Risk analysis of the rice supply chain in Cambodia

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Abstract

Purpose – This paper aims to analyze the risks faced by the Cambodian rice supply chain (RSC), including risk identification, risk investigation and risk management.

Design/methodology/approach – The first qualitative area of exploration from this exploratory sequential design is to identify the potential risks, in which the authors conduct in-depth interviews with ten different experts in Cambodia. Using the structural equation model (SEM) in AMOS and descriptive statistics analysis, this study investigates the risks that affect the RSC performance on an environmental, social and economic basis and subsequently proposes risk management strategies. The authors collect quantitative data from 200 Cambodian farmers through interviews and surveys.

Findings – The results illustrate that the farm households face 18 risk factors. The researchers consolidate 18 risk factors into four classifications: supply risks, production risks, demand risks and environmental risks. Nine experts out of the ten who were interviewed (90%) consider themselves "highly vulnerable" (with a rating of 4 or 5 on the Likert scale), while only one expert has a "neutral" stance (with a rating of 3 on the Likert scale); these results concerning risk identification are visualized in the likelihood effect matrix of the RSC. After investigating the risks, the authors found that RSC performance is significantly affected by the RSC risks. In particular, four groups are created, representing two different approaches to mitigate, avoid, transfer and cope with agricultural risks, i.e. *ex ante* and *ex post* risk management strategies.

Originality/value – This study fully answers research questions regarding risk identification, risk investigation and risk management.

Keywords Farm households, Risk identification, Risk investigation, Risk management, Structural equation model, Cambodian rice supply chain

Paper type Research paper

1. Introduction

Agriculture is integral to Cambodia, both in terms of its economy and way of life (Chung *et al.*, 2019). The Royal Cambodian Government (RCG) announced its ambition to turn the kingdom into a primary "rice–white gold" exporting country in the global market. The RCG aims to promote agricultural development at a new pace and on a new scale so as to broaden and strengthen the foundation of economic growth while improving people's livelihoods and accelerating poverty alleviation (Royal Government of Cambodia, 2010).

In the Khmer Empire/Angkorian Civilization from the 9th to the 14th century AD, many temples (including Angkor Wat Temple) (Miksic and Yian, 2016; Nesbitt, 1997), an extensive agriculture network and a large irrigation system (Arias *et al.*, 2012) were constructed. After that, political instability and wars marked the country, negatively affecting the economy and devastating Cambodian rice exports right until the 1990s (Cosslett and Cosslett, 2018; Dijkstra, 2019; Nesbitt, 1997).

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For at least 2000 years, Khmer farmers have been producing rain-fed rice. Today, rice production still functions as the basis of the Cambodian economy (Kea *et al.*, 2016). As a postconflict nation, Cambodia has achieved remarkable economic growth in the last decade and a half (Turner *et al.*, 2017). However, Cambodia's agricultural industry faces many constraints, challenges and risks (Asian Development Bank, 2014; Dalgliesh *et al.*, 2016; Eliste and Zorya, 2015; Mao *et al.*, 2014; Mishra *et al.*, 2018; Sithirith, 2017; Stewart and Coclanis, 2018).

The research findings from the literature review prove that supply chain risk factors (including uncertainty) negatively affect performance (Bavarsad *et al.*, 2014; Linn and Maenhout, 2019). Since there is a lack of current research and insufficient information regarding this situation in Cambodia, given this opportunity, the researchers believe it is also essential to analyze the risks in the rice supply chain (RSC) that play a significant role in the country. Therefore, the research herein is designed to fill this gap.

The primary objective of this research was to analyze the RSC risks in Cambodia (including risk identification, risk investigation by using structural equation model [SEM] and risk management). The result of this scientific research will be helpful for the farming community, the national government, commercial institutions, academics and all other stakeholders along the RSC, including nongovernmental organizations (NGOs), development agencies and various other parties.

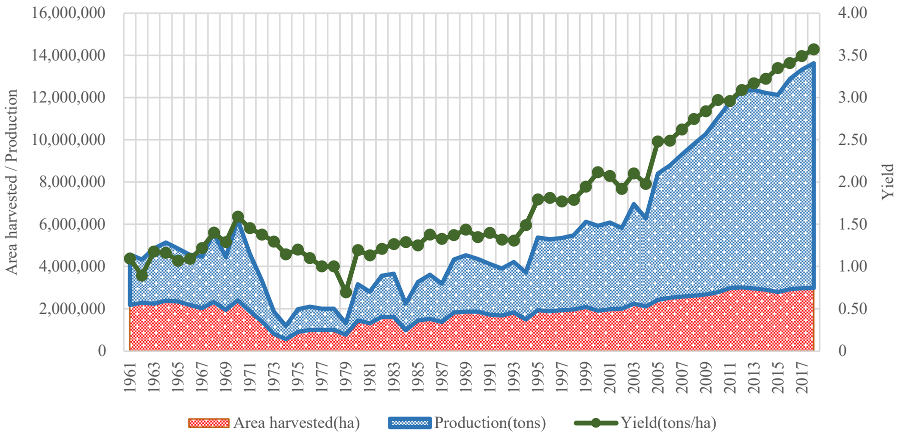
The researchers have organized the rest of this article as follows: Section 2 illustrates the overview of the RSC (literature review); Section 3 shows a new conceptual framework for risk analysis of the RSC in Cambodia; in Section 4, the researchers demonstrate the research methodology used in the study; in Section 5, the researchers give the results and discussion of the study and finally, in Section 6, the researchers present their conclusions and recommendations.

2. An overview of the literature review of rice supply chain

The RCG succeeded in attaining status as a middle-income country (MIC) in July 2016, and it alleviated the poverty rate from 47.8 (2007) to 13.5% (2014) (Fung and McAuley, 2020). While poverty alleviated significantly, the number of vulnerable people in Cambodia also rose significantly (Eliste and Zorya, 2015). Although the World Bank now classifies Cambodia as a lower MIC, the kingdom remains one of the least developed countries (LDCs) in the world according to the United Nations (UN). The kingdom aims to become eligible for LDC graduation by 2024 (World Bank, 2017). In addition, gross domestic product (GDP) per capita in 2017 was only US$ 1,384.42, which is still low when compared to global standards (Fung and McAuley, 2020). In total, 37% of Cambodia's GDP depends on agriculture, 70% of its workforce relies on agriculture and about 80% of farmers grow rice. On a positive note, since the year 2000, Cambodia has successfully become self-sufficient regarding rice production although pockets of deficits do still exist (Stewart and Coclanis, 2018). Figure 1 demonstrates that rice is one of Cambodian society's most critical agro-food products. The average rice yield in Cambodia is 3.57 t/ha, and the total production is 10,647,212 tons, with the total area harvested reaching 2,981,680 ha in 2018 (FAOSTAT, 2020).

2.1 Risk factors in Cambodia

Analysis of the existing studies enabled the identification of four risk categories mentioned across the literature, namely supply risks, production risks, demand risks and environmental risks (Figure 2). Our results show the 18 risk factors and the frequency of indications in articles. As demonstrated in Table 1, factor 6 (biological risks) and factor 14 (natural disasters) were mentioned most often.



Source(s): Authors' own making by using data from FAOSTAT (2020)

Figure 1.
Area harvested, productions and yield of rice in Cambodia

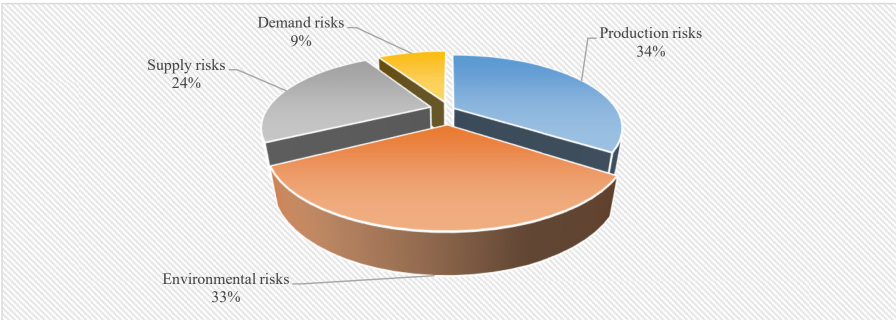


Figure 2.
Frequency of risks in the sample

Analysis of the frequency of mention illustrated that production risks occurred most often in the literature, mentioned in 20 of the 28 articles, followed by environmental risks (19/28), supply risks (14/28) and demand risks (5/28). The frequency of mention did not significantly reflect the risk prioritization. The risk prioritization in the supply chain relied on the highest risk to the lowest risk in terms of probability of occurrence, the severity of effect, etc (Rohmah *et al.*, 2015). Thus, the frequency analysis showed some risk factors commonly illustrated in the agricultural supply chain.

The researchers identified different risk factors in Cambodia across the 28 sample articles (Table 2. Articles by factors).

2.2 Sustainable performance and potential risk effects

Sustainable performance refers to consideration of the dimension of environmental performance, the dimension of social performance and the dimension of economic performance. We discovered that the economic performance holds a considerable percentage of all performance types, while other performance clusters earned limited considerations, particularly social performance and environmental performance (Table 3, Figure 3).

Some of the nine observed variables indicate related contexts or similar concepts. The number of observed variables had to be clustered to improve the results' accuracy and

Risk factors in the rice supply chain	Count
The factors of supply risks	
1. Rising costs of raw materials	3
2. Rising costs of services	6
3. Lack of high yield seeds	3
4. Lack of labor	10
5. Lack of equipment and machinery	2
The factors of production risks	
6. Biological risks	16
7. Lack of financial capital	4
8. Misuse of fertilizer or/and pesticide	7
9. Lack of agricultural know-how	11
The factors of demand risks	
10. Low prices of rice products	4
11. Lack of market information	2
12. Uncertainty of market demand for quantity	1
13. Uncertainty of market demand for quality	1
The factors of environmental risks	
14. Natural disasters	15
15. Lack of irrigation systems	10
16. Lack or poor condition of basic infrastructure	3
17. Inadequate support from the government	5
18. COVID-19	1

Table 1. Classification of significant risks faced by rice supply chains

analysis efficiency. Then, nine observed variables were consolidated into three latent variables. Environmental performances encompass the consumption rate of energy, the consumption rate of natural resources and environmental pollutants. Social performances are food insecurity, poverty and farmers' knowledge. Economic performances include the rice yield of farming households, rice quality and return on investment (ROI).

Supply chain performance is affected by risk factors in Cambodia. A massive share of the past agricultural increase was driven by farmland expansion. The expansion of agricultural land has contributed to accelerated deforestation, particularly in upland areas of the country. However, farmers have not been able to substantially increase their income because the agricultural land has remained unchanged. Moreover, Cambodia exported almost all of its crops to neighboring countries without processing them in the agro-processing industry. This shows a weakness in supply chain management (raw material collection, finance, logistics, transport, storage and information) (Eliste and Zorya, 2015). For example, Cambodia planned to export at least one million tons of rice in 2015, but the kingdom did not achieve the said goal; in fact, the 2015 measurement for exported rice was only 538,396 tons in the same year. This outcome shows that the Royal Government of Cambodia (RGC) does not have the ability and cannot support rice farmers to produce large-scale rice production (Bunnarith, 2016). Rice farming in Cambodia is also vulnerable to climate change (floods and drought) (Dalgliesh *et al.*, 2016; Mishra *et al.*, 2018). Also, the kingdom has abundant water resources in the rainy season but faces water scarcity in the dry season. This poses an enormous problem for the long-term development in Cambodia (Sithirith, 2017).

2.3 Risk management

Risk management strategies can be articulated as *ex ante* or *ex post* approaches. *Ex ante* actions occur before a risk event happens, and *ex post* management strategies occur after people have been made aware of it (Jaffee *et al.*, 2010; World Bank, 2016).

No	Author(s)	Risk factors
1	Bairagi *et al.* (2020)	6, 14
2	Castilla *et al.* (2019)	6, 9
3	Ches and Yamaji (2016)	2, 4
4	Chhun *et al.* (2019)	6, 9
5	Dalgliesh *et al.* (2016)	1, 2, 14
6	Dany *et al.* (2015)	14, 17
7	Flor *et al.* (2018)	4, 6, 8, 14, 17
8	Flor *et al.* (2019a)	6, 8
9	Flor *et al.* (2019b)	6, 8, 9
10	Grunfeld and Ng (2013)	9
11	Horita (2016)	10, 12, 13
12	Hossain (2018)	18
13	Iwahashi *et al.* (2021)	4, 6, 14, 15
14	Kea *et al.* (2016)	2, 5, 6, 7, 8, 9, 14, 15, 16, 17
15	Kong and Castella (2021)	10, 14
16	Mao *et al.* (2014)	1, 4, 5, 6, 7, 8, 9, 10, 11, 14, 15, 16, 17
17	Martin (2017)	4, 6, 9, 14
18	Martin *et al.* (2021)	2, 4, 6, 8, 9, 14, 15
19	Mishra *et al.* (2018)	1, 2, 3, 7, 9, 11, 14, 15
20	Montgomery *et al.* (2017)	3, 4, 6, 7, 10, 14, 15
21	Nguyen *et al.* (2019)	4, 6, 14, 15, 16
22	Schreinemachers *et al.* (2015)	8, 9, 17
23	Schuch *et al.* (2021)	15
24	Seng (2014)	4, 6, 14, 15
25	Sithirith (2017)	15
26	Turner *et al.* (2017)	3, 9
27	Wokker *et al.* (2014)	6, 14
28	Xangsayasane *et al.* (2019)	2, 4, 6

Note(s): Demographic information: Cambodia (the authors' country or the authors' collected data and reported data)

Table 2.
Articles by factors

N°	Sources	Performance
1	Wokker *et al.* (2014)	7
2	Kea *et al.* (2016)	7
3	Mao *et al.* (2014)	5
4	Martin. (2017)	7
5	Martin *et al.* (2021)	7
6	Mishra *et al.* (2018)	5, 7, 8
7	Montgomery *et al.* (2017)	2, 7
8	Nguyen *et al.* (2019)	2, 8
9	Rambonilaza and Neang (2019)	3, 7, 8
10	Sithirith (2017)	7
11	Thanawong *et al.* (2014)	1, 2, 3, 7, 9
12	Kadigi *et al.* (2020)	4, 5, 6, 7, 9

Table 3.
Articles by performances in Cambodia and other countries

The third output of this study is to propose appropriate solutions, which include *ex ante* risk management strategy (risk mitigation, risk avoidance and risk transfer) and *ex post* risk management strategy (risk coping). Risk mitigation refers to plans aimed at reducing the effects of the risks and/or lessening the likelihood of such occurrence; risk avoidance occurs when there are high risks. Additionally, when stakeholders can transfer risks from one party to another party or process, risk transfer (e.g. insurance) occurs (APICS, 2017). Moreover, risk

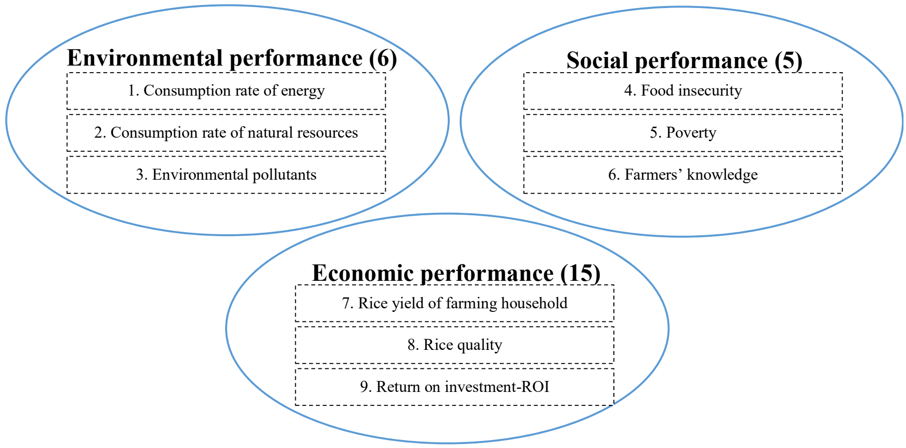


Figure 3. Three clusters of sustainable performance in the literature of rice supply chain

coping is needed to help rescue stakeholders from the situations in which they may find themselves following adverse effects and better absorb them. Risk-coping strategies include likelihood recovery programs, donations (in-kind or cash), etc. Quick interventions are often financially beneficial and reduce loss (World Bank, 2016).

3. A new conceptual framework for risk analysis of the rice supply chain in Cambodia

The conceptual framework in this study is achieved by a content analysis using triangulation data. The researchers used this content analysis technique to identify risk factors, performance factors and risk management strategies in the selected articles. The proposed conceptual framework (mixed method) is shown as follows:

4. Research methodology

This study applied diverse rules of thumb to establish the sample size of ten experts in Battambang province for the qualitative methodology to achieve saturation. The advantages of rules of thumb are quick and convenient.

This research employed "A-priori Sample Size Calculator for Structural Equation Models" to find 200 Cambodian farmers (the sample size) in Battambang province to achieve saturation in the quantitative methodology. This is because it is a reliable statistics tool (adequate power in SEM) and is widely used in similar research studies (see Table 4).

Parameter	Values
Expected effect size	0.3
Statistical power	0.8
Number of unobserved variables	9
Number of observed variables	27
p-value	0.05

Note(s): Therefore, sample size (quantitative) is 200 Cambodian farmers
Source(s): Soper (2020a, b)

Table 4. A-priori sample size calculator for SEM

The researchers employed an expert sampling method to choose each expert for in-depth interviews as part of a qualitative design. This sampling technique is significant because it is considered the best method to elicit the perspective of rice-farming specialists with a high level of knowledge and experience in a related field.

For the quantitative design, the researchers use simple random sampling, namely a probability sampling technique, for this study. The advantages of such simple random sample method are the accuracy of representation, the fact that there is no need to divide the population into sub-categories and an equal chance of selection.

This research design and the process comprised a set of mixed methods applied for data collection and analysis to measure the variables stated in the research problems. This design goes along with the conceptual framework (Figure 4) to explore the set of research questions.

IBM SPSS AMOS (analysis of moment structures), SPSS (Statistical Package for the Social Sciences) and MS Excel are used to analyze the data.

The researchers used descriptive and inferential statistics for data analysis, including arithmetic mean, sum, percentage, skewness, kurtosis, standard deviation, standard error, coefficient of variation (CV) and SEM, etc.

5. Results and discussion

We used the index of consistency (IOC) to examine the construct validity and the consistency of the findings from the questionnaires. If the IOC score is found between 0.00 and 0.49, it is excluded from the questionnaire. But the question of items with more than 0.50 IOC score means validity, readability, clarity and comprehensiveness (Muangpan, 2015). We requested five experts who earned Ph.D. degrees and have experience of more than five years to determine the IOC score. The overall IOC score is 0.9.

We tested variables using Cronbach's alpha. In general, reaching the value of alpha 0.70 or greater is deemed acceptable and self-consistent (Taber, 2018). In the second pilot test from 30 samples, Cronbach's alpha was 0.93.

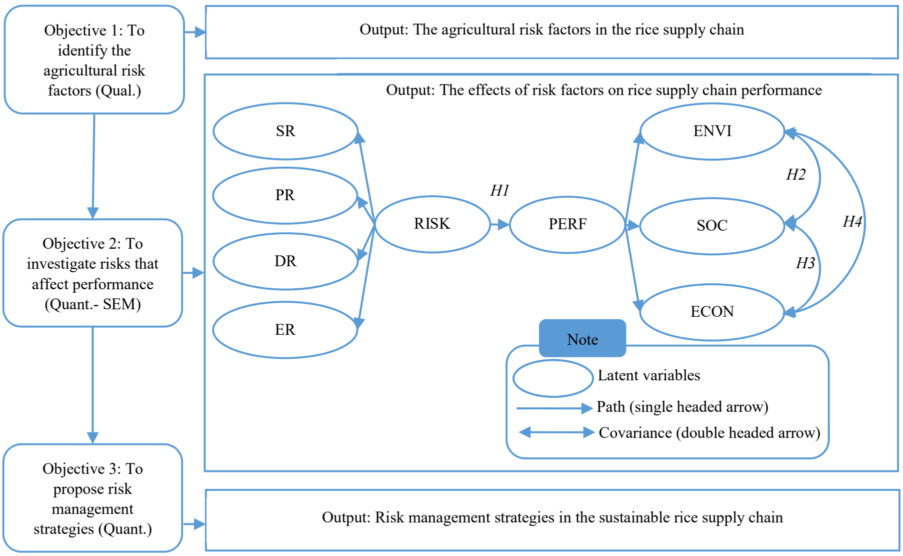


Figure 4.
The proposed conceptual framework for the research (mixed method)

5.1 Risk identification of the rice supply chain

After confirming and adding risk factors (the first pilot test from 20 samples), the results indicate that the farmers face 18 risk factors.

The researchers conducted in-depth interviews one by one with experts to prioritize risk factors. The arithmetic mean of all experts was found to be 4.30 on the five-point Likert scale ranging from "strongly disagree" to "strongly agree." Nine experts (90%) consider themselves "highly vulnerable" (point 4 or 5 on the Likert scale), while only one expert deemed their position to be "neutral" (point 3 on the Likert scale).

The 18 risk factors are depicted in the "likelihood/effect" matrix. The risks in the RSC in Cambodia can be compared concerning their likelihood of occurrence and their effect. The most critical risks in the RSC can also be identified. Figure 5 demonstrates the "likelihood/effect" matrix result.

More importantly, the researchers asked the experts to estimate the risk prioritization in their RSC. The risk prioritization relied on expected loss (expected loss scenarios = likelihood*effect). Figure 6 depicts these results.

5.2 Risk investigation of the rice supply chain

As it can be seen from Figures 5 and 6 (risk assessment matrix and risk prioritization of RSC), expected loss scenarios are high. Hence, the researchers attempted to gain some in-depth insights for investigating 18 risk factors that affect RSC performance in Cambodia. The SEM, known as causal modeling or analysis of covariance structures, is used in the second objective for investigating:

The researchers employ SEM because it is a useful statistical tool to analyze the relationship between latent variables. Latent variables refer to latent factors that researchers cannot observe directly. Instead, they are estimated by a set of manifest variables. Manifest variables (observed variables) are measured directly by the researchers.

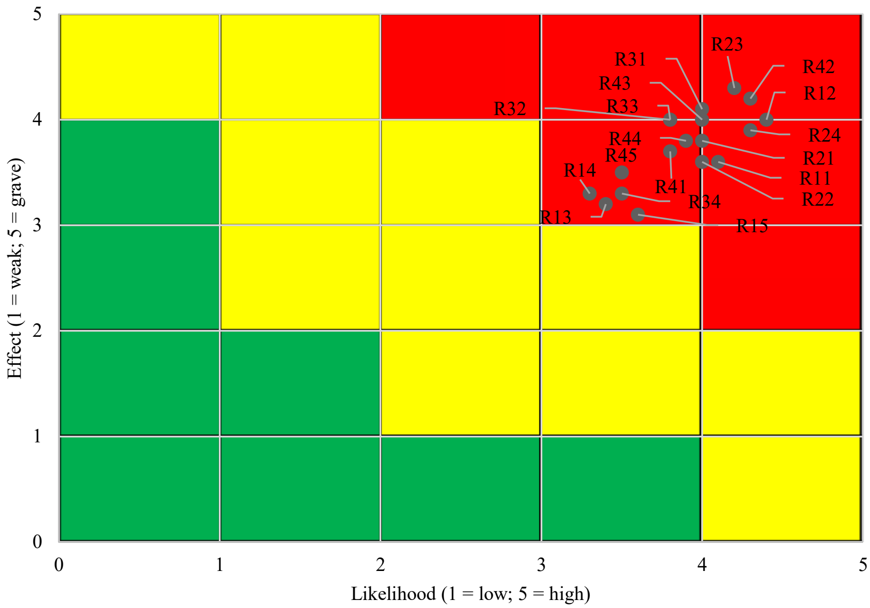


Figure 5.
The risk assessment matrix of rice supply chain in Cambodia

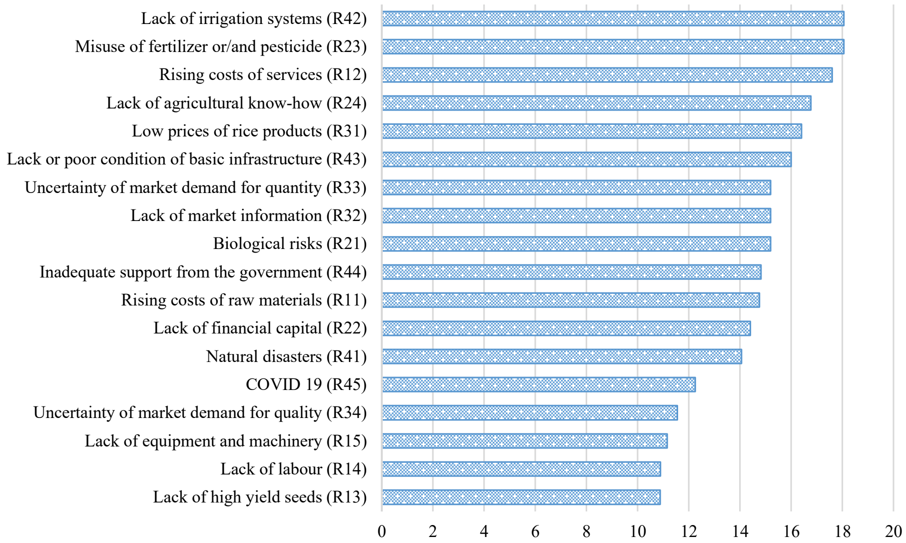


Figure 6.
Risk prioritization in the rice supply chain

To analyze the SEM, the researchers had to first check the assumptions of SEM, such as normality, no systematic missing data, linear relationships, adequate sample size, correct model specification, etc. There is an assumption that the normality of the data can be ascertained by checking the mean, standard deviation, coefficient of variation, skewness and kurtosis. The data are still considered to be normal if the kurtosis value is between −10 and + 10 and the skew value is between −2 and +2 (Collier, 2020). The research results demonstrate that the data are normal (Table 5).

Table 5 shows descriptive statistics of all risk factors and performances from 200 farmers. The low prices of rice products are highly vulnerable (mean = 4.4; standard deviation = 1.0; coefficient of variation = 22.6; skewness = −1.9; kurtosis = 3.4).

Initially, the researchers analyze the first measurement model (risks) and second measurement model (performances). If measurement models (Figure 7) are acceptable, we analyze the full research model (Figure 8). Both the first and second measurement models showed the need for modification (e.g. Figure 9).

Table 6 shows that chi-square (X^2) = 116.139; degrees of freedom (df) = 205; relative chi-square (X^2/df) = 0.567; p-value = 1.000; root mean square error of approximation (RMSEA) = 0.000; root mean square residual (RMR) = 0.026; goodness-of-fit index (GFI) = 0.960; normed fit index (NFI) = 0.951; Tucker–Lewis index (TLI) = 1.076. Following Schumacker and Lomax (2016), model-fit criteria are X^2/df < 2; p-value > 0.05; RMSEA and RMR < 0.05; GFI, NFI and TLI > 0.95. Therefore, the SEM of this study is deemed to be a satisfactory fit.

It is required that the critical ratio (CR) be greater than 1.96 in order for the estimates to be considered significant (Schumacker and Lomax, 2016). We found that all estimates are positive values following logical directions (Figure 10 and Table 6). The CR for the estimates in this study ranges from 2.681 to 6.020 as demonstrated in (Table 7). In this regard, we can make decisions and form the conclusions as follows:

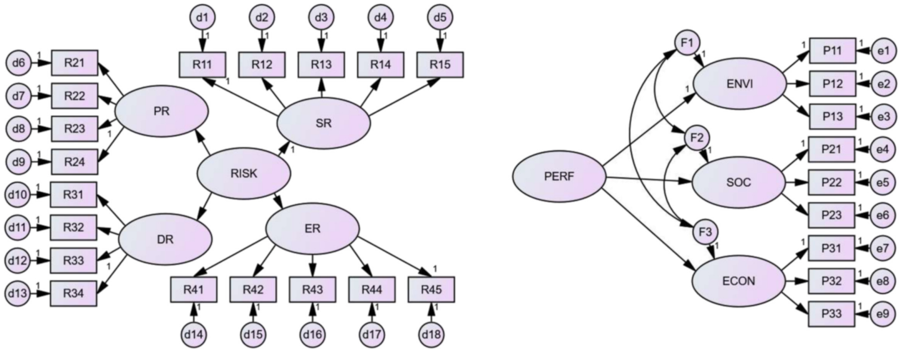
H1. t = 3.480*** > 1.96. The test is significantly different from zero at the 0.001 level (two-tailed). RSC performance is significantly affected by the RSC risks.

Risk	Var.	M	SD	CV (%)	SK	KU
The factors of supply risks (SR)						
1. Rising costs of raw materials (fertilizer, pesticide, high-yield seeds and fuel)	R11	4.1	1.1	26.0	(1.4)	1.6
2. Rising costs of services (transportation, labor, interest rates or/and credit and other agricultural services)	R12	3.9	1.0	24.7	(1.0)	0.8
3. Lack of high yield seeds	R13	3.8	0.9	24.8	(0.6)	0.2
4. Lack of labor	R14	3.6	1.0	28.7	(0.6)	0.0
5. Lack of equipment and machinery	R15	3.8	1.0	26.3	(0.6)	(0.1)
The factors of production risks (PR)						
6. Biological risks such as weeds (wild plants); pests (insects, rats, snails or birds); crop diseases (bacteria, viruses or fungi)	R21	4.0	0.9	22.3	(0.9)	0.8
7. Lack of financial capital	R22	4.0	0.9	21.8	(0.7)	0.1
8. Misuse of fertilizer or/and pesticide	R23	3.9	0.9	23.1	(1.1)	1.5
9. Lack of agricultural know-how	R24	4.1	0.8	19.0	(0.8)	1.0
The factors of demand risks (DR)						
10. Low prices of rice products	R31	4.4	1.0	22.6	(1.9)	3.4
11. Lack of market information	R32	4.3	0.9	20.4	(1.5)	2.7
12. Uncertainty of market demand for quantity	R33	4.1	0.9	22.1	(1.2)	1.7
13. Uncertainty of market demand for quality or/and food safety requirements	R34	4.1	0.8	20.2	(0.8)	0.5
The factors of environmental risks (ER)						
14. Natural disasters (flood and drought)	R41	4.1	0.9	21.3	(0.7)	0.1
15. Lack of irrigation systems	R42	4.2	0.8	19.7	(1.1)	1.5
16. Lack or poor condition of basic infrastructure (roads and electricity)	R43	3.9	0.9	23.3	(0.6)	0.2
17. Inadequate support from the government (lack of agricultural know-how training and/or lack of public extension services)	R44	4.0	0.9	21.9	(0.8)	0.3
18. Pandemic risks (COVID-19)	R45	4.1	1.0	23.5	(1.1)	0.9
Performance (PERF)						
Environmental performance (ENVI)						
1. The consumption rate of energy, which includes electricity and oil	P11	3.9	0.8	22.1	(0.8)	1.2
2. The consumption rate of natural resources, such as water and land	P12	3.8	0.7	19.7	(0.8)	1.9
3. The environmental pollutants (water, land and air)	P13	4.0	0.9	23.4	(0.9)	0.9
Social performance (SOC)						
4. Food insecurity (the scale of accessibility to foods and eating patterns)	P21	3.7	0.8	22.8	(0.5)	0.3
5. Poverty	P22	4.1	0.9	22.4	(0.9)	0.8
6. Farmers' knowledge	P23	4.0	0.8	20.7	(0.7)	0.8
Economic performance (ECON)						
7. Rice yield of farming household	P31	3.9	0.9	21.8	(0.6)	0.4
8. Rice quality (nutritional benefits, softness, aroma and physical appearance)	P32	3.8	0.8	21.4	(0.6)	0.7
9. Return on investment (ROI) (net profit divided by the costs of investment)	P33	4.0	0.9	22.0	(0.7)	0.5

Table 5. Descriptive statistics of all risk factors and performances ($n = 200$)

H2. $t = 2.681^{**} > 1.96$. The test is significantly different from zero at the 0.01 level (two-tailed). There is a relationship between environmental performance and social performance.

H3. $t = 4.604^{***} > 1.96$. The test is significantly different from zero at the 0.001 level (two-tailed). There is a relationship between social performance and economic performance.



Measurement model 1: risks

(a)

Measurement model 2: Performances

(b)

Figure 7.
Measurement model 1 and 2

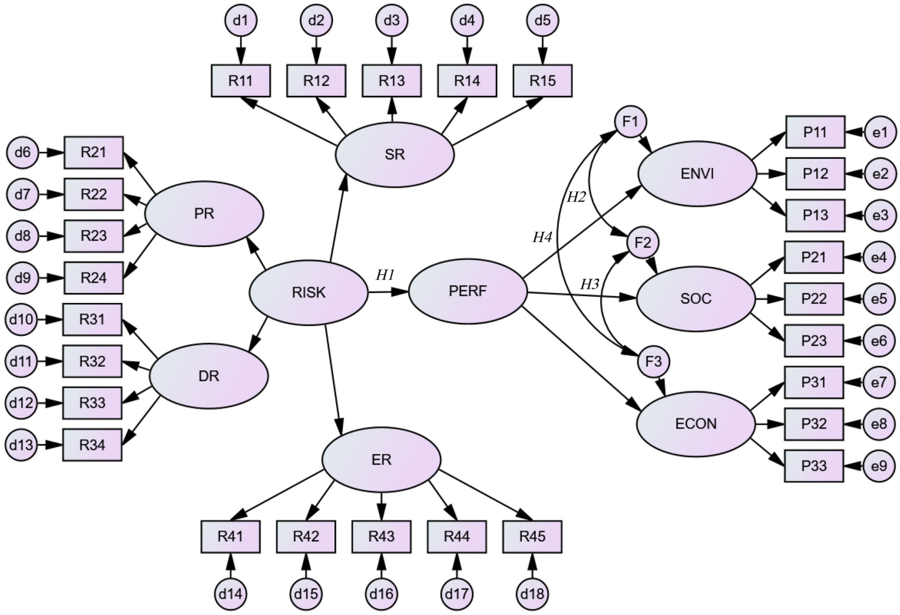


Figure 8.
Research conceptual model: SEM

H4. t = 3.515*** > 1.96. The test is significantly different from zero at the 0.001 level (two-tailed). There is a relationship between environmental performance and economic performance.

The squared multiple correlation coefficient (SMCC or R^2) shows the proportion of the total variation accounted for or explained for in the dependent variables (Y) by the set of independent predictor variables (X) (Schumacker and Lomax, 2016). It is required that R^2 be greater than 0.30 for good variables (Bavarsad *et al.*, 2014). Table 6 shows all SMCCs in this study are greater than 0.30, and all standardized regression weights (Table 7) are considered

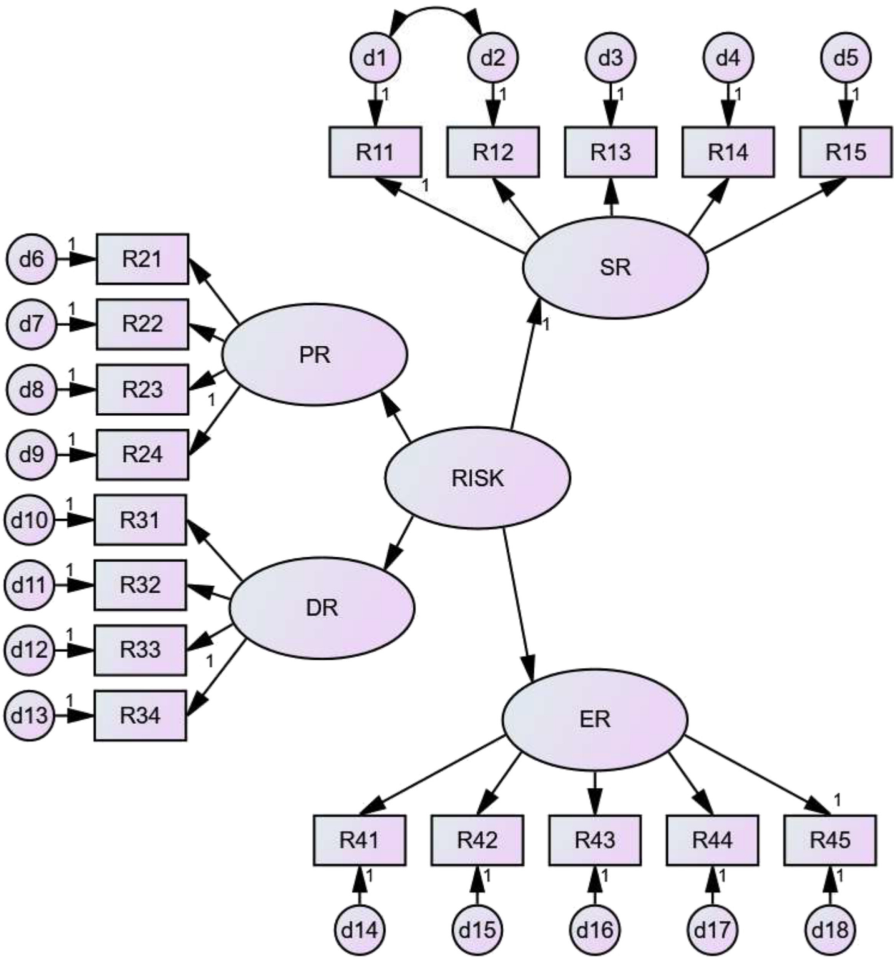


Figure 9. Modification measurement model 1 (risks)

to be significant. More importantly, environmental performance can demonstrate 81.2% of the variance of the RSC performance.

From the analysis of the risk on performances (observed variables), the environmental pollutant (P13) has the highest-effect value, followed by the consumption rate of natural resources (P12), the consumption rate of energy (P11), poverty (P22), rice yield (P31), farmers' knowledge (P23), food insecurity (P21), ROI (P33) and rice quality (P32); the standardized indirect (mediated) effect values of risk on performances are 0.612, 0.578, 0.501, 0.467, 0.454, 0.454, 0.409, 0.349 and 0.327, respectively. Also, the analysis shows that the low price of rice products (R31) is the most critical factor. When demand risk goes up by 1 SD, R31 goes up by 0.67 SD (Figure 10).

5.3 Risk management for rice supply chains

From the research herein, we found the risk factors and highlighted the effects on RSC performance. Thus, we can suggest risk management strategies to deal with the anticipated risks.

Table 6.
Results of hypothesis testing for investigating risks that affect performance

	Risk			Performance			
	Totals effects (TE)	Direct effects (DE)	Indirect effects (IE)	Totals effects (TE)	Direct effects (DE)	Indirect effects (IE)	*R*-square
Supply risks	1.00	1.00	–	–	–	–	
Production risks	1.00	1.00	–	–	–	–	
Demand risks	1.00	1.00	–	–	–	–	
Environmental risks	1.00	1.00	–	–	–	–	
Performance	1.00	1.00	–	–	–	–	
Environmental performance	0.90	–	0.90	0.90	0.90	–	0.812
Social performance	0.64	–	0.64	0.64	0.64	–	0.410
Economic performance	0.58	–	0.58	0.58	0.58	–	0.332

Note(s): Chi-square = 116.139; df = 205; Relative chi-square = 0.567; *p*-value = 1.000; RMSEA = 0.000; RMR = 0.026; GFI = 0.960; NFI = 0.951; TLI = 1.076

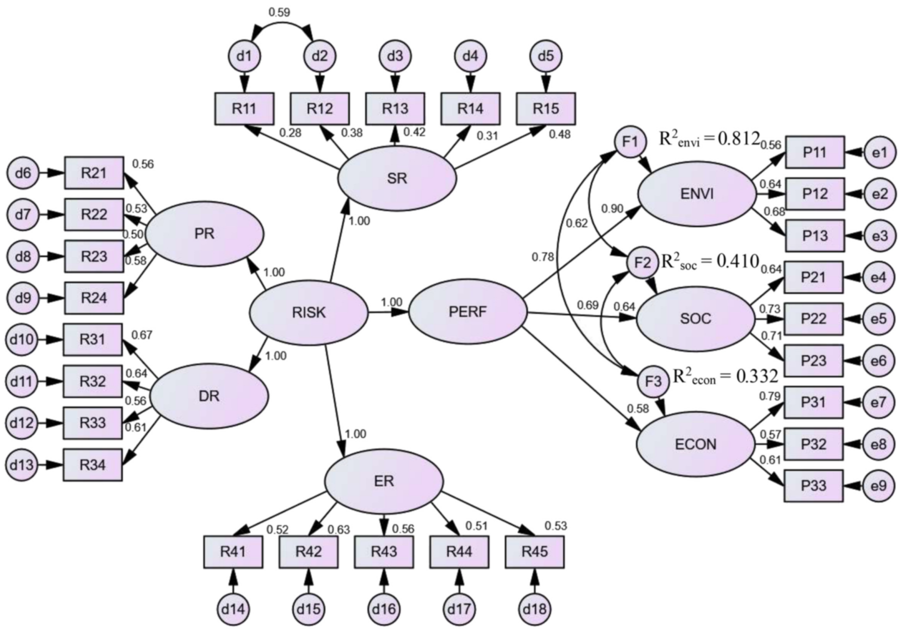


Figure 10.
SEM for investigating risks that affect performance

After interviewing and surveying 200 Cambodian farmers, the study results in Table 8 highlight the different risk management strategies for RSCs. In the overview, Table 8 indicates that most of the arithmetic mean (92%) is greater than or equal to 4 on the five-point Likert scale (4 = agree; 5 = strongly agree).

Risk management in the RSC concerns issues of development efficiency and effectiveness and is not just a matter related only to farmers. Notably, this study only focuses on farmers

			CR	P
Performance	←	Risk	3.480	***
Environmental performance	←	Performance		
Social performance	←	Performance	5.614	***
Economic performance	←	Performance	6.020	***
Supply risks	←	Risk		
Production risks	←	Risk	3.538	***
Demand risks	←	Risk	3.691	***
Environmental risks	←	Risk	3.483	***
Environmental performance	↔	Social performance	2.681	**
Social performance	↔	Economic performance	4.604	***
Environmental performance	↔	Economic performance	3.515	***

Table 7. Estimates: critical ratio (CR)

and the relevant stakeholders (e.g. government) who help farmers to manage risks in the RSC. To ensure efficiency and effectiveness in risk management strategies, the following are monitoring and coordinating actors: (1) Ministry of Agriculture, Forestry and Fisheries (MAFF); (2) Ministry of Commerce (MOC); (3) Ministry of Economy and Finance (MEF); (4) Ministry of Foreign Affairs and International Cooperation (MFAIC); (5) Ministry of Health of Cambodia (MOH); (6) Ministry of Industry, Science, Technology and Innovation (MISTI); (7) Ministry of Land Management, Urban Planning and Construction (MLMUPC); (8) Ministry of Mines and Energy (MME); (9) Ministry of Planning (MOP); (10) Ministry of Public Works and Transport (MPWT); (11) Ministry of Rural Development (MRD); (12) Ministry of Water Resources and Meteorology (MOWRAM); (13) National Bank of Cambodia (NBC); (14) farmers and (15) related stakeholders, as shown in Table 8.

6. Conclusions and recommendations

This research aimed to analyze the risks in the Cambodian RSC. It involved three research questions: (1) What are the agricultural risk factors affecting the RSC? (2) What are the effects of risk factors on RSC performance? (3) What actions should stakeholders take to manage the RSC risks?

Three primary conclusions emerged from the research's results: first, there has been an attempt to identify risk factors in the RSC in Cambodia, and the results indicated that farmers encountered 18 risk factors. Risks, which agricultural stakeholders encounter, can be organized into four categorizations, namely supply risks, production risks, demand risks and environmental risks. Second, we investigated risks that affect RSC performance (environmental, social and economic aspects) using the SEM. The SEM of this study is a satisfactory fit for all indices, including (X^2/df), *p*-value, RMSEA, RMR, GFI, NFI and TLI. All statistical hypothesis testings were found to be significant. Especially, the results show that RSC performance is significantly affected by the RSC risks. This finding is as same as that of Linn and Maenhout (2019) who concluded that the RSC performance is significantly impacted by uncertainty. Third, we proposed appropriate solutions to mitigate, avoid, transfer and cope with agricultural risks. The findings revealed that risk management strategies should include *ex ante* and *ex post* risk management strategies.

A few recommendations could be put forward to help develop the Cambodian RSC in several ways. First, Cambodian farmers need to pay additional attention to risk identification, risk investigation, risk management and the effective application of this academic study into practical activities. Second, the RGC, a significant actor, should continue to make policies, prepare plans and develop strategies as proposed by researchers with respect to the risk

Risk management strategies and relevant stakeholders	Tools	Mean (n = 200)	Standard deviation	Standard error
Risk management strategies for supply risks				
Seek alternative suppliers' (Farmers); (Related stakeholders)	RM; RC	4.1	0.8	0.1
Promote contract farming' (MAFF); (Farmers); (Related stakeholders)	RT; RM	4.0	0.9	0.1
Provide the incentive to local seed producers and distributors' (MAFF); (Related stakeholders)	RM	4.2	0.8	0.1
Use the system of "sharing-hand": help each other during the farming period; improve agricultural management practices (e.g. using direct seeding)' (Farmers); (Related stakeholders)	RM; RC	3.9	0.9	0.1
Offer tax incentives to incentivize the imports of equipment and machinery' (MEF); (Related stakeholders)	RM	4.0	0.9	0.1
Risk management strategies for production risks				
Improve agricultural management practices for biological risks (e.g. better water management, improve seeds); improve the agricultural extension services to commune level' (Farmers); (MAFF); (Related stakeholders)	RM; RC	4.1	0.9	0.1
Encourage agricultural microfinance' (MEF); (NBC); (Related stakeholders)	RM	4.1	0.8	0.1
Encourage and promote policy on sustainable utilization of farming land (e.g. effective mapping)' (MLMUPC); (MAFF); (MOP: National Institute of Statistics of Cambodia-NIS); (Related stakeholders)	RM	4.1	0.9	0.1
Develop public policies and enforce regarding sanitary and phytosanitary standards (e.g. food safety); use pesticide and fertilizer effectively; avoid risky practices through organic farms' (MAFF); (MISTI); (MOH); (MOC); (Farmers); (Related stakeholders)	RC; RM; RA	4.1	0.9	0.1
Improve productivity by using high-yielding seed and modern agricultural techniques' (MAFF); (Farmers); (Related stakeholders)	RM; RC	4.2	0.9	0.1
Support and establish farmer organization' (MAFF); (Related stakeholders)	RM; RC	4.1	0.8	0.1
Improve agricultural training' (MAFF); (Related stakeholders)	RM; RC	4.3	0.8	0.1
Risk management strategies for demand risks				
Conduct comprehensive research or study on national and international markets, which are potential for rice, to explore the opportunities; broadcast and spread the research results to a wide range of rice producers' (MOC); (MAFF); (Related stakeholders)	RM	4.2	0.8	0.1
Improve transparency and market information' (MAFF); (Related stakeholders)	RM; RC	4.2	0.8	0.1
Promote contract farming with millers/buyers' (MAFF); (Farmers); (Related stakeholders)	RT; RM	4.1	0.9	0.1
Improve warehouse management' (Farmers); (Related stakeholders)	RM; RT	4.1	0.8	0.1
Seek alternative buyers' (MAFF); (Farmers); (Related stakeholders)	RM; RC	4.3	0.9	0.1

Table 8.
Risk management strategies for rice supply chains

(*continued*)

Risk management strategies and relevant stakeholders	Tools	Mean (n = 200)	Standard deviation	Standard error
Risk management strategies for environmental risks				
Adapt for climate change (e.g. agricultural diversification); purchase insurance; aid or charity from government, international organization and other donors' (Farmers); (Related stakeholders)	RT; RM; RC	3.9	0.8	0.1
Develop irrigation (use existing water resources effectively; repair and upgrade existing irrigation; invest in new irrigation)' (MOWRAM); (MFAIC); (Farmers); (Related stakeholders)	RM; RC	4.2	0.8	0.1
Construct and maintain roads in the countryside (link rice production areas to markets)' (MRD); (MPWT); (Related stakeholders)	RM; RC	4.4	0.8	0.1
Reduce electricity price and promote electric power transmission to rural areas' (MISTI); (MME: Electricity Authority of Cambodia-EAC); (Related stakeholders)	RM; RC	4.1	0.9	0.1
Improve the agricultural extension services to commune level' (MAFF); (Related stakeholders)	RM; RC	4.2	0.8	0.1
Improve agricultural know-how training' (MAFF); (Related stakeholders)	RM; RC	4.3	0.7	0.1
Manage COVID-19 affects farmers by investing in the vaccination program, quarantine program, robust health systems and advanced R&D' (MOH); (Related stakeholders)	RM; RC	4.2	0.8	0.1

Note(s): RM: risk mitigation; RA: risk avoidance; RT: risk transfer; RC: risk coping

Table 8.

management strategies. Moreover, risk management interventions can be associated with the public stakeholders, such as government policy, public investment, agricultural training and extension services. Third, NGOs should continue to play their part in helping to support the supply chain. They can provide training, especially to create development programs or projects, to find optimal ways to improve the current problems related to the supply chain. Fourth, even though this study focuses only on farmers, further coordination may be needed from commercial institutions. Risks can also extend over the inbound stage and the outbound stage; thus, they can impact farmers and the multiple stakeholders involved in the different stages of the supply chain. When commercial players coordinate efficiently, they are able to help farmers and protect their interests sustainably.

With regard to study limitations, the following aspects should be noted. This study pays attention to the RSC in Cambodia exclusively. Also, we only focused on farmers and relevant stakeholders who help farmers. Further study could be useful for the transfer of ideas to different stakeholders in the same or other sectors and the same or other countries to test the general validity of the results.

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