# RISK ANALYSIS OF RICE SUPPLY CHAIN IN CAMBODIA: A CONCEPTUAL FRAMEWORK

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## Abstract

Rice is integral to Cambodia, yet farm households face many risks. This paper is aimed to analyze risks in the Cambodian rice supply chain (including risk identification, risk investigation, and risk management) by reviewing the extant literature to develop a new conceptual framework. A systematic literature review of the published papers from 2013 to 2021 relied on thematic, descriptive, and content analysis. The results indicated that the farmers encountered eighteen risk factors. The researchers consolidated eighteen risk factors into four categories: supply risks, production risks, demand risks, and environmental risks. Furthermore, the researchers classified performance affected by agricultural risks into three major categories: environmental, social, and economic performance. More importantly, the findings revealed that risk management strategies included ex-ante risk management strategies (risk mitigation, risk avoidance, risk transfer) and ex-post risk management strategies (risk coping). This article provides up-to-date content to aid practitioners, policymakers, and academicians in better understanding a new conceptual framework for risk analysis of the rice Supply Chain (SC) in Cambodia. The literature review will highlight a potential research gap in previous studies and provide ideas for future research. Due to many risks in the Cambodian rice supply chain, there exists an urgent need to pay additional attention to these matters.

**Keywords:** Risk Identification, Risk Investigation, Risk Management, Cambodian Rice Supply Chain, Farm Households

## Introduction

Agriculture is integral to Cambodia (a low-income country) (Chung et al., 2019), yet Cambodia's agricultural industry faces many challenges, constraints, and risks (Asian Development Bank, 2014; Dalgliesh et al., 2016; Eliste & Zorya, 2015; Mao et al., 2014; Mishra et al., 2018; Sithirith, 2017; Stewart & Coclanis, 2018). Thirty-seven percent of Cambodia's GDP depends on agriculture, and 70 percent of the workforce relies on agriculture; and about 80 percent of farmers grow rice. On a positive note, Cambodia has since 2000 been successfully self-sufficient regarding rice production; although pockets of deficits still exist (Stewart & Coclanis, 2018). There remain

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risks in Cambodian agriculture. A huge share of the past agricultural increase was driven by farmland expansion. The expansion of agricultural land has contributed to accelerated deforestation, especially in upland areas. On the other hand, farmers could not increase their income substantially because they unchanged agricultural land. Also, poverty was alleviated significantly, but the number of vulnerable people in Cambodia still rose significantly. Vulnerability proves the most significant among the smallest farms. Furthermore, the kingdom exported almost all crops to neighboring countries without processing them in the agro-processing industry. This reveals a weaknesses in supply chain management (raw material collection, finance, logistics, transport, storage, and information) (Eliste & Zorya, 2015). For instance, the Royal Government of Cambodia planned at least 1 million ton of rice export in 2015, but the kingdom did not achieve the goal; in fact, the 2015 measurement for exported rice product was only 538,396 tons in 2015 (Bunnarith, 2016). In Cambodia, rice farming is also vulnerable to climate change (drought and floods) (Dalgliesh et al., 2016; Mishra et al., 2018). Moreover, Cambodia faces water scarcity in the dry season but has abundant water resources in the rainy season. This poses an enormous problem in long-term development (Sithirith, 2017). As claimed by the Cambodian government, rural and agricultural development—including rice production development—, is a priority in the national strategic development plan for poverty alleviation and economic growth (Chung et al., 2019).

The researchers primarily attempted to analyze risks in the Cambodian rice supply chain (including risk identification, risk investigation, and risk management) by reviewing the extant literature to develop a new conceptual framework.

## Objectives

1. To identify the agricultural risk factors in the rice supply chain
2. To investigate risk factors that affect to rice supply chain performance in Cambodia
3. To propose risk management strategies in the sustainable rice supply chain management in Cambodia

## Literature Review

### Major Risks and Potential Risk Effects in Cambodia

#### Supply Risks in Cambodia

Cambodian farmers encountered many issues: in-adequate agricultural inputs, high costs of farming inputs, and lack of farm equipment (Mao et al., 2014). Normally, they were small-scale farmers, who employed a few agricultural workers and farmed seasonally to supply domestic markets. The farmers could not access loans from agricultural banks to purchase machinery and equipment; thus, they have had to use savings or borrow from dealers or financial institutions that provided high-interest rate loans (24 percent per year in Cambodia while below 1 percent per year in Vietnam). Domestic

manufacturers typically produce farm equipment and machinery for small-scale farmers without sophisticated processes such as threshers, water pumps, locally made trucks for transporting, trailers, and miscellaneous spare parts. Cambodia is still importing large-scale machinery (tractors, walking tractors, etc.) from other countries like the US, China, Japan, India, Thailand, and Belorussia (Kea & Pich, 2016).

**Production Risks in Cambodia**

A significant amount of rice production is lost due to biotics (e.g. weeds, pests, and diseases) (Bairagi et al., 2020; Castilla et al., 2019; Chhun et al., 2019; Martin et al., 2021; Mishra et al., 2018). Weeds were a significant problem for 93 percent of farmers, of which 70 percent of them claimed a yield loss of greater than 20 percent was suffered (Chhun et al., 2019). Martin (2017) demonstrated that Cambodia's average rice paddy yield at approximately 3 tons per hectare is about 50 percent of the yield potential, and losses caused by the competitions of weeds proved to be a significant issue. Castilla et al. (2019) assessed in farmers' fields the intensity of setbacks caused by biological issues (diseases, pests, and weeds) and rice yield. The results showed that most survey farmers earned lower yields than the national average of 4.03 tons per hectare, which could be attributed to the low efficiency of their crop and biological management strategies (Castilla et al., 2019).

Mishra et al. (2018) investigated the impact of abiotic stress (including access to capital in rice production) on smallholders in Cambodia. The result showed that the lack of working capital because of loan inaccessibility or/and low return could result in higher technical inefficiency in the Provinces of Cambodia (Mishra et al., 2018). According to Montgomery et al. (2017), the lack of funds was ranked by participants (research samples) as the fourth most crucial issue to production. While 34 percent of respondents listed the lack of funds as an issue to their system, 91 percent of samples had cash flow insufficiency every year.

Kea and Pich (2016) illustrated that farmers applying poison to remediate grass and insects in province posed a significant negative effect on rice output. This issue could be the result of farmers' misuse of poison in rice crops; most smallholder rice farmers have little education (Kea & Pich, 2016), and many do not follow the guidelines for using pesticides and other chemicals. These practices result in damage to crops and also pollute or harm environmental conditions (Flor et al., 2019b; Martin, 2017).

**Demand Risks in Cambodia**

Previous studies have identified the following issues: low prices of rice products, lack of market information, and uncertainty of market demand (Horita, 2016; Kong & Castella, 2021; Mao et al., 2014; Mishra et al., 2018; Montgomery et al., 2017). An officer from the Ministry of Economy and Finance also noted that Cambodian rice millers and foreign traders usually decide the prices of farmers' rice (Horita, 2016). The research reveals that most farmers (Mao et al., 2014) did not get enough

support from the government in terms of marketing. One farmer asserted that the government should help them; otherwise, most villagers will give up and migrate to another country (Mao et al., 2014).

**Environmental Risks in Cambodia**

Rice farming in Cambodia is highly vulnerable to climate change (drought and floods) and weak infrastructure (Dalgliesh et al., 2016; Mao et al., 2014; Mishra et al., 2018; Sithirith, 2017). Cambodia has abundant water resources in the rainy season and water scarcity in the dry season; this poses an enormous problem for long-term development (Sithirith, 2017). Drought significantly affects rice farming inefficiency in Cambodia (Mishra et al., 2018). The over-abundance of water in the rainy season causes frequent floods and damage; thus, the operation and maintenance of large-scale irrigation systems are inadequate (Sithirith, 2017). Cambodian farmers can primarily grow rice only once per year due to the lack of irrigation systems and good water management practices (Kea & Pich, 2016). In fact, farmers lack not only irrigation systems but also basic infrastructure such as roads and electricity (Mao et al., 2014).

The Royal Government of Cambodia planned at least 1 million ton for rice export in 2015, but the kingdom did not achieve that in its planning (exported rice products only amounted to 538,396 tons in 2015). There are many reasons for this outcome: First, the Royal Government of Cambodia (RGC) does not have the ability and cannot support rice farmers to produce large-scale rice production. Second, the RGC hasn't formulated policies or have the ability to buy rice products to stock in the warehouse for export. Third, the RGC does not have the ability to manage the national market. Fourth, the RGC does not impose policies that manage traders or private companies in purchasing rice products from farmers. Fifth, the RGC is still not in control of rice import and export (Bunnarith, 2016).

During the coronavirus crisis, the Royal Government of Cambodia permitted only the export of fragrant rice, but the government reserved other types for domestic sales to ensure local food safety. Indeed, the COVID-19 pandemic is the issue, and as a result, Cambodian farmers decrease agricultural products in Cambodia and negatively affect the farmers' livelihoods (Hossain, 2018).

**Risk Factors in Cambodia**

Analysis of the frequency of mention (Table 1 and 2) indicated that the farmers encountered eighteen risk factors. The researchers consolidated eighteen risk factors into four categories: supply risks, production risks, demand risks, and environmental risks. Moreover, analysis of the existing studies illustrated that production risks occurred most often in the literature, mentioned in 20 of 28 articles, followed by environmental risks (19/28), supply risks (14/28), and demand risks (8/28). The frequency of mention did not significantly reflect the prioritization of risk. The prioritization of risk factors in the supply chain depended on the highest risk to the lowest risk concerning the likelihood of occurrence, the effect, etc. Thus, the frequency analysis showed that some risk factors are illustrated commonly in the agricultural supply chain.

**Table 1** Classification of significant risks

| Risk Factors in Rice Supply Chain | Obs. Var. | Count |
|---|---|---|
| **The factors of Supply Risks (SR)** | | |
| 1. Rising costs of raw materials (fertilizer, pesticide, high yield seeds, and fuel) | SR1 | 3 |
| 2. Rising costs of services (transportation, labor, interest rates or/and credit, and other agricultural services) | SR2 | 6 |
| 3. Lack of high yield seeds | SR3 | 3 |
| 4. Lack of labor | SR4 | 10 |
| 5. Lack of equipment and machinery | SR5 | 2 |
| **The factors of Production Risks (PR)** | | |
| 6. Biological risks such as weeds, pests, and crop diseases | PR6 | 16 |
| 7. Lack of financial capital | PR7 | 4 |
| 8. Misuse of fertilizer or/and pesticide | PR8 | 7 |
| 9. Lack of agricultural know-how | PR9 | 11 |
| **The factors of Demand Risks (DR)** | | |
| 10. Low prices of rice products | DR10 | 4 |
| 11. Lack of market information | DR11 | 2 |
| 12. Uncertainty of market demand for quantity | DR12 | 1 |
| 13. Uncertainty of market demand for quality or/and food safety requirements | DR13 | 1 |
| **The factors of Environmental Risks (ER)** | | |
| 14. Natural disasters (flood, drought) | ER14 | 15 |
| 15. Lack of irrigation systems | ER15 | 10 |
| 16. Lack or poor condition of basic infrastructure (roads, electricity) | ER16 | 3 |
| 17. Inadequate support from the government (lack of agricultural know-how training, and/or lack of public extension services) | ER17 | 5 |
| 18. Pandemic risks (COVID-19) | ER18 | 1 |

**Table 2** Articles by factors in Cambodia

| No | Author (s) | Risk Factors (Observed Variables) |
|---|---|---|
| 1 | Bairagi et al. (2020) | PR6 and ER14 |
| 2 | Castilla et al. (2019) | PR6 and PR9 |
| 3 | Ches and Yamaji (2016) | SR2 and SR4 |
| 4 | Chhun et al. (2019) | PR6 and PR9 |
| 5 | Dalgliesh et al. (2016) | SR1, SR2, and ER14 |
| 6 | Dany et al. (2015) | ER14 and ER17 |
| 7 | Flor et al. (2018) | SR4, PR6, PR8, ER14, and ER17 |
| 8 | Flor et al. (2019a) | PR6 and PR8 |
| 9 | Flor et al. (2019b) | PR6, PR8, and PR9 |
| 10 | Grunfeld and Ng (2013) | PR9 |
| 11 | Horita (2016) | DR10, DR12, and DR13 |
| 12 | Hossain (2018) | ER18 |
| 13 | Iwahashi et al. (2021) | SR4, PR6, ER14, and ER15 |
| 14 | Kea and Pich (2016) | SR2, SR5, PR6, PR7, PR8, PR9, ER14, ER15, ER16, and ER17 |
| 15 | Kong and Castella (2021) | DR10 and ER14 |
| 16 | Mao et al. (2014) | SR1, SR4, SR5, PR6, PR7, PR8, PR9, DR10, DR11, ER14, ER15, ER16, and ER17 |
| 17 | Martin (2017) | SR4, PR6, PR9, and ER14 |
| 18 | Martin et al. (2021) | SR2, SR4, PR6, PR8, PR9, ER14, and ER15 |
| 19 | Mishra et al. (2018) | SR1, SR2, SR3, PR7, PR9, DR11, ER14, and ER15 |
| 20 | Montgomery et al. (2017) | SR3, SR4, PR6, PR7, DR10, ER14, and ER15 |
| 21 | Nguyen et al. (2019) | SR4, PR6, ER14, ER15, and ER16 |
| 22 | Schreinemachers et al. (2015) | PR8, PR9, and ER17 |
| 23 | Schuch et al. (2021) | ER15 |
| 24 | Seng (2014) | SR4, PR6, ER14, and ER15 |
| 25 | Sithirith (2017) | ER15 |
| 26 | Turner et al. (2017) | SR3, PR9 |
| 27 | Wokker et al. (2014) | PR6, ER14 |
| 28 | Xangsayasane et al. (2019) | SR2, SR4, and PR6 |

**Sustainable Performance**

Sustainable performance refers to consideration of the dimension of environmental performance, the dimension of social performance, and the dimension of economic performance. According to table 3, the researchers found that the economic performance holds a major consideration of all performance types, but other performance clusters earned limited considerations, particularly environmental performance and social performance. Some of the nine observed variables show similar concepts or related contexts. The number of observed variables had to be clustered to improve the analysis efficiency and the results' accuracy. Then, the researchers consolidated nine observed variables into three latent variables. Environmental performances encompass (P1) the consumption rate of energy (e.g. oil), (P2) the consumption rate of natural resources (water and land), and (P3) environmental pollutants (water, land, and air). Social performances are (P4) food insecurity (the scale of accessibility to foods and eating patterns), (P5) poverty, and (P6) farmers' knowledge. Economic performances include (P7) the rice yield of farming households, (P8) rice quality (nutritional benefits, softness, aroma, and physical appearance), and (P9) Return on Investment (ROI).

**Table 3** Articles by performances (PERF) in Cambodia and other countries

| Performances in the Rice Supply Chain | | |
|---|---|---|
| **Latent Var.** | **Obs. Var.** | **References** |
| ENVI | P1 | Thanawong et al. (2014) |
| | P2 | Dalgliesh et al. (2016), Montgomery et al. (2017), Nguyen et al. (2018), Nguyen et al. (2019), and Thanawong et al. (2014) |
| | P3 | Rambonilaza and Neang (2019) and Thanawong et al. (2014) |
| SOC | P4 | Dalgliesh et al. (2016) and Kadigi et al. (2020) |
| | P5 | Mao et al. (2014), Mishra et al. (2018), and Kadigi et al. (2020) |
| | P6 | Chhay et al. (2017), Flor et al. (2018), and Kadigi et al. (2020) |
| ECON | P7 | Bairagi et al. (2020), Castilla et al. (2019), and Ches and Yamaji (2016), Chhay et al. (2017), Chhun et al. (2019), and Mukhopadhyay (2021) |
| | P8 | Mishra et al. (2018), Nguyen et al. (2019), and Rambonilaza and Neang (2019) |
| | P9 | Chhay et al. (2017), Thanawong et al. (2014), and Kadigi et al. (2020) |

**Risk Management**

Approaches of risk management consist of ex-ante and ex-post strategies (Lam et al., 2015; Saqib et al., 2016). Risk management strategies are risk mitigation, risk avoidance, risk transfer, and risk coping (Bairagi et al., 2020; Zandi et al., 2020). Moreover, risk management interventions can be incorporated with the public stakeholders such as agricultural training, extension service, government policy, and public investment (Bairagi et al., 2020; Kong & Castella, 2021; Turner et al., 2017). To ensure efficiency and effectiveness in risk management strategies, the following monitoring and coordinating actors in Cambodia are: (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 (Table 4).

**Methodology**

The researchers used a systematic literature review to evaluate academic papers. The components of a systematic review are identification, screening, eligibility, and inclusion (Stovold et al., 2014).

Notably, this study only focuses on farmers and relevant the stakeholders (e.g. government) who help farmers. The first qualitative area of exploration from this exploratory sequential design is to confirm and identify the risk factors, in which the researchers conduct in-depth interviews with ten different experts in Cambodia. The researchers collect quantitative data from two hundred Cambodian farmers through surveys and interviews.

First, the researchers focused on papers sourced, with specific search criteria, from databases such as Science Direct, EBSCO host, Taylor & Francis, ProQuest, and Google Scholar. The search criteria for our research included: risk analysis of agricultural supply chain or agricultural supply chain in Cambodia. The researchers mainly targeted papers published between 2013 and 2021.

Second, the researchers pre-screened for removing duplicate records, evaluating titles, and assessing abstracts. Paper screening aims to determine the general concepts relative to Supply Chain Risk Management (SCRM). Then, the researchers assessed entire-text articles. The final count for our review totaled 43 articles.

The researchers used content analysis to identify risk factors, performance factors, and risk management strategies in the selected articles. Without the help of content analysis, it would have been impossible to consolidate into clusters in SCRM.

For SEM, two main variables for this scientific study include latent and observed variables. Latent variables refer to variables that the researchers cannot observe directly, including (1) risk, (2) supply risks, (3) production risks, (4) demand risks, (5) environmental risks, (6) performance, (7) environmental performance, (8) economic performance, and (9) social performance (Figure 1). Observed variables, or manifest variables, are measured directly by the researchers, encompassing indicators in each individual (see Table 1, Table 2, and Table 3).

To ensure the reliability of our study, the researchers strongly considered only international journal articles and conferences realized in English. Thus, the researchers neglected master's independent studies and theses, doctoral dissertations, and unpublished papers. In addition, papers that discuss SCRM without considering the criteria of risk identification, investigation of sustainable performance, and risk management were not included in our scope.

**Results and Discussion**

The conceptual framework in this study is achieved by created via 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. Even though this study (reviewing the extant literature to develop a new conceptual framework) is related to developing and developed countries, most literature concentrates on developing countries because they are associated with Cambodia, the Least Developed Country (LDC). On the other hand, few academic papers are relevant to this study (case study in Cambodia); this review cannot go in-depth insights into Cambodia. The proposed conceptual framework (mixed method) for risk analysis of the rice supply chain in Cambodia is shown as Figure 1.

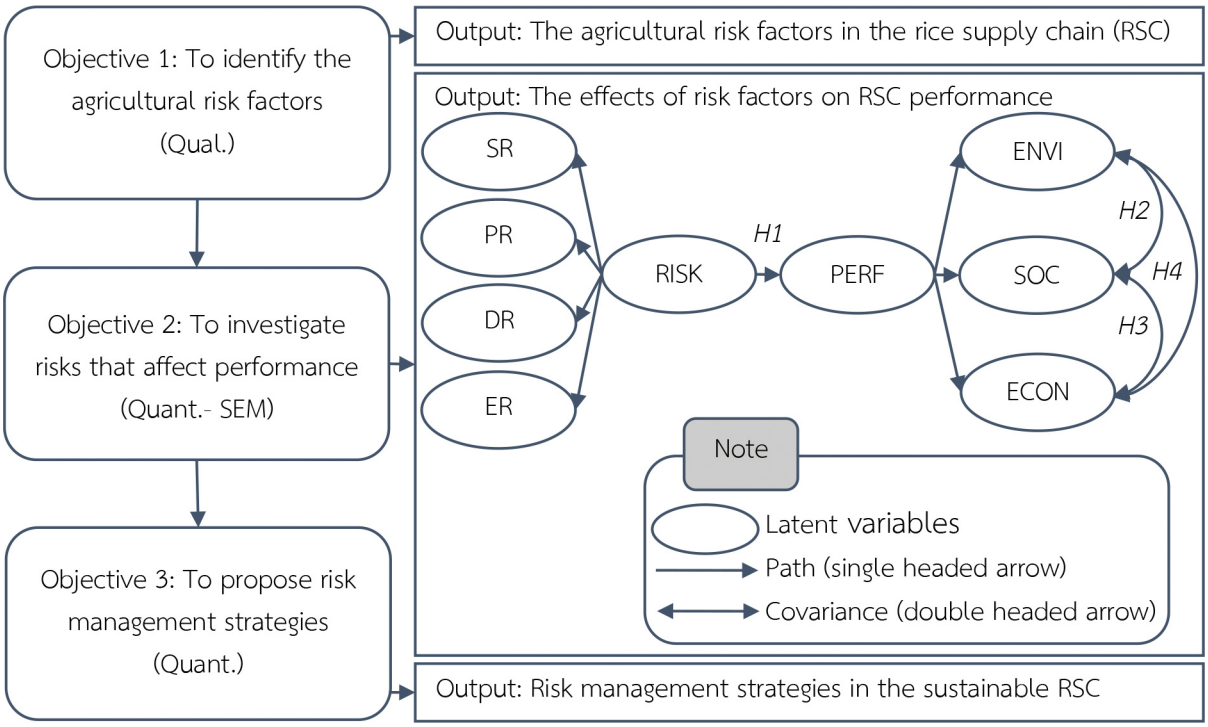


**Figure 1** The Proposed Conceptual Framework for the Research (Mixed Method)

The primary objective of this conceptual framework is to analyze the risks in the rice supply chain in Cambodia. A mixed-methods approach (qual. and quant.) is crucial in this conceptual framework. This conceptual framework relies on academics in the wide range of fields between integrated theory and practice in the supply chain. Figure 1 shows a new conceptual framework for risk analysis of RSC.

The first step of this process is risk identification and risk prioritization to (1) gather the secondary data for a desk-level analysis and collect preliminary data (open-ended survey) to confirm factors and (2) conduct an in-depth interview with ten experts to prioritize the risk factors. The risk prioritization matrix helps classify risks in terms of likelihood and severity of effects.

The Structural Equation Model (SEM), known as causal modeling or analysis of covariance structures, is used in the second objective for investigating risks that affect rice supply chain performance, including Environmental (ENVI), Social (SOC), and Economic (ECON) aspects. The authors use SEM because it is a useful statistical tool to analyze the relationship between latent variables. Latent variables are variables that authors cannot observe directly. Instead, they are estimated by a set of observed variables. Observed variables (manifest variables) are measured directly by the authors.

The end output of this conceptual framework is to propose appropriate solutions to mitigate, avoid, transfer, and cope with agricultural risks, as shown in Table 4 risk management strategies for the Rice Supply Chain (RSC).

**Table 4** Risk management strategies for rice supply chains

| Risk Management Strategies and Stakeholders | Tools | References |
|---|---|---|
| **Risk Management Strategies for Supply Risks** | | |
| Seek alternative suppliers' (Farmers); (Related Stakeholders) | RM and RC | Donkor et al. (2021) |
| Promote contract farming' (MAFF); (Farmers); (Related Stakeholders) | RT and RM | Ba et al. (2019) |
| Provide the incentive to local seed producers and distributors' (MAFF); (Related Stakeholders) | RM | Mishra et al. (2018) and Turner et al. (2017) |
| 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 and RC | Dalgliesh et al. (2016), Ches and Yamaji (2016), and Flor et al. (2018) |
| Offer tax incentives to incentivize the imports of equipment and machinery' (MEF); (Related Stakeholders) | RM | Fukai et al. (2019) |
| **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 and RC | Schreinemachers et al. (2015), Castilla et al. (2019), Chhun et al. (2019), Montgomery et al. (2017), Martin (2017), Kea and Pich (2016), Flor et al. (2018), and Turner et al. (2017) |
| Encourage agricultural microfinance' (MEF); (NBC); (Related Stakeholders) | RM | Mishra et al. (2018), Kea and Pich (2016), and Turner et al. (2017) |
| 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 | Kea and Pich (2016) and Turner et al. (2017) |
| 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, and RA | Schreinemachers et al. (2015), Flor et al. (2019a), Rambonilaza and Neang (2019), and Turner et al. (2017) |
| Improve productivity by using high-yielding seed and modern agricultural techniques' (MAFF); (Farmers); (Related Stakeholders) | RM and RC | Schreinemachers et al. (2015), Chhun et al. (2019), Mishra et al. (2018), Turner et al. (2017), and |
| Support and establish Farmer Organization' (MAFF); (Related Stakeholders) | RM and RC | Turner et al. (2017) |
| Improve agricultural training' (MAFF); (Related Stakeholders) | RM and RC | Kea and Pich (2016), Grunfeld and Ng (2013), and Turner et al. (2017) |

**Table 4** Risk management strategies for rice supply chains (Cont.)

| Risk Management Strategies and Stakeholders | Tools | References |
|---|---|---|
| **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 | Turner et al. (2017) |
| Improve transparency and market information' (MAFF); (Related Stakeholders) | RM and RC | Turner et al. (2017) |
| Promote contract farming with millers/buyers' (MAFF); (Farmers); (Related Stakeholders) | RT and RM | Ba et al. (2019) |
| Improve warehouse management' (Farmers); (Related Stakeholders) | RM and RT | Turner et al. (2017) |
| Seek alternative buyers' (MAFF); (Farmers); (Related Stakeholders) | RM and RC | Donkor et al. (2021) |
| **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, and RC | Dalgliesh et al. (2016), Mishra et al. (2018), Montgomery et al. (2017), Turner et al. (2017), and Nguyen et al. (2019) |
| Develop irrigation (use existing water resources effectively; repair and upgrade existing irrigation; invest in new irrigation)' (MOWRAM); (MFAIC); (Farmers); (Related Stakeholders) | RM and RC | Mishra et al. (2018), Nguyen et al. (2019), Sithirith (2017), Wokker et al. (2014), and Turner et al. (2017) |
| Construct and maintain roads in the countryside (link rice production areas to markets)' (MRD); (MPWT); (Related Stakeholders) | RM; RC | Mao et al. (2014), Kea and Pich (2016), and Turner et al. (2017) |
| Reduce electricity price and promote electric power transmission to rural areas' (MISTI); (MME: Electricity Authority of Cambodia-EAC); (Related Stakeholders) | RM and RC | Mishra et al. (2018), Mao et al. (2014), and Turner et al. (2017) |
| Improve the agricultural extension services to commune level' (MAFF); (Related Stakeholders) | RM and RC | Schreinemachers et al. (2015), Nguyen et al. (2019), and Turner et al. (2017) |
| Improve agricultural know-how training' (MAFF); (Related Stakeholders) | RM and RC | Schreinemachers et al. (2015), Mishra et al. (2018), Montgomery et al. (2017), Martin (2017); Nguyen et al. (2019), Chhay et al. (2017), and Turner et al. (2017) |
| Manage COVID-19 affects farmers by investing in the vaccination program, quarantine program, robust health systems, and advanced R&D' (MOH); (Related Stakeholders) | RM and RC | Gates (2015) and Gates (2020) |

**Note :** RM: Risk Mitigation, RA: Risk Avoidance, RT: Risk Transfer, and RC: Risk Coping

## Conclusion and Recommendations

This study presents a new conceptual framework for risk analysis of the rice supply chain in Cambodia. This framework allows us to analyze risk in the rice supply chain from a holistic perspective.

The outcome of this article includes the agricultural risk factors in the rice supply chain, the effects of risk factors on rice supply chain performance, and risk management strategies in the sustainable rice supply chain.

Research gaps emerged from the literature review highlighting a potential gap in existing studies. There is missing or insufficient information on risk analysis of the rice supply chain in Cambodia. There is a lack of information for some risk factors or the likelihood of particular risk factors or the severity of effects; this information is crucial for proposing risk management strategies. Moreover, few academic papers are relevant to this study (i.e. the case study of Cambodia), and there are inadequate articles offering in-depth insights into Cambodia. For instance, we found only one paper (Hossain, 2018), a brief review, about the risk of COVID-19 in Cambodia.

Risk management in the rice supply chain is an issue of development efficiency and effectiveness, not just a matter related only to farmers. A mix of community self-help culture and government intervention could promote paddy production and entrepreneurial innovations.

While we have reviewed a comprehensive evaluation for risk analysis of the rice supply chain, we still see three primary limitations. First, we may not have considered all existing articles on this topic because we collected from only five electronic academic databases. Second, we mainly have reviewed international journal papers, excluding master's independent studies and theses, doctoral dissertations, and unpublished papers. Third, we limited our study to articles dating from 2013 to 2021 and to relevant SCRM, and we only reviewed 43 articles for this topic. Overall, the study in this area is not substantial enough compared to other fields of SCRM.

A holistic perspective of the past findings to Supply Chain Risk Mnagement (SCRM) is insufficient in the current literature. Due to a potential research gap in previous studies, scholars could also adapt this study by applying to different stakeholders in the same or other sectors and the same or other countries.

## References

Asian Development Bank. (2014). *Improving rice production and commercialization in Cambodia: Findings from the farm investment climate assessment*. http://hdl.handle.net/11540/4083

Ba, H. A., De Mey, Y., Thoron, S., & Demont, M. (2019). Inclusiveness of contract farming along the vertical coordination continuum: Evidence from the Vietnamese rice sector. *Land Use Policy, 87*, 104050.

Bairagi, S., Mishra, A. K., & Durand-Morat, A. (2020). Climate risk management strategies and food security: Evidence from Cambodian rice farmers. *Food Policy, 95*, 101935.

Bunnarith, C. (2016). The policy of rice exportation product to abroad of Cambodia. *Policy, 6*(10), 83-92.

Castilla, N. P., Stuart, A. M., Makara, O., Sathya, K., Somany, S., Kumar, V., & Ratna Hadi, B. A. (2019). Characterization of cropping practices, pest constraints, and yield variation in irrigated lowland rice of Cambodia. *Crop Protection, 135*, 104906.

Ches, S., & Yamaji, E. (2016). Labor requirements of System of Rice Intensification (SRI) in Cambodia. *Paddy and Water Environment, 14*(2), 335-342.

Chhay, N., Seng, S., Tanaka, T., Yamauchi, A., Cedicol, E. C., Kawakita, K., & Chiba, S. (2017). Rice productivity improvement in Cambodia through the application of technical recommendation in a farmer field school. *International Journal of Agricultural Sustainability, 15*(1), 54-69.

Chhun, S., Kumar, V., Martin, R. J., Srean, P., & Hadi, B. A. R. (2019). Weed management practices of smallholder rice farmers in Northwest Cambodia. *Crop Protection, 135*, 104793.

Chung, S., Takeuchi, J., Fujihara, M., & Oeurng, C. (2019). Flood damage assessment on rice crop in the Stung Sen River Basin of Cambodia. *Paddy and Water Environment, 17*(2), 255-263.

Dalgliesh, N. P., Charlesworth, P., Lonh, L., & Poulton, P. L. (2016). Promoting resilience in Cambodian lowland rice ecosystems—Farming system research to support flexible climate response strategies for smallholder farmers. *Field Crops Research, 198*, 148-159.

Dany, V., Bowen, K. J., & Miller, F. (2015). Assessing the institutional capacity to adapt to climate change: A case study in the Cambodian health and water sectors. *Climate Policy, 15*(3), 388-409.

Donkor, E. A., Garnevska, E., Siddique, M. I., & Donkor, E. (2021). Determinants of rice farmer participation in the direct marketing channel in Ghana. *Sustainability, 13*(9), 5047.

Eliste, P., & Zorya, S. (2015). *Cambodian agriculture in transition: Opportunities and risks*. Worldbank. http://documents.worldbank.org/curated/en/805091467993504209/Cambodian-agriculture-in-transition-opportunities-and-risks

Flor, R. J., Chhay, K., Sorn, V., Maat, H., & Buyung Asmara Ratna, H. (2018). The technological trajectory of integrated pest management for rice in Cambodia. *Sustainability, 10*(6), 1732.

Flor, R. J., Maat, H., Hadi, B. A. R., Kumar, V., & Castilla, N. (2019a). Do field-level practices of Cambodian farmers prompt a pesticide lock-in? *Field Crops Research, 235*, 68-78.

Flor, R. J., Maat, H., Hadi, B. A. R., Then, R., Kraus, E., & Chhay, K. (2019b). How do stakeholder interactions in Cambodian rice farming villages contribute to a pesticide lock-in? *Crop Protection, 135*, 104799.

Fukai, S., Xangsayasane, P., Manikham, D., & Mitchell, J. (2019). Research strategies for mechanised production of rice in transition from subsistence to commercial agriculture: A case study from Khammouan in Lao PDR. *Plant Production Science, 22*(1), 1-11.

Gates, B. (2015). The next epidemic--Lessons from Ebola. *The New England Journal of Medicine, 372*(15), 1381-1384.

Gates, B. (2020). Responding to COVID-19—A once-in-a-century pandemic? *New England Journal of Medicine, 382*, 1677-1679.

Grunfeld, H., & Ng, M. L. H. (2013). A multimedia approach to ODL for agricultural training in Cambodia. *International Review of Research in Open and Distance Learning, 14*(1), 222-238.

Horita, A. (2016). Farming for survival and rice for investment: The intersection of Japanese aid and Cambodian development. *Asia Pacific Viewpoint, 57*(2), 232-243.

Hossain, S. T. (2018). Impacts of COVID-19 on the agri-food sector: Food security policies of Asian productivity organization members. *The Journal of Agricultural Sciences, 15*, 116-132.

Iwahashi, Y., Ye, R., Kobayashi, S., Yagura, K., Hor, S., Soben, K., Homma, K., Greggio, N., & Habyarimana, E. (2021). Quantification of changes in rice production for 2003-2019 with MODIS LAI data in Pursat Province, Cambodia. *Remote Sensing, 13*(10), 1971.

Kadigi, I. L., Mutabazi, K. D., Damas, P., Richardson, J. W., Bizimana, J. C., Mbungu, W., Mahoo, H. F., & Sieber, S. (2020). An economic comparison between alternative rice farming systems in Tanzania using a Monte Carlo simulation approach. *Sustainability, 12*(16), 6528.

Kea, S., Li, H., & Pich, L. (2016). Technical efficiency and its determinants of rice production in Cambodia. *Economies, 4*(4), 22.

Kong, R., & Castella, J. C. (2021). Farmers' resource endowment and risk management affect agricultural practices and innovation capacity in the Northwestern uplands of Cambodia. *Agricultural Systems, 190*, 103067.

Lam, A., Zhang, T., & Lai, K. K. (2015). A study on Hong Kong rice supply chain risk management with value chain analysis. In *Industrial Engineering, Management Science and Applications 2015* (pp. 491-499). Springer.

Mao, N., Grunfeld, H., DeLacy, T., & Chandler, D. (2014). Agriculture and tourism linkage constraints in the Siem Reap-Angkor region of Cambodia. *Tourism Geographies, 16*(4), 669-686.

Martin, R., Chhun, S., Yous, S., Rien, R., Korn, C., & Srean, P. (2021). Survey of weed management practices in direct-seeded rice in Northwest Cambodia. *Agronomy, 11*(3), 498.

Martin, R. J. (2017). Weed research issues, challenges, and opportunities in Cambodia. *Crop Protection, 134*, 104288.

Mishra, A. K., Bairagi, S., Velasco, M. L., & Mohanty, S. (2018). Impact of access to capital and abiotic stress on production efficiency: Evidence from rice farming in Cambodia. *Land Use Policy, 79*, 215-222.

Montgomery, S. C., Martin, R. J., Guppy, C., Wright, G. C., & Tighe, M. K. (2017). Farmer knowledge and perception of production constraints in Northwest Cambodia. *Journal of Rural Studies, 56*, 12-20.

Mukhopadhyay, D. (2021). Spatial and temporal pattern of rice yield growth in Asian countries from 1961 to 2016: An exploratory econometric analysis. *Ekonomika Poljoprivrede, 68*(1), 23-35.

Nguyen, T. T., Nguyen, T. T., & Grote, U. (2019). Multiple shocks and households' choice of coping strategies in rural Cambodia. *Ecological Economics, 167*, 106442.

Nguyen, T. T., Do, T. L., Parvathi, P., Wossink, A., & Grote, U. (2018). Farm production efficiency and natural forest extraction: Evidence from Cambodia. *Land Use Policy, 71*, 480-493.

Rambonilaza, T., & Neang, M. (2019). Exploring the potential of local market in remunerating water ecosystem services in Cambodia: An application for endogenous attribute non-attendance modeling. *Water Resources and Economics, 25*, 14-26.

Saqib, S. E., Ahmad, M. M., Panezai, S., & Ali, U. (2016). Factors influencing farmers' adoption of agricultural credit as a risk management strategy: The case of Pakistan. *International Journal of Disaster Risk Reduction, 17*, 67-76.

Schreinemachers, P., Afari-Sefa, V., Heng, C. H., Dung, P. T. M., Praneetvatakul, S., & Srinivasan, R. (2015). Safe and sustainable crop protection in Southeast Asia: Status, challenges and policy options. *Environmental Science & Policy, 54*, 357-366.

Schuch, E., Dirks, S., Nhim, T., & Richter, A. (2021). Cooperation under social and strategic uncertainty--The role of risk and social capital in rural Cambodia. *Journal of Behavioral and Experimental Economics, 90*, 101642.

Seng, K. (2014). Determinants of farmers? Agricultural diversification: The case of Cambodia. *Asian Journal of Agriculture and Rural Development, 4*(8), 414-428.

Sithirith, M. (2017). Water governance in Cambodia: From centralized water governance to farmer water user community. *Resources, 6*(3), 44.

Stewart, M. A., & Coclanis, P. A. (2018). *Water and power: Environmental governance and strategies for sustainability in the Lower Mekong Basin*. Springer.

Stovold, E., Beecher, D., Foxlee, R., & Noel-Storr, A. (2014). Study flow diagrams in Cochrane systematic review updates: An adapted PRISMA flow diagram. *Systematic Reviews, 3*(1), 54.

Thanawong, K., Perret, S., & Basset-Mens, C. (2014). Eco-efficiency of paddy rice production in Northeastern Thailand: A comparison of rain-fed and irrigated cropping systems. *Journal of Cleaner Production, 73*, 204-217.

Turner, M., Korm, R., & Veara, K. (2017). Government policy and private sector development in post-conflict states: Growing Cambodia's rice production and export industries. *The Economic and Labour Relations Review, 28*(2), 252-269.

Wokker, C., Santos, P., & Bansok, R. (2014). Irrigation water productivity in Cambodian rice systems. *Agricultural Economics, 45*(4), 421-430.

Xangsayasane, P., Phongchanmisai, S., Vuthea, C., Makara, O., Chay, B., Mitchell, J., & Fukai, S. (2019). A diagnostic on-farm survey of the potential of seed drill and transplanter for mechanised rice establishment in Central Laos and Southern Cambodia. *Plant Production Science, 22*(1), 12-22.

Zandi, P., Rahmani, M., Khanian, M., & Mosavi, A. (2020). Agricultural risk management using fuzzy TOPSIS Analytical Hierarchy Process (AHP) and Failure Mode and Effects Analysis (FMEA). *Agriculture, 10*(11), 504.

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