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Value of food loss in ASEAN countries and its relationship with economic growth

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Abstract The research finding showed that the Food Loss (FL) value as a percentage of GDP in Cambodia, Laos, Myanmar, and Vietnam (CLMV countries) which it was clearly shown higher than Indonesia, Malaysia, the Philippines, and Thailand. In particular, Cambodia revealed the highest FL value as a percentage of GDP at 1.60%, which implied the lower level of development in post-harvesting and processing technologies as well as transportation in CLMV countries, while in Thailand and Malaysia, the FL values as a percentage of GDP were only 0.17% and 0.07%, respectively. Furthermore, in seven of these countries rice showed the highest FL value, while for Malaysia palm oil showed the highest FL value. On the other hand, in Indonesia the FL value of the palm oil continually increased at an average of 16% per year. In the 2000s, the ratio increased dramatically in Indonesia, from 3.60% during 1991–2000 to 24.43% during 2001–2010. Apart from rice in CLMV countries, it was further discovered in CLMV countries that significant FL values could also be found for bananas, cassava, maize, sugar cane, and sweet potato. In addition, estimates from an econometric model implicitly showed that the economic growth of ASEAN countries occurred at the expense of a higher food loss value. Economic development should therefore not focus purely on the expansion of conventional GDP only, but should also consider sustainability. Each country should set forth a target of "inclusive economic growth". To reduce loss from the production processes and marketing, it is suggested that the economic system called the "circular economy for food" should be adopted. The government should divert more investment toward R&D regarding post-harvesting technologies and logistics system development to minimize the loss of agricultural products.

Keywords: Value of food loss, Sustainable development goal, ASEAN countries, Economic growth

Introduction

Under the mainstream paradigm, the essential goals of economic development: economic growth, price stability, low unemployment rate, and income distribution are generally set by each country individually. On the other hand, the Millennium development goals (MDGs) adopted by the United Nations (UN), which aimed at addressing an array of issues that included

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slashing poverty, hunger, disease, gender inequality, and access to water and sanitation. It ended in 2015. UN initiated comprehensive discussions to establish a post-2015 development agenda based on the paradigm of "Sustainable Development". The main task was to develop Sustainable Development Goals (SDGs), which were a collection of 17 global targets, set out to achieve sustainable development in future (United Nations Thailand, 2015a). Target 12.3 guidance was that by the year 2030, the global food waste per capita will be reduced to half its present rate at the retail and consumer level. Food loss could be reduced in the production process, post–harvest, and over the entire supply chain (United Nations Thailand, 2015b).

Various definitions of food waste and loss are utilized by different international organizations including the European Union, the Food and Agriculture Organization (FAO), and the Organisation for Economic Co-operation and Development (OECD). The difference between food loss and food waste is as follows: food loss means decreasing the food quantity occurring during production and processing for the entire supply chain. On the other hand, food waste means the loss of a quantity of food resulting from the decision to abandon such foods while they are still able to be consumed. This normally takes place at the late stage of the supply chain, that is, at the retail and food service business level as well as at the consumer level (Office of Agricultural Economics, 2017).

According to FAO, the value of global food loss in 2010 was more than USD 1.01 trillion, which is comparable to 1,300 million tons of food, or 1/3rd of the total food volume produced globally. It has been estimated that 12–37% of the volume of rice produced in Southeast Asia is lost during harvesting, processing, transportation, and storage, while 30% of vegetables and fruits are lost during transportation due to heat and being crushed from poor storage. Most of the paddy fields in which food loss is significantly found are small ones (Council on Foreign Relations, October 30, 2014); especially, those in Cambodia, Laos, Myanmar, and Vietnam (CLMV countries), from which most of the agricultural production occurs.

At the same time, agricultural production in CLMV countries is in the process of undergoing development in the whole agricultural product supply chains, such as through the improvement of harvesting technologies and road network development. Presently, the aforementioned countries continue to suffer from the issue of food loss. Other ASEAN member states, such as Indonesia, Malaysia, Thailand, and the Philippines, also need to develop strategic plans to address the issue of food loss. Given the above, the question naturally arises as to what the value of food loss is in ASEAN countries, and how do such losses relate to, or impact, economic growth in each country.

Food loss (FL)–occurs unintentionally in each step of production, from planting, storing, transporting, packing, and ~~the~~ marketing agricultural products (Sawaya, 2017). Although, the FL volume in developed countries is not significantly different from developing countries. 40% of such FL in developed countries, however, occurs at the retail and consumption levels, while in the case of developing countries, FL mostly occurs at the post-harvest and processing level (FAO, 2011). Most previous research on FL has been outstandingly performed in the last 5 years as the issue is quite new. According to the literature review, the studies done previously can be divided into two main groups: the first group emphasize how to estimate or calculate the FL volume, while the second group focus on how to reduce the FL volume. Estimations of the FL volume have been carried out in certain developed countries such as the US (Buzby and Hyman, 2012). However, questions have been raised as to the estimation methods used, such as the form of aggregation of food losses of individual food items being misleading in the case of the US (Koester, 2013).

This has led to an effort to develop new methods, such as the estimation method developed by the United States Department of Agriculture, using Economic Research Service (ERS)'s Loss-Adjusted Food Availability data estimated amount, value, and calories of postharvest food losses at the retail and consumer levels (Buzby *et al.,* 2014). There have also been other studies performed with an aim to develop specific methods for estimating food loss during the post-harvest, retail, and consumer stages (Chapman, 2014). In the case of Switzerland, a certain amount of research was conducted to identify the food loss volume and to analyze the causes at the different levels of the supply chain (Beretta *et al.,* 2013). Some analyses have even been extended to assessing the environmental impacts caused by food loss, such as in the Swiss potato supply chain (Willersinn *et al.,* 2017). A study was performed to estimate FL in New Zealand in 2011 and suggested that the FL volume was more than 224,000 tons, out of which as much as 103,000 tons came from the industrial sector (Reynolds *et al.,* 2016). A study was conducted in Ethiopia as an example developing country to find out how much food loss of cassava occurred at the post-harvest stage and reported that stockpiling at the farm and marketplace incurred 30–50% food losses, while insect pest damage was primarily responsible for food losses at the farm and market level (Parmar *et al.,* 2018). The above studies contribute to the overall continuous effort to estimate and analyze the causes of food loss. More recently, the methodologies used for FL estimation have been reviewed with an aim to close the gap between estimations and to offer more appropriate alternatives for a more accurate estimation (Chaboud, 2017; Magalhães *et al.,* 2017; Salihoglu *et al.,*

2018). Moreover, the related economic issues have also recently been considered in a methodology for estimating FL (Koester, 2017).

With respect to FL and food waste (FW) reduction, a number of studies have been performed in Arab countries (Abiad and Meho, 2018) and others, including an investigation of organization management with an aim to reduce food loss (Irani *et al.,* 2017), a discussion of the role of reuse and recycling in reducing FL and FW can be seen in Redlingshöfer *et al.* (2017). Other work includes a simulation of various temperature scenarios with field experiments were conducted in order to analyze food loss in the farm under changing climatic conditions (Tito *et al.,* 2018), and the development of a conceptual framework in order to find smart packaging capable of reducing food loss at the consumer level (Yokokawa *et al.,* 2018). However, attempts to reduce food loss at the farm in low income countries must be adopted concurrently with a policy to mitigate the problems arising from food loss at the retailer and consumer level too (Krishna Bahadur *et al.,* 2016). Furthermore, it should always be taken into account that the efforts to address FL and FW problems may ultimately cause resource efficiency to be decreased (Koester, 2014). In addition to those key issues, quantitative research was conducted in Scotland to survey the attitude of vegetable and fruit growers toward FL and FW (Beausang *et al.,* 2017). There also have been studies performed analyzing the socio-economic factors and food loss in low income countries (Krishna Bahadur *et al.,* 2016). Despite the above, knowledge about FL in ASEAN countries is still limited, especially in regards to the estimation of the FL value in ASEAN countries and the analysis of the relations between FL and economic growth. The objectives of the research project were to estimate the value of FL in ASEAN countries and to explore its relationship with Gross Domestic Product in each country.

Methods

To attain the first objective of the research project, tracking down the economic concept of Segrè *et al*. (2014), the research method was separated into two steps: (i) Computation of the values of major FL in ASEAN countries and (ii) summation of the values of major FL in each country. The scope of the study was concentrated on six types of major FL in each country. These were selected by the average quantity of FL during 1991 to 2013 deriving from FAO website. Afterward, the Producer Price was utilized for computation of the values of FL. Definitions of loss and producer price, item code of variables, and data range of items in ASEAN countries are presented in more detail in FAO website. In order to attain the second objective of the research project, the

econometric model was based on Krishna Bahadur *et al*. (2016). The more detailed research methods and procedures are as follows:

The research calculated the food loss values of six major agricultural products in Cambodia, Laos, Myanmar, and Vietnam (generally known as the CLMV countries), as well as Thailand, Malaysia, Indonesia, and the Philippines. The FL volume refers to the definition given by FAO, while the computation of FL value is as follows in Eq. 1:

$$VL_{ij,t} = L_{ij,t} P_{ij,t} \quad (1),$$

where $VL_{ij,t}$, $L_{ij,t}$, and $P_{ij,t}$ are the FL value, FL volume, and the producer price of agricultural product item i in country j during year t, respectively, where $i = 1$ refers to bananas, 2 (beans), 3 (cassava), 4 (coconuts), 5 (eggs), 6 (maize), 7 (milk), 8 (oranges), 9 (palm oil), 10 (palm kernel oil), 11 (pineapples), 12 (potatoes), 13 (rice), 14 (soybeans), 15 (sugar cane), and 16 (sweet potatoes). Eq. 1 was based on the economic concept of Segrè *et al.* (2014). Details of the definition of each product are given in in FAO website. for $j = 1$ (Cambodia), 2 (Laos), 3 (Myanmar), 4 (Vietnam), 5 (Indonesia), 6 (Malaysia), 7 (the Philippines), and 8 (Thailand) over time t = 1991 to 2013. However, there are only limited data available for certain agricultural products.

Next, the values of all six types of major FL were combined in each country as follows in Eq. 2:

$$y_{jt} = \sum_{i=1}^{6} VL_{ij,t} \quad (2),$$

where y_{jt} refers to the FL value in country j during the period t. Eq. 2 was based on the economic concept of Segrè *et al.* (2014). Then, the relation between the FL value and real Gross Domestic Product (GDP) was analyzed, in which the FL value was converted into real terms using a GDP deflator, which is a measure of the level of prices of the products in an economy in a particular year. Such a relation is subject to an econometric model in the manner of a Log-Log model as the following in Eq. 3:

$$Ln\left(y_{jt}\right) = \beta_0 + \beta_1 Ln\left(x_{jt}\right) + e_{jt} \quad (3),$$

where Ln refers to the natural logarithm and e_{jt} refers to error terms behaving as white noise. Eq. 3 was based on Krishna Bahadur *et al*. (2016). In

addition, the appropriateness of the statistical method for the estimates of the model under Eq. (3) above is subject to the need to consider the following issues:- first, the results need to be reviewed to consider if there are any significant econometric problems, including Lagrange multiplier test (LM test) to check for autocorrelation, the White test to check for heteroskedasticity, and the Ramsey regression equation specification error test (RESET) as a test for reviewing specification errors. Second, the statistical significance needs to be determined for the test results of the independent variables, and lastly, the parameters need to be reviewed by the adjusted R-squared.

Results

The research results are discussed in 3 parts as follows: the first part presents the results of the estimations of the FL values as a percentage of GDP, while the second part differentiates six types of major FL in each country, and the last part discusses the analysis of the relations between the real value of FL and real GDP as following.

When considering the FL loss in CLMV countries, it was found that during 1991–2013, the values ranged from USD 32.85 million to USD 637.52 million and when presented as a percentage of GDP, the figures were in the range of 0.71% to 1.60%. When comparing the percentages to those of Indonesia, Malaysia, the Philippines and Thailand, the CLMV countries clearly showed higher values, especially in the case of Cambodia, where the FL as a percentage of GDP was the highest at 1.60% (Table 1). With respect to Thailand and Malaysia, the FL values as a percentage of GDP were only 0.17% and 0.07%, respectively; clearly lower than that of Indonesia at 0.42%.

Table 1. Estimated food loss value and as a percentage of GDP in selected ASEAN countries[1/]

	Value (Million USD)			% of GDP		
	1991-2000	**2001-2013**	**1991-2013**	**1991-2000**	**2001-2013**	**1991-2013**
Cambodia	45.72	166.43	128.15	1.34	1.73	1.60
Laos	14.36	38.54	32.85	0.89	0.66	0.71
Myanmar	72.36	199.38	144.15	1.02	0.88	0.94
Vietnam	294.03	663.95	637.52	0.94	0.78	0.79
Indonesia	864.00	2,079.44	1,550.99	0.45	0.39	0.42
Malaysia	55.62	134.93	104.71	0.07	0.07	0.07
The Philippines	218.33	395.32	318.37	0.30	0.26	0.27
Thailand	203.64	504.57	373.73	0.15	0.19	0.17

[1]/Figures are shown as the average value for the period concerned. Definitions of loss and producer price, item code of variables, and data range of each item in ASEAN countries are presented in more detail in FAO website.

Table 2. Estimated value of food loss of six major agricultural products in CLMV countries

	Cambodia (Million USD) [1/]					
	Rice	**Cassava**	**Oranges**	**Bananas**	**Pineapples**	**Sweet potatoes**
1995-2000	36.93 (-11.62%)	0.92 (34.54%)	5.30 (-0.22%)	1.61 (-21.75%)	0.56 (28.25%)	0.40 (-0.81%)
2001-2012	120.88 (24.86%)	38.89 (75.77%)	6.37 (11.01%)	1.87 (17.26%)	0.66 (9.61%)	0.42 (16.73%)
1995-2012	92.90 (14.13%)	9.74 (63.64%)	5.88 (6.33%)	1.78 (5.78%)	0.63 (15.09%)	0.41 (11.57%)
	Laos (Million USD) [1/]					
	Rice	**Cassava**	**Bananas**	**Sugar cane**	**Sweet potatoes**	**Maize**
1997-2000	10.75 (-21.03%)	0.49 (-33.19%)	0.75 (-19.38%)	1.26 (6.06%)	0.90 (-26.39%)	0.22 (-28.08%)
2001-2013	21.23 (14.97%)	6.86 (52.48%)	3.61 (27.90%)	3.09 (19.92%)	1.89 (27.77%)	1.86 (33.61%)
1997-2013	18.76 (8.22%)	5.36 (36.42%)	2.94 (19.03%)	2.66 (17.32%)	1.65 (17.61%)	1.48 (22.04%)
	Myanmar (Million USD) [1/]					
	Rice	**Beans**	**Potatoes**	**Maize**	**Milk**	**Sugar cane**
1991-2000	42.71 (14.08%)	13.30 (17.01%)	3.58 (15.01%)	2.30 (11.77%)	7.77 (-1.64%)	2.70 (12.53%)
2001-2013	94.19 (16.05%)	71.65 (19.69%)	14.11 (21.70%)	11.22 (23.72%)	5.45 (3.36%)	5.70 (32.98%)
1995-2012	71.80 (15.24%)	46.28 (18.60%)	9.53 (18.96%)	7.34 (18.83%)	6.90 (0.36%)	4.39 (24.61%)
	Vietnam (Million USD) [1/]					
	Rice	**Maize**	**Bananas**	**Cassava**	**Sugar cane**	**Sweet potatoes**
2000-2013	497.69 (10.69%)	39.49 (46.26%)	33.85 (28.39%)	27.95 (6.87%)	27.04 (12.79%)	11.51 (10.36%)

[1]/Figures in parentheses are the average annual percentage growth rates. Definitions of loss and producer price, item code of variables, and data range of item in ASEAN countries are presented in more detail in FAO website.

Of the six types of major FL in the selected ASEAN countries, the FL value of rice was the highest in seven of those countries compared to the FL values of the other products covered here, except for Malaysia in which the FL value of palm oil was the highest compared to that of the other products (Tables 2 and 3). What concerns us is that the countries with significant roles in rice production and marketing in Indonesia, Thailand, and the Philippines, showed FL values during the period 1991–2013 of around USD 840.01, 267.31, and 146.66 million, respectively. It was discovered that for Indonesia in particular, FL increased at an average of about 16% in the same period. In the 2000s, a dramatic increase occurred from 3.60% during 1991–2000 to 24.43% during

2001–2010. For Thailand and the Philippines, the values increased annually at an average of 8–9% (Table 3). While rice production and marketing in CLMV countries is still being developed to modern standards, the FL value of rice in these countries increased at an average of 8–15% per year. In Vietnam alone, the FL value during 2000–2013 was as high as USD 497.69 million, which was higher than that of both the Philippines and Thailand. Moreover, in the case of Laos, although the FL value of rice increased at an average of 8% each year, during the 2000s, the average annual percentage growth rates increased dramatically from -21.03% during 1997–2000 to 14.97% during 2001–2013 (Table 2).

Table 3. Estimated value of food loss of six major agricultural products in Indonesia, Malaysia, the Philippines, and Thailand

	Indonesia (Million USD) [1/]					
	Rice	**Cassava**	**Maize**	**Coconuts**	**Bananas**	**Sweet potatoes**
1991-	421.20	108.60	81.65	135.56	103.08	13.92
2000	(3.60%)	(3.42%)	(7.18%)	(1.39%)	(12.42%)	(1.42%)
2001-	1,162.17	372.10	232.83	195.55	165.80	34.38
2013	(24.43%)	(21.94%)	(15.52%)	(18.77%)	(16.76%)	(17.86%)
1991-	840.01	257.53	167.10	165.56	134.44	25.48
2013	(15.91%)	(14.37%)	(12.11%)	(10.54%)	(14.70%)	(11.13%)
	Malaysia (Million USD) [1/]					
	Palm oil	**Rice**	**Maize**	**Eggs**	**Bananas**	**Palm kernel oil**
1993-	19.85	N/A	N/A	15.39	15.44	2.97
2000	(4.20%)			(-3.95%)	(5.57%)	(9.72%)
2001-	52.34	23.50	22.42	25.48	51.68	7.98
2013	(15.56%)	(15.02%)	(10.98%)	(11.17%)	(3.90%)	(16.32%)
1997-	39.96	23.50	22.42	21.63	16.19	6.07
2013	(11.58%)	(15.02%)	(10.98%)	(5.88%)	(3.82%)	(14.01%)
	The Philippines (Million USD) [1/]					
	Rice	**Bananas**	**Sugar cane**	**Pineapples**	**Maize**	**Sweet potatoes**
1991-	102.78	51.68	39.75	12.04	7.98	4.10
2000	(6.38%)	(3.90%)	(1.18%)	(-1.98%)	(4.42%)	(-1.54%)
2001-	180.42	134.49	51.98	12.33	11.09	5.00
2013	(9.23%)	(10.87%)	(7.65%)	(8.34%)	(9.18%)	(7.73%)
1991-	146.66	98.49	46.67	12.20	9.74	4.61
2013	(8.06%)	(8.02%)	(5.01%)	(4.12%)	(7.23%)	(3.94%)
	Thailand (Million USD) [1/]					
	Rice	**Cassava**	**Pineapples**	**Soybeans**	**Maize**	**Sugar cane**
1991-	134.50	22.54	16.68	12.94	10.13	6.85
2000	(3.48%)	(10.48%)	(-3.64%)	(11.55%)	(4.04%)	(0.56%)
2001-	369.48	52.41	15.40	36.53	16.31	14.44
2013	(12.34%)	(18.52%)	(11.34%)	(11.14%)	(9.92%)	(15.56%)
1991-	267.31	39.43	15.96	26.27 (11.31%)	13.62	11.14
2013	(8.72%)	(15.23%)	(5.21%)		(7.51%)	(9.42%)

[1/]Figures in parentheses are the average annual percentage growth rate. Definitions of loss and producer price, item code of variables, and data range of item in ASEAN countries are presented in more detail in in FAO website.

Apart from the FL value of rice, CLMV countries also experienced food losses of other agricultural products, including bananas, cassava, maize, sugar cane, and sweet potato. The FL values of these products in Cambodia and Laos during the 1990s and 2000s increased dramatically. In Cambodia, for example, the FL of bananas increased from -21.75% in 1995–2000 to 17.26% during 2001–2012. In the case of Laos, the average annual percentage growth rates of FL of bananas, sweet potato, and maize increased from a negative value in 1997–2000 to 20%–50% during 2001–2013. There were other agricultural products with FL in each CLMV country, such as oranges and pineapples in Cambodia, and beans, milk, and potatoes in Myanmar (Table 2). In the case of Indonesia, Malaysia, the Philippines, and Thailand, in addition to rice, the food loss of maize and bananas also raised concern (Table 3). According to the above, this implies that the production and marketing processes of maize and bananas in ASEAN countries give rise to a FL value that should be an issue of concern for the respective countries. In Indonesia, the FL of maize during 1991–2013 reached its highest value at USD 167.10 million and increased at an average of 12.11% annually. With respect to bananas, the FL values in Indonesia, the Philippines, and Malaysia were approximately equal to USD 134.44, 98.49 and 16.19 million, respectively. The Philippines showed a prominent increase during the 1990s and 2000s (Table 3).

This part ends with the estimates from the econometric modeling, demonstrating the relation between the real value of FL and real GDP in ASEAN countries. After adjusting the residuals of the model with first-order autoregressive moving average models, it was revealed that the estimates of the model were reliable from an econometrics point of view. This is because: (1) the p-value in the LM (1) test, the White test, and the Ramsey test reflected that it was not able to reject a null hypothesis at the statistical significance of 0.05. Therefore, the model did not fall within significant concerns, including for autocorrelation, heteroskedasticity, and specification errors. That is, the error terms behaved well in an econometric sense. (2) The adjusted R-squared was in the range of 0.80–0.95 and (3) the independent variables were at statistical significances of 0.10 and 0.05, respectively (Table 4). It can thus be concluded that the model was appropriate for our economic interpretation as the percentage of change in real GDP affected the percentage of change in the real value of FL in the same direction with statistical significance. Estimates from an econometric model implicitly showed that the economic growth of ASEAN countries occurred at the expense of a higher food loss value. Therefore, the long-term economic goal should be concerned the inclusive economic growth and economic development in order to diminish losses from production

processes and the marketing of agricultural produce, which should, at the same time, lead to a circular economy for food.

Table 4. Estimates from the econometric model

	$Ln(y_{jt})$ **(Real value of food loss)** [1/]			
	Cambodia (*j*=1)	**Laos (*j* =2)**	**Myanmar (*j* =3)**	**Vietnam (*j*=4)**
C	-17.42	-9.34	-0.65	-1.17
	(-2.24)**	(-4.46)**	(-0.51)^{NS}	(-1.10)^{NS}
$Ln(x_{jt})$ (Real GDP)	2.46	1.49	0.59	0.68
	(2.97)**	(6.27)**	(4.60)**	(7.32)**
Adjusted R-Squared	0.94	0.95	0.88	0.80
LM (1) test p-value	0.56	0.86	0.79	0.19
White test p-value	0.72	0.25	0.39	0.29
Ramsey test p-value	0.77	0.11	0.51	0.26
	$Ln(y_{jt})$ **(Real value of food loss)**			
	Indonesia (*j*=5)	**Malaysia (*j*=6)**	**The Philippines (*j*=7)**	**Thailand (*j*=8)**
C	-4.14	-8.39	-2.26	-13.08
	(-1.97)*	(-3.27)**	(-1.32)^{NS}	(-6.74)**
$Ln(x_{jt})$ (Real GDP)	0.90	1.09	0.69	1.54
	(5.66)**	(5.17)**	(4.80)**	(9.88)**
Adjusted R-Squared	0.83	0.85	0.83	0.88
LM (1) test p-value	0.66	0.17	0.19	0.79
White test p-value	0.28	0.28	0.29	0.22
Ramsey test p-value	0.16	0.41	0.16	0.11

[1/]The numbers in parentheses are the *t* statistics. * and ** denote statistical significance at the 0.10 and 0.05 levels, respectively, while *NS* stands for Not Statistically Significant.

Discussion

The results of the estimations of the FL values as a percentage of GDP in Indonesia, Malaysia, the Philippines and Thailand, and the CLMV imply a lower level of development in post-harvest and processing technologies as well as with transport and shipment in CLMV countries. Th,se results supported the study by Segrè *et al.* (2014), in which the authors indicated that effective infrastructure would be beneficial in aiding the transport of food from provincial areas to the main cities. However, some developing countries have inadequate transport and communication systems that cannot facilitate efficient food product distribution. Aggravated by improper management of agricultural product marketing, this can lead to higher food losses before the products reach their destination. In addition, the results reflect the different levels of logistics

development in the respective countries. By comparing the Logistics Performance Index in five countries, Alavi *et al*. (2012) reported that Thailand and Malaysia were among the group of high performers, while Indonesia and Vietnam were in a group with lower performance, and the Philippines was in the middle of the two groups. At the same time, the results of the estimations of the FL values for six major agricultural products in each country support the findings of Kumar and Kalita (2017), FAO (2018) and Saba and Ibrahim (2018) on the issue of post-harvest losses at different stages in Asian rice production.

Furthermore, this also backs up the policy recommendations offered by Bandumula (April 2017) that to facilitate the international trade of rice in Asia, the government should take proper steps to diminish production losses in the supply chain. In order to decrease these losses, it is necessary to examine the supply chain of maize and bananas in each country. Although this is one of the limitations of our study, we may apply the notions and recommendations from other countries to help develop our own policy.

For instance, Samuel *et al*. (2011) suggested that in order to minimize loss in maize production in Nigeria, the harvest method and product storage management must be improved. The Energy Centre (May 2016) suggested that to reduce loss in maize production in Ghana in the supply chain, especially at the post-harvest stage, the product must be sun-dried, while the post-harvest technology must be improved and the product must be properly handled, e.g., the use of a more effective method of storage. Furthermore, the FAO (2014) suggested Kenya's food loss reduction measures for dessert and plantain bananas should include a training provision for people involved in the supply chain.

The estimated econometric model implies that the economic growth in ASEAN countries is at the expense of food loss value in that country. Particularly, Cambodia showed that if the real GDP increases by 1%, FL will increase by 2.46%. Economic development should not therefore be emphasized based only on the growth of conventional real GDP. This supports the notion that economic development should be in line with the goal of inclusive economic growth. Hanson (2013) stated that setting out clear targets for the reduction of food loss and waste in the agricultural sector would be of benefit for inclusive economic development. At the same time, the economic structure of ASEAN countries under the mainstream paradigm should be comprehensively reviewed toward the promotion of the concept of the circular economy for food. Fassio and Tecco (2019) suggested that this concept would facilitate the reduction of FL in line with SDG. Furthermore, the food system could be fertile ground in which to test and implement regenerative, optimize and loop actions, by focusing in particular on the up-cycling principle and on

new processes of eco-design, with relevant contribution on SDG 9, 12, and 17. Moreover, Principatoa *et al.* (2019) revealed empirical findings from Italy's pasta supply chain, showing that the circular economy could reduce the FL volume. Furthermore, the pasta supply chain is a good example of the circular economy as little is lost. FL in the field is very limited, while the straw obtained during the harvest is normally used as animal feed and litter.

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