



Welfare of the rubber crop diversity farmers under risks of price in Thailand

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Abstract

The presence of risks in rubber markets would have significant adverse effects on farmers' welfare. Crop diversity is usually proposed as a countermeasure to mitigate the negative environmental impacts and high price risks faced by monocultural rubber farmers. Given that most farmers in developing countries are risk-averse, the present study aims to examine the differences in price risk experienced by crop diversity and monoculture rubber farmers, while illustrating the welfare impacts of crop diversity within a theoretic risk-averse framework. Standard deviation is employed as a measure of price risk indices for rubber and other major agricultural products. The data on prices of main agricultural products were obtained from the Office of Agricultural Economics (OAE), covering the period from 2002 to 2021. The estimated price risk indices for rubber prices and prices of 18 other major crops indicate that the annual rubber price risk index is highest among all major agricultural products in Thailand, with a value of .417. In comparison, the average price risk indices of food crops and horticulture/fruit crops are .252 and .257, respectively. These elevated levels of rubber price risks could result in substantial risk costs and decreased welfare for farmers engaged in monoculture practices, particularly those who are trapped in poverty. This confirms the potential benefit associated with adopting crop diversity to enhance household welfare within the rubber industry, providing compelling evidence supporting efforts towards promoting rubber crop diversity plantation and sustainable development of rubber industry in Thailand.

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Introduction

The agriculture sector in Thailand is highly market-orientated and deeply integrated into international markets. According to the agricultural statistics reported by OAE, the agricultural sector contributed 8 percent to the GDP in 2019, with approximately one-third of the Thai labor force employed in this sector. As a significant global exporter of agricultural products, Thailand exported 1.3 trillion baht (0.039 trillion US dollar) in 2021 (Bangkokbiznews, 2022). Following the data from Department of Trade Negotiations (DTN), rubber, cassava, and rice constitute the majority share (57% in 2021) of total Thai agricultural exports (Department of Trade Negotiations [DTN], 2021). Notably, nature rubber serves as a vital income source for about 1 million agricultural households and plays a crucial role in driving the economic growth in Thailand. Since the introduction of rubber trees in Thailand, the rubber industry has had significant progress due to the tropical climate and effective cultivation methods, leading to Thailand's emergence as the world's top producer and exporter of rubber (Thailand Board of Investment, 2017). The popularity of the rubber industry in Thailand has been driven by high rubber prices and promotional policies, including poverty reduction programs. Over time, the area dedicated to rubber cultivation in Thailand has expanded from .48 million hectares in 1960 to 3.38 million hectares in 2011. And the nature rubber production has grown at a speed of 5.81 percent. By 2020, the cultivation area had further increased to 3.57 million hectares with the harvest area covering 3.29 million hectares and yielding a total rubber production of 4.69 million tons.

However, there are some challenges for the sustainable development of the rubber industry due to the popularity of monocultural rubber plantations (Benton et al., 2003; Erskine et al., 2006; Smajgl et al., 2015), which are associated with adverse environmental impacts include deforestation, loss of crop diversity, soil erosion, drought and hydrological service depletion, as well as increased vulnerability to natural disasters such as fire and flood (Baltodano, 2000; Jongrungrot, 2014; Liu et al., 2018; Somboonsuke et al., 2018). Furthermore, the agricultural prices have exhibited significant fluctuations in recent years, particularly in the natural rubber market. Agriculture is susceptible to unpredictable factors such as rainfall, pest and disease outbreaks, and demand shocks. Particularly, economic crisis and economy slowdowns in the European Union, USA, and China have negatively

impacted the rubber market over the past decade. The price of Standard Thai Rubber 20 has continuously decreased from 141.35 baht per kilogram in 2011 to 42.64 baht per kilogram in 2020. This sharp decline has direct economic and social repercussions on rubber farmers. Various strategies have been proposed to address this issue including promoting rubber crop diversity as a way of efficient land management that enhances sustainability at both household and community level.

In rubber crop diversity plantations, rubber trees are cultivated alongside various crops on rubber farms. The number of diversified crops in rubber farms depends on factors such as the availability of household labor, geographic and climatic conditions, etc. Diversified crops in rubber plots can include staple foods, vegetables, and fruits directly consumed by households, as well as other economic trees and herbs. Therefore, rubber crop diversity farms are likened to living refrigerators that provide varieties for the local ecosystem (Kheowvongri & Pechkeo, 2017). By earning income from both rubber outputs and other diversified crops, farmers engaged in crop diversity can generally stabilize their incomes while also improving food availability and security and enhancing welfare over time. However, intercropping diversified crops within rubber plantations necessitates additional inputs and more complex farm management, leading to increased investment costs and reduced off-farm income opportunities. Given the existence of price fluctuations in rubber markets, monoculture farmers often find themselves vulnerable to high price risks. Actually, in light of the declining rubber price, the Thai government has issued various policies to promote rubber crop diversity; however, the adoption of such practices remains limited in Thailand (Charernjiratragul et al., 2015). Farmers' perceptions of rubber crop diversity significantly vary due to the volatile nature rubber markets (Charernjiratragul et al., 2017). And promoting rubber crop diversity and achieving sustainable development of the Thai rubber industry still face significant challenges, as farmers have long favored profitability (especially when the rubber price is high) and simpler farm management despite the drawbacks of income instability and environmental degradation.

Moreover, taking the risk-averse framework into consideration, the substantial volatility in rubber prices significantly further undermines the welfare of rubber farmers as most of them are risk-averse. However, there is a dearth of literature focusing on welfare changes among monoculture and rubber crop diversity farmers under different levels of risk in Thailand. To deepen the understanding of rubber crop diversity and its welfare impacts for risk-averse farmers,

it is necessary to illustrate the differential effects of price risk between monoculture and crop diversity systems. Therefore, taking risk costs into consideration, this study aims to illustrate the welfare impacts of crop diversity using a theoretic model within a risk-averse framework.

Literature Review

The diversity farm is proposed as a long-term sustainable solution to price instability. Many countries, such as Mexico, Kenya, Tanzania, India, Nepal, China, Indonesia, etc., encourage farmers to adopt crop diversity (Costedoat et al., 2015; Office of the National Economic and Social Development Council, 2011; Ottaviani & Scialabba, 2011; Smajgl et al., 2015). Di Falco and Chavas (2009) have indicated crop diversity can effectively reduce risk costs, especially for the risk-averse farmers and a high level of crop diversity would protect farmers against market risks while improving their welfare and agroecosystem resilience. In Indonesia specifically, rubber crop diversity has been adopted by farmers as a countermeasure against fluctuations in rubber prices. Williams et al. (2001) reveal that the practice of rubber crop diversity in Jambi, Indonesia alleviates economic crisis impacts on farmers. Diversified crops contribute to approximately 70 percent of total income for rubber smallholders in Indonesia. Moreover, particularly for small-scale farmers, diversified crops, including food and fruit crops significantly improve the food availability and security (Charemnjiratragul et al., 2017).

Limited literature exists on the welfare evaluation of rubber crop diversity farmers in Thailand under risks. Longpichai and Kongmanee (2019) have investigated risk perception among rubber farmers in southern Thailand, covering nine categories of risk including climate and natural disasters, financial, government policy/institution, market, household, labor, production, land, and price risks. The findings indicate that price risk is perceived as the most significant threat to rubber farmers' income and livelihoods. And increasing crop diversity in rubber farms emerges as an important strategy to manage such risks. However, to the best of the authors' knowledge, no study has evaluated the welfare impacts of price risks across rubber diversity and non-diversity groups in Thailand. The present study aims to examine the costs associated with price risk encountered by monoculture and crop diversity rubber farmers while exploring differences in their welfare implications. By providing a comprehensive understanding of the relationship between rubber price risks and farmers' welfare, this research contributes to deepening insights into the significance of prompting rubber crop diversity.

Methodology

Theoretic Model of Welfare Changes under Risks for Rubber Farmers

The market economy is characterized by inherent risks that have a direct impact on the behavior and welfare of farmers. Specifically, rubber farmers mainly face two types of risks, namely, production risks and price risks, which are closely intertwined within the markets. These risks are significantly influenced by factors such as rainfall, weather conditions, diseases, etc., leading to substantial yield fluctuations for rubber farmers, which exacerbates in rubber monoculture systems. Furthermore, price risk plays a pivotal role in shaping production behavior for rubber farmers; it not only exhibits strong correlations with domestic production but also experiences significant impacts from global market equilibrium. At the individual household level, prices of rubber products and other key agricultural commodities are, safely to say, exogenous variables, and notable volatility has been observed in these prices over recent years, resulting in substantial income instability.

Consequently, such yield and price risks have strong impacts on the welfare of farmers in Thailand. And these risks vary across different crops and would also influence the production behavior of rubber farmers. To shed light on this issue, it is necessary to propose a theoretic model that defines the welfare for rubber farmers with uncertain income. Such model would facilitate the measurement of welfare costs associated with risks, while logically expecting rubber farmers to maximize their welfare based on a utility function. The utility function $u(y)$ is defined over income y which depends on both the price p and production q of various crops within the rubber households. It should be noted that when prices are stabilized at \bar{p} and production remains constant at \bar{q} , an assured income \bar{y} can be obtained (Equation (1)).

$$\begin{cases} y = pq \\ \bar{y} = E y = \bar{p} \bar{q} \end{cases} \quad (1)$$

As mentioned before, the influential factors and risks in rubber markets would lead income fluctuations for rubber farmers. To take the risks δ into consideration, it is beneficial to assume that the random income y represents either a low or high value with the probability of π and $1-\pi$ (Equation (2)).

farmers is relatively smaller than that for monocultural rubber famers, i.e., $var(q_{div}) < var(q_{mon})$, due to trade-offs in different crop plantations under risk conditions (Gouel & Jean, 2015; Hauser et al., 2015; Simien & Penot, 2011). Similarly, Sarwosri and Mußhoff (2020) have found that the volatility of the prices faced by crop diversity farmers is expected to be lower than that experienced by monoculture farmers, namely, $var(p_{div}) < var(p_{mon})$, as diversified crops enable farmers to obtain income from various types of crops and mitigate risks. In total, the income variance for crop diversity farmers tends to be smaller compared to monocultural farmers, namely, $\delta_{div}^2 < \delta_{mon}^2$. That has important implications for risk sharing, as transferring risk to less risky productions can effectively reduce risk costs for rubber farmers. In general, diversifying rubber plantations by increasing the number of crops in their farms enables farmers to mitigate high-risk levels in agricultural production and market prices and achieve lower risk levels. Consequently, based on the utility function of the rubber farmers, the risk cost incurred by rubber crop diversity farmers would be lower than that faced by monoculture rubber farmers (i.e., $\rho_{div} < \rho_{mon}$) (Equation (9)). This also implies a welfare improvement for those rubber farmers who adopt crop diversity practices.

$$\rho_{mon} = -\frac{1}{2} \delta_{mon}^2 \cdot \frac{u''(\bar{y})}{u'(\bar{y})} > \rho_{div} = -\frac{1}{2} \delta_{div}^2 \cdot \frac{u''(\bar{y})}{u'(\bar{y})} \quad (9)$$

Empirical Model of Price Risk Evaluation

The volatility of income for rubber farmers arises from both the variation of production and market prices. Given the predominantly fixed land, infrastructure, and technology in rubber plantations, in practice, the risk costs for individual farmers in the short run primarily stem from price fluctuations in the rubber markets. Due to data availability constraints, the present study specifically focuses on analyzing price risk and its welfare implications for rubber farmers. Some studies have been conducted on price risks, and the associated welfare costs and policies (Fafchamps, 1992; Gouel & Jean, 2015; Knudsen & Nash, 1990), and there are various ways to evaluate the price risks. Sadoulet and Janvry (1995) suggest that measuring price instability generally requires detrending time series data. Therefore, a regression is performed using the natural logarithm of real prices (p) as the dependent variable and time (t) as the independent variable (Equation (10)):

$$\ln p_t = \alpha + bt + \varepsilon, \quad (10)$$

Where b represents the growth rate of real price p and ε is a random error. Computing the estimated values $\hat{p}_t = e^{\alpha+bt}$ and the relative residuals $\hat{u}_t = \frac{p_t - \hat{p}_t}{\hat{p}_t}$. Following the study of Knudsen and Nash (1990), the price risks index $I(p)$ for the series p used in this study is the standard error derived from a time-trend regression, namely, the standard deviation of \hat{u} (Equation (11)):

$$I(p) = \sqrt{\frac{1}{n} \sum_t \hat{u}_t^2} \quad (11)$$

Data Source

The prices risk indices are composed by considering the main crops. According to the NABC (2021), in 2019, agricultural land covered 46.53 percent of the kingdom, with an area of 23.88 million hectares. Paddy rice was the predominant crop choice for farmers, occupying 9 million hectares (41% of cultivated land). Rubber ranked second with approximately 3 million hectares or about 15 percent of the cultivated land. Sticky rice emerged as the third most popular option among Thai farmers, covering about 2.5 million hectares or about 11 percent of the cultivated land (Figure 2). And together, other major agricultural crops including sugarcane, maize, cassava, palm, longan, durian, pineapple, mangosteen, coffee, rambutan, peanut, mung bean, lychee, soybean, garlic, and onion, accounted for a total of 33 percent of cultivated land in Thailand.

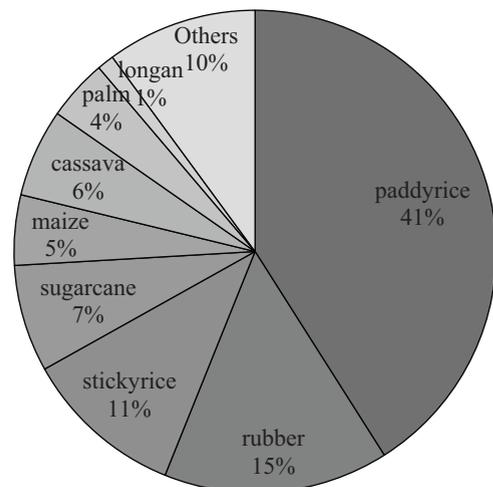


Figure 2 The distribution of major crops in Thailand's agricultural land area
Source: NABC (2021)

Therefore, the evaluation of price risks incorporates all publicly available price information on the 19 main crops in Thailand. These prices are officially derived from a consistent time series dataset spanning from 2002 to 2021, which constitutes a monthly agricultural product prices database openly accessible and maintained by the Office of Agricultural Economics. The Office of agricultural economics reports agricultural prices annually and seasonally, providing valuable information on all 19 major agricultural products in Thailand: sugarcane, pineapple, peanut, maize, paddy rice, sticky rice, cassava, soybean, mung bean, garlic, onion, longan, rubber (raw rubber sheet 3 at farm-gate), palm, rambutan, coffee, lychee, mangosteen, and durian.

Descriptive Analysis

To clearly illustrate the price fluctuations of main crops, the 19 agriculture products are categorized into two groups: food crops and horticulture and fruit crops. Table 1 presents the dynamic prices of these 19 main agricultural crops in Thailand from 2002 to 2021. Over the past two decades, rubber prices have consistently remained higher than those of other major agricultural crops while exhibiting significant volatility. In 2002, rubber was priced at approximately 26 baht/kg, slightly surpassing coffee, garlic and other major agriculture products. However, the rubber and coffee experienced a rapid surge in prices that peaked in 2011, making rubber the most valuable crop among the major agricultural products in Thailand. Unfortunately, thereafter followed a sharp decline in the rubber price which briefly rebounded during 2016–2017 but fell again in 2018 before experiencing slight growth since then. This clear indication of high price risks associated with rubber has left many rubber households uncertain about their prospects.

Conversely, other crop prices exhibited relatively smaller fluctuations compared to rubber prices. The garlic price maintained relative stability before 2008; however, it peaked at 77.15 baht/kg in 2014 and consistently remained above the rubber price until 2019. Over the past two decades, the prices of peanut and mung bean gradually increased. After 2019, the price of peanut nearly reached the level of the rubber price. Maize, paddy rice, soybean, etc., demonstrated relatively smaller volatilities in their prices. Thus, incorporating food crops into rubber diversity farms can mitigate overall price risks while stabilizing income and improving food availability for the households.

Table 1 The annual price of rubber and other major crops in 2002–2021 (baht per kilogram)

Time	food crops										horticulture and fruit crops								
	rubber	sugarcane	pineapple	peanut	maize	paddy rice	sticky rice	cassava	soybean	mung bean	garlic	onion	palm	coffee	rambutan	longan	lychee	mangosteen	durian
2002	27.69	0.44	4.23	11.74	4.09	5.33	5.27	1.04	10.39	12.85	24.59	6.31	2.30	26.46	5.96	11.53	15.09	9.64	16.05
2003	37.76	0.44	4.1	15.22	4.42	6.94	5.81	0.89	10.21	12.92	27.41	13.61	2.34	29.38	10.17	14.10	19.50	18.53	18.25
2004	44.13	0.41	4.58	13.98	4.45	8.46	6.27	0.88	11.26	13.68	19.40	4.45	3.11	26.74	7.46	13.02	8.38	14.12	16.31
2005	53.57	0.57	3.69	13.4	4.8	7.69	6.06	1.37	10.72	17.39	21.96	4.93	2.76	31.23	7.97	12.56	10.15	11.46	16.29
2006	66.24	0.69	2.45	13.58	5.24	8.03	7.61	1.21	10.49	17.94	27.52	14.73	2.39	43.81	15.77	17.14	16.92	19.47	18.97
2007	68.90	0.64	4.41	14.63	6.63	9.18	10.71	1.38	11.31	19.66	34.60	8.03	4.07	55.86	8.84	16.06	7.71	9.84	16.75
2008	73.66	0.62	4.25	17.85	7.64	12.54	6.33	1.73	16.90	16.58	17.81	3.43	4.23	61.43	9.50	26.25	18.83	12.19	20.93
2009	58.47	0.75	5	20.88	5.38	13.82	9.36	1.32	14.57	22.58	23.37	7.31	3.64	67.08	12.34	22.26	8.74	9.81	21.52
2010	102.76	0.88	5.51	20.86	8.03	13.17	15.11	2.08	13.98	33.99	49.53	11.15	4.26	58.95	13.36	29.22	14.38	13.00	25.36
2011	124.16	0.93	4.92	23.44	7.61	14.96	13.61	2.69	15.30	25.49	37.37	13.80	5.34	71.96	16.80	24.33	27.09	25.01	27.76
2012	87.15	0.94	3.3	27.16	9.35	15.37	11.93	1.99	15.75	20.77	29.27	6.53	4.91	68.86	13.39	24.24	10.97	17.04	31.92
2013	74.75	0.89	4.53	40.23	7.19	14.86	12.59	2.09	18.24	23.05	46.88	9.39	3.54	70.78	21.01	25.77	17.96	18.90	40.45
2014	53.93	0.86	7.15	41.85	7.13	12.91	10.14	2.19	18.08	32.95	77.15	9.78	4.27	65.49	18.34	25.37	11.7	20.18	34.29
2015	44.17	0.81	10.29	45.12	7.76	11.98	11.53	2.15	15.46	32.79	65.17	8.79	4.04	68.86	22.07	28.57	15.77	34.87	46.96
2016	48.81	0.80	10.18	45.4	7.01	8.80	10.67	1.67	14.47	27.01	75.47	13.20	5.41	61.33	34.20	33.24	27.59	35.56	62.96
2017	55.81	0.90	4.95	38.83	6.1	11.43	9.16	1.52	15.73	24.77	81.65	14.42	4.10	81.08	25.39	22.35	20.22	40.10	71.81
2018	40.96	0.72	2.97	44.49	7.97	15.20	9.83	2.25	16.38	21.25	57.81	9.46	3.11	69.35	23.14	26.72	22.15	43.57	78.16
2019	41.04	0.60	5.91	52.93	7.67	14.28	13.86	2.07	15.97	22.28	36.44	10.24	2.60	67.82	25.82	26.31	40.01	29.02	99.86
2020	44.85	0.73	10.68	49.72	7.65	10.92	10.65	1.89	16.71	22.92	34.47	9.06	4.27	66.54	23.48	22.28	22.78	39.63	102.15
2021	51.97	0.93	6.16	45.55	8.57	9.65	7.81	2.09	17.16	25.37	41.94	8.66	6.50	68.37	19.46	21.65	23.55	48.77	113.98

Source: OAE (2022)

Fruits are also widely cultivated in rubber crop diversity farms in Thailand. The comparison of rubber and fruits prices further highlights the higher risks observed in rubber prices over the past two decades. Coffee experienced a significant surge from 26.46 baht/kg in 2002 to 67.08 baht/kg in 2009. Both coffee and rubber are major commodities in international markets. Interestingly, while the rubber price exhibited substantial fluctuations over time, the coffee price demonstrated a steady increase with small volatility. Moreover, there were clear upward trends observed for fruit crops such as durian and mangosteen. The durian prices have witnessed rapid growth, notably an increase from 16.05 baht/kg in 2002 onwards. Since 2015, the durian prices have surpassed that of rubber and continued to soar, reaching 113.98 baht/kg by 2021. Mangosteen prices gradually increased throughout the period and nearly reached the level of rubber price in 2018. Other horticulture and fruit crops such as palm, rambutan, longan, and lychee maintained relatively stable price growth during this period as well, indicating that those crops could serve as viable options for rubber diversity farmers to ensure their welfare while transferring risks.

Results and Discussion

With data on prices of 19 major agricultural products, including sugarcane, pineapple, peanut, maize, paddy rice, sticky rice, cassava, soybean, mung bean, garlic, onion, longan, rubber (raw rubber sheet 3 at farm-gate), palm, rambutan, coffee, lychee, mangosteen, and durian, price risk indices have been estimated for those crops during the period of 2002–2021. To check the robustness in assessing price risks, both annual and seasonal risk indices are reported in Table 2. The results show that rubber exhibits the highest annual price risk with a value of 0.417 among the examined major agricultural products in Thailand. In comparison to this figure, the food crops group shows an average price risk index of 0.252 while the horticulture and fruit crops group has an average index value of 0.257 respectively. Specifically, based on the annual price risks, it is evident that lychee (0.381), garlic (0.372), pineapple (0.347), and mangosteen (0.303) have experienced relatively higher levels of annual price risk compared to other commodities such as sugarcane (0.195), durian (0.1777), maize (0.170), peanut (0.164), and soybean (0.124).

Table 2 The annual and seasonal price risk indices of major crops in Thailand in 2002–2021

Variable	Annual price data			Seasonal price data		
	Mean	SD	Risk index	Mean	SD	Risk index
Rubber	60.04	23.49	0.417	61.27	26.99	0.482
Food crops average	13.92	5.25	0.252	13.97	5.27	0.248
sugarcane	0.73	0.17	0.195	0.73	0.18	0.202
pineapple	5.46	2.38	0.347	5.44	2.36	0.341
peanut	29.84	14.71	0.164	29.93	14.94	0.145
maize	6.73	1.52	0.170	6.79	1.55	0.170
paddy rice	11.28	3.09	0.248	11.35	3.11	0.227
sticky rice	9.72	2.91	0.276	9.83	2.91	0.250
cassava	1.73	0.50	0.234	1.73	0.52	0.257
soybean	14.45	2.73	0.124	14.53	2.71	0.128
mung bean	22.31	6.27	0.237	22.58	6.65	0.254
garlic	41.49	20.11	0.372	41.65	19.91	0.367
onion	9.36	3.36	0.406	9.06	3.17	0.385
Horticulture and fruit crops average	26.62	12.10	0.257	29.21	16.21	0.402
longan	22.15	6.14	0.221	24.74	6.91	0.276
palm	3.86	1.13	0.242	3.85	1.23	0.280
rambutan	16.72	7.56	0.254	18.17	9.27	0.442
coffee	58.07	16.87	0.219	58.02	17.01	0.225
lychee	17.97	7.95	0.381	18.93	9.77	0.616
mangosteen	23.54	12.64	0.303	31.44	31.95	0.626
durian	44.04	32.41	0.177	49.32	37.32	0.352

Source: calculated by authors (2022).

When it comes to seasonal price series, the rubber seasonal price risk (0.482) is also higher than that of other major agricultural products, except for lychee and mangosteen partially due to their strong seasonality of harvests and demand. Specifically, only fruit crops such as mangosteen, lychee, and rambutan have experienced relatively high levels of price risks with corresponding values of 0.626, 0.616, and 0.442 respectively. Conversely, food crops like maize and peanut have demonstrated relatively low levels of seasonal price risks, with values of 0.170 and 0.145 respectively. Overall, there are significant price risks in rubber markets as indicated by a higher seasonal price risk index comparing to the average seasonal price risk indices of both food crops, and horticulture and fruit crops groups.

Given the prevalence of monoculture rubber farms, such price risks would result in substantial risk costs and then a significant decrease in welfare for the rubber farmers, particularly those who are trapped in poverty. However, different crops exhibit varying price risk performance, which consequently influences the production behavior of rubber farmers. According to the findings, the variance of agricultural prices for crop diversity farmers is relatively smaller than that for monocultural rubber farmers: $var(p_{div}) < var(p_{mon})$, primarily due to diversified crops enabling farmers to generate income from various crops and mitigate price risks effectively. This has important implications for risk sharing and rubber crop diversity. In general, by increasing the number of crops on rubber farms, diversity farmers can transition high-price-risk monocultural rubber plantations to a lower-risk production system through crop diversification. Consequently, such transition would lead to decreased risk costs for rubber crop diversity farmers: $\rho_{div} < \rho_{mon}$, implying an improvement in their welfare.

These findings suggest that diversity crops in rubber farms is a viable long-term solution to mitigate price instability, which is consistent with previous studies. Longpichai and Kongmanee (2019) emphasized the significance of managing rubber price risks for farmers and proposed increasing crop diversity as an important strategy. Some studies also recommend crops diversification as a means to reduce risk costs, particularly for risk-averse farmers who allocate their lands to diverse crops to secure returns on productions and create more diverse agroecosystem (Di Falco & Chavas, 2009; Williams et al., 2001).

Conclusion and Recommendation

Nature rubber plantation is a popular choice for farmers in Thailand, but the presence of high price risks in rubber markets has strong adverse effects on farmers' welfare. The volatile and declining rubber prices over the past decade have left many rubber households trapped in uncertainty and low income. Crop diversity is usually proposed as the countermeasure to mitigate the price risks and income volatility. This study employs a theoretic model under a risk-averse framework to illustrate how these risks affect farmers' welfare differently across crop diversity and non-diversity groups. Using price data from the Office of Agricultural Economics spanning from 2002 to 2021, both annual and seasonal price risk indices for 19 main crops have been estimated.

The results indicate that rubber generally exhibits the highest risk index compared to food crops, and horticulture and fruit crops, suggesting that monoculture rubber farmers suffer larger risk costs than those practicing rubber crop diversity. Moreover, food and fruit crops such as soybean, peanut, durian, longan, etc., demonstrate lower price risk indices and can be intercropped with rubber trees in rubber diversity farms to reduce overall price risks while stabilizing income and improving food availability for households. Consequently, adopting rubber crop diversity would improve the welfare of rubber farmers and provide ecological benefits to the local eco-system, which are crucial for the sustainable development of the rubber industry.

The Thai government's efforts to stabilize rubber prices for farmers have proven costly and generally insufficient in benefiting rubber farmers. A more effective strategy would involve promoting crop diversity in rubber plantations. To support this, the government should provide incentives and subsidies such as new seeds/plants, especially during the initial stages of rubber tree cultivation. Improving market accessibility and implementing diversified sales channels through various avenues such as local superstores, local companies, cooperative organizations, and contract farming, are crucial in fostering rubber crop diversity and greatly benefit farmers, especially for smallholders. Furthermore, facilitating knowledge dissemination systems and implementing subsidy policies are recommended approaches to promote rubber crop diversity in Thailand.

Finally, there are some limitations in the present study. The evaluation of price risks relies solely on secondary data. To enhance the depth of the analysis and comprehensively evaluate the welfare impacts,

it is essential to gather more detailed information. Specifically, incorporating characteristics of risk-averse individuals and exploring rubber farmers' perception of crop diversity should be considered in future studies. Therefore, conducting a farmer survey and focusing on specific regions in Thailand can provide valuable insights into the risk-averse individuals and their perception of rubber crop diversity, thereby enriching the analysis price risk and its welfare impacts in the near future.

Conflict of Interest

The authors declare that there is no conflict of interest.

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