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Impact of Chemical Pesticides Use in a Social Accounting Matrix Framework: A Case Study of Thailand*

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Abstract

Although there are several studies on the impact of pesticides use, there is no consistent conclusion about such evidence on capturing the socioeconomic independence. The propose of this paper is to investigate the economy-wide impact of pesticide use in Thailand. The research data and methodology in this paper are depended on a social accounting matrix framework incorporating the pesticide-related illness as an additional sector, following Resosudarmo and Thorbecke (1998), to explain the impact of the pesticides on the related agricultural sector, food sector, and the social welfare of different households. Thus, the main characteristics of the Thai economy can be comprehensively described by providing information contained in this framework. In this respect, the several data sets are constructed to include the economic and social structure interdependencies, which are necessary to analyze the policy implications, especially industrial policy. The results were analyzed according to the general equilibrium theory and the Leontief multiplier matrix. It reveals that the food industry and the economy are significantly affected by the pesticides. One of the most interesting findings of this paper suggest that the food sector needs to determine its output to avoid bottleneck situations and create equality across the food production system.

Keywords: Pesticides, Economic Impact, Food Industry, Social Accounting Matrix, Thailand

JEL Classification Code: E01, E16, L66, N55, Q18

1. Introduction

In 2014, Thailand had more than 80 percent of its population living in the rural-agricultural area, while between 2015 and 2018, its poverty rate increased from 7.2 % to 9.8 % (World Bank, 2020). Despite various poverty reduction measures in recent years, the Northern, Northeastern, and Southern regions of Thailand had the slowest rate in poverty reduction (Yang, 2019). These regions are more impoverished, fragile, less diversified, and more agriculturally-based. Besides, the Thai agricultural sector is sensitive to changes in commodity prices, while the majority of farmers have insufficient fertile land and small capacity in hiring high-waged farm-hands and controlling pests, and natural disasters, including droughts and floods to ensure higher yields. The use of Paraquat, Chlorpyrifos, and Glyphosate – the three hazardous chemical-pesticides has been considered a powerful tool to protect crops and increase yields and, thus, is one of the ways to help deal with the poverty and food insecurity issues.

Historically, the concern about the intensity of agrochemicals usage and the associated risks of increased environmental contamination and human exposure had grown along with the need for enlargement and development of the agricultural industry that had made Thailand a world leader in food exports for over several decades. The pesticide residue on foodstuffs is also a fact known by both foreign

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and domestic consumers as well as ordinary people, not only among the educated. Although recently there has been increased support for reducing pesticide use and promoting instead chemical-free farming, many people reckoned the success might be achieved at a cost with a lower possibility to produce a massive amount of food, and the dissatisfaction among the poor farmers from a reduced farm yield and the poor consumers from higher food prices. Hence, the use of the three dangerous agrochemicals in this country remains prevalent as a common practice. However, excessive use of the three chemicals could lead to many problems such as the high and acute toxicity from Paraquat to the exposed farmers who do not have education or knowledge adequate for managing the use of pesticides discriminately (Baharuddin et al., 2011; Gawarammana & Buckley, 2011).

Chlorpyrifos, exposable by humans through ingestion of contaminated fruits and vegetables, has been found to carry risks to child development during the mother's pregnancy and increase cancer risk significantly (Lee et al., 2004; Callahan et al., 2017; Silver et al., 2017). Glyphosate is often present in food chains and as an air contaminant, especially in agricultural regions (Myers et al., 2016); and the study by Parvez et al. (2018) found that Glyphosate is correlated significantly with reduced pregnancy lengths of women. Pienkhuntod et al. (2020) also found that Thailand is associated with health aspect of poverty over the past three decades. That means the chemicals used, not only have both long-term and short-term adverse health and poverty impacts on the exposed individuals, but also bring the danger to the next generations. So far, much of the available literature on the chemicals has dealt with the question of impact on human health as a non-monetary measure; but few works have addressed the question of economic impact. Thus, this paper aims to answer the following question: How do pesticides affect the economy?

The economic impact assessment of pesticide use on the economy is still one of the neglected topics in the recent literature on economic development. The impact was studied intensively in the early 1990s. Several studies, for instance, Pimentel et al. (1992), Pimentel et al. (1995), Evans (1995), Bailey et al. (1999), and Pretty et al. (2000), had been carried out on the external cost of general pesticide use in developed countries. Resosudarmo and Thorbecke (1998) showed how, in the past, the study into the impact of pesticide use was rather concerned with the economy by creating a social accounting matrix to analyze the effect of pesticide-related illness on household incomes. Despite this, the assessment served to explain the unique structure of the Indonesian economy. On the other hand, a few recent attempts in the Thai literature had been made (Praneetvatakul et al., 2013; Grovermann et al., 2017) to estimate the economic impact. So far, however, the problem with previous studies is that they do not take account of evidence on capturing the socioeconomic independence nor do they examine the structure of the Thai economy to create an ex-post assessment on a variety of pesticide reduction strategies.

A better understanding of the impact of chemical pesticides use on the socio-economic structure of Thailand needs to be studied. We then employed a social accounting matrix (SAM) for Thailand in this study to assess the economic impact of the pesticides net import policy due to the insufficient domestic supply of specific types of pesticides, and after that, we assumed the full pesticides use. The results will include the impacts of pesticides use on the agricultural sector, the food sector, the social welfare of different households in the agricultural and the non-agricultural sectors, and the solution to promote food safety policy in a distressed Thai economy. The three dangerous chemical pesticides are used as a case study because the National Committee on Hazardous Substances still has rejected banning these chemicals (the Hazardous Substance Act B.E. 2535 and its amendments B.E. 2562), which are known as dangerous chemicals in the world these days. It is essential to assess the impact of the pesticides use and then design and implement the food production and processing policies that have to take into account the sustainable economic development goal such that the relevant public and private entities can develop their policies to support the development of the food production industry toward a better version of sustainability.

In this study, the framework to analyze the impact is that arising problem of pesticide use may cause an impact on the factor market in agriculture, and then it will transcend the food sector and the whole economy due to market linkage by the price mechanism, including backward and forward activities. If the equilibrium of each market changes, the equilibrium of the other markets could be changed as well. The agricultural sector is recognized as an important source of household income. When farmers cultivate the food crops, they help create additional income and jobs, which set in motion further production activities for them. This is known as the economic multiplier effect and it takes into account all the effects of spending and income working through a complex chain of market activity. Finally, the income will be used in part for food purchasing and the household payment, which people later receive food safety from the production system. To examine the impact of pesticide use from the interlinkages in the economy, SAM is a working method we need to employ.

The other part of paper is organized into five sections. The general methodology of SAM is presented in section 2. The third section will examine how we construct SAM. The other section looks at the findings, focusing on the two key themes, which are the impact of pesticides net import value on food sector and the economy. The final section represents the conclusions with the critique of the findings and draws policy-relevant implications about the Thai economy and food safety.

2. Social Accounting Matrix

Following Breisinger et al. (2010), a social accounting matrix or SAM is a representation of the economy that encapsulates the interlinkages and the circular flow of the whole economic accounts, which consists of six majors accounts: (1) production activities, (2) commodity markets, (3) factors of production, (4) account of institutions (e.g., households and government), (5) capital account or investment account, and (6) the rest of the world.

Each of the major accounts in a SAM is connected by transfers and transactions from sectors to institutions. The production activities purchase capital and labor inputs from the factors market and use these for producing goods and services. The goods and services are also distributed into different sectors by the commodity markets. Some of these are supplemented by imports from the rest of the world and then sold through commodity markets to institutions, while each expenditure of institution becomes income to another institution. For example, households and government purchase goods and services from the commodity markets, the markets will provide the sales income to producers (i.e., production activities) and this income will be supported by the need of continuous production process. Moreover, there will be inter-institutional transfers between households and government, namely, taxes and savings. And these transfers ensure that the circular flow of incomes is closed.

The account in a SAM has its own row and column in which the payments or expenditures are listed in columns, while the receipts are represented in row. As each account of SAM must be balanced, the totals of row and column sums must be equal to an equilibrium because every expenditure by an account in the economy also represents a receipt to some other account in the system.

2.1. SAM Multiplier Analysis

SAM multipliers are an extension of Leontief 's classic input-output model. While the input-output model concentrates on linkages of production activities and commodities, SAM model also include consumption linkages of institutions that typically include households and government. Therefore, SAM multipliers tend to be larger than multipliers of input-output. On the other hand, households are often disaggregated into different groups to identify distributional impacts, for example agricultural household and non-agricultural household. SAM multiplier models have been used to resolve a wide variety of issues ranging from trade policies and macroeconomic shocks to agricultural and non-agricultural linkages (Pyatt & Round, 1979; Hayden & Round, 1982; Resosudarmo & Thorbecke, 1998; Tarp et al., 2002).

The impact of any change in the exogenous demand accounts in the SAM model can be estimated by the SAM multiplier. Because in the model we treat households as endogenous, this leaves three possible sources of stimulus for demand, including: demand of export, government spending, and demand of investment. The changes in exogenous demand for these accounts are then transferred to endogenous accounts: production sectors and households. Furthermore, these impacts have both direct and indirect impacts. The direct impacts are those of the sector, which is directly impacted by the shock. For example, an increase in exogenous demand for country's agricultural exports has a direct impact on their agricultural sector. For the indirect impacts, it can have impacts arising from the links of the agricultural sector to other sectors and the economy-wide. These indirect impacts, in turn, can be divided into linkages between consumption and production. When we sum up all the direct and indirect impacts, we will receive a measure of the SAM multiplier from the shock.

The production linkages are defined by the input-output part of SAM. The linkages are also separated into backward and forward linkages. The backward linkages are the demand for additional inputs that producers use to provide additional goods or services. In other words, an exogenous shock could raise output in production that also means the additional amounts of goods and services are available for use as inputs to other sectors for their own production. For example, increase in agricultural production demands intermediate goods like pesticides, fertilizers, and new machinery. Then, it stimulates production in other sectors to supply these intermediate goods. Accordingly, the more input-intensive the production technology of a sector is, the stronger are its backward linkages, while the forward linkages are responsible for expanded input supply to upstream sectors. For example, when the agricultural production is expanded by an exogenous shock, the food sector can be supplied with more products, which stimulate demand for food production system.

A SAM solves the equilibrium level for all the endogenous accounts when a shock gives a changing in the exogenous account. SAM multipliers are intended to examine the impacts from the shock on the economy on income distribution across household socio-economic groups. To measure the value of all linkages between production and consumption, they capture direct and indirect impacts of the circular flow of income during the first and all subsequent rounds.

2.2. SAM Multiplier Formula

We use matrix algebra to drive the SAM multiplier formula. A two-sector in the SAM is used to demonstrate the underlying equations. Table 1 presents the SAM entries that are represented as symbols. For example, X_1 refers to the gross output from activity 1, and Y refers to the total spending from household.

Where X is gross output of each activity (i.e., X_1 and X_2)

Z is total demand for each commodity (i.e., Z_1 and Z_2)

V is total factor income (equal to household income)

Y is total household income (equal to total factor income)

E is exogenous component of demand (government, investment, and exports)

To derive a coefficients matrix called "M-matrix", we divide each column in Table 1 by the total of its column. Then we will receive the matrix that excludes the exogenous components of demand as shown in Table 2 below.

Where a is technical coefficient (i.e., input or intermediate shares in production)

b is the share of domestic output in total demand

v is the shared of value-added or factor income in gross output

l is the share of total demand from imports or commodities taxes

c is the share of household consumption expenditure

s is the household saving rate (i.e., savings as a share of household income)

From the symbols in the SAM, the decomposition of SAM multipliers can be illustrated as follows.

$$Z_1 = a_{11}X_1 + a_{12}X_2 + c_1Y + E_1 \quad (1)$$

$$Z_2 = a_{21}X_1 + a_{22}X_2 + c_2Y + E_2 \quad (2)$$

Table 1: Entry of SAM represented as symbols

	Activities		**Commodities**		**Factors**	**Households**	**Exogenous demand**	
	***A*₁**	***A*₂**	***C*₁**	***C*₂**	***F***	***H***	***E***	**Total**
A_1			X_1					X_1
A_2				X_2				X_2
C_1	Z_{11}	Z_{12}				C_1	E_1	Z_1
C_2	Z_{21}	Z_{22}				C_2	E_2	Z_2
F	V_1	V_2						V
H					$V_{1+}V_2$			Y
E			L_1	L_2		S		E
Total	X_1	X_2	Z_1	Z_2	V	Y	E	

Table 2: M-matrix

	Activities		**Commodities**		**Factors**	**Households**	**Exogenous demand**	
	***A*₁**	***A*₂**	***C*₁**	***C*₂**	***F***	***H***	***E***	**Total**
A_1			$b_1 = X_1/Z_1$					X_1
A_2				$b_2 = X_2/Z_2$				X_2
C_1	$a_{11} = Z_{11}/X_1$	$a_{12} = Z_{12}/X_2$				$c_1 = C_1/Y$	E_1	Z_1
C_2	$a_{21} = Z_{21}/X_1$	$a_{22} = Z_{22}/X_2$				$c_2 = C_2/Y$	E_2	Z_2
F	$v_1 = V_1/X_1$	$v_2 = V_2/X_2$						V
H					1			Y
E			$l_1 = L_1/Z_1$	$l_2 = L_2/Z_2$		$s = S/Y$		E
Total	1	1	1	1	1	1	E	

$$X_1 = b_1 Z_1 \tag{3}$$

$$X_2 = b_2 Z_2 \tag{4}$$

$$Y = v_1 X_1 + v_2 X_2 \tag{5}$$

It can be seen from the row of C_1 and C_2 in Table 2 that the Equations (1) and (2) are total demand Z in each sector. This value is the sum of intermediate input demand from activities, consumption demand from household, and E which is other exogenous source of demand, for example public consumption, investment, and trade with the rest of the world. Equations (3) and (4) are demonstrated by the row of A_1 and A_2 that the gross output X is only part of total demand Z. In Equation (5), we also know that total household income Y depends on the share of factor payments in each sector to household. In addition, substituting Equations (3) and (4) into the Equation (5) gives the following identity for total household income Y. This mapping can be written by the Equation (6) below:

$$Y = v_1 b_1 Z_1 + v_2 b_2 Z_2 \tag{6}$$

In Equations (1) and (2), we can now replace X and Y with Equations (3), (4) and (6).

$$Z_1 = a_{11} b_1 Z_1 + a_{12} b_2 Z_2 + c_1 \left(v_1 b_1 Z_1 + v_2 b_2 Z_2 \right) + E_1 \tag{7}$$

$$Z_2 = a_{21} b_1 Z_1 + a_{22} b_2 Z_2 + c_2 \left(v_1 b_1 Z_1 + v_2 b_2 Z_2 \right) + E_2 \tag{8}$$

We transfer all terms, except for exogenous demand E, to the left.

$$Z_1 - a_{11} b_1 Z_1 - c_1 v_1 b_1 Z_1 - a_{12} b_2 Z_2 - c_1 v_2 b_2 Z_2 = E_1 \tag{9}$$

$$Z_2 - a_{21} b_1 Z_1 - c_2 v_1 b_1 Z_1 - a_{22} b_2 Z_2 - c_2 v_2 b_2 Z_2 = E_2 \tag{10}$$

Lastly, Z terms are grouped together.

$$\left(1 - a_{11} b_1 - c_1 v_1 b_1\right) Z_1 + \left(-a_{12} b_2 - c_1 v_2 b_2\right) Z_2 = E_1 \tag{11}$$

$$\left(-a_{21} b_1 - c_2 v_1 b_1\right) Z_1 + \left(1 - a_{22} b_2 - c_2 v_2 b_2\right) Z_2 = E_2 \tag{12}$$

Now, we can see matrix format by using matrix algebra to convert Equations (11) and (12).

$$\begin{pmatrix} 1 - a_{11} b_1 - c_1 v_1 b_1 & -a_{12} b_2 - c_1 v_2 b_2 \\ -a_{21} b_1 - c_2 v_1 b_1 & 1 - a_{22} b_2 - c_2 v_2 b_2 \end{pmatrix} \begin{pmatrix} Z_1 \\ Z_2 \end{pmatrix} = \begin{pmatrix} E_1 \\ E_2 \end{pmatrix} \tag{13}$$

From the first term in Equation (13), we have:

$$\begin{pmatrix} 1 - a_{11} b_1 - c_1 v_1 b_1 & -a_{12} b_2 - c_1 v_2 b_2 \\ -a_{21} b_1 - c_2 v_1 b_1 & 1 - a_{22} b_2 - c_2 v_2 b_2 \end{pmatrix} = I - M \tag{14}$$

M is known as the coefficient matrix and I is called the identity matrix. Moreover, by renaming the other two vectors Z and E, Equation (13) can be expressed as Equation (15).

$$\left(I - M\right) Z = E \tag{15}$$

Finally, by rearrangement, we arrive at the multiplier formula or, more precisely, the SAM multiplier matrix $\left(I - M\right)^{-1}$ in Equation (16).

$$Z = \left(I - M\right)^{-1} E \tag{16}$$

This formula reveals that total demand can be calculated by multiplying the multiplier matrix by exogenous demand. When exogenous demand E increases, after taking into account all rounds of direct and indirect linkage impacts, we will end up with a final increase in total demand equal to Z (that is, a multiple of the direct shock). The linkage effects information from the SAM is integrated into the multiplier formula by means of the coefficient matrix M. With this formula, we can now examine the impacts of an exogenous demand shock on the economy.

2.3. Two Types of SAM Multiplier

The source of SAM multipliers is created by the intercorrelations between the production interactions and the institutional transactions. The industry does activities and commodities, and there gives impact through production linkages, it is known as the Type I multiplier (Miller & Blair, 2009), then it expenses factors, i.e., compensation for employee and income for the owner. The households will receive money through the factors account that does not directly from the accounts of activities and commodities. In addition, the Type I multiplier is considered as indirect impact. While the Type II of SAM multiplier assumes that each additional income of households goes to local households to buy goods and services through the commodities account, which drive the induced effect on production activities onwards.

3. Constructing SAM for Thailand 2018

The main characteristics of the Thai economy can be described by giving the information contained in the SAM. This construction is demanded by several data sets and it cannot be avoided by the economic and social structure interdependencies, which are necessary to analyze the policy implications. In order to see the effects more clearly, the more disaggregated the SAM, the more visible the impacts will be. We aggregate the SAM based on the existing linkages between one exogenous account, i.e., the net import value of the three dangerous chemical pesticides, and 26 accounts of endogeny, i.e., we focus on the related food activities and income distribution. We then receive the 27x27 matrices of disaggregated SAM.

This paper aims to shed new light for Thailand on the impact of pesticide use through a case study of the three dangerous chemical pesticides on household and food sectors, especially focusing on the food sector that has been linked to maize, cassava, fruits, sugar cane, and oil palm. These are the related agricultural products allowed to be produced with the use of pesticides, and therefore adopted to be upstream of the food sector in this disaggregated SAM. The endogenous accounts are divided into six main accounts and 26 sub-accounts that include two sub-accounts of agricultural production activities, eight sub-accounts of industrial production activities, one sub-account of pesticide-related illnesses, four sub-accounts of factors, six sub-accounts of institutions, one sub-account of capital account, and one sub-account of the rest of the world. They are listed below.

Table 3: The endogenous accounts of disaggregated SAM

Main accounts	Sub-accounts
Food Production activities	
1. Agricultural sector	– Related agricultural products (i.e. Maize, Cassava, Fruits, Sugar cane, and Oil palm) – Other agricultural products
2. Food sector	– Grinding of maize – Flour and other grain milling – Animal feed – Tapioca milling – Canning and preservation of fruit and vegetables – Sugar – Coconut and palm oil – Other industry products
3. Service sector	– Restaurants and drinking places – Other service products
4. Other production activities	– Sum of the rest of account in Input-output table
Pesticide-related illnesses	
Factors	
1. Labor	– Agricultural household – Non-agricultural household
2. Capital services	– Agricultural household – Non-agricultural household
Institutions	
1. Households	– Agricultural household – Non-agricultural household
2. Firm	– Firm
3. Government	– Government
4. Tax	– Direct tax – Indirect tax
Capital account	
The rest of the world	

Data for this aggregated SAM were collected from the National Economic and Social Development Board of Thailand (NESDB) in the unit of million baht, using a combination of the Input-Output table in 2010 and National Income accounts in 2018. Due to the limitation of the Thai statistics, the Input-Output table was adapted by the growth rate of GDP between 2010 and 2018. Therefore, the Thai disaggregated SAM data used in this study are based on the data of the Thai economy in 2018. Following Resosudarmo and Thorbecke (1998), we comprise the proxy of cost of treatment for the pesticides-related illnesses from the National Health Security Office (NHSO) of Thailand into the SAM as an endogeny. Because of the lacking data, we also assumed that Thailand has done with full pesticide use, i.e., using it as its net import. Then, we used the well-known RAS method for balancing the aggregated SAM.

4. Impact on Food Industry and the Economy

We capture the policy impact of the dangerous pesticides net import value through the stronger forward linkages between the related agricultural activity and the food production activities as detailed in Figure 1. Currently, the highest proportion of related agricultural production that contributes to the Thai economy is fruits at a percentage of 55.49, while sugar, palm oil, and maize grinding account for the highest proportion of food production that has been transformed from sugar cane, oil palm, and maize, respectively.

SAM reports over a specified time period the value of all transactions in the circular flow of national revenue and expenditure in the economy. The total output impact for each food sector is obtained from the multiplication of the matrix of multipliers and the vector of food final-demand expenditures (see Figure 2). 100% of the pesticides net import was identified to affect the food sector. To illustrate, the increase of 1 million baht of this net import for growing the related agricultural products induces an additional increase of 3.25, 3.99, 3.86, 3.01, 3.04, 3.13, 7.66 million baht in grinding of maize, flour and other grain milling, animal feed, tapioca milling, canning and preservation of fruit and vegetable, sugar, coconut and palm oil, respectively. The interesting finding was that there is a high dependency on the usage of pesticides. As shown in Figure 2, palm oil is considered to get the most impact among the food sector at the rate of 27.43%, while flour and animal feed are considered to get the subordinate impact. Other related sectors with significant increase include related agriculture and restaurants and drinking places. The original increase of a million baht of this net import generates an induced additional demand of 1.56 million baht for the related agricultural output and a 2.56 million baht increment in demand for restaurants and drinking places production.

Table 4 lists some columns of the multiplier matrix computed from the SAM, defining the net import value of the three dangerous chemical pesticides as an exogenous account. Interpretation of the type I multipliers column indicates that the increase in the pesticides net import of one million baht induces an increase of food production of 3.264 million baht in the grinding of maize sector, 3.849 million baht in the flour and other grain milling sector, 3.695 million baht in the animal feed sector, 3.000 million baht in the tapioca milling sector, 3.188 million baht in the canning and preservation of fruit and vegetable sector, 3.251 million baht in the sugar sector, and 3.948 million baht in the coconut and palm oil sector. Totaling only the food sector creates 25.274 million baht in the whole economy by summing the total multipliers on the food sector. It also creates a total of 2.715 million baht of household income. Nevertheless, the strategy has not escaped inequality in labor wages.

Figure 1: Share of related agricultural products and its food linkages

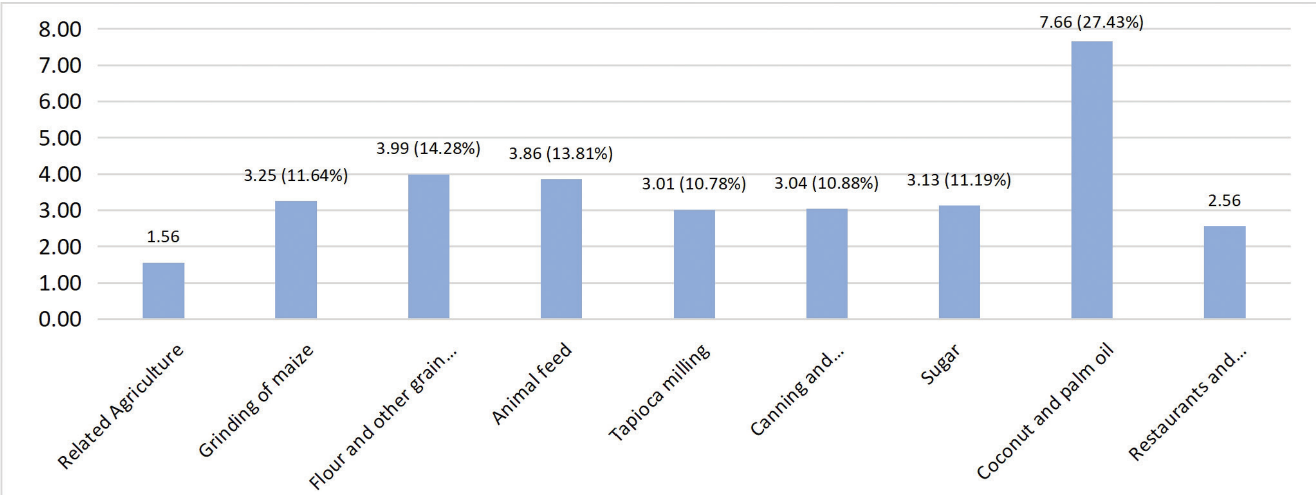

Figure 2: The impact of the pesticides net import value on food production activities

Moreover, there is the cost of treatment for the pesticides-related illness. The findings in row 14 reveal an increase in one million baht of the pesticides net import generates 0.253 million baht illnesses cost in grinding of maize, 0.217 million baht in canning and preservation of fruit and vegetables, and 0.359 million baht in sugar, totaling 0.829 million baht. While the column 14 shows that an increase in the pesticides net import for the agro-food sector induces the high cost of treatment in palm oil and animal feed. As Thailand has a Universal Coverage Health Care program, this means that most of the illness cost of palm oil sector is supported by the government, while the grinding of maize, canning and the preservation, and sugar sectors are more on their own support. The last one, column 26, shows the contrast impact of the pesticides net import. The impact of injection that induced from the rest of the world on the food sector seems to be small and the total multiplier effect on household income is only a 0.004 million baht increment with an unequal share between agricultural and non-agricultural households.

5. Conclusions and Policy Implications

The lack of the economy-wide impact assessment of pesticide use in Thailand and particularly the scarcity of previous research works to reach conclusions concerning the consequences of the three dangerous chemical-pesticides' (i.e., Paraquat, Chlorpyrifos, and Glyphosate) use on the economy have entitled these pesticides to be used for improving the Thai agricultural productivity under the Hazardous Substance Act B.E. 2535 and its amendments B.E. 2562. Any policy changes regarding the ban or the restricted permission of the use of these pesticides will have tremendous implications on the related agricultural sector, food sector, and farming households due to market linkages. Thus, this issue has drawn considerable interest from different stakeholder groups and is worth investigating.

This paper has explained where and to what extent the impact of the use of hazardous pesticides is felt in different segments of the Thai economy. We analyze the data from a SAM by adding the pesticide-related illness sector following Resosudarmo and Thorbecke (1998). By adding the net import value of the pesticides into the SAM, our work has led us to conclude that the food industry and the economy are significantly affected by the three dangerous chemical pesticides. The computational results placed upper limits on the quantitative impact of the pesticides intended to describe both benefits and costs for farmers. The SAM proved to be 25.274 times on food sector, 2.715 times on household income, and 0.829 times on pesticide-related illnesses. However, the criterion of economic behavior included in the SAM analysis emphasizes existing sectoral linkages in the economy. While other agricultural activities are not allowed to use the pesticides, the indirect effect of pesticides use on the related agricultural sector is significant because there is more integration with the pesticides. The increase in output in the related agricultural sector could lead to an increase in output in the food sector resulting in a more output supply to restaurants and drinking places and fulfill the bigger final demands. Besides, even maize has the smallest share in the related agricultural sector, its role in the food sector is not small by being the main ingredient in the flour, animal feed, and grinding of maize components. It means that the need for pesticides use is high in maize, which is a raw material for food production activities in the supply chain. On the other hand, the share of fruits is the largest in the related agricultural sector but with only a tiny effect to generate impact and share in the food linkage, i.e., only for canning and the preservation of fruit component. It may be assumed that the fruits sector still lacks innovation to create other kinds of food products. The assumption about cassava is practically the same as the fruits sector, lacking innovation for further processing into other products and cassava still being the pesticides-consuming crop. However, the forward linkages of flour, animal feed, and palm oil are higher than average. Thus, it is important to ask whether the food production level is enough to avoid bottleneck situations among the intricate dependency in the economy.

Table 4: SAM multipliers

		Type II multipliers					**Type I multipliers**						
		26	**14**	**19**	**20**		**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	Related Agri.	0.000	0.137	0.000	0.000		0.047	0.000	0.000	0.000	0.041	0.067	0.000
2	Other Agri.	0.005	0.000	0.182	0.216		0.000	0.077	0.271	0.008	0.000	1.472	0.000
3	Grinding.	0.000	0.000	0.000	0.008		3.264	0.000	0.000	0.001	0.007	0.000	0.000
4	Flour.	0.000	0.000	0.000	0.006		0.000	3.849	0.000	0.000	0.000	0.000	0.052
5	Animal feed.	0.000	0.008	0.001	0.000		0.000	0.002	3.695	0.000	0.000	0.014	0.117
6	Tapioca milling	0.000	0.001	0.000	0.000		0.000	0.000	0.000	3.000	0.000	0.000	0.000
7	Canning.	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	3.188	0.013	0.000
8	Sugar	0.000	0.000	0.002	0.000		0.259	0.000	0.000	0.000	0.001	3.251	0.000
9	Palm oil.	0.000	0.404	0.041	0.062		0.000	0.021	0.063	0.003	0.000	0.282	3.948
10	Other Indus.	0.003	0.000	0.319	0.000		0.000	0.000	0.000	0.000	0.085	0.000	0.000
11	Restaurants.	0.000	0.000	0.000	0.062		0.006	0.000	0.013	0.005	0.063	0.000	0.000
12	Other Serv.	0.002	0.000	0.000	0.217		0.051	0.000	0.041	0.000	0.304	0.000	0.000
13	Others	0.001	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.643	0.000	0.000
14	Pesticide-related illnesses	0.002	0.736	0.000	0.000		0.253	0.000	0.000	0.000	0.217	0.359	0.000
15	Agri. Labor	0.000	0.347	0.035	0.052								
16	Non-Agri. Labor	0.000	0.000	0.007	0.000								
17	Agri. CS.	0.002	0.906	0.092	0.136								
18	Non-Agri. CS.	0.000	0.000	0.011	0.000								
19	Agri. HH.	0.000	0.000	0.000	0.000								
20	Non-Agri. HH.	0.004	0.000	0.000	2.078								
21	Firm	0.000	0.000	0.000	0.000								
22	Govt.	0.000	0.000	0.000	0.000								
23	Direct tax	0.000	0.000	0.000	0.012								
24	Indirect tax	0.000	0.000	0.001	0.000								
25	CA.	0.000	0.000	0.000	0.000								
26	ROW.	0.000	0.004	0.000	0.000								
Total multipliers													
Food sector		0.000	0.551	0.044	0.137		3.575	3.872	3.772	3.010	3.301	3.627	4.117
Labor wage		0.000	0.347	0.042	0.052		0.036	0.047	0.217	0.050	0.135	0.631	0.000
Household income		0.004	0.000	0.000	2.078		0.362	0.038	0.454	0.333	1.521	0.006	0.000

Note: 0.0000 = less than 0.0001.

Another conclusion is that the demand for extra food products will, in turn, stimulate activity in the related agricultural sector. The increased activity in the related agricultural sector will create greater demand for the pesticides net import. It is important to note that a higher volume of pesticides net import will be corresponded by a larger amount of pesticides use and higher pesticides-related illness cost if we do not manage well the food industry system. Palm oil and animal feed can spend less on the cost of illnesses but receive more support from the Thai government. Overall, there is the pesticides use for food demand in Thailand more than trading to aboard, and another finding that raises the economic concern is the inequality of income distribution from the food production activities.

Consequently, the findings of our study have serious implications for the management of the economy and the provision of essential food safety policy.

1. Finding innovation for fruit and cassava to create new food products. Also, building business networks as well as the development of the strategic intuition capability should be performed for developing competitive skills of entrepreneurships and sharing innovative ideas among them. These could affect innovation capability to enhance business and industry outcomes (Hareebin, 2020; Aujirapongpan et al., 2020). Then, it will contribute more impact multipliers to the economy.
2. The Thai government should conduct and develop the food management system on flour, animal feed, and palm oil due to high dependency in the pesticides impact and being the high output sectors, to avoid bottleneck situations.
3. Considering the distribution of the government support for pesticides-related illnesses, grinding of maize, canning and preservation of fruit, and sugar sectors have made smaller impact multiplier on the other food sectors but they are more responsible for the illnesses cost. They need support from the government.

Finally, future studies on the current topic are therefore recommended. We might add the consideration on the environmental cost because pesticide reductions can involve environmental advantages (Mullen, 1995), and we might produce an up-to-date SAM due to the rapid structural transformation of the economy.

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