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Economic Impact Evaluation of Livestock Research Investments in Thailand

Kampanat Vijitsrikamol[1]

Assistant Professor, Department of Agricultural and Resource Economics, Faculty of Economics, Kasetsart University, Bangkok, Thailand[1]

ABSTRACT— The Thai government has been heavily supporting Thailand's livestock research projects for many years. Indeed, 4,046 projects were funded in the years 2008-2017 with a budget totaling more than 1.8 million THB (present value, 2008 as base year with 5% discount rate). The projects sought to find solutions to specified problems and to recommend sustainable development innovations to stimulate growth within Thailand's livestock industry, often with domestic and international dimensions: animal feed and health, economic and commercial trade policies, logistics and supply chain infrastructure, and epidemic prevention and management. This study undertook to evaluate the economic impact and overall value of Thailand's livestock research projects, focusing on the academic and economic impacts of the projects over the past recent decade, 2008-2017. Primary data were collected from several field surveys and interviews of researchers, users, and related stakeholders. Secondary data were obtained from the National Research and Innovation Information System (NARIIS), the National Research Council of Thailand (NRCT). Changes in economic surplus was primarily used to evaluate the economic impact, by applying NPV, BCR, and IRR indexes. The study's research using scholarship citation databases revealed that Thailand's livestock research projects, during this period, were increasingly published and cited in highly regarded international academic journals, but in recent years, to a lesser extent in Thai scholarly research journals. This is likely related to increasing interest and awareness internationally about the growth and innovation in Thailand's livestock industry. To assess the economic impact of the funded research projects, this study selected eight projects that were regarded as particularly successful; these projects have prompted practical implementations and led to notable beneficial commercial, economic, or environmental impacts. These economic and socio-environmental outcomes illustrate the potential benefits and justify the investments that have made in Thailand's livestock research. Consequently, the Thai government has begun to track the management of livestock research funds and projects even more thoroughly. Overall, the analysis of the data indicates that Thailand's investment in livestock research has strengthened the competitiveness of the Thai livestock industry; furthermore, the policy reforms and technical innovation fostered by the research has facilitated operational aspects of even small and mid-size livestock entrepreneurs and enterprises, enabling them to perform well in domestic and international markets.

KEYWORDS: Research impact, Research investment, Impact evaluation, Livestock, Thailand.

1. INTRODUCTION

The livestock industry in Thailand is highly profitable and is continuing to grow every year. This has been due in large part to an increase in population and the consequent increase in demand, but there has also a shift to more meat consumption per household. Recent data indicates that 95.78% of the Thai population consume meat and related products; indeed, 31.98% of the Thai population consume meat daily [12]. The data reveal that domestic consumption behavior relates directly to a Thai family's household budget—average expenditure per household for meat and meat products totaled 352,617 THB in 2016. On an international scale, in that same year, 127,930,895 kilograms of livestock products and processed meat (value 13,707,062,470 THB) were exported from Thailand [5], [6]. The major trading partners for livestock product

exports are Japan, the European Union, and the United Kingdom. Although these importers impose strict food safety and health inspections and apply rigid guidelines for imported goods, they readily received Thailand's exports, which provides some testament to the reliability of Thai livestock export products. These successes can be attributed to the Thai government's concerted efforts to emphasize the importance of the livestock industry, as evidenced by the type of hefty research, which often has focused on critical industry support mechanisms: supply chain infrastructure, development of farming methods and systems that meet international health and food safety standards, development of disease control technologies, and increasing competency support intended to improve Thailand's competitiveness in the international marketplace. This sector has performed well due to the know-how and practical knowledge that has been gained from rigorous research in a wide array of agricultural aspects of the livestock industry—spanning animal breeding and husbandry, livestock disease control, agro-environmental conservation topics, animal food and crop management, logistics infrastructure, and even international trade policies.

Succinctly, research has been the foundation of the economic success of Thailand's livestock industry. The generous budgets allocated for national animal research projects have provided a range of benefits that have promoted socioeconomic development in the nation. The most notable developments include the general base of knowledge, and resulting innovation, that has led to the formulation of beneficial economic and business development policies in both public and private sectors. These initiatives have raised the awareness of research departments of universities, commercial enterprises, and scholarship/research grant providers, regarding livestock issues in Thailand, and these entities have also supported efforts to innovate and to find creative, viable ways to enhance the sustainability development of the nation's livestock industry. In just one decade (2008-2017), the Thai government supported 4,046 livestock research projects with a total value of 1,788 million THB to elevate the income potentials for the Thai livestock industry. Between 2013-2017, the number of research projects and their budgets increased significantly—more than double in just four years. In this period (2013-2017), the cumulative national research budget was 800 million THB (Figure 1). The funding provided by these funding sources was intended to address specific shortcomings and needs within the livestock industry and to promote the industry's development. Thus, the evaluation analyzed budgets allocated to each research project and its actual outcomes, using key criteria: consistency, economic efficiency, effectiveness, and sustainability [14].

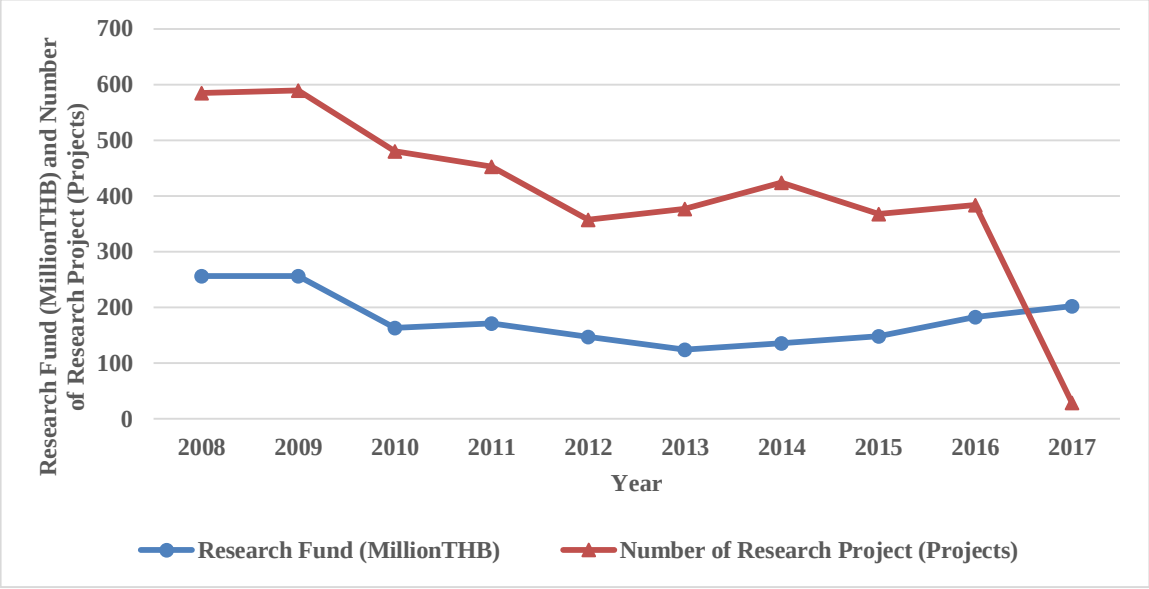

Figure 1. Livestock research budget allocation, 2008-2017 [13] The discount rate for the research budget is 5% (base year 2008).

The focus and topics studied by the livestock research projects that the Thai government supported over the past ten years has varied widely, but there were mainly eight topics that focused on economic livestock issues: fish, beef cattle and buffalo, shrimp, poultry, dairy cattle, swine, goats and sheep, and insects/pests. These projects examined facets of the livestock industry that continue to have widespread economic impact. They provided the base of knowledge and experience that greatly facilitated raising livestock profitably in Thailand and introduced uses of technology that match global technological standards. For the period of this study (2009-2017), research involving clown fish (in high demand with high value for aquariums but hard to raise outside its natural coral reef habitats) ranked first in terms of the number of projects and size of budgets (1,259 projects, 420.93 million THB budgeted); beef cattle and buffalo research ranked second (709 projects, 374.66 million THB budgeted; and shrimp research ranked third (534 projects, 321.92 million THB budgeted (Figure 2).

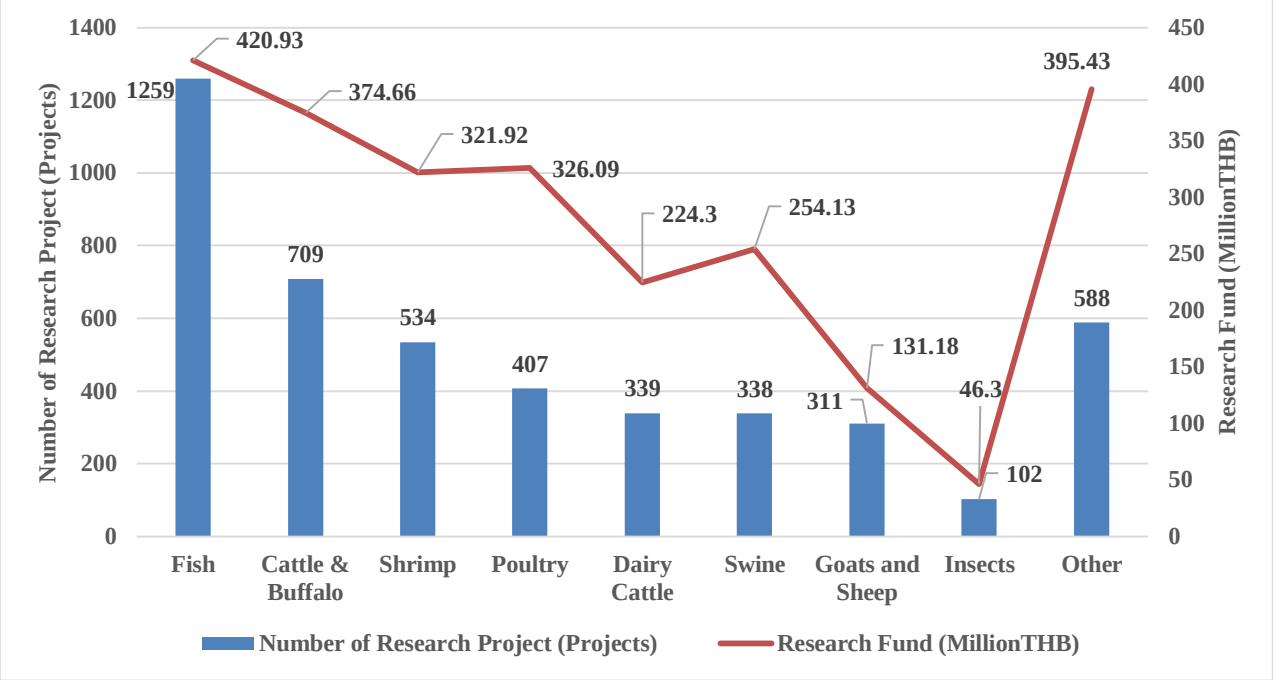

Figure 2. Numbers and budgets of livestock research by animal types, 2008-2017 [13] The discount rate for the research budget is 5% (base year 2008).

The central question raised by research budget allocators is: "how can research budgets effectively create a positive economic change on national productivity?" This question is the core concern and appears in the impact evaluation of agricultural research organizations throughout the world [10], including Thailand.

However, previously there had not been a concrete research project that systematically evaluated the economic impact of the livestock research in Thailand, particularly on the distinct aspects that form this study: academic, economic, and environmental aspects. Indeed, this study stands out as the first research project that investigates and evaluates the impacts of the Thai livestock research. This study focused on the recent ten years, 2008-2017, because of the massive financial resources expended during this period. The goals were to examine, assess, and highlight the livestock research funded by the Thai government that has provided the most economic value, and specifically to provide guidance for future Thai livestock research.

2. Material and Methods

2.1 Data Collection

Two types of data were collected and used in this study:

(1) Primary data. Primary data were obtained from several field surveys and interviews of researchers, users, and related stakeholders (agriculturalists, farmers, agencies, or commercial enterprises who could use the research findings within their roles related to the facet of the research under study). These data were purposely used to evaluate the economic impacts of eight livestock research projects categorized into three different categories—commercial uses, epidemic mitigation, and species conservation and environmental preservation. The data were calibrated in terms of research adoption, changes in economic surplus, and life cycle of business and technology.

(2) Secondary Data. Secondary data were derived from three sources. The main data were retrieved from the National Research and Innovation Information System (NARIIS) [13] database (containing the data of 3,958 livestock research projects undertaken between 2008-2017), and databases managed by other related government departments (which collected data for 88 livestock research projects). In total, there were 4,046 livestock research projects, labeled in this study as "NRIIS+ database". This database was used to select high impact research projects.

The second source of secondary data was obtained from reputable research and scholarly citation databases that index both domestic and international publication—Scopus, Sciencedirect, and the Thailand Citation Index (TCI) [17], [18], [20], [23]. This data set was used to assess and display the academic impacts of the Thai livestock research.

The third source of secondary data was collected from the TEEB Valuation Database (The Economics of Ecosystems and Biodiversity), which was used for benefit transfer analysis.

2.2 Analytical Methodology

There were two parts of the analytical methodology:

(1) Academic impact analysis of the Thai livestock research relied on bibliometrics, which is a quantitative analysis of published works, based on the number of research projects and citations [4]. Research publications included peer-reviewed research scholarship published and cited in reputable academic journals [9] [15]. The data analyzed frequency of publication and citation of Thai livestock research over the past decade (2007-2018). The goals were to investigate the worldwide trends and the proportions of total publications and citations involving livestock research that were dedicated to Thai livestock research.

(2) Economic impact evaluation of the Thai livestock research involved either ex-post or ex-ante evaluation, used to analyze the economic impacts of selected livestock research projects. In total, eight livestock research projects from the NARIIS+ database were selected as case studies. The selection criteria comprised two aspects—high value of research budget and high socioeconomic value as rated by users and experts (Delphi technique). The eight research projects were classified and subdivided into three different categories, as illustrated in Table 1.

Table 1. List of selected Thai livestock research projects used to calibrate economic impacts

Livestock research categories	Titles of the projects

Commercial uses	(1) Establishment of Nutrient Composition of Dairy Cattle Feed in Thailand (2) Establishment of "Korat Meat Chicken" Strain for Small Farmers and Community Enterprise (3) Crocodile Blood Capsule: Industrial Revolution to the Healthcare Industry
Epidemic mitigation	(1) Development of recombinant 3ABC-based ELISA to differentiate vaccinated from FMDV-infected animals (2) Guidelines for preventing re-current outbreak of porcine epidemic diarrhea in Thailand (3) Stability, Survival and Transmission of Avian Influenza virus (H5N1) (4) Early Mortality Syndrome (EMS) in Thailand
Species conservation and environmental preservation	(1) Research and Development Program for Marine Beautiful Fish Breeding Technology: Anemonefishes

The economic impact evaluation used in the study sought to calculate "changes in economic surplus" derived from research target users. These changes occurred in form of social, economic, or environmental changes. Accordingly, the benefits from the research projects were compared under the basis of double differences: with versus without research projects and before versus after research projects. In other words, the counterfactual principal was emphasized in the evaluation [3]. In general, the economic impact evaluations were classified into three types, differentiated by timeframe: ex- ante, ongoing, and ex-post evaluations (as determined by the different evaluation timeframes and purposes). Ex-ante evaluation is normally used to prioritize the research funds. Ongoing evaluation is effective for monitoring a projects' progress and to set a framework to determine whether the project should proceed as planned or stop prior to causing further damage. Lastly, ex-post evaluation is used to assess the impacts upon completion of the research projects [10].

Most of the economic impact evaluations in this study involved either ex-post or ex-ante evaluations [11], [16], [19]. To measure the change in economic surplus, "cost-benefit analysis" (CBA) was used as the analytical tool to evaluate the economic impact [2], [8]. CBA can reliably and effectively measure the economic viability of the livestock research project investments in terms of net present value (NPV), benefit-cost ratio (BCR), and internal rate of return (IRR) (Table 2).

Table 2. Economic indicators of the research impact evaluation

Economic Indicator	Formula	Criteria
Net Present Value (NPV)	$NPV = \sum_{t=0}^{T} \frac{(B_t - C_t)}{(1+r)^t}$	NPV > 0
Benefit Cost Ratio (BCR)	$BCR = \frac{\sum_{t=0}^{T} B_t (1+r)^{-t}}{\sum_{t=0}^{T} C_t (1+r)^{-t}}$	BCR > 1
Internal Rate of Return (IRR)	$\sum_{t=0}^{T} \frac{(B_t - C_t)}{(1+IRR)^t} = 0$	IRR > r

Note: B_t = research benefits of year t (t= 0, 1, 2……, T)
C_t = research costs of year t (t = 0, 1, 2……, T)
r = discount rate (5% in this study)
T = total years of the evaluation timeframe

In addition to the CBA analytical tool, a "benefit transfer technique (BT)" [7] was used to evaluate the economic impacts of the research on species conservation and environmental preservation. Based on the BT,

the project entitled "Research and Development Program for Marine Beautiful Fish Breeding Technology: Anemonefishes" was selected for analysis and evaluation. The clown fish had two distinct benefits: increased monetary profits within the clown fish business, and better conservation and environmental preservation in fisheries that had otherwise suffered due to over-catching. The benefit transfer (BT) is an econometric tool that transfers beneficial outcomes from other similar studies to this study, based on estimated coefficients, adopted and adjusted to the study's unique influencing factors (such as ecosystem, climate and landscape, services from the ecosystem, and socioeconomic pattern of the selected areas of the study). The benefit value is then transferred into the value of the areas of interest by adjusting the currency and by constructing specific local variables via the following formula:

$$V_{pj}|Q_{pj} = V_{si}|Q_{si}$$

where the value (V_{si}) and context (Q_{si}) of the study area i, respectively, are used to evaluate the value (V_{pj}) of policy area j, under the context (Q_{pj}) of policy area j.

The data used to transfer the benefits to the study were referred from the TEEB Valuation Database (The Economics of Ecosystems and Biodiversity). This database is a collection of many ecosystem and biodiversity evaluation research projects completed in various countries. In this case, the TEEB Valuation Database contained 1,310 research projects that were calibrated into this study. Of these 1,310 projects, there was only one research project that matched the clown fish project in Thailand. This match was characterized by the aspects of coral reef and open ocean ecosystem with biocontrol. This project's raw data (currency and base year) was adjusted to the Thai baht and the same base year. After the BT process was completed, the value of the benefits was subjected to CBA analysis for further economic impact evaluation.

3. RESULTS AND DISCUSSION

3.1 Academic Impacts of the Thai Livestock Research

The analysis of the number of publications and citation gleaned from three different databases (Scopus, Sciencedirect, and TCI) from 2007-2017 revealed that the number of Thai livestock research studies that were published and cited increased significantly across the international platforms, Scopus and Sciencedirect. In Scopus, over the course of these ten years, Thai research publications were cited 99,660 times, derived from 7,243 journal articles. On average, the number of articles and citations grew annually by 9% and 18%, respectively (Figure 3). Similarly, the Sciencedirect database produced 20,627 citations derived 1,536 journal articles, with an annual average growth of 14% (articles) and 60% (citations) (Figure 4). This indicates that over the past ten years, scholarship regarding Thailand's research on livestock has become markedly more respectable and reliable among international researchers and publishers.

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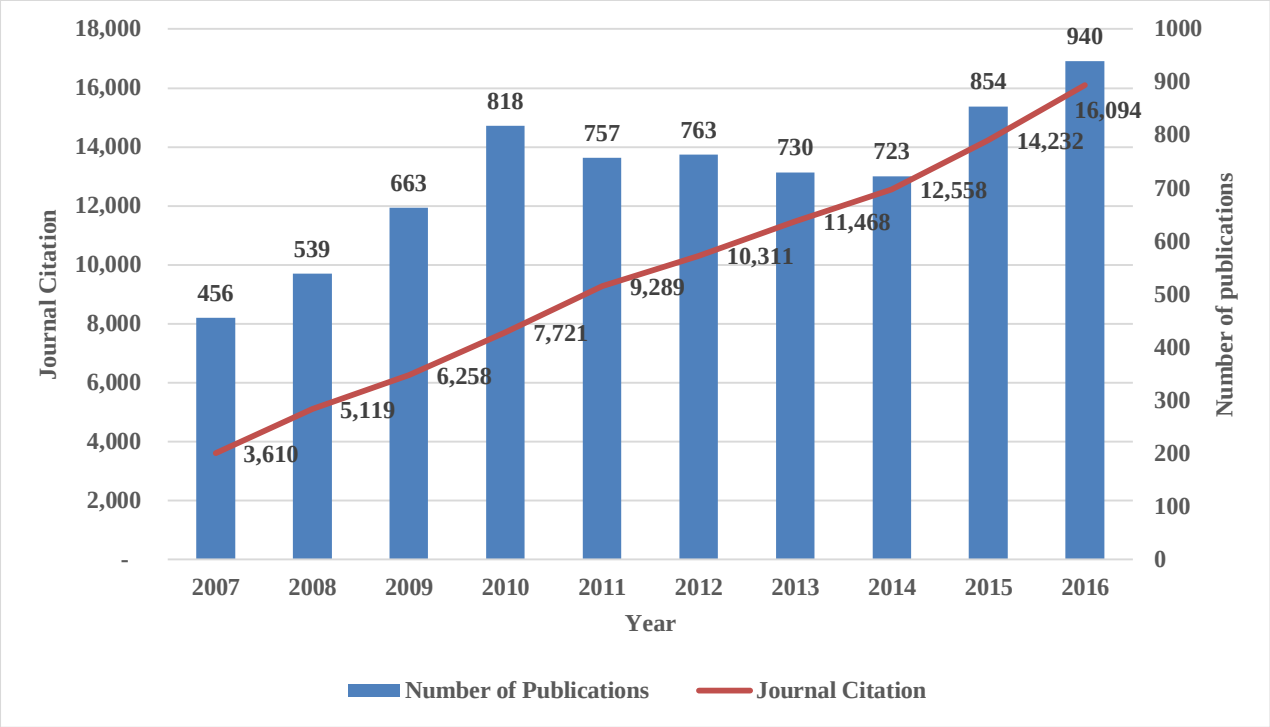

Figure 3. Thai livestock research publications and citations on Scopus database (2007-2017)

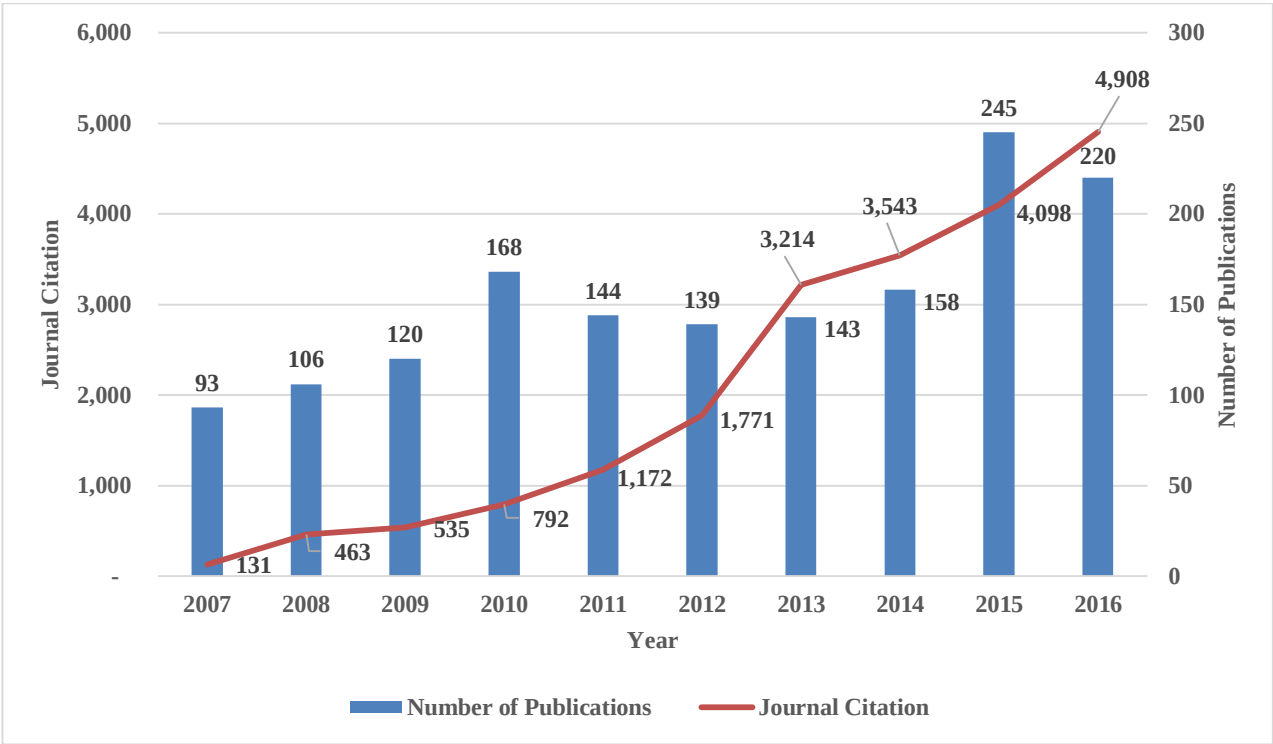

Figure 4. Thai livestock research publications and citations on ScienceDirect database (2007-2017)

On the other hand, based on the result of searches conducted in the TCI database, Thai livestock research fluctuated both in terms of the number of published articles and citations domestically. Over the past decade, the total number of citations was only 335, from 792 journal articles. Indeed, the number of citations in the most recent two years decreased drastically, as seen in Figure 5.

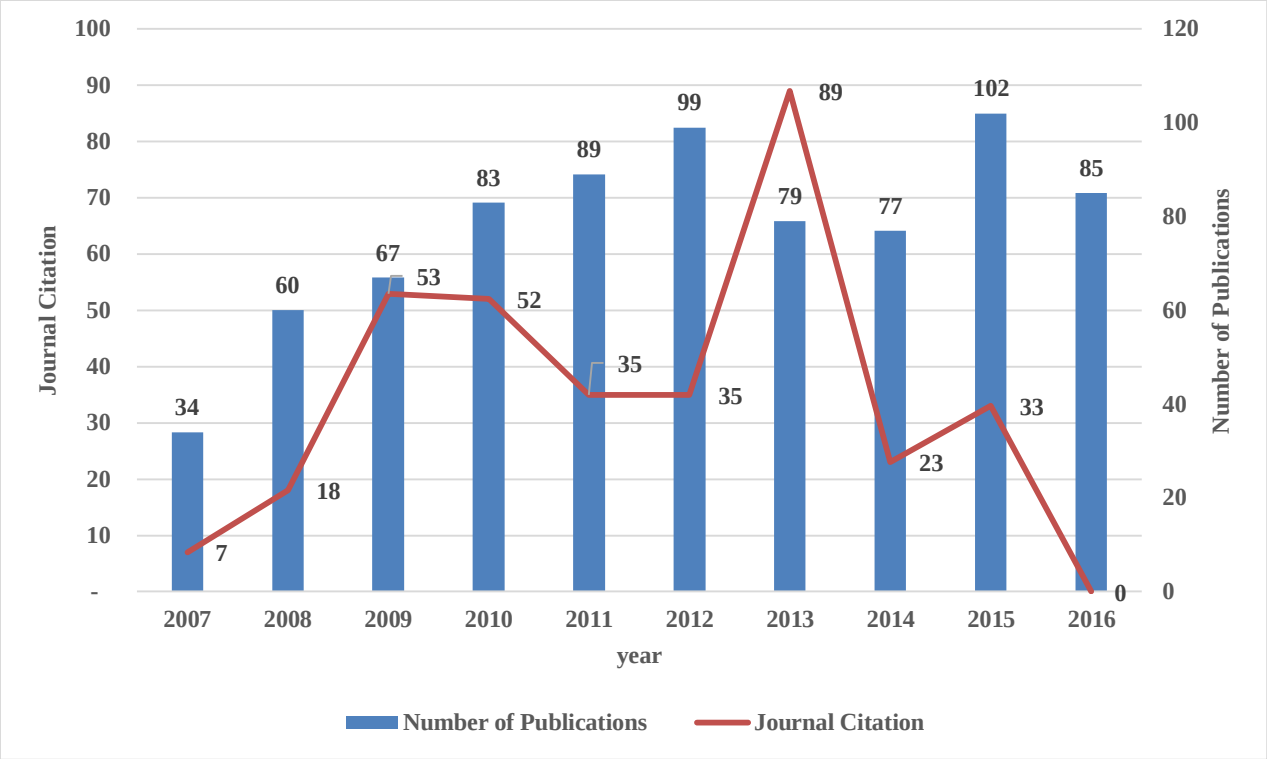

Figure 5. Thai livestock research publications and citations on TCI database (2007 – 2017)

Overall, the data collected from domestic and international scholarship citations platforms suggest that Thai researchers tend to publish more (and are thereby more frequently cited) on the international stage than domestically.

3.2 Economic Impacts of the Thai Livestock Research

The concept of research-to-impact pathway was the first step of the economic impact evaluation, and, as previously mentioned, eight livestock research projects were selected to represent the national economic impacts. The focus was on four components: research inputs, research output(s), research outcome(s), and research impact(s) [21]. Key factors that motivate researchers to focus their research and deliver valuable outcomes and impacts are knowing who the target research users are and what the research adoption process is most likely to be. Indeed, the targeted users can be differently grouped and have different needs; the users in this study were diverse—government livestock departments, commercial entrepreneurs, other researchers, farmers, policymakers, and other industry related stakeholders. The study found that there were strikingly different types of outputs. The commercial use livestock research delivered technological innovations that strengthened the market competitiveness of Thailand's livestock industry. The innovations included development of improved feed formula for dairy cattle, development of better breed of broiler chicken (with a well-articulated marketing plan), and breakthrough crocodile blood health supplement capsule. The economic impacts of these projects were considered in the context of incremental monetary profits compared to the users' status quo or compared to the situation before the innovations had taken place (with and without situation). This is known as an economic impact evaluation using counter factual conditions, which is derived from calculations reflecting changes in economic surplus.

The research outcomes of the epidemic mitigation research were demonstrated in a variety of forms: pharmacopoeia products or vaccine prototypes to prevent or relieve livestock epidemic, disease infection test kits, and farm management guidelines for epidemic prevention. The economic impacts were evaluated in

terms of decreases in monetary losses or damages after the measures were utilized compared to historic losses and damages from livestock epidemics. These economic impacts covered a wide array of variables linked to the national livestock supply chain. The research dedicated to species conservation and environmental preservation was initiated to enhance the development of the clown fish farming business, as a substitute to over-catching and removing this species from their natural habitats (coral reefs). The overall impacts can be categorized by two characteristics: economic impacts associated with incremental business gains (profits), primarily benefiting entrepreneurs, and environmental impacts associated with a decrease in biodiversity losses, such as over-catching species in their natural habitats (Table 3).

Table 3. Research-to-Impact pathway of selected Thai livestock research

Livestock type/ Selected research	**Inputs**		**Outputs**	**Outcomes**		**Impacts** (under counterfactual condition)
	Time Period	**Budget** (THB)		**Users**	**Changes**	
Commercial use livestock research						
Dairy Cattle Research: (1) Establishment of Nutrient Composition of Dairy Cattle Feed in Thailand	2017-2018 (1 year)	4,152,500	Dairy cattle feed formula	1) Dairy Cattle Cooperatives 2) Department of Livestock Development 3) Enterprises	First establishment of national guideline for dairy cattle feed formula	Incremental profit from dairy sales
Poultry Research (2) Establishment of "Korat Meat Chicken" Strain for Small Farmers and Community Enterprise	2009-2019 (10 years)	71,839,826	1) Broiler breed 2) Marketing plan for processed chicken meat	1) Broiler farmers 2) Slaughter units and meat processing entrepreneurs	Farmers, entrepreneurs, and consumers attain higher quality broiler	Incremental profits across supply chain of Korat broiler
Reptile Research (3) Crocodile Blood Capsule: Industrial Revolution to the Healthcare Industry	2006-2016 (10 years)	9,200,000	New health supplement products: crocodile blood capsule	Entrepreneurs	New health supplement products for entrepreneurs and consumers	Incremental profit for entrepreneurs from sales
Livestock epidemic mitigation research						
Beef Cattle and Buffalo Research (1) Development of recombinant 3ABC-based ELISA to differentiate vaccinated from FMDV-infected animals	2007-2013 (6 years)	9,157,500	FMD Test kits	Department of Livestock Development	Thailand can produce its own FMD test kits	1) Decrease in imports of FMD test kits 2) Increase in export of quality pork from Thailand
Swine Research (2) Guidelines for preventing re-current outbreak of porcine epidemic diarrhea Thailand	2010-2011 (1 year)	5,200,000	PED vaccine	1) Department of Livestock Development 2) Enterprises	At least 20% of porcine breeding stock is saved from PED	Decrease in mortality rate of piglets
Poultry research (3) Stability, survival and transmission of avian influenza virus (h5n1)	2004-2010 (6 years)	2,814,700	Database of avian influenza characteristi cs (focusing on resistance and transmission aspects)	1) Department of Livestock Development 2) Entrepreneurs 3) Farmers	Eradication of avian influenza epidemic in the Thai poultry industry	1) Decrease in economic loss in the poultry industry due to epidemic 2) Increase in poultry exports from Thailand

Prawn and shrimp research (4) Early Mortality Syndrome (EMS) in Thailand	2013-2017 (4 years)	50,512,458	1) EMS test kits 2) Guidelines for EMS-free shrimp farm management	1) Department of Livestock Development 2) Enterprises 3) Farmers	1) Decrease in shrimp mortality rate 2) Decrease in prevalence rate of EMS in shrimp	Decrease in economic losses from EMS for the shrimp industry
Species conservation and environmental preservation research						
Marine fishery research	2003-2005 (2 Years)	10,010,096	Complete clown fish	1) Major fish breeders	1) Guidelines for major and	Economic impact:
Livestock type/ Selected research	**Inputs**		**Outputs**	**Outcomes**		**Impacts** (under counterfactual condition)
	Time Period	**Budget** (THB)		**Users**	**Changes**	
(1) Research and development program for marine beautiful fish breeding technology: anemonefishes			aquaculture technology	2) Minor fish breeders	minor entrepreneurs farming fish 2) Decreased clow fish catch from natural resources	Incremental profit from clown fish business Environmental impact: Decrease in marine biodiversity losses

Livestock research has been generously supported and promoted by the Thai government in recent decades, and the research results have created distinctive, beneficial economic and environmental impacts. The eight research case studies selected for this study stood out economically (quantifiable value added) compared to rest of the livestock projects. Of the eight projects, only two of the research projects involved ex-ante evaluation, the rest underwent ex-post evaluation. The CBA in the forms of NPV, BCR, and IRR was executed to present economic impacts of the selected livestock research (Table 4).

As shown in Table 4, most of the eight selected livestock research satisfied the economic viability criteria (NPV>0, BCR>1, and IRR>r). The livestock epidemic mitigation research delivered the highest economic impacts, compared with the other two research categories. This outcome is not a surprise because of the tremendous national historic losses and damages caused by livestock epidemics. Moreover, these losses adversely affected a wide swath of associated stakeholders throughout the long market supply chain. In terms of commercial use research, the reptile research, which produced health supplement capsules, achieved the highest NPV record in the category.

Even though dairy cattle research ranked second in terms of NPV, as indicated in Table 4, it had the highest BCR and IRR values compared to the rest of the selected case studies. The reason is that in the past the dairy industry in Thailand had never had its own dairy feed formula. Farmers used western feed formula which were physically and economically inefficient because it did not make efficient use of local Thai feed ingredients.

As for the marine fishery research, it was worthwhile for the Thai government to invest in conservation and environmental preservation research focusing on this species (clown fish) because all the economic impact indicators showed desirable economic and environmental national benefits. The success of research such as this indicates that the departments that are responsible for the livestock research funding should continue to provide financial support, ideally if the research is tied to an identified policy or commercial objective, with the ultimate goal of elevating that type of livestock research that is most likely to contribute the most favorable, beneficial impacts to a range of stakeholders.

Table 4. Economic and environmental impacts of selected livestock research in Thailand

Livestock type / selected research	Evaluation period	Evaluation method		NPV (THB)	BCR	IRR (%)
		Ex-post	Ex-ante			
Commercial use livestock research						
Dairy Cattle	2017-2027		X	440,586,380	89.36	155.89
Poultry	2004-2010	X		18,591,727	1.14	10.00
Reptile	2006-2018	X		546,862,532	34.81	63.50
Livestock epidemic mitigation research						
Beef Cattle and Buffalo	2007-2027		X	243,807,217	12.35	35.49
Swine	2010-2017	X		174,712,765	25.47	211.00
Poultry	2009-2018	X		14,567,105	1.14	10.00
Prawns and Shrimp	2013-2018	X		1,937,355,075	29.15	2.96
Species conservation and environmental preservation research						
Marine Fishery	2003-2018	X		27,902,103	1.35	12.00

Note: Table 4 was derived from Table 3 in which 8 selected case studies were similarly applied.

4. CONCLUSION

The evaluation of the impacts achieved by Thailand's livestock research over a recent 10-year span (2008-2017) shows that the Thai government has generously and successfully supported research projects, and the outcomes have had real economic benefits and have helped to enhance the nation's competitiveness in the international livestock industry. Over the course of the ten years, the National Research Council of Thailand funded 4,046 livestock research projects, totaling 1,788,223,139 THB. This study set out to evaluate the projects, focusing on two distinctive aspects: academic and economic impacts. The major concept used to evaluate the projects was the value of change in economic surplus associated with counterfactual conditions. NPV, BCR, and IRR indicators were used as quantitative tools to analyze the economic impacts of the livestock research and were applied to eight selected livestock research case studies. The first part of the analysis, based on the number of research publications and citations to the Thai livestock research projects, showed that Thailand's focus on livestock research has become significantly more acceptable academically, and is increasingly being referenced by reliable international scholarly sources. This indicates that there has been valuable national developments and spill-over effects internationally stemming from the research done in Thailand. The second part of the analysis indicated that all eight of the sample livestock research case studies satisfied the economic impact criteria; all provided the country with beneficial economic and environmental impacts that reached to the nation's many stakeholders. Therefore, the lessons learned, and the future policy recommendation is that future financial and technical support to the livestock research should continue until the national goals for this sector are achieved. Indeed, other countries can learn from these case studies, and from the published reports, in order to develop their own strategies for livestock research investment, appropriate for their own socio-economic environments. These criteria imply: relevance, efficiency, effective and sustainability which are the global criteria for research evaluation.

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