surveillance system planners to have a holistic view of the surveillance process, which involves many participants. Here are some policy recommendations:

i) In regard to the time period of economic impact, i.e. it might take longer than one year for the adoption of a digital animal surveillance system. Advanced technology is not the only key to success, but time is still needed to demonstrate its impact;

ii) Awareness of the two kinds of motivation between social and monetary incentives. The monetary incentive requires a budget to increase reporters' efforts. When the payment is terminated, the effort will decrease over time and, after using a monetary incentive, there cannot be a return to using social incentives later. Social incentives should be an effective way to motivate reporters because the cost of social incentives is lower compared to monetary incentives.

iii) Improvement of farmers' education and farm experience to enhance farmers' animal diseases reporting behavior, such as training for farmers with little farming experience and educational support for farmers with a limited education;

iv) In regard to reducing the optimistic bias of farmers, such as by setting up an official notification on smartphones about the animal disease situation and the probability of infection.

6.1.2 Benefits and perspectives of this study

1) Benefits of the digital surveillance system

The benefit of this study is not only with respect to digital animal disease surveillance systems, but also human disease. This study aims to stimulate farmers to improve the digital surveillance system in a holistic way by reporting animal diseases they are confronted with using a smartphone application. This study points to the gap in behavioral understanding, which is the motivation of the reporters between social and monetary incentive, and the impact of the optimistic bias on the farmer's report behavior. The benefit can be adjusted to understand the pandemic problem, such as the Coronavirus disease 2019 or COVID-19. Many cases of low preventative behavior might be explained by the optimistic bias. The expected risk of COVID-19 infection and actual risk could explain the preventative behavior of people and improve the policy to better control the diseases. With this perspective, the study of optimistic bias could be developed to explore the solution to reduce the impact of the optimistic bias on COVID-19 preventative behavior.

2) Indirect benefit on food security enchantment

The benefit of this study is not only directed towards policy makers, but also towards increasing food security. The benefit of this study on the food security issue is indirect. The direct benefit is the improvement of planning and development of effective digital animal disease surveillance systems. An effective surveillance system can lead to the reduction of animals lost due to animal diseases and increase of food safety against zoonoses. The animal loss reduction effect on food security comes from increasing food supply stability. Moreover, the stability of the food supply can reduce the food price variation, which impacts on food security issues in the dimension of food accessibility by reducing the shock of food supply decreases. If there are food supply decreases due to animal diseases while the food demand remains at the same level, the food prices increase because the quantity on the demand side is higher than the quantity on the supply side. Food is a necessary product for everyday life. The elasticity of food is very low. This means that when the food price increases, the demand of food does not change. People still need food to maintain their lives. If we can make food prices more stable, this also means that the society can have greater food security, especially poor people who have a low income. In addition, with an effective animal disease surveillance system, the impact of zoonoses on food products decreases. This means the medication costs also decrease.

3) The theoretical benefits

The theoretical benefits, in this study, the results, demonstrate the contrast of the mainstream economic assumption, which assumes that people are economically rational beings. If reporters or farmers need to make a decision, which is an animal disease reporting decision in this study, they always make a decision based on a cost and benefit evaluation, and attempt to maximize their utility from the decision they made. This study demonstrates that the economically rational assumption cannot be solely used to as an explanation for individual behavior in the PODD project. It is rather a mixture of human cognitive bias which can be concluded.

For example, an adverse selection of farmers cannot make a correct prediction of the farmers' report behavior. The high fixed costs farmers did not report less than the low fixed cost farmers, even though their economic loss in case of animal disease control is higher. Another example, the standard economics of labor cannot explain why the PODD reporters still maintained their effort, even when the payment was terminated, or why the PODD reporter with social incentives were willing to work with zero wage.

The results demonstrate that there are other factors beyond maximizing the utility approach for making a decision, such as the incentive between social and monetary incentive, or the optimistic bias in their decision making. This study supports the argument of behavioral economics, which contrasts with the assumption of economically rational beings, to explain the decision making behavior.

4) Experimental approach improvement

In addition, this study extended the real situational experiment of behavioral economics in the area of the animal disease surveillance system, because the PODD project was the pilot project which was arranged in a real situation and not in an experimental setup. Participants in the project were real farmers and government agencies. In the concept of social and monetary markets, this study demonstrates the middle relationship between social and monetary markets because the activity of the animal diseases reporting does not benefit the individual as the other previous study, but is social beneficial. It can be a new area for understanding more about the monetary and social markets, because the social benefit can reduce the effect of monetary markets and compromise with the social markets for a while.

Moreover, in the moderation of the optimistic bias, the indirect calculation of optimistic bias was used by through the differentiation of farmer's expected and actual risk. This can be of benefit for the future research of optimistic bias, especially in the study area of animal disease and reporting behavior, because most of the optimistic bias research used the direct method.

6.2 Limitations and directions for further research

There are three main limitations in this study: time limitation, technical and budget limitation, and data limitation. This section gives an explanation of each limitation and the recommendation for future research.

6.2.1 Time limitation

The time period of the economic impact assessment is only one year based on the available data in the PODD project. It is possible that in 2015 - 2016, which was the evaluated the economic impact period of the PODD project, there were no animal diseases or outbreaks in the area. Moreover, it is possible that the PODD system needs a prolonged observation and data set to demonstrate the economic impact, as in the case of the smartphone application of Doctorme. The further research on the economic impact assessment should take this into consideration and set the time period of economic assessment for longer than one year. If it is possible to collect the data for 5 or 10 years, it might show more impact and the impact trend in each year.

6.2.2 Technical and budget limitation

This study was designed in the central part of Chiang Mai province because of the stability of the mobile signal. Moreover, it was a long-term study of the actual project which involves studying the real situation. It involved handling a large budget and the PODD project had to run the process on time. We could not find more samples to extend the sample size or use systematic sampling in this study. There are some challenges for future studies, such as differences in culture or geography, for comparing the impact of the social and monetary markets.

Because of the limitation, in this study, we focus only on the number of reports. Further studies could be extended to study the quality of reports in order to gain a greater understanding of the effect of monetary and social incentives on participatory surveillance systems. Moreover, the amount of monetary incentive might be changed to demonstrate the effect of the level of monetary on the effort. On the other hand, social incentives might be changed to another kind such as a gift or gratitude from the society or government agencies.

6.2.3 Data limitation

In this study, the economic impact assessment used only the total variable cost of backyard chicken farmers based on the available data on the PODD project. In addition, the farmers in this part of the study were a different group. It would be better if further research can collect the data from the same farmers in the form of time series data. To extend the knowledge, the further research should include more economic variables, such as livestock income, fixed costs (in cases of animal disease preventive renovation), and profit. Moreover, the impact assessment should be expanded to other kinds of livestock such as swine, diary, and beef cattle to study and compare the economic impact on other kinds of livestock. Finally, the economic impact in this study focused on the farmers' side. Further research should extend to the consumers' side or the environmental impact in order to estimate the impact on other dimensions.

In addition, there was limited preventative behavior data based on the PODD project. For the calculation of the expected risk of farmers in this study, four preventative behaviors were used (animal disease information update, use of the necessary vaccines, livestock health check, and farm cleaning). Further research could add more preventative behavior, which is suitable to the situation and area of study, to improve the accuracy of the expected risks of farmers, such as the hygienic standard.

The last data limitation was the actual risk of animal diseases in the study area. The official report of animal diseases did not represent the actual risk because of many lost cases or no reporting to the livestock department. In this study, the actual risk was calculated by the number of infected farmers and the number of all participating farmers. Further research could improve the actual risk calculation by data collection of all farmers in the area to estimate the actual probability. However, this is associated with greater time and budget consumption. In the beginning of this study (2016), there was an effort to do this, but the study area was announced to be a foot-and-mouth outbreak area. Unfortunately, the data collection of all farmers in the area was terminated by the outbreak regulations.

Summary

Zoonotic diseases are a continuously significant threat to global human and livestock health (causing millions of deaths yearly). Zoonotic diseases are not only a human health threat, but also a threat to animal health and welfare. Moreover, they have a high impact on national economies and food security due to productivity and production reduction. Expanding worldwide travel and global trade increases the importance of the threat of zoonotic diseases. The increase in global meat consumption contrasts with the escalating instability of the global meat market, which is affected by the increase of livestock densities, changes in production intensity, and slaughtering systems, causing animal disease outbreaks to spread widely. This study focuses on the animal disease surveillance system in Thailand as an important world meat exporter. In 2014, the Participatory One Health Disease Detection project, or PODD was set up by the veterinary inspection authorities to test animal epidemic control systems using smartphone applications in the Chiang Mai province in northern Thailand

The main objectives of this study are (i) to evaluate the economic impact of the PODD system on farmers by impact assessment (n = 177) (ii) to demonstrate the impact of monetary and non-monetary incentives on the PODD reporters by the experimental approach (n = 17), (iii) and to present the effect of the socioeconomic factors and behavioral bias on farmers' animal disease reporting behavior with the logit model (n = 467).

Focusing on the first objective, the results of this study concluded that there is an impact on the farmers. The technology alone cannot improve animal health security in the short-term. In the second objective, the results concluded that, in the case of the PODD reporters, the decision of using monetary incentives to motivate most of the PODD reporters has a negative impact in the long-term. Losing reporter motivation and effort reflected to the low efficiency of the digital surveillance system of PODD and no impact on farmers. Concerning In the last objective, the results concluded that the optimistic bias of farmers has a very high impact on their decision making about reporting animal diseases on their farm. Just one infected farm in the case of dairy milk farmers can spread the foot-and-mouth disease to other farms. The new digital animal health surveillance system alone is not enough to reduce the impact of animal diseases of

farmers. Suitable motivation for the reports and awareness of farmers' optimistic bias in animal disease reporting cannot be neglected in digital animal disease surveillance system improvement.

Overall, it can be concluded that the digital animal disease surveillance system is a powerful instrument for reducing the impact of animal diseases and increasing food safety and security. However, application of this advanced technology still needs time to demonstrate the impact and to be broadly adopted by users. In terms of motivation, the monetary incentive can increase the effort of report in the short run but it comes at a high cost and has a negative impact in the long-term. While the social incentive costs less and is more effective in the long-term. Where farmers' animal disease reporting behavior is concerned, the optimistic bias is the highest influential factor on the farmers' reporting decisions, in an inverse correlation.

Zusammenfassung

Zoonotische Krankheiten stellen eine anhaltend große Bedrohung für die Gesundheit von Mensch und Tier dar (sie verursachen jährlich Millionen von Todesfällen). Zoonosen stellen nicht nur eine Gefahr für die menschliche Gesundheit dar, sondern auch für die Gesundheit und das Wohlergehen der Tiere. Darüber hinaus haben sie aufgrund von Produktivitätseinbußen einen hohen Einfluss auf die Volkswirtschaften und die Ernährungssicherheit. Der Anstieg des weltweiten Reiseverkehrs und des globalen Handels erhöht die Bedeutung der Bedrohung durch Zoonosen. Die Zunahme des weltweiten Fleischkonsums steht im Gegensatz zur eskalierenden Instabilität des globalen Fleischmarktes, der durch die gesteigerten Viehbestandsdichten, Veränderungen der Produktionssyteme und der Schlachtsysteme beeinflusst wird, was zu einer weiten Verbreitung von Tierseuchenausbrüchen führt. Diese Studie konzentriert sich auf ein Tierseuchenüberwachungssystem in Thailand, einem weiltweit wichtigen Fleischexporteur. Im Jahr 2014 wurde von den Veterinärinspektionsbehörden das Projekt Participatory One Health Disease Detection (PODD) ins Leben gerufen, um Tierseuchenkontrollsysteme mit Smartphone-Anwendungen in der Provinz Chiang Mai im Norden Thailands zu testen.

Die Hauptziele dieser Studie sind (i) die Bewertung der wirtschaftlichen Auswirkungen des PODD-Systems auf die Landwirte durch eine Folgenabschätzung (n = 177), (ii) der Nachweis des Einflusses von monetären und nicht-monetären Anreizen auf die PODD-Berichterstatter durch einen experimentellen Ansatz (n = 17), (iii) und die Darstellung des Einflusses der sozioökonomischen Faktoren und Verhaltensverzerrungen auf das Meldeverhalten der Landwirte bei Tierseuchen mit dem Logit-Modell (n = 467).

Gemäß dem erste Ziel kamen die Ergebnisse dieser Studie zu dem Schluss, dass es eines Einflusses auf die Landwirte gibt. Die Technologie allein kann die Sicherheit der Tiergesundheit kurzfristig nicht verbessern. Bezüglich des zweiten Ziels, konnte gefolgert werden, dass die Entscheidung, PODD-Berichterstatter durch monetäre Anreize zu motivieren, langfristig negative Auswirkungen hat. Der Verlust der Motivation und des Einsatzes der Berichterstatter konnte auf die geringe Effizienz des digitalen Überwachungssystems des PODD zurückgeführt werden. Beim letzten Ziels

kamen die Ergebnisse zu dem Schluss, dass die optimistische Voreingenommenheit der Landwirte einen sehr großen Einfluss auf ihre Entscheidungsfindung bei der Meldung von Tierkrankheiten auf ihrem Betrieb hat. Nur ein infizierter Betrieb kann im Falle von Milchviehhaltern die Maul- und Klauenseuche auf einen anderen Betrieb übertragen. Das neue digitale Tiergesundheitsüberwachungssystem allein reicht dabei nicht aus, um die Auswirkungen von Tierkrankheiten der Landwirten zu verringern. Bei der Verbesserung des digitalen Tierseuchenüberwachungssystems dürfen die Motivation für die Berichterstattung und das Bewusstsein für die optimistische Voreingenommenheit der Landwirte bei der Meldung von Tierseuchen nicht vernachlässigt werden.

Insgesamt ist zu schlussfolgern, dass das digitale Tierseuchenüberwachungssystem ein wirksames Instrument zur Verringerung der Auswirkungen von Tierseuchen und zur Erhöhung der Lebensmittelsicherheit und -sicherheit darstellt. Allerdings wird noch Zeit benötigt, bis die Auswirkungen dieser fortschrittlichen Technologie abgeschätzt werden können und sie von den Anwendern adoptiert wird. Was die Motivation betrifft, kann der monetäre Anreiz die Motivation für die Berichterstattung erhöhen, aber er ist mit hohen Kosten verbunden und hat langfristig negative Auswirkungen. Der soziale Anreiz kostet hingegen weniger und ist auf lange Sicht wirksamer. Bezüglich des Meldeverhaltens der Landwirte auf Tierseuchen, ist die optimistische Verzerrung in umgekeheter Korrelation und der höchste Einflussfaktor auf die Meldeentscheidungen der Landwirte.

References

Aanensen, D. M., Huntley, D. M., Feil, E. J., Al-Own, F., & Spratt, B. G. (2009). EpiCollect: Linking smartphones to web applications for epidemiology, ecology and community data collection. *PLoS ONE, 4*(9), e6968. doi:10.1371/journal.pone.0006968

Adeogun, O., Ajana, A., Ayinla, O., Yarhere, M., & Adeogun, M. (2008). Application of Logit Model in Adoption Decision: A Study of Hybrid Clarias in Lagos State, Nigeria. *American-Eurasian Journal of Agricultural & Environmental Sciences, 4*(4), 468-472.

Animal Health in the World – Overview. (2019). Retrieved from World Organisation for Animal Health: http://www.oie.int/animal-health-in-the-world/

Anokwa, Y., Hartung, C., Brunette, W., Borriello, G., & Lerer, A. (2009). Open source data collection in the developing world. *Computer, 42*(10), 97-99. doi:10.1109/MC.2009.328

Ariely, D. (2010). *Predictably irrational: The hidden forces that shape our decisions.* New York: Harper Perennial.

Ariely, D. (2016). *Payoff: The Hidden Logic That Shapes Our Motivations.* New York: Simon & Schuster.

Bloom, E., de Wit, V., & Carangal San—Jose, M. J. (2005). *ERD Policy Brief NO. 42 : Potential Economic Impact.* Manila: Asian Development Bank.

Brownstein , J. S., Freifeld , C. C., Reis , B. Y., & Mandl , K. D. (2008). Surveillance Sans Frontières: Internet-based emerging infectious disease intelligence and the HealthMap project. *PLoS Med, 5*(7), e151.

Brownstein, J. S., Freifeld, C. C., & Madoff, L. C. (2009). Digital Disease Detection — Harnessing the Web for Public Health Surveillance. *N Engl J Med, 360*(21), 2153–2157. doi:10.1056/NEJMp0900702

Brugere, C., Onuigbo, D. M., & Morgan, K. L. (2017). People matter in animal disease surveillance: Challenges and opportunities for the aquaculture sector. *Aquaculture, 467*, 158-169.

Bruinsma, J. (2003). *WORLD AGRICULTURE : TOWARDS 2015/2030 AN FAO PERSPECTIVE.* London, UK: Earthscan Publications Ltd .

Burger, J. M., & Burns, L. (1988). The illusion of unique invulnerability and the use of effective contraception. *Personality and Social Psychology Bulletin, 14*, 264–270.

Cambodia Malaria Surveillance System. (n.d.). Retrieved December 20, 2019, from InSTEDD: http://ilabsoutheastasia.org/project/cambodia-malaria-surveillance-system/

Chaudhary, A. K. (2013). IMPACT OF BEHAVIORAL FINANCE IN INVESTMENT. *International journal of management research and business strategy, 2*(2), 85-92.

Cheng , M. (2017, May 3). *WHO Handbook for Journalists: Influenza Pandemic. World Health Organization.* Retrieved from World Health Organization: http://www.who.int/csr/don/Handbook_influenza_pandemic_dec05.pdf

Cheng, M. (2005, December 30). *WHO Handbook for Journalists: Influenza Pandemic.* Retrieved from World Health Organization: http://www.who.int/csr/don/Handbook_influenza_pandemic_dec05.pdf

Clement, J. (2018, Febuary 13). *Global number of YouTube viewers 2016-2021*. Retrieved 4 5, 2020, from statista: https://www.statista.com/statistics/805656/number-youtube-viewers-worldwide/

Country Report: Thailand. (2019, January). Retrieved from The Quality Assurance Agency: https://www.qaa.ac.uk/docs/qaa/international/country-report-thailand-2019.pdf?sfvrsn=ab3fc081_6

Crociata, A., Agovino, M., & Sacco, P. L. (2015). Recycling waste: Does culture matter? *Journal of Behavioral and Experimental Economics, 55*, 40-47.

Cueva, C., Iñigo, I.-O., Esther, M.-P., Giovanni, P., Marcello, S., Haihan, Y., & Vita, Z. (2016). Cognitive (ir)reflection: New experimental evidence. *Journal of Behavioral and Experimental Economics, 64*, 81-93.

Cummings, K. M., Becker, M. H., & Maile, M. C. (1980). Bringing the models together: An empirical approach to combining variables used to explain health actions. *Journal ofBehavioral Medicine, 3*, 123-145.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S., & Courbois, C. (1999). *Livestock to 2020: The next food.* Washington, DC: IFPRI/FAO/ILRI (International Food Policy Research Institute/FAO/International Livestock Research Institute).

European Commission. (2019, 18 11). *AGRI-FOOD TRADE STATISTICAL FACTSHEET*. Retrieved from European Commission: https://ec.europa.eu/agriculture/sites/agriculture/files/trade-analysis/statistics/outside-eu/countries/agrifood-thailand_en.pdf

Eurostat. (2020, June 12). *Glossary:Livestock unit (LSU)*. Retrieved from European Commission : https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Livestock_unit_(LSU)

FAO. (2002). *Animal diseases: implications for international meat trade*. Rome: FAO.

FAO. (2004). *Transboundary Animal Diseases. Assessment of socioeconomic impacts and institutional responses. Livestock policy* (Livestock Information and Policy Branch ed.). (M. J. Otte , R. Nugent , & et al, Eds.) Food and.

FAO. (2017, October 1). *Food Balance Sheets: Meat - Food supply quantity*. Retrieved from Food and Agriculture Organization of the United Nations: http://www.fao.org/faostat/en/#data/FBS

FAO. (2018, April). *Meat Market Review*. Retrieved from Food and Agriculture Organization of the United Nations : http://www.fao.org/economic/est/est-commodities/meat/meat-and-meat-products-update/en/

FAO. (2019, April 24). *FAO Agri-Environmental Indicators Update: Livestock Patterns*. Retrieved from Food and agriculture organization: http://www.fao.org/economic/ess/environment/data/livestock-patterns/en/

FAO. (2019, March). *Meat Market Review* . Retrieved from Food and Agriculture Organization of the United Nations: http://www.fao.org/economic/est/est-commodities/meat/meat-and-meat-products-update/en/

FAO, OIE, & WHO. (2019). *Taking a Multisectoral, One Health Approach: A Tripartite Guide to Addressing Zoonotic Diseases in Countries.* WHO.

Fiske , A. P. (1992). The four elementary forms of sociality: Framework for a unified theory of social relations. *Psychological review, 99*, 689-723.

Food and Agriculture Organization. (1999). *Manual on Livestock Disease Surveillance and Information Systems.* Retrieved from Food and Agriculture Organization: http://www.fao.org/3/x3331e/X3331E00.htm#TOC

Frey, B. S., & Gallus, J. (2016). Awards as non-monetary incentives. *Evidence-based HRM, 4*(1), 81-91. doi:10.1108/EBHRM-05-2015-0016

Gneezy, U., & Rustichini, A. (1970). A Fine is a Price. *Journal of Legal Studies, 29*. doi:10.1086/468061

Google Map (2017). Map of Thailand and Chiang Mai province. Download on 10.12.2017.

Graham , M., & Dutton, W. H. (2014). *Society and the Internet: How Networks of Information and Communication are Changing Our Lives.* Oxford Scholarship Online. doi:10.1093/acprof:oso/9780199661992.001.0001

Harris, A. J., & Hahn, U. (2011). Unrealistic optimism about future. *Psychol Rev, 118,* 135–154.

Helweg-Larsen, M., & Shepperd, J. A. (2001). Do Moderators of the Optimistic Bias Affect Personal or Target Risk. *Personality and Social Psychology Review, 5*(1), 74–95.

Helweg-Larsen, M., & Shepperd, J. A. (2001,). Do Moderators of the Optimistic Bias Affect Personal or Target Risk Estimates? A Review of the Literature. *Personality and Social Psychology Review, 5*(1), 74-95.

Heyman, J., & Ariely, D. (2004). Effort for payment. A tale of two markets. *Psychological Science, 15*(11), 787-93. doi:10.1111/j.0956-7976.2004.00757.x

Horby, P., Pfeiffer, D., & & Oshitani, H. (2013). Prospects for Emerging Infections in East and Southeast Asia 10 Years after Severe Acute Respiratory Syndrome. *Emerging Infectious Diseases, 19*(6), 853-860. doi:10.3201/eid1906.121783.

Integrating Mobile E-Health into Diabetes Management and Hypertension in Cambodia. (n.d.). Retrieved December 19, 2019, from InSTEDD: http://ilabsoutheastasia.org/project/integrating-mobile-e-health-into-diabetes-management-and-hypertension-in-cambodia/

Keusch , G. T., Pappaioanou , M., Gonzalez , M. C., Scott , K. A., & Tsai , P. (2009). *In Global Surveillance and Response to Emerging Zoonotic Diseases.* Washington, DC: National Academies Press.

Kristjanson, P., Waters-Bayer, A., Johnson, N., Tipilda, A., Njuki, J., Baltenweck, I., . . . MacMillan, S. (2010). *Livestock and Women's Livelihoods: A Review of the Recent. Discussion Paper No. 20.* Nairobi, Kenya: ILRI.

Larwood, L. (1978). Swine flu: A study of self-serving biases. *Journal of Applied Social Psychology, 8*, 283–289.

Lieberman, D. (2002). *Make Peace with Anyone: Breakthrough Strategies to Quickly End Any Conflict, Feud or Estrangement.* California: St. Martin's Press.

Lore, T. (2009). *Introduction to Participatory Epidemiology and its Application to Highly Pathogenic Avian Infl uenza Participatory Disease Surveillance - A Manual for Participatory Disease Surveillance Practitioners.* Regal Press Kenya Limited.

Madoff, L. C. (2004). ProMED-mail: an early warning system for emerging diseases. *Clin Infect Dis, 39*, 227–32. doi:PubMed: 15307032

Madoff, L. C. (2004). ProMED-mail: An Early Warning System for Emerging Diseases. *International Society for Infectious, 39*, 227-232. doi:10.1086/422003

Madoff, L. C., & Li, A. (2014). Web-based surveillance systems for human, animal, and plant diseases. *Microbiol Spectrum, 2*(1), OH0015-2012. doi:10.1128/microbiolspec.OH-0015-2012.

Maslow, A. (1943). A Theory of Human Motivation. *Psychological Review, 50*(4), 370-96.

McKenna, F. P. (1993). It won't happen to me: Unrealistic optimism. *British Journal of Psychology, 84*, 39–50.

Morgan, N., & Prakash, A. (2006). International livestock markets and the impact of animal disease. *Revue scientifique et technique (International Office of Epizootics), 25*(2), 517-528.

Morse, S. S., & et al. (2012). Prediction and prevention of the next pandemic zoonosis. *Lancet , 380*(9857), 1956-1965. doi:10.1016/S0140-6736(12)61684-5

O'Sullivan, O. P. (2015). The Neural Basis of Always Looking on the Bright Side. *Dialogues in Philosophy, Mental and Neuro Sciences, 8*(1), 11-15.

OIE. (2019, 12 10). *FAO, OIE, and WHO launch a guide for countries on taking a One Health approach to addressing zoonotic diseases*. Retrieved from World Organization for Animal Health: https://www.oie.int/en/for-the-media/pressreleases/detail/article/fao-oie-and-who-launch-a-guide-for-countries-on-taking-a-one-health-approach-to-addressing-zoonoti/

Our world in data. (2019, October 2). *Meat consumption vs. GDP per capita*. Retrieved from Our world in data: https://ourworldindata.org/grapher/meat-consumption-vs-gdp-per-capita?time=1990..2013&country=CHN+THA+VNM+MMR

Our world in data. (2019, October 2). *Meat consumption vs. GDP per capita*. Retrieved from Our World in data: https://ourworldindata.org/grapher/meat-consumption-vs-gdp-per-capita?country=USA+CHN+MEX+THA+OWID_WRL+ETH+BGD+AFG

Our World In Data. (2019, December 10). *Meat supply per person*. Retrieved from Our World In Data: https://ourworldindata.org/grapher/meat-supply-per-person?tab=chart&time=1961..2013&country=Oceania+Americas+Europe+OWID_WRL+Asia+Africa

Paul, M., & et al. (2010). Anthropogenic factors and the risk of highly pathogenic avian influenza H5N1. *Veterinary Research, 41*(3). doi:10.1051/vetres/2009076

Perloff, L. S., & Fetzer, B. K. (1986). Self-other judgments and perceived vulnerability to victimization. *Journal of Personality and, 50,* 502–510.

PODD. (n.d.). Retrieved December 10, 2019, from Opendream: https://www.opendream.co.th/project/podd

Rae, A. (1998). The effects of expenditure growth and urbanisation on food consumption in East Asia: a note on animal products. *Agricultural Economics, 18*(3), 291–299.

Revell, B. J. (2015). One Man's Meat … 2050? Ruminations on Future Meat Demand in the Context of Global Warming. *Journal of Agricultural Economics, 66*(3), 573–614. doi:10.1111/1477-9552.12121

Rushton, J., Viscarra, R., Guerna Bleich, E., & Mcleod, A. (2005). Impact of avian influenza outbreaks in the poultry sectors of five South East Asian countries (Cambodia, Indonesia,Lao PDR, Thailand, Viet Nam) outbreak costs, responses and potential long term control. *World's Poultry Science Journal, 61*(3), 491-514. doi:10.1079/WPS200570

Sandel , M. (2012). *What money can't buy: The moral limits of markets.* New York: Farrar: Straus and Giroux.

Santini, F., Ronzon, T., Dominguez, I. P., Enciso, S. R., & Proietti, I. (2017). What if meat consumption would decrease more than expected in the high-income countries? *Bio-based and Applied Economics, 6*(1), 37-56. doi:10.13128/BAE-16372

Sharot, T. (2011). The optimism bias. *Current biology, 21*(23), r941-r945.

Sheer, V. C., & Cline, R. J. (1994). he development and validation of a model explaining sexual behavior among college students : Implications for AIDS communication campaign. *Human Communication Research, 21*, 280–304.

Smolinski, M. S., Crawley, A. W., Baltrusaitis, K., Chunara, R., Olsen, J. M., Wójcik, O., & et al. (2015). Flu Near You: Crowdsourced Symptom Reporting Spanning 2 Influenza Seasons. *Am J Public Health, 105*(10), 2124-2130. doi:10.2105/AJPH.2015.302696

Smolinski, M. S., Crawley, A. W., Olsen, J. M., Jayaraman, T., & Libel, M. (2017). Participatory Disease Surveillance: Engaging Communities Directly in Reporting, Monitoring, and Responding to Health Threats. *JMIR Public Health Surveill, 3*(4). doi:10.2196/publichealth.7540

Snyder, C., & Nicholson, W. (2016). *Microeconomic Theory Basic Principles and Extensions* (12 ed.). Boston (MA): Cengage learning .

Steinfeld, H., Gerber, P., Wassenaar, T. D., Castel, V., Rosales, M., & de Haan, C. (2006). *Livestock's Long Shadow: Environmental Issues and Options.* Rome, Italy: Food & Agriculture Org.

Susumpow, P., Pansuwan, P., Sajda, N., & Crawley, A. (2014). Participatory disease detection through digital volunteerism: how the doctorme application aims to capture data for faster disease detection in thailand. *the 23rd international conference on World wide web companion* (pp. 663-666). NY: Association for Computing Machinery. doi:10.1145/2567948.2579273

Tilman, D., Balzer, C., Jason, H., & Befort, B. L. (2011). Global food demand and the sustainable intensification of agriculture. *Proceedings of the National Academy of Sciences of the United States of America, 108*(50), 20260-20264. doi:10.1073/pnas.1116437108

Venkiteswaran , G. (2019, December 20). *Re-thinking media reform in Southeast Asia: promoting a participatory approach*. Retrieved from Heinrich-Böll-Stiftung:

https://www.boell.de/en/2018/02/08/re-thinking-media-reform-southeast-asia-promoting-participatory-approach-more-democratic

Vital Wave Consulting. (2009). *mHealth for development: The opportunity of mobile technology for healthcare in the developing world.* Washington, DC: UN Foundation - Vodafone Foundation Partnership.

Vohs, K. D., Mead, N. L., & Goode, M. R. (2008). Merely activating the concept of money changes personal and interpersonal behaviour. *Current Directions in Psychological Science, 17*(3), 208-212.

WHO. (2011, April 30). *Influenza*. Retrieved from World Health Organization: https://www.who.int/influenza/human_animal_interface/avian_influenza/h5n1_research/faqs/en/

WHO. (2013, February 20). *Pandemic Influenza Preparedness Framework for the sharing of influenza viruses and access to vaccines and other benefits*. Retrieved from World Health Organization: http://www.who.int/entity/influenza/resources/pip_framework/en/index.html

WHO. (2017, March 3). *Influenza*. Retrieved from World Health Organization: http://www.who.int/influenza/human_animal_interface/avian_influenza/h5n1_research/faqs/en/

WHO. (2017). *Pandemic Influenza Risk Management: A WHO guide to inform and harmonize national and international pandemic preparedness and response.* Geneva: World Health Organization.

WHO. (2019, December 3). *Public health surveillance.* Retrieved from World Health Organization: https://www.who.int/topics/public_health_surveillance/en/

Wolf, C. (2006), "Livestock Disease Eradication Programs and Farm Incentives: The Case of Bovine Tuberculosis in Michigan", in D. Hoag, S. Koontz and D. Thilmany (eds.), The Economics of Livestock Disease Insurance: Concepts, Issues and International Case Studies, CABI press, Oxfordshire, UK, pp. 181-192.

Wolf, C. A. (2013). Livestock disease indemnity design: considering asymmetric information. *LIVESTOCK DISEASE POLICIES: BUILDING BRIDGES BETWEEN SCIENCE AND ECONOMIES* (pp. 127-137). OECD publishing.

World Bank. (2019, 11 18). *GDP (current US$) - Thailand, Singapore, Indonesia, Philippines, Vietnam*. Retrieved from The World Bank: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?end=2018&locations=TH-SG-ID-PH-VN&start=2008&type=points&view=chart

World Bank. (2020, September 9). *Population, total - Thailand*. Retrieved from The World Bank: https://data.worldbank.org/indicator/SP.POP.TOTL?locations=TH

World Health Organization. (2006). *Communicable disease surveillance and response systems: Guide to monitoring and evaluating*. Retrieved from World Health Organization: https://www.who.int/csr/resources/publications/surveillance/WHO_CDS_EPR_LYO_2006_2.pdf

World Organization for Animal Health. (2018). *Manual 5: Surveillance and Epidemiology*. Paris: OIE.

Yano, T., Phornwisetsirikun, S., Susumpow, P., Visrutaratna, S., Chanachai, K., Phetra, P., & et al. (2018). A Participatory System for Preventing Pandemics of Animal Origins: Pilot Study of the Participatory One Health Disease Detection (PODD) System. *JMIR Public Health Surveill*, *4*(1). doi:10.2196/publichealth.7375

Curriculum Vitae

Personal Details

Name	Tossapond Kewprasopsak
Address	104 Moo 5 Tumbon Mae Hia Muang, Chiang Mai, Thailand 50100
Email	dhossapond@gmail.com
Nationality	Thai
Date of birth	December, 24th 1988
Phone	+6688 251 9986

Academic education and professional experience

2007-2011	Bachelor of Sociology and Anthropology, Chiang Mai University, Thailand
2011	Research assistant in the Project of a Communal Irrigation System, Farming Productivity and Water Use Efficiency: The case of 'Muangfai' in Northern Thailand under responsibility of faculty of business, Charles Sturt University
2012	Research assistant in the Project of Rethinking the Quality Assurance in Sociology and Anthropology, Chiang Mai University, Thailand
2012 - 2013	Research assistant in the Project of Integrated Community-based Forest and Catchment /management through an Ecosystem Service Approach (CBFCM) under responsibility of Thai Pollution Control Department and The United Nations Development Programme (UNDP)
2012 - 2015	Master of Economics, Chiang Mai University, Thailand

2014 - 2015 Research assistant in the Project of One Health Participatory Epidemiology: Participatory Animal Health Digital Surveillance–Effective one health model preventing pandemic at its source, Chiang Mai University

2015 - 2021 Doctorate degree in the PhD program of Global Food Security with the major of Behavioral Economics, (Dr. sc. agr), University of Hohenheim, Stuttagrt/Germany

Relevant awards and fellowships

2015 FSC Excellence PhD Scholarship, University of Hohenheim, Germany

Thesis:

Irrational Economic Decision Behavior for Choosing Major in Higher Education, MSc. (Econ.), Chiang Mai University

Presentations at academic conference

2015 Irrational Economic Decision Behavior for Choosing Major in Higher Education in the 9th National Conference of Economists, Kasetsart University, Thailand, January 11th, 2015

2017 Approaches of young scientists from FSC, University of Hohenheim and the Center for Development Research (ZEF), University of Bonn in World Food Day Colloquim 2017, University of Hohenheim, Germany, October 19th, 2017

Affidavit

Declaration in lieu of an oath on independent work
according to Sec. 18(3) sentence 5 of the University of Hohenheim's Doctoral Regulations for the Faculties of Agricultural Sciences, Natural Sciences, and Business,
Economics and Social Sciences

1. The dissertation submitted on the topic
   Behavioral Economic Impact on Animal Health Surveillance System in Thailand
   is work done independently by me.
2. I only used the sources and aids listed and did not make use of any impermissible assistance from third parties. In particular, I marked all content taken word-for-word or paraphrased from other works.
3. I did not use the assistance of a commercial doctoral placement or advising agency.
4. I am aware of the importance of the declaration in lieu of oath and the criminal consequences of false or incomplete declarations in lieu of oath.

I confirm that the declaration above is correct. I declare in lieu of oath that I have declared only the truth to the best of my knowledge and have not omitted anything

Stuttgart, November 2020 Tossapond Kewprasopsak