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Article

Evaluating the Impact of Technological Adaptation in Third-Party Logistics on Farming Household Sustainability: The Mediating Role of Supply Chain Robustness

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ABSTRACT

Agriculture is recognized as a key determinant in the economic vitality of Sri Lanka. The prominent challenges faced by farmers include the pervasiveness of middlemen, insufficient storage infrastructure, substandard transportation between supply chain participants, and inadequate mechanization within the agricultural sector. This research primarily investigates the influence of Third-Party Logistics – including warehousing, distribution, and order fulfillment – on optimizing farmers' rewards, a process moderated by technology adaptation and mediated by supply chain robustness. The principal objective of this study is to explore and scrutinize the impact of logistics and its constituents on the optimization of compensations and additional benefits for farmers, which can be achieved by enhancing the supply chain through technological adaptation. To meet this objective, the researcher adopted a pragmatic philosophical position coupled with a deductive methodology. The research was conducted among farmers in the Northern Province of Sri Lanka. A sample of 180 farming households was chosen through a stratified simple random sampling technique that encompassed all Districts within the Province. An explanatory mixed method was employed as the methodological preference for the study, supplemented by a cross-sectional approach under the time horizon. The study's findings revealed that Third-Party Logistics positively impact reward maximization, and further demonstrated the moderating and mediating effects of technology adaptation and supply chain resilience. In conclusion, the paper presents recommended strategies, which include advancements in logistical practices and the implementation of updated technological solutions within agriculture. These recommendations could be adopted by farmers to maximize the monetary and non-monetary benefits.

Introduction

In line with the study findings of Ragu-Nathan and Rao (2006), a supply chain represents the interconnected processes between an organization and its suppliers that deliver products to end-users. The supply chain involves various components and functions, contributing to the transformation and delivery of products or services from their origin to the consumer. Effective supply chain management has significantly fostered economic growth across different sectors (Min, 2015; Agrawal, 2017).

Key supply chain practices, emphasized by Zhou and Benton (2007) and Hugos (2024), encompass strategies such as enhancing inventory velocity, applying lean logistics principles, proficiently managing supply chains, and incorporating Third-Party Logistics (3PL). Tan (2002) underscores the importance of maintaining rapid inventory turnover for cash flow, which entails minimizing warehouse product levels. Lean logistics prioritizes the elimination of non-value-added activities, fostering a "pull" process rather than a "push" approach, as highlighted by Squire et al. (2006).

In line with the study findings of Carter and Rogers (2008), and Serdarasan (2013), the third-party logistics (3PL) industry plays a crucial role in shaping various aspects of the supply chain. It influences critical processes including managing supplier performance, diversifying the supplier base, compressing cycle times, segmenting the supply chain, and implementing advanced supply chain technology. 3PLs contribute significantly to evaluating and overseeing supplier performance by offering transparent insights into key performance indicators such as on-time deliveries, product quality, and responsiveness. They facilitate supplier base

diversification, providing companies with flexibility and varied options through engagements with multiple suppliers. In transportation and logistics, 3PLs contribute to cycle time compression by optimizing routes, reducing lead times, and ensuring timely deliveries. Their adept management of transportation and order fulfillment processes expedites the overall supply chain cycle. Additionally, 3PLs demonstrate proficiency in handling specific supply chain segments, such as warehousing and order fulfillment, allowing companies to focus on core competencies while ensuring optimization and avoiding resource misallocation. Furthermore, 3PLs invest significantly in cutting-edge technologies, including Warehouse Management Systems, order tracking systems, and advanced analytics tools. This commitment to technological advancement positions 3PLs as valuable partners for companies aiming to align with contemporary best practices, thereby enhancing overall efficiency, effectiveness, and competitiveness in supply chain management.

According to Sakalasooriya (2021), Sri Lanka, endowed with abundant resources across its coastal, intermediate, and central regions, boasts several industries that have been operational for thousands of years. Agriculture, in particular, plays a pivotal role in the country's economy. As a developing nation, Sri Lanka produces a variety of fruits and vegetables and leads in cultivating commodities like rice, coconut, tea, onion, potatoes, chilies, sugar cane, and rubber, which are significant revenue sources (Weerakkody & Mawalagedera, 2020). Agricultural operations encompass the production and distribution of farm supplies, storage of produced supplies, the transformation of raw materials into finished products, and the final distribution of

commodities (Department of Census and Statistics [DCS], 2017; DCS, 2019). Despite ongoing industrialization and tertiarization in recent decades, agriculture remains a cornerstone of economic development in Sri Lanka, being a significant part of the historic Silk Route (Udara et al., 2022). Approximately 31.8% of the population is engaged in agriculture, which includes both animal husbandry and crop cultivation, contributing to 18% of the nation's GDP (Panabokke, 2018). The livelihood of a large portion of the Sri Lankan population is directly or indirectly linked to agriculture (Udara et al., 2022). Following the study findings of Govinnage and Sachitra (2019), the global integration of consumer markets, local Sri Lankan farmers stand to benefit significantly from the international demand for agricultural products. This optimistic outlook persists, notwithstanding initial concerns about the potential adverse effects of globalization on the agricultural sector. By seizing these global opportunities, Sri Lankan farmers can not only mitigate potential challenges but also harness the expansive market potential, thereby contributing positively to the country's economic growth through the export of agricultural goods.

During the early 19th century, interest in supply chain management grew in Sri Lanka, primarily driven by trends in organizational consolidation at the farm input, processor, and supermarket levels, new agricultural regulations implemented by the government, enhanced management systems and food safety protocols, heightened market competition, and increased global trade (Lancsar & Louviere, 2006). While Sri Lanka has a robust level of agricultural production, it struggles with marketing (Dharmaratne, 2014). Notably, the Northern Province contributes more than

5% of the country's overall yield and engages in various agricultural activities, such as horticulture and cereal production (Kirshanth & Sivakumar, 2018; Canfora, 2016). As discussed by Dharmaratne there has been a noticeable rise in sharecropping relationships between private dealers and farmers. However, despite high farm output, the region faces significant challenges, primarily due to the lack of joint planning and collaborative strategies for value growth. According to Morgan and Murdoch (2010), farmers from the Northern Province typically engage in an unstable agricultural supply chain and struggle to mitigate associated risks due to a limited understanding of the underlying problems. This situation is compounded by an ineffective supply chain, resulting in difficulties both during post-harvest storage and the delivery of goods to consumers. The agricultural supply chain across Sri Lanka, particularly in the Northern Province, faces numerous challenges. Issues include small to medium farmer fragmentation, lack of scale economies, low levels of processing or value addition, and impacts from fluctuating external factors such as weather, crop seed quality, and cultivation methods (Marambe et al., 2017; Srinivasa et al., 2016). Furthermore, the region's supply chain is characterized by long lead times, indicating a lack of flexibility in crop production to adapt to rapidly changing external conditions.

The study, through empirical findings, has discerned five primary challenges confronting farmers in the Northern Province concerning supply chain practices. Farmers are often forced into distress sales of their produce, mainly onions, due to an absence of organized marketing. Traders and middlemen often exploit farmers, buying goods at a marginal price and selling

them at a significantly higher margin (Munasinghe et al., 2010). After harvesting, crops like onions and tomatoes lose weight and quality if not stored properly, leading to economic losses for farmers. Farmers turning to third-party warehouse providers face further inefficiencies (Boundeth et al., 2012). Especially in areas like Killinochi and Mannar, the remote location of farmers inhibits their access to main markets. Consequently, farmers are forced to sell produce locally at marginal prices. The third-party transport providers' services are often inadequate due to underdeveloped road systems (Jayatissa et al., 2012). Furthermore, high labor costs and a reluctance to use modern technology, such as automatic weeders and milking machines, negatively impact potential profits, especially in potato farming. Farmers usually resort to conventional machinery (Tekana & Oladele, 2011).

Evidence supporting these problems is substantial. For instance, Munasinghe et al. (2010), highlight that Northern Province farmers lack market information, resulting in knowledge gaps. Overproduction and poor storage facilities led to high crop spoilage during the Maha season in 2017 and 2018, causing significant financial losses. Moreover, the government's efforts to introduce supply chain concepts in agriculture have been largely unsuccessful, with less than 5% usage of support applications like Govi Mithuru in the Northern Province (Dharmasena, 2010). Farmers' reluctance towards advanced mechanization and preference for traditional farming practices has been further confirmed by a government poll (Nishanthan et al., 2013). Alarmingly, suicide rates among farmers have increased due to economic distress, with an estimated 15 attempts per 100,000 farmers (Knipe et

al., 2017). This distress is often linked to the inability to obtain fair returns on their yield, mostly due to middlemen's exploitation. In response to the identified problems, this study aims to analyze the impact of Third-Party Logistics and its components on maximizing the rewards and benefits for farmers. The focus is on enhancing the supply chain through the adaptation of technological advancements, which could potentially improve the returns for farmers. Furthermore, the rest of the paper is structured as below: the literature review provides a comprehensive examination of various concepts and theories related to supply chain, supply chain competencies, agriculture, and agricultural supply chain, as well as a detailed evaluation of the study's identified variables. Subsequently, the paper delves into the research design/philosophy and examines the proposed hypothesis. The focus then shifts to data analysis, which includes goodness of fit measurements for quantitative data, demographic analysis, variable analysis, and hypothesis testing. This is followed by a discussion section, where the paper's objectives and hypotheses are explored in depth. The paper concludes with recommendations and potential future implications of the study.

Review of Literature

Managing the agricultural supply chain is key to maximizing rewards, and modern technology can enhance this process (Lezoche et al., 2020). Supply chain competencies serve as a framework to identify influential elements, with various theories analyzing these competencies differently (Halldorsson et al., 2007). While the literature has examined agricultural supply chain elements and supporting theories, it lacks insights into the

relationship between these elements, reward maximization, and technology adaptation. Therefore, a methodical examination of agricultural supply chain competencies, reward maximization, and technological adaptation is necessary to comprehend their interrelationship.

An Overview of Supply Chain Management

Stevenson and Spring (2007) and Mentzer et al. (2001) described the supply chain as a network extending from a company's suppliers to the end user, detailing how products or services are transferred. Supply chain management, according to Jacobs et al. (2011), involves managing the flow of goods and services, and streamlining related activities to maximize customer value and secure a competitive advantage. This process includes diverse activities such as information system integration, coordination planning, and control activities (Larson & Rogers, 1998). David et al. (2004) stated supply chain management is integral to "make or buy" decisions, controlling each step of raw material transformation to product distribution. This management introduces predictability, enabling entities to respond positively to dynamic demand. Supply chain competencies are skills and knowledge that enhance performance, including capacity planning, demand management, and logistics warehousing (Sheehan et al., 2014). Van Hoek et al. (2002) highlighted labor as a key competency, while Carr and Smeltzer (2000) underlined purchasing skills. The logistics framework, encompassing operational and planning processes, is crucial for supply chain effectiveness (Closs & Mollenkopf, 2004). These competencies help the supply chain respond to challenges and improve efficiency (Carr et al., 2000; Gammelgaard

& Larson, 2001). Subsequently, the paper delves into an in-depth evaluation of the agricultural industry and the related supply chain.

Sri Lanka is recognized as a leading global nation with 7% of its GDP reliant on agriculture and related sectors (Central Bank of Sri Lanka [CBSL], 2019). Its primary agricultural activity focuses on rice production, with the main cultivation seasons being Maha and Yala. Another significant crop is tea, primarily grown in the central highlands, which contributes to the country's foreign exchange. In addition to rice and tea, Sri Lanka also produces vegetables, fruits, and oilseeds. Over 25% of the country's workforce is employed in the agricultural sector (Samansiri & Wanigasundera, 2019). Despite being a fertile tropical land capable of cultivating a wide variety of crops, Sri Lanka faces significant challenges in agricultural productivity and profitability. According to Kumar and Parikh (2017), there has been limited adaptation of mechanized farming due to government changes and new rules. The agricultural industry operates largely independently, with the majority of support coming from the government and minimal participation from private entities. This lack of investment has restricted the industry's growth compared to other sectors in the country. There are numerous issues affecting the agricultural industry, which is a livelihood for millions of people. The author identifies overlooked problems that are not commonly discussed in media and urban circles. After careful analysis, it is clear that the primary cause of these issues is the supply chain components associated with agriculture.

Li et al. (2006) described agricultural supply chain management as a rapid process involving the movement of goods from

production to end-users. This process encompasses post-consumption and pre-production activities in the agri-food industry and is viewed as a dynamic method of planning the agri-food supply chain. It helps reduce challenges faced by agri-food supply chain members and maximizes profits. The performance of agri-food supply chain management is determined by food quality and safety (Akkerman et al., 2010). Chan et al. (2006) suggested the evaluation of supply chain performance can be based on product performance, process efficiency, and the quality of services rendered. Bogataj et al. (2005) emphasized the stability of the agri-food supply chain, identifying key factors influencing the hygiene and quality of perishable products in the supply chain. The quality, safety, and freshness of these perishable goods are maintained through proper storage, thermal facilities, appropriate information systems, and suitable operational modes during logistics (Manning et al., 2006). Trienekens and Zuurbier (2008) highlighted the necessity for government departments to ensure the quality and safety of agricultural food products by implementing effective legislation and regulations. However, crop production in Sri Lanka is notably low due to the lack of technological adaptation among farmers. A study conducted in the Northern Province reveals inefficiencies in inventory handling, capacity planning, mechanization, packaging, and crop control (De Silva et al., 2019). These challenges primarily stem from the farmers' poor technological adaptation. Implementing production protocols and integrating information technology into the agri-food supply chain, especially in logistics, can enhance efficiency and effectiveness. The agricultural supply chain in the context of Sri Lanka is provided in *Figure 1* below. The

paper evaluates the substantial impact of Third-Party Logistics [TPL] on the agricultural supply chain. It further reviews various literature on the importance of TPL for agriculture and its role in promoting sustainability.

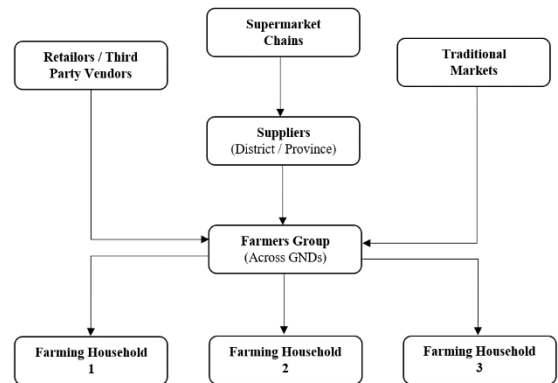


Figure 1: Traditional Agriculture Supply Chain Northern Sri Lanka

Source: (Developed by the Author)

Third-Party Logistics

According to Skjoett-Larsen (2000), Third-Party Logistics (TPL) evolved from transportation companies extending their services to customers. It involves outsourcing transport and logistics activities which are neither consignors nor consignees, including services like warehousing, distribution, and order fulfillment. TPL, introduced during the 1980s transport industry deregulations, has rapidly advanced with technological progression (Lumsden, 2003). Although not common in the agricultural industry in the early 21st century, many agricultural firms in Sri Lanka now deem TPL crucial. The firms scarcely outsource warehousing, distribution, and order fulfillment to TPL providers, but adopting such practices could enhance productivity efficiency (Samansiri & Wanigasundera, 2019). Ballou (2010) suggested that farmers adopting TPL can

benefit from economies of scope and scale, reducing costs and enhancing net value. The impact depends on the type of logistic provider involved. Agrawal (2017) highlighted that TPL providers introduce essential skills into the supply chain, such as high coordination ability and pooling of reliable partners, leading to more efficient inter-firm goods flow. Outsourcing to third parties reduces capital investments and associated financial risks. Well-established warehousing and distribution systems require significant capital investment; outsourcing these activities can substantially reduce capital expenditure, stabilizing revenue (Samansiri & Wanigasundera, 2019).

Adhikarinayake (2015) described warehousing as a process carried out by specialized agencies for commercial gain. It involves technical personnel who guard and manage goods, abiding by laws and public authority supervision. Warehousing encompasses the storage, transport, handling, and distribution of inputs, finished goods, and commodities (Jacob et al., 2014). Sundaram (2014) associated subsistence farming and below-subsistence levels with the lack of, or defective, warehousing. This leads to agricultural produce loss during transit, with wastage and spillover between production and customer reaching, accounting for 5%-10% losses (Donahaye et al., 2016). Standard warehousing can motivate farmers to sell their products when market prices are optimal (Adigal & Singh, 2015). Technological advancements in warehousing enable perishable goods storage, helping farmers obtain better prices (Gupta, 2010). Warehousing and storage played a crucial role in the success of the green revolution in many agricultural nations. In the context of agriculture, warehousing is pivotal. Similar to

transportation, storage is a core economic function. There's typically a time lag between production and consumption; during this period, commodities are stored by the producer, middleman, or consumer (Bowersox, 2018). In Sri Lanka, commodities are often stored by producers who lack sufficient storage systems (Wasala et al., 2014). TPL providers can offer warehousing services, carrying excess produce forward to future consumers (Kulkarni, 2012). Given the seasonal nature of agricultural production and year-round consumption, warehousing becomes essential in TPL and agriculture (Ashenbaum et al., 2015). Warehousing significantly affects the flow of goods from producers to consumers. It strengthens the supply chain, preventing food waste and shortages due to inadequate transport and storage (Wasala et al., 2014). Appropriate storage facilities prevent loss and increase supply chain efficiency (Jacob et al., 2014). Warehousing stabilizes prices by equating supply and demand, preventing distress in sales when prices are at their lowest post-harvest (Ashenbaum et al., 2015). It also reduces transportation pressure during peak post-harvest demand and prevents damage during handling and storage (Donahaye et al., 2016). Effective warehouse management can consequently improve supply chain efficiency and enhance farmer satisfaction by facilitating the implementation of more lucrative pricing strategies.

Korgaonker (1990) defined distribution as a process that moves goods from the supplier to the manufacturer and finally to the point of sale, involving activities such as customer service, shipping, warehousing, inventory control, private truck fleet operation, packaging, receiving, materials handling, and plant, warehousing, and store planning. It also includes the integration of

information (Cilliers & Nagel, 1994). Goh and Ang (2000) highlighted distribution as an essential part of the supply chain management cycle, with profit margins being determined by the speed at which raw materials are converted into end goods and reach customers (Lynch, 2002). According to Bloomen and Petrov (2012), in the agricultural industry, distribution falls into two main categories: commercial and physical distribution. Commercial distribution focuses on sales and returns on investments, often involving third-party individuals in the Agri supply chain process (Millen & Sohal, 2010). Physical distribution includes a variety of activities from the supply of finished goods to the consumers, to ensuring efficiency through proper handling of distribution components like transportation, logistics, packaging, and inventory control (Lynch, 2002). As articulated by Sohail et al. (2008), the overarching objective of distribution is to ensure the timely and appropriate delivery of raw materials and components, whether in partial or fully finished form, to their designated destinations, and in optimal condition. Proper channel selection, including the most efficient route planning and transportation mode selection, is crucial. From obtaining raw materials like livestock feed, seeds, pesticides, fertilizers, and agri-chemical packing materials to delivering end products, distribution plays a crucial role. Any reduction in distribution standards impacts agricultural crop production due to improper storage and packaging of finished goods, leading to spoilage or damage of produce (Stank et al., 2003; Razzaque & Sheng, 2014).

Order fulfillment, according to Christopher (2000), is a continuous process that starts with the customer and ends with delivering the finished goods. It's considered a cycle

time that begins from the point of order receipt to delivering the ordered goods. It's a complex process encompassing various tasks, resources, and agents, involving sales commitment, credit checking, manufacturing, logistics, accounts receivables, and relationships with external suppliers (Lee & Billington, 2001). The order fulfillment process primarily encompasses order management, manufacturing, and distribution. It aims to deliver products of the required quality to fulfill customer orders at the right time and place and maintain robustness to handle uncertain conditions resulting from internal and external environmental variations (Malone, 2000). Effective order fulfillment can enhance the efficiency of the Agri supply chain network within a firm, as suggested by Perini and Susi (2004). It includes receiving the order from the sales point through the downstream in the supply chain, managing inventory and lead time, receiving materials for manufacturing from suppliers, and maintaining stability in the supply network during the manufacturing process. Material and capacity availability should be handled efficiently to ensure an effective supply chain function.

Robustness of Supply Chain

Robustness in supply chains refers to the ability to resist changes without altering the initial stable configuration (Barabasi & Albert, 1999). Hendricks and Singhal (2005) explained that supply chains are embedded in a dynamic environment exposed to disruptions such as natural disasters, economic recessions, unexpected accidents, and terrorist attacks. Disruptions can initially affect certain individuals within the network but can gradually propagate and potentially amplify, causing a substantial

impact on interconnected entities (Lee et al., 1997). Thadakamalla et al. (2004) argued that disruptions lead to a breakdown of normal operations, and a small breakdown can result in a catastrophic failure, slowing the flow of goods, services, and information, thereby causing higher costs or drops in sales. According to Lee et al. (1997), a robust supply chain retains its stability and withstands shocks instead of adjusting to them. Disruptions in agriculture primarily occur through inefficient Third-Party Logistics linked to the firms (Klau & Weiskircher, 2005). Robustness is a process that requires anticipation of change before its occurrence (Hendricks & Singhal, 2005). Mondal et al. (2014) stated that robustness is a property that allows a system to function despite internal and external disruptions. Discussion of robustness in supply chain management should consider the systems involved in the network, the functions of each entity, and the perturbations. Wagner and Bode (2006) asserted that supply chain robustness should focus on strengthening the network by avoiding risks related to demand, supply, or catastrophic events. The main vulnerabilities in the supply chain include customer dependence, supplier dependence, increased uncertainty, reduced transparency and visibility, and supplier concentrations. Prioritizing robustness can mitigate associated operational and supply chain risks, thereby strengthening productivity and improving satisfaction levels in the agriculture industry (Stricker & Lanza, 2014). Zhang and Wang (2011) emphasized that supply chain partners contribute significantly to supply chain success. Different strategies should be followed to strengthen the supply chain, with Third-Party Logistics (TPL) acting as a key determinant. Modernizing storage and transportation facilities to meet dynamic

market demands is essential for enhancing overall operations. According to Tang et al. (2016), implementing an assembly line procedure within the Agribusiness can increase productivity. The assembly line practice, when implemented by entities in the supply chain, can enhance packaging, inventory handling, and order handling, ultimately developing the robustness of the supply chain.

Reward Maximization

Herzberg (1982) described a reward as recognition for an individual's services, efforts, or achievements, which can be either monetary or non-monetary. Monetary rewards involve financial incentives, while non-monetary rewards involve non-cash compensation. Huirne et al. (1988) suggested that rewards for farmers primarily come from production, financial incentives, and job satisfaction. The efficiency of the supply chain significantly influences these rewards, establishing a proportional relationship between supply chain efficiency and earned rewards. Production, as defined by Varley and Tolley (2000), is an organized sequence of activities that transform resources into finished products, such as goods and services, following market demands. This production process can be categorized into primary, secondary, and tertiary production. Brush (1992) suggested the factors of production usually consist of land, labor, capital, and enterprise. These economic resources are scarce compared to their demand, making them key determinants of the rewards earned by farmers. According to Esham and Usami (2005), an efficient warehousing system improves supply chain sustainability, consequently enhancing rewards earned by matching market demands promptly. This

stability improves supplier-manufacturer relationships, allowing farmers to obtain raw materials at a reasonable market value, reducing production costs, and building farmer confidence by minimizing wastage through effective warehousing (Esham et al., 2006). Monetary rewards, mainly in the form of financial incentives, motivate individuals to meet targets (Vermillion et al., 1995). Revenue, earned from business activities, is a major form of monetary reward for farmers (Little & Watts, 2008). Factors influencing revenue include marketing strategy, technology, automation, and the ability to leverage consumers' digital footprints (Wijayarathna, 2010). Revenue can be categorized as either operating or non-operating, with the former arising from core business activities and the latter from secondary activities. Supply chain strength is also linked to demand forecasting accuracy, reducing overproduction loss, and maximizing financial rewards for farmers (Stones, 2005). Effective distribution, including inventory control, warehousing, and shipping, contributes to supply chain strength and increases farmers' monetary rewards by reducing wastage and related costs (Esham & Usami, 2005). Coughenour and Swanson (2010) posited that job satisfaction, where an employee feels motivated, content, and satisfied with their job, is also a type of reward. This satisfaction impacts supply chain efficiency in agricultural production (Flores & Sarandon, 2004). Key factors determining job satisfaction for farmers include compensation or ROI, respect, recognition, and the challenges faced (Moro et al., 2008). Stable and strong supply chains center the entire agricultural supply chain on the farmers, increasing their bargaining power and reducing the influence of middlemen (Moro et al., 2008). This stability leads to

self-actualization and self-esteem among farmers, ultimately increasing their financial satisfaction by improving ROI (Willock et al., 2009).

Technological Adaptation in Agri Supply Chain in Northern Sri Lanka

According to Ekanayake et al. (2018), technological adaptation, particularly in supply chain management and Third-Party Logistics, has a significant impact on farming. Such technology can increase profitability, production, and satisfaction among farmers (Karippacheril et al., 2013; Ackerley et al., 2010). Among numerous technological advancements, the Farm Management system and the Mobile trading application hold substantial significance. Sorensen et al. (2011) highlighted that Farm Management Software aids production through yield enhancement, handling tasks from operational planning to documentation. Bourlakis and Bourlakis (2006) mentioned that this system facilitates data collection, allowing better competition in the market. It also aids in controlling resources, finances and adhering to regulations. Lokanathan and Kapugama (2012) further add that the system acts as an integrated circuit, reducing inventory costs, improving operations planning, integrating individuals, and enhancing efficiency in warehousing, inventory forecasting, and order fulfillment (Chow et al., 2017). As for Mobile trading Applications, De Silva et al. (2019) indicated that 60% of farmers in Northern Sri Lanka are smallholders, who face financial hardship due to middlemen and lack of capital. The stress induced by such conditions has led to an alarming increase in suicides among rural farmers. Baumuller (2016) suggested that mobile trading can alleviate these issues by enhancing supply

chains and maximizing rewards. One notable example is the BOT framework, a mobile application that connects farmers and buyers, simplifying and expediting trading processes (Patel et al., 2010). Further, the government and private investors have developed additional applications like Govi Mithuru and Govipola. The former was launched in 2015 to support farmers throughout their farming process, providing timely and individualized information via voice messages (Dialog, 2020; Palmer & Darabian, 2017). Govipola, on the other hand, aims to ensure fair market prices for farmers and provide transparency in price trends (Faaiz & Kohombange, 2019). While the technologies mentioned are available in the market, they are not yet widely adopted by farming households. In essence, the technological instruments pinpointed in these studies have the potential to assist farmers in several aspects, most importantly by reinforcing the supply chain, which ultimately results in enhanced benefits for farmers.

Theoretical Framework and Its Criticism

Third-Party Logistics (TPL) is seen as an effective governance structure capable of enhancing efficiency in supply chain management decisions. The author of this study employs four theories to explain its application to TPL, focusing on interfirm interaction, contracts, long-term relationships, and firm competencies. Principal-Agent Theory applied to TPL suggests an interfirm contracting perspective. This focuses on creating efficient contracts between the buyer and seller of logistic services, with incentives based on performance or behavioral outcomes. The TPL providers' payment depends on the measurement and control of

their performance (Hertz & Alfredsson, 2003).

The Transaction Cost Analysis suggests that by reducing the supplier base of transport firms and creating long-term relationships with key supply chain operators, a firm can minimize costs associated with gathering supplier information, negotiating contracts, and enforcing post-negotiation. Safeguards must be incorporated into TPL agreements to avoid opportunistic behavior, such as penalty clauses for poor performance, joint investments, training programs, and labor exchange (Halldorsson, 2002).

The Network Perspective Theory emphasizes the value of openness and trust in cooperation among firms to enhance efficiency in administrative and logistical systems. Firms can benefit from the resources and skills of Third-Party Logistics providers through close cooperation, leading to a reduction in costs and contractual safeguards (Haakansson & Ford, 2002; Haakansson, 1987; Haakansson et al., 1999). The Resource-based View, another theory applied to TPL, provides insight into the boundaries of the firm considering the limited availability of resources and capabilities in the market. The TPL acts as a conduit for improving logistic services and achieving mutual transfer of logistics experience. Long-term commitments, customized solutions, and mutual adjustments enhance the uniqueness and heterogeneity of logistics capabilities and resources (Halldorsson & Skjoett-Larsen, 2004). The ultimate goal is to create a learning environment, fostering the development of core logistics competencies. In addition, the features of these theories are outlined in the following *Table 1*.

Characteristics	Principal Agent Theory [PAT]	Transaction Cost Analysis [TCA]	Resource-Based View [RBV]	Network Theory [NT]
Behavioural Assumptions	Disparity in information between the freight sender and the third-party logistics provider, and conflicts in objectives.	Safeguards are fostered by trust based on calculations and specialized investments aimed at long-term agreements.	Establishment of personal trust, mutual learning, and the exchange of knowledge.	Building personal trust, sharing information, and fostering a mutually beneficial situation.
Problem Orientation	Evaluating performance, utilizing activity-based costing, maintaining transparency with open-book management, and using incentives.	What function should be delegated to a Third-Party Logistics (TPL) provider?	Cultivating skills internally and fostering competencies between the shipper and the Third-Party Logistics (TPL) provider.	Establishment of relationships through communication and interaction.
Time Dimension Unit of Analysis	Static Official Third-Party Logistics Agreements	Static Third-Party Logistics Services, Transactional Expenses, and Logistic Efficiency	Dynamic Shared Resources and Capabilities between the freight sender and Third-Party Logistics Provider	Dynamic Relationship between the freight sender and Third-Party Logistics Provider
Nature of Relations	Negative relationships and contract terms can influence both the quantity and type of activities outsourced.	Impersonal relationships, frequent bids to gauge the Third-Party Logistics market, emphasis on cost-effectiveness, and short-term contracts.	Mutually beneficial resources, fostering new skills through Third-Party Logistics relationships.	Verbal agreements, leveraging resources owned by Third-Party Logistics firms, and ongoing Third-Party Logistics contracts.
Primary Domain of Interest	Harmonization of contracts based on behaviour and results.	Investment in specialized resources (like warehouses, IT, personnel), and reducing transaction costs.	Cultivating new skills (such as batch monitored shipments, merge in transit, track, and trace capabilities).	Joint adjustment of IT systems, processes, and routines.

Table 1: Summary view of theoretical framework applied to Third-Party Logistics

Source: (Developed by the Author)

Methodology of the Study

The methodology primarily centers around the hypothesis substantiated by the conceptual framework, research design, target population, sample design, techniques for data collection, data sources, and procedures for data management.

Conceptual Framework

Drawing from the extensive literature review, this study posits a hypothesis that the efficacy of the supply chain, encompassing third-party logistics functions such as warehousing, distribution, and order fulfillment, exerts a substantial influence on overall supply chain robustness, thereby indirectly impacting reward maximization (Lee & Billington, 2001; Millen & Sohal, 2010; Donahaye et al., 2016; Esham et al., 2006). A comprehensive depiction of all

identified variables is presented in *Figure 2* below. Additionally, literature findings provide compelling evidence supporting the mediating role of supply chain robustness in the context of reward maximization (Hendricks & Singhal, 2005; Stricker & Lanza, 2014; Tang et al., 2016). Moreover, key insights gleaned from works by Ekanayake et al. (2018), Karippacheril et al. (2013), and Ackerley et al. (2010) suggest a significant association between technological adaptation, third-party logistics, and the robustness of the supply chain. In summary, based on the literature, the author posits the following hypotheses.

Hypothesis 1: Warehouse facilities have a positive effect on Reward Maximization.

Hypothesis 2: Distribution has a positive effect on Reward Maximization.

Hypothesis 3: Order fulfillment has a positive effect on Reward Maximization.

Hypothesis 4: The robustness of the supply chain mediates the relationship between the warehouse facilities, distribution and order fulfillment, and Reward Maximization.

Hypothesis 5: The technology adaptation moderates the relationship between the Third-Party Logistics and the Robustness of the Supply Chain.

Research Philosophy

The research philosophy employs an assortment of data collection techniques, steered by the author's comprehension of philosophical outlooks, theoretical development, and methodological preferences. This study employs a quantitative method, involving a questionnaire survey to collect and analyze data (Arend, 2003; Rasovska et al., 2008). The study is mainly anchored in a pragmatist philosophical viewpoint (Halfpenny, 1987; Reason, 2003). It emphasizes established theories and empirical discoveries to scrutinize the interrelation between independent and dependent variables, thereby adopting a deductive approach (Manna & Waldinger, 1980). The importance of Third-Party Logistics in bolstering supply chain resilience is explored, concluding that its fortification yields maximum benefits for farmers. A cross-sectional study design was employed as the most fitting to tackle the research queries due to the consistent behavior of the variables over time. The target population for this analysis comprises farming households from the Northern Province of Sri Lanka, particularly from the regions of Jaffna, Killinochi, Mannar, Mullaitivu, and Vavuniya. This choice was influenced by the predominant agricultural issues in this

region (Chief Secretariat's Secretary Northern Province [CSSNP], 2019; CSSNP, 2020; DCS, 2019). The research primarily employs a two-step sampling approach, beginning with a stratified simple random sampling, followed by a subsequent simple random sampling. The chosen stratum for this process is determined by the household head. Within the Northern Province of Sri Lanka, there are a total of 4,395 households led by females, distributed across different districts: 2,709 in Jaffna, 669 in Kilinochchi, 273 in Mullaitivu, 378 in Mannar, and 366 in Vavuniya (DCS, 2022). Upon conducting a preliminary study, it was observed that there is heterogeneity within the samples of each stratum. Simultaneously, each stratum, when compared to other districts in the Northern Province, was deemed homogeneous. Subsequently, within the specified strata of the province, 36 households were randomly selected from each district using simple random sampling, resulting in a total sample size of 180 farming households in the Northern Province for this study.

The data collection strictly adheres to the code of conduct and regulations set by the Department of Survey Regulations Sri Lanka. Owing to the psychological insecurity instilled within households as a consequence of the three-decade-long Civil War in Sri Lanka and its aftermath, the freedom to articulate viewpoints is constrained by diverse means. To proactively address the identified grey area, participating farming households in the study are granted complete freedom to articulate their viewpoints during the questionnaire survey. Anonymity for questionnaire responses is assured. Furthermore, the survey is conducted at the farmers' convenience. The collected data were analyzed using SPSS v21 software.

Findings

This section systematically evaluates the survey data by commencing with a rigorous examination of its validity and reliability. Subsequently, it conducts a thorough analysis of the identified variables. The section culminates with the formal testing of hypotheses.

Goodness of Measures of Quantitative Analysis

The quantitative data collected were assessed for their quality using factor analysis, followed by validity and reliability tests. The sample for quantitative analysis comprised responses from 180 farming households across Jaffna, Kilinochchi, Vavuniya, Mannar, and Mullaitivu, obtained through a direct questionnaire survey. Per Guion (2004), a comprehensive evaluation was conducted to ascertain the validity, appropriateness of tests, ethical considerations, and financial implications associated with measuring the concepts or constructs inherent in the questions. Construct Validity was primarily based on Convergent and Discriminant analysis. The Conducted Convergent Validity indicated that the main study successfully met the minimum threshold limits as per the decision criteria outlined under the methodology aforementioned.

Upon individual evaluation of the results, it was evident that the Kaiser-Meyer-Olkin (KMO) values for all variables exceeded the threshold value (>0.5), implying that the sampling was adequate. Bartlett's test confirmed the significance of the variables under study, as all variables had significance levels below the threshold value (<0.005) (Garcia-Santillan et al., 2012). It was noted that the Composite Reliability (CR) for all

identified variables was above the minimum required value of 0.7 (Purwanto, 2021). The Average Variance Extracted (AVE) measures were above the threshold limit of 0.5 (Adedeji et al., 2017). Thus, it was concluded that the data satisfies the requirements for convergent validity. *Table 2* below demonstrates the convergent validity of the variables.

Table 2: Convergent Validity of Variables

Variable	KMO (>.5)	Sig. of Bartlett's test (<.05)	(AVE) (>.5)	CR (>.7)
Warehousing	0.775	χ^2 : 474 Sig: 0.000	0.643	0.899
Distribution	0.725	χ^2 : 925 Sig: 0.000	0.706	0.920
Order Fulfilment	0.661	χ^2 : 291 Sig: 0.000	0.525	0.844
Robustness of Supply Chain	0.712	χ^2 : 570 Sig: 0.000	0.583	0.867
Technology Adaptation	0.806	χ^2 : 726 Sig: 0.000	0.681	0.911
Reward Maximisation	0.810	χ^2 : 850 Sig: 0.000	0.764	0.942

Source: (Developed by the Author)

The author conducted a reliability test to assess the internal consistency of the measures, specifically the inter-item consistency reliability, using Cronbach's alpha coefficient. The summary of the test results is provided in *Table 3* below. The analysis indicates that the criteria based on the literature's lowest threshold for Cronbach's alpha coefficient have been achieved. Therefore, the reliability analysis suggests that the data collected through the questionnaire successfully meets the decision criteria.

Table 3: Overall Reliability of Variables

Variable	Cronbach's Alpha (> 0.7)
Independent Variables	
Warehousing	0.843
Distribution	0.873
Order Fulfilment	0.737
Moderating Variable	
Technology Adaptation	0.879
Mediating Variable	
Robustness of the Supply chain	0.812
Dependent Variable	
Reward Maximisation	0.910

Source: (Developed by the Author)

With the aid of validity and reliability analysis, all criteria were successfully met.

Demographic Analysis

The demographic analysis was primarily focused on attributes such as gender, age, location, farming experience, educational qualifications, annual income, and farming methods. The majority of the respondents, approximately 88%, were farmers aged between 26 and 45 years. Furthermore, around 78% of these respondents had attained either a primary or secondary level of education. The study discovered a gender proportion of about 3:1 between male and female farmers, indicating an encouraging trend toward the participation of women in farming. To ensure neutrality in the simple random sampling, an equal number of respondents were chosen from each district. About 78% of farmers in the Northern Province had over five years of experience in farming and allied fields. The farmers mainly employed agricultural techniques such as intercropping, multiple cropping,

and intensive cropping, in a ratio of 1:3.5 respectively. Moreover, a significant portion of the farmers, over 65%, reported an annual income above Rs. 250,000.

Descriptive Analysis

The descriptives of the variables are as follows,

Table 4: Descriptive Statistics Summary

Variables	Mean	Median	Std. Deviation	Variance	Skewness
Independent Variables					
Warehousing	2.4467	2.20	0.65471	0.429	1.177
Distribution	2.5667	2.40	0.59439	0.353	1.224
Order Fulfilment	2.5133	2.20	0.48720	0.237	0.700
Moderating Variable					
Technology Adaptation	2.4444	2.00	0.66905	0.448	1.061
Mediating Variable					
Supply Chain Robustness	2.5611	2.4000	0.57240	0.328	1.063

Dependent Variable

Reward Maximization	2.6367	2.4000	0.59174	0.350	1.215
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Source: (Developed by the Author)

The independent variable, warehousing, demonstrated a positive skewness of +1.177, implying that most farmers experience inadequate warehousing. This claim is substantiated by a median value of 2.2 and a mean value of 2.447. With a coefficient of variance at 0.265, which is less than 1, the data suggest that responses are tightly distributed around the mean, thus, underscoring the prevalent issue of poor warehousing. Distribution, another facet of Third-Party Logistics, displayed a positive skewness of +1.224, further affirming the inadequate distribution situation in the Northern Province. The coefficient of variance, at 0.231, indicates that responses cluster strongly around the mean of 2.567, signifying farmer dissatisfaction with existing distribution systems. The last segment under Third-Party Logistics, order fulfillment, showed a relatively lower skewness of +0.7, suggesting a prevalence of weak order fulfillment methods and techniques. The weak order fulfillment scenario is further highlighted by the coefficient of variance at 0.194, which hovers closely around the mean value of 2.513. Farmers' responses from the Northern Province revealed negligible technological adaptations concerning Third-Party Logistics components, a claim reinforced by response bias, as evidenced by the skewness of +1.061 and a coefficient of variance of 0.274 dispersion around the mean of 2.444. The study found the supply chain's

robustness, a variable mediating the condition between Third-Party Logistics and reward maximization, to be generally weak. This is suggested by a positive skewness of +1.063, pointing to weak supply chain practices in the Northern Province. This situation is further confirmed by a concentration of responses around the mean value of 2.561 and a coefficient of variance of 0.22.

The findings overall suggest that farmers in the Northern Province receive limited incentives in terms of yield, benefits, satisfaction, and sales. This argument is bolstered by the survey results, which show most of the responses leaning towards the positive side of the bell curve, with a value of +1.215, indicating a minimal level of rewards earned by the farmers.

Hypothesis Testing

The first hypothesis suggests that warehousing significantly influences reward maximization. The Pearson correlation coefficient of this hypothesis is found to be +0.954, indicating a strong association between the variables. Moreover, the observed p-value is less than the threshold (α) of 0.05, and the regression coefficient is a significant 0.862 at the 0.05 significance level. Consequently, warehousing is a reliable predictor of reward maximization. Using the Pearson correlation coefficient of warehousing, we derive a coefficient of +0.862 and an intercept of 0.527. When these coordinates are applied to the simple linear regression model ($Y = \beta_0 + \beta_1 X$), the relationship is expressed as:

$$\text{Reward Maximization} = 0.527 + 0.862 * (\text{Warehousing}) \tag{1}$$

The second hypothesis in the study proposes

that Distribution significantly influences reward maximization. With a Pearson correlation coefficient of +0.905, the association between the independent and dependent variables is strong. The p-value is also observed to be 0.000, which is less than the threshold value of 0.05. The regression coefficient of +0.901 is considered significant at 0.05, affirming that distribution is a strong predictor of reward maximization. Applying these findings to the simple linear regression model, the relationship is expressed as:

$$\text{Reward Maximization} = 0.324 + 0.901 * (\text{Distribution}) \quad (2)$$

The third hypothesis suggests that Order fulfillment significantly influences reward maximization. The association observed among the variables is +0.782, revealing a strong correlation. This relationship is substantiated by a p-value lower than the threshold and a regression coefficient of 0.949 significant at the 0.05 threshold. Therefore, it supports the hypothesis that order fulfillment is a significant predictor of reward maximization. Upon applying the Pearson correlation coefficient to the simple linear regression model, the relationship is:

$$\text{Reward Maximization} = 0.251 + 0.949 * (\text{Order Fulfilment}) \quad (3)$$

The fourth hypothesis posits that the robustness of the supply chain mediates the relationship between warehousing facilities, distribution, order fulfillment, and reward maximization. A Sobel test (as shown in *Figure 3*) was conducted to assess the mediating effect of the robustness of the supply chain between the independent variables (Warehousing, Distribution, Order fulfillment) and the dependent variable

(Reward Maximization). This test, essentially a specialized t-test, investigates the statistical significance of the mediating variable. All identified explanatory variables have probability values less than the threshold of 0.05, leading to the conclusion that the Sobel mediator test is statistically significant. Moreover, it suggests that the explanatory variables (warehousing, distribution, and order fulfillment) influence the dependent variable (Reward Maximization) in the presence of the mediator (robustness of supply chain). *Table 4* displays the test outcomes of the Sobel test.

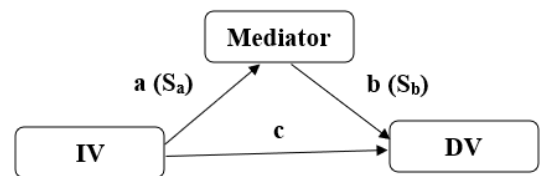


Figure 3: Sobel Test

Source: (Developed by the Author)

The final hypothesis of the study suggests that technology adaptation serves as the moderator between warehouse facilities, distribution & order fulfillment, and the robustness of the supply chain. To determine the moderating effect, multiple regression was conducted among the interaction variables, independent variables, and the Mediating Variable (Robustness of Supply chain) (Vij & Farooq, 2017; Hall & Rosenthal, 1991). The results show that the significance value observed under the interaction variable is less than the threshold of 0.05, implying that the interaction is statistically significant. Overall, the impact between the regressors (warehousing, distribution, order fulfillment) and the regress and (robustness of the supply chain)

is moderated by technology adaptation.

Table 4: Sobel Test Results of the Mediating Effect of Robustness of Supply Chain

	Sobel Test Statistics	p-value	Significant / Not Significant
Mediation of Robustness of Supply Chain on Warehousing and Reward Maximization	5.323	0.000	Significant
Mediation of Robustness of Supply Chain on Distribution and Reward Maximization	8.329	0.000	Significant
Mediation of Robustness of Supply Chain on Order Fulfilment and Reward Maximization	11.556	0.000	Significant

Source: (Developed by the Author)

Discussion

Overall, the study conducted concludes that warehousing, distribution, and order fulfillment influence reward maximization which is mediated by the robustness of the supply chain and moderated by technology adaptation. The paper showcases the importance and robustness of the agricultural supply chain and the importance of technology adaptation in the 21st century (Akkerman et al., 2010).

The study findings indicate that warehousing facilities in the Northern province face numerous challenges, including post-harvest damages, insufficient storage capacity, ineffective Third-Party Logistics strategies, and substandard

transportation within the supply chain, resulting in lower profits for farmers. These results corroborate previous studies by Adhikarinayake (2015), Sundaram (2014), Donahaye et al. (2016), Ashenbaum et al. (2015), Wasala et al. (2014), and Jacob et al. (2014). Both current and past research emphasize that high-standard warehousing boosts farmers' ability to sell products at optimal market prices. The research also reveals the poor quality of farmers' distribution facilities in the Northern Province. Issues concerning drying, cleaning, milling, packing, and a lack of direct and indirect sales facilities were prevalent. Adequate distribution facilities are key to maximizing farmer profits, as supported by studies by Korgaonker (1990), Cilliers and Nagel (1994), Goh and Ang (2000), Bloomen and Petrov (2012), and Sohail et al. (2008). Both current and past research suggest that low distribution standards negatively impact crop production effectiveness, resulting in spoilage or damage to the produce. Further, the findings highlight that farmers face challenging contractual obligations, limited interest in in-farm value creation from firms, and a lack of responsiveness to customer demand. Effective order fulfillment is crucial in determining production and financial rewards, in line with viewpoints from Christopher (2000), Lee and Billington (2001), Malone (2000), and Perini and Susi (2004). Both sets of research underscore the importance of effective order fulfillment to the agricultural supply chain's effectiveness. Lastly, the study shows that farmers have a limited adaptation to technological platforms and a significant knowledge gap. This is supported by Ekanayake et al. (2018), Karippacheril et al. (2013), and Ackerley et al. (2010), who posit that the presence of technology can improve efficiency and

effectiveness.

The research paper explores the application of four distinct theories in decision-making regarding supply chain management: Transaction Cost Analysis (TCA), The Principal-Agent Theory (PAT), The Network Theory (NT); and the Resource-Based View (RBV). TCA and PAT, rooted in neo-classical economic theory, aid in managing the supply chain in various ways. These include deciding on in-house activities and outsourcing aspects of the supply chain to third-party firms, identifying roles and responsibilities of supply chain participants, safeguarding firms from opportunistic behavior, and establishing incentives to enhance supply chain outcomes. However, TCA and PAT theories have limitations due to assumptions about human behavior and static views of boundaries. In response, complementary theories like NT and RBV are employed in this study. NT examines how companies within a supply network can adapt their processes and systems through interaction and exchange, emphasizing the importance of third-party firms in creating operational effectiveness within the supply chain. RBV, complementing TCA, focuses on resources, capabilities, and competencies both within individual firms and in connections between firms in the supply chain. It helps in deciding which activities to outsource and which to keep in-house, based on the capabilities of potential partners in the supply chain. The dimensions of Third-Party Logistics for the selected sample highlight a minimal availability of facilities, suggesting the need for highly efficient and effective third-party service providers. Here, NT and RBV aid in effective decision-making concerning selection criteria. These theoretical frameworks guide entities in making appropriate decisions regarding warehousing, distribution, and order

fulfillment. By employing these theories, strength can be fostered in the supply chain, reflected in the form of financial incentives, production increases, or satisfaction for farmers. Nonetheless, firms should be careful when selecting the appropriate theory to explain inter-firm cooperation due to the potential for contradictory explanations. The empirical findings of this research indicate that individuals/entities involved in agribusiness don't merely respond to PAT and TCA, but also to the contingencies associated with both.

Overall, for an agricultural supply chain to be efficient, farmers must have efficient warehousing, distribution, and order fulfillment facilities. Technology adaptation is also a significant factor in improving their economic condition. This study aimed to investigate the relationship between Third-Party Logistics and farmer rewards, the mediating effect of the robustness of the agricultural supply chain, and the moderating effect of technology adaptation. It successfully demonstrated a significant relationship between independent and dependent variables, along with a mediating and moderating effect.

Conclusion

The primary aim of this research was to investigate the impact of Third-Party Logistics on farmers' reward maximization, with the robustness of the supply chain acting as a mediating variable and technology adaptation as a moderating variable. An empirical study was conducted for this scientific research, with findings based on a sample of 180 farming households. These findings address issues highlighted in the Introduction section. Nearly 78% of the respondents indicated low levels of reward maximization, reflecting

the poor quality of Third-Party Logistics facilities. Theories related to this phenomenon are discussed in the following section. The author has developed a model to predict reward maximization, with this chapter explaining key survey findings, their potential contributions to related theories, and anticipated future research based on these findings.

The research findings reveal a statistically significant relationship between the independent and dependent variables. The sample group consisted of 77.22% (or 139) male farmers. Notably, 53 respondents (29.44% of the sample) were farmers aged 41 years and above, and 63 (35% of the sample) had been engaged in agriculture for over a decade. These farmers, having weathered a decade of agricultural challenges, have the potential for future progress. It is inferred that these farmers can find satisfaction in their limited revenue. A small improvement in these farmers' supply chain practices could significantly enhance their overall operations. Technology, as a moderating variable, was found to have a significant impact on strengthening the supply chain. Hence, technology adaptation and knowledge are crucial for revenue maximization. Notably, 39 respondents (or 21.67% of the sample) reported an annual revenue above Rs. 300,000. Upon analysis, it was observed that these 39 respondents were also the ones who had attained at least a bachelor's degree and adopted intensive cropping, highlighting the important role education plays in revenue generation. However, logistic functions were less effective due to a knowledge gap regarding modernization and mechanization. Although third-party providers were integrated into the supply chain, their effectiveness was significantly hindered due to trust issues and other limitations in the Northern province

market. The preliminary study conducted by the researcher before running the real survey indicated that farmers lacked confidence and networking capabilities, often exploited by middlemen. Ineffective warehousing, distribution, and order fulfillment facilities provided by third-party entities within the villages critically influenced revenue, establishing the dimensions of Third-Party Logistics as the independent variable. The mediating variable, the robustness of the supply chain, exhibited a significant relationship, mediating between the independent and dependent variables. The problems identified among the farmers in the Northern province are mainly due to the ineffective application of Third-Party Logistics, impacting the strength of the supply chain. It was identified that poor supply chain application was a key factor determining revenue.

Overall, the study confirmed a significant relationship among the variables considered. To summarize, the independent and moderating variables have a close relationship with the demographic factors studied, and all the independent variables are connected to the dependent variable through the mediating variable.

Implications

The research paper addresses the dimensions of Third-Party Logistics and how they intertwine with Principal-Agent Theory, Network Theory, Transaction Cost Analysis, and Resource-Based View explored in the study. The research reveals that agriculture in the Northern province requires significant improvements, particularly in areas such as Third-Party Logistics, technology adaptation, and the Agri Supply Chain Robustness.

Farmers exhibit notable gaps in their

adaptation to warehousing, distribution, and order fulfillment facilities. Although new facilities are being introduced for TPL, many farmers seldom employ effective outsourcing techniques. Common practices include forming partnerships or opting for managed services. Trust limitations have led most farmers to seek third-party firms within their familiar locales. However, partnering with third-party providers with limited capabilities has led to a critical market situation with limited growth potential. On the other hand, under managed services, the third-party provider's responsibility is broader, encompassing complete functions like transportation systems or storage systems management. Farmers often hesitate to adopt this strategy due to time constraints, as they balance between coordinating with logistics providers and cultivating their crops. Given these conditions, the research suggests shifting from Third-Party Logistics to Fourth-Party Logistics [FPL] could enhance revenue and supply chain efficiency (Jones & Rashid, 2020). In line with the view of Sullivan (2021), unlike TPL, FPL involves outsourcing the entire supply chain management to a provider that oversees warehousing, shipping, freight forwarding, and supply chain, agents. The FPL provider focuses on integrating and optimizing various supply chain aspects, thus improving service levels, and simplifying logistics functions. The transition to FPL can rapidly boost capacity and expand the business nationally and internationally. Technology is identified as a key factor in moderating the effectiveness of TPL and the strength of the supply chain. Despite the

availability of mobile applications connecting farmers and retailers, the effective utilization of technology remains low (Khan et al., 2019; Ogbuide & Ele, 2015). Unlike the integration of TPL with a mobile application, incorporating the FPL into cloud systems, particularly System Application and Products [SAP], amplifies transparency concerning climate variations, raw material sourcing, tracking capabilities, and adherence to regulations (Gupta & Singh, 2021).¹

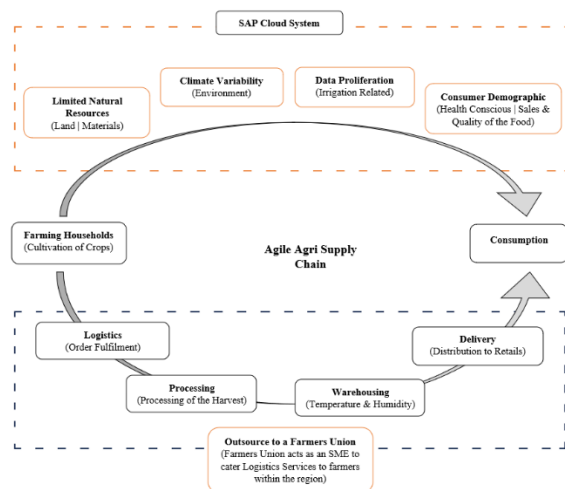


Figure 4: Agile Supply Chain to Bring Robustness and Efficiency

Source: (Developed by the Author)

The agricultural supply chain in the Northern Province is currently underperforming due to a lack of comprehensive integration. Its main process is the movement of raw materials from suppliers to farmers, and then from farmers to consumers via intermediaries.

The findings will be discussed following the commercial implementation of the proposed model with a threshold level of the sample population.

¹ The model, proposed and developed by the author, Gopikrishna Selvananthan, is currently under testing in Northern Sri Lanka since the fourth quarter of 2022. These test results pave the way for future research.

This simplistic structure doesn't allow for much environmental interaction or predictive capacity. However, the study suggests that technology has the potential to drastically enhance the efficiency of the agricultural supply chain by transforming the facets of third-party logistics and reinforcing the supply chain as a whole. Thus, in concurrence with the recommendations provided earlier, the author of this study proposes an adaptive supply chain that integrates the principles of Fourth-Party Logistics and technological applications, intending to achieve greater productivity and consumption efficiency. The recommended supply chain is illustrated in *Figure 4*.

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