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Research Article

CARRYING CAPACITY MODEL OF FOOD MANUFACTURING SECTORS FOR SUSTAINABLE DEVELOPMENT FROM USING ENVIRONMENTAL AND NATURAL RESOURCES OF THAILAND

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ABSTRACT

The objective of this research is to propose an indicator to assess and rank environmental problems caused by production within the food manufacturing sector of Thailand. The factors used to calculate the real benefit included the costs of natural resources, energy and transportation, fertilizer and pesticides, and sanitary and similar service. The highest environmental cost in terms of both natural resources materials and energy and transportation was ice, while the highest environmental cost for fertilizer and pesticides was coconut and palm oil. Confectionery had the highest environmental cost for sanitary and similar services. Overall, real estate gained the highest real benefit, while repair not classified elsewhere had the lowest real benefit for the company. If Thailand uses an indicator of environmental harm, especially within the food manufacturing sector, it could help to formulate efficient policies and strategies for the country in three areas of development, which are social, economic, and environmental development.

Keywords: food manufacturing; environment cost; indicator; carrying capacity; revenue; sanitary and similar services; modeling.

INTRODUCTION

Among the most important factors in the development of a country are environmental and natural resources [Asian Development Bank, 2014; TDRI, 2007; Chen, 2010]. However, the social and economic changes within Thailand have caused the deterioration of environmental and natural resources, i.e. loss of forests and wild animals, mangrove forests [TDRI, 2007], water resources [Bodini et al., 2002] and increased waste. Furthermore, the amount of natural resources is limited [Allen et al., 1995], whereas the consumption of natural resources is unlimited [Chen et al., 2010], and this can cause the environmental and natural resources to decrease immediately [Harwick, 1998] and continuously. The Thai government has foreseen this issue, leading them to announce a sustainable development policy with the aim to increase economic growth together with social and environmental development [TDRI, 2006]. The environmental and natural resource degradation should be the first priority for Thai society in making a development plan [ADB, 2014], which must correspond with the economic and social development strategy of the Ministry of Natural Resources and Environment [NESDB, 2015].

ADB [2014] stated that the principal policy of the country must address environmental problems and impacts after the policy is implemented. The previous policy, however, did not focus sufficiently on environmental issues, leading to ineffective management of environmental problems [Hammond *et al.*, 1995; Marull *et al.*, 2010; Yigitcanlar and Dizdaroglu, 2015]. The Index of Sustainable Economic Welfare (ISEW) is an indicator used to direct sustainable development of the country and for economic welfare measurement [Simpson, 1996; Marull *et al.*, 2010; Yigitcanlar and Dizdaroglu, 2015]. The ISEW is an indicator to specify sustainable development of the country and economic welfare measurement [Hammond *et al.*, 1995; Bodini, 2002; McMullan, 2013; Yigitcanlar et al., 2015]. ISEW does not only consider consumption value, but also incorporates unsustainable environmental costs and social costs [Brent, 2006]. Comparing ISEW per capita with GDP per capita of Thailand for the period from 1977 to 2003 shows that ISEW per capita before 1977 was consistent with GDP per capita, during which time the growth rate was positive [ADB, 2014]. However, after 2003 the two indices diverged and the growth rate decreased [NESDB, 2015]. ISEW per capita decreased by 6.70% whereas GDP per capita fell only by 0.89%. The data also show that before 1977, ISEW per capita was higher than GDP per capita, but from 2003 to the present ISEW per capita was lower than GDP per capita because of the increasing foreign investment in Thailand [NESDB, 2015; TDRI, 2007]. This is the main factor related to the degradation of environmental and natural resources, and has led to the decrease of ISEW per capita [TDRI, 2007].

Thailand has developed the economic rapidly. It was found that Food Manufacturing industry has been expanding continuously, which change from 1.15% in 1999 to 27.63% in 2014. As a result, GDP per capita has been constantly increasing as shown in Figure 1 [NESDB, 2015] and the urban area continues growth. Furthermore, the tourism industry expanded together with manufacturing industry. It gives the advantage to the economics of the country, whose current economic has improved because the amount of capital steadily flows in the economic system. Moreover, many investors from other countries came to invest in Thailand, where rational of economic of country has developed [NESDB, 2015]. However, Businesses and consumers are the major players in the economic system [Kennedy *et al.*, 2007; Liang and Zhang, 2009; Li *et al.*, 2012]. Consumers want to gain high utilization under limited budgets, whereas businesses aim to maximize their profit and reduce expenditures [Lenzen, 1998; Hugo and Pistikopoulos, 2005; Pantavisid, 2012]. Neither party pays attention to the environmental cost, causing over-consumption and over-production [TDRI, 2007; Duchin, 2008; Benoit, 2009; Chen *et al.*, 2010; ADB, 2014]. However, the sustainable development for the country should develop in three dimensions, collectively [Adams, 2009; Ukaga *et al.*, 2010; Yigitcanlar and Dizdaroglu, 2015], namely economic, social, and environmental. Previously, Thailand gave priority to developing only the economic growth. Moreover, the National Economic and Social Development Board [2015] stated that firms did not consider the cost from natural resources materials, energy and transportation, fertilizer and pesticides, and sanitary and similar services, which represent environmental costs [2015]. As a result, Thailand did not achieve sustainable development because economic growth goes together with higher environmental cost [Brent *et al.*, 2006; Grossmann, 2009; Duque *et al.*, 2010].

Accordingly, the formulation of policy and strategies to develop the country must concern real benefit and environmental costs in the three areas mentioned above [Bodini, 2002; TDRI, 2005; Ness *et al.*, 2007; Salema *et al.*, 2010; Ukaga *et al.*, 2010; ADB, 2014; NESDB, 2015]. In addition, the prioritizing of environmental problems should be clearly defined [ADB, 2014]. All of these factors could be included in an index to indicate environmental problems and lead to sustainable solutions in the future, which is the main emphasis of this research.

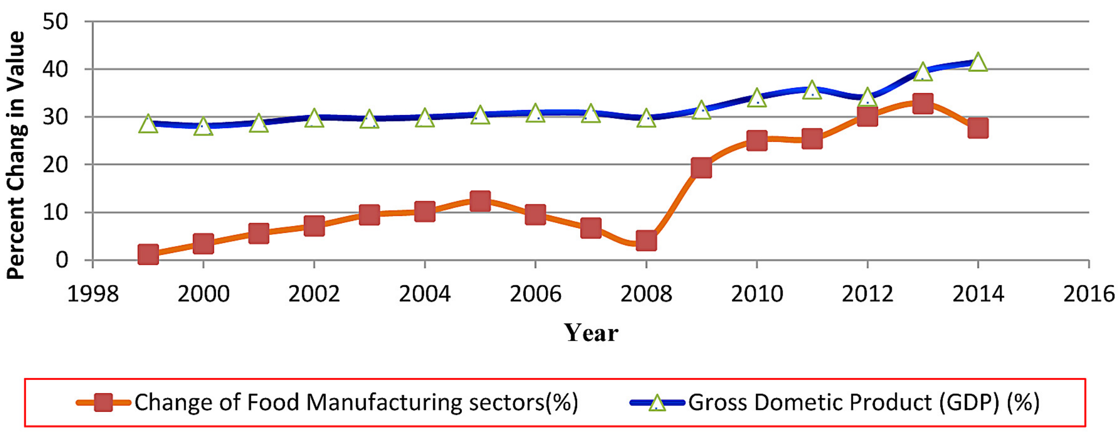

Figure 1. The relationship between changing rate of manufacturing industry (percentage) and the ratio of production to GDP (percentage)

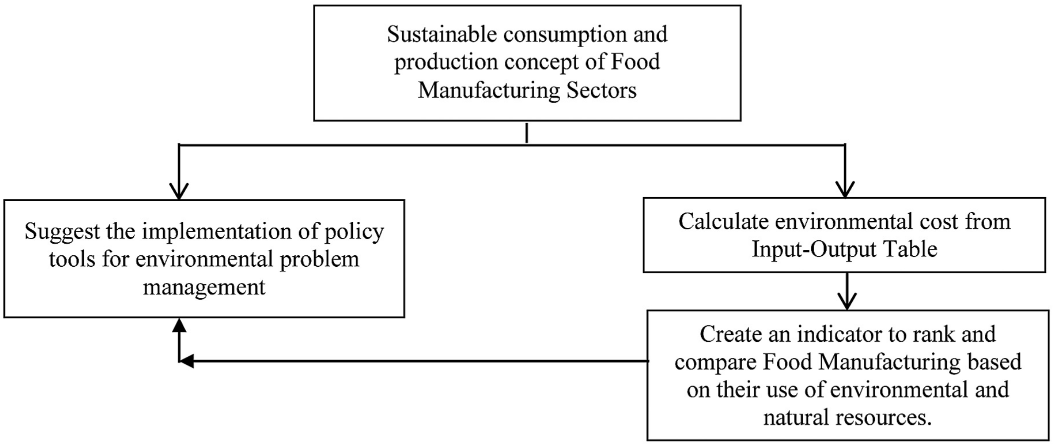

Figure 2. Conceptual framework

Objectives

To propose an indicator to evaluate environmental impacts from the food manufacturing sector of Thailand, leading to more sustainable consumption and production in this sector of the economy.

Conceptual framework

The conceptual framework (Figure 2) for selection of product sectors for evaluating their shadow environmental cost is based on aims and concepts of sustainable development [NESDB, 2015]. Three supporting concepts are welfare economics of Pigou [Pigou, 1960; Zhang, 2012; ADB, 2014], natural resource economics, and ecology economics [Yigitcanlar and Dizdaroglu, 2015; Zhang, 2012].

MATERIALS AND METHODS

The model in this study is related to the input-output table, in which the relationship of the data are categorized by rows and columns as follows in Table 1 [Leontief, 1986; Karna and Engstrom 1994; Lee et al., 2009]. Rows present output distribution of product sector *i* for *n* product sectors and the Gross product of product sector *i* can be defined, for $1 \le i \le n$, by:

$$X_i = \sum_{j=1}^{n} X_{ij} + F_i \tag{1}$$

where: X_i – refers to Gross product of product sector *i*,
X_{ij} – refers to product distribution of product sector *i* of goods and services production for product sector *j*,
F_i – refers to the final demand of product sector *i*.

Columns show the structure of expense or cost of goods production for product sector *j* (X_i) that can be defined, for $1 \le j \le n$, by:

$$X_i = \sum_{j=1}^{n} X_{ij} + V_j \tag{2}$$

where: V_j – refers to value added of product sector *j*, only if input value is directly proportional to output value.

Then X_{ij} can be defined by the relationship of output (X), input coefficient (A) and final demand (F) of production structure for an economic system that can be defined by:

Table 1. Matrix used to create the input-output table of production sectors

Producing sector \ Using sector		Processing sectors		Final demand				Total outputs (X)
		1	2					
Processing sectors	1	X_{11}	X_{12}	c_1	i_1	g_1	e_1	X_1
	2	X_{21}	X_{22}	c_2	i_2	g_2	e_2	X_2
Payments sectors	Value added	l_1	l_2	l_c	l_1	l_g	l_e	L
		n_1	n_2	n_c	n_1	n_g	n_e	N
	Imports	m_1	m_2	m_c	m_1	m_g	m_e	M
Total outlays (X’)		X_1	X_2	C	I	G	E	X

$$X = AX + F \tag{3}$$

$$X = [I - A]^{-1} F \tag{4}$$

where: $[I–A]^{-1}$ is the Leontief inverse matrix (or inverse matrix) [Leontief, 1936], which is important for economic system analysis when using the input-output table.

The inverse matrix acts as a direct and indirect input coefficient of a production supply chain that can be used for supply chain length and intensity calculation. Environmental cost of the production of each good or service can be calculated using the multiplication of the environmental cost coefficient and the inverse matrix. Finally, the result represents the total effect of a supply chain by giving the accumulated environmental cost of each good produced. The result also shows intensity of backward environmental effects of direct and indirect inputs and outputs. Furthermore, the result presents names, sectors and intensities of environmental costs that are useful to formulate an efficient policy and in environmental problem solving [Lave et al. 1995].

Relationships in the input-output table affects the output of each product sector (ΔF), which is called the multiplier for final goods and services. Equation 5 presents the calculation of the multiplier.

$$\Delta X = [I - A]^{-1} \Delta F \tag{5}$$

If final demand (ΔF) increases, environmental cost will increase (ΔE). Equation 6 calculates the increase of environmental cost:

$$\Delta E = R[I - A]^{-1} \Delta F \tag{6}$$

RESULTS AND DISCUSSION

The results of the environmental costs, real benefit, and forward linkage are classified by each category of the production. Table 2 lists the top ten food manufacturing sectors in terms of forward linkage, real benefit, and each category of environmental cost. Real benefit is the revenue for a sector, minus the environmental costs. The average real benefit was 0.93. If the real benefit for a given industry is lower than the average, it can be considered to represent a loss, while values higher than the average represent profit. The average value for environmental cost in natural resource materials was 0.05; for energy and transportation, 0.10; for fertilizer and pesticides, 0.008; and for sanitary and similar services, 0.0002. If the cost for a particular industry is lower than the average, there is further capacity for production. Environmental cost values that are higher than the average signify that there is no further capacity for production.

Highlights from the findings include the following:

- The food manufacturing sector with the highest environmental cost in terms of natural resource materials was ice. The cost index was above the average, signifying that this sector does not have the capacity for further production. In contrast, the lowest environmental cost was tobacco products.
- Ice also had the highest environmental cost for energy and transportation. The lowest environmental cost for this sector was tobacco products.
- The highest environmental cost in terms of fertilizer and pesticides was coconut and palm oil, while the lowest environmental cost was Ice.
- Confectionery were found to have the highest environmental cost for sanitary and similar services. In contrast, tobacco products had the lowest environmental cost of this category.
- The highest real benefit in the food manufacturing sector was tobacco products, while the lowest real benefit was ice. The lowest real benefit could signify loss in profit.
- The highest forward linkage in the food manufacturing sector was for canning and preserving of meat, while the lowest forward linkage was tobacco products.

This research is a pilot study of environmental costs of production of services in the economic system of Thailand, using the input-output database to account for differences among sectors. Environmental cost contributes damage to the environment and is affected by the behavior and decisions of producers, consumers, and the government [Bailey et al., 2004; Benoit, 2009; Xu, 2010; ADB, 2014; TDRI, 2015[. The environmental cost cannot be estimated from the activities occurring in the market alone. Instead, the estimation of the environmental cost of each production sector in Thailand needs to incorporate shadow environmental cost, which reflects environmental cost [Pantavisid, 2012]. The information can be used to compare the environmental cost of production sectors, and could help to create an environmental problem management indicator [McMullan, 2013; ADB, 2014]. The Shadow environmental cost modeled in this study relies on four groups of economic data, including costs of

Table 2. Analysis in top 10 of each production sector

Forward linkage		Real benefit		Natural resources materials cost		Energy and transportation cost		Fertilizer and pesticides cost		Sanitary and similar services cost	
value	sectors	value	sectors	value	sectors	value	sectors	value	sectors	value	sectors
0.7855	Canning and preserving of meat	0.9212	Tobacco products	0.0506	Ice	0.4893	Ice	0.0977	Coconut and palm oil	0.0058	Confectionery
0.7607	Slaughtering	0.8053	Tobacco processing	0.0446	Monosodium glutamate	0.1569	Monosodium glutamate	0.0336	Tapioca milling	0.0058	Bakery products
0.7292	Tapioca milling	0.7931	Distilling and spirits blending	0.0140	Noodles and similar products	0.1444	Tapioca milling	0.0222	Grinding of maize	0.0022	Noodles and similar products
0.7213	Coconut and palm oil	0.7712	Breweries	0.0098	Canning and preserving of meat	0.1436	Coconut and palm oil	0.0203	Tobacco processing	0.0019	Soft drinks and carbonated water
0.6853	Noodles and similar products	0.7490	Grinding of maize	0.0094	Tobacco processing	0.1297	Noodles and similar products	0.0201	Rice milling	0.0019	Coffee and tea
0.6827	Coffee and tea	0.7433	Sugar	0.0090	Confectionery	0.1207	Confectionery	0.0097	Flour and other grain milling	0.0013	Grinding of maize
0.6460	Monosodium glutamate	0.7413	Slaughtering	0.0090	Tapioca milling	0.1184	Canning and preserving of meat	0.0095	Coffee and tea	0.0011	Canning and preservation of fruit and vegetables
0.6392	Grinding of maize	0.7219	Rice milling	0.0088	Other food products	0.1173	Sugar	0.0092	Monosodium glutamate	0.0009	Canning and preserving of meat
0.6332	Confectionery	0.7065	Coffee and tea	0.0081	Coconut and palm oil	0.1138	Canning and preservation of fruit and vegetables	0.0089	Canning and preservation of fruit and vegetables	0.0009	Ice
0.6308	Rice milling	0.6996	Canning and preserving of meat	0.0078	Canning and preservation of fish and other sea foods	0.1107	Canning and preservation of fish and other sea foods	0.0086	Noodles and similar products	0.0008	Slaughtering

natural resources materials, energy and transportation, fertilizer and pesticides, and sanitary and similar services [TDRI, 2005; Pantavisid, 2012].

The results of this examination of environmental costs by each sector is consistent with the research of Zhang [2010], Pantavisid [2012], and the results of the real benefit analysis is also consistent with the research of Sanguanwongthong [2013], which they used the average value to create the environmental costs index. From the research found that when comparing the average and the result from the comparison, there are 23 sectors in environmental costs of natural resource material has higher value than the cost of average criteria. Likewise, 25 sectors of energy and transportation, 12 sectors of fertilizer and pesticide, and 21 sectors of sanitary and similar service found that the result from the research are higher than the average. Thus, from the past, Thailand did not take interest in such environmental costs indicator, which led to damage of the environmental and natural resources because of used over carry capacity.

The highest environmental costs are ice, coconut and palm oil, and confectionery. They give negative impact to the environmental and natural resources. The government must reduce environmental cost and announce protection scheme not affecting in the future, which should contain with proactive and reactive strategy. Proactive strategy is utilizing eco-friendly input and process (green growth), while reactive strategy is to improve the law, especially pulloters pays principle (PPP), to perform effectively and efficiently with offenders [TDRI, 2007; ADB, 2014; Pantavisid, 2012; Zhang, 2010].

From the analysis, thus, canning and preserving of meat have the highest environmental problem and ranked in the second highest environmental cost. Moreover, it generates low revenue, which leads to low real benefit. This production sector must resolve the problem immediately because the calculated value, higher than the standard value that resulted in carrying capacity. It is not only canning and preserving of meat ought to solve the problem urgently, the other 9 sectors in sequence also need to resolve the problem. If the problem is not solved urgently, it is difficult to do in the future and contribute huge damage. When comparing environmental problem with real benefit found that 10 having problem sectors did not give high real benefit. Consequently, the government should pay attention to agricultural sector and service sector or other sector because both of them generate high income to the country with low environmental cost. However, Thailand must monitor closely to sectors having potential to have environmental problem in short time by seeing the environmental cost. All of them highly link to the economic leading to over consumption in necessary environmental natural resources.

The results of this research could also be applied to environmental problem management under the sustainable production concept with a limitation of administrative resources. It leads to efficient environmental consumption by the society [TDRI, 2007]. The classification of natural resources and environmental capital of the whole system can be implemented at the micro level [ADB, 2014], while the classification from green value added and the forward linkage is for decision making at a macro level [NESDB, 2015; TDRI, 2007; Zhang, 2012; ADB, 2014]. Consequently, using the correct data allows for efficient environmental problem-solving [TDRI, 2007].

Thailand and other ASEAN countries have not created an environmental problem indicator using real benefit, environmental cost, and environmental problems, and this has led them to formulate ineffective policies and plans for their countries [ADB, 2014]. More developed countries, like Japan and European countries, give importance to environmental stewardship, and their efforts can be reflected in higher green GDP. This methodology would help Thailand formulate efficient policy and forecast future conditions more accurately, allowing the nation to deal with crises arising from environmental problems [TDRI, 2007; Sanguanwongthong, 2013].

CONCLUSIONS

Canning and preserving of meat, ice, coconut and palm oil, and confectionery contribute highest environmental problem and environmental cost that giving low real benefit. besides, they use environmental natural resources over carrying capacity. However, other 9 production sectors also need to solve immediately because all of them are also using environmental and natural resources over carrying capacity. Petroleum and refineries must monitor closely. Pipeline and gas distribution have the highest environmental cost. The government must find solution to reduce such cost in order to increase real benefit, which is advantage to Thailand. In the past, Thailand did not give importance to the environmental cost that led to economic crisis many times and tool long time. Consequently, the result of this operation can be used to support economic planning of the country and management guideline for the country.

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