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Digitally Enabled Shrimp Farming: A Service-Dominant Logic View

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Completed Research

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Abstract

Digital technologies have made a significant impact in agriculture, helping farmers access information from a wide range of markets and get better prices for their products. In particular, aquaculture and shrimp culture are some of the fastest-growing agricultural sub-sectors providing food for the world's growing population. The shrimp supply chain in developing countries like India is not efficient and hence unsustainable. The main challenge in aquaculture is the uncertainty found in all stages, including supply, production and distribution. Our study seeks to address the following questions: what are the sources of information inefficiency in the shrimp supply chain? How could a service dominant-logic view of the shrimp farming supply chain inform digitally-enabled innovation in a developing country context? The core contribution of this work is a framework theoretically informed by service-dominant logic and information requirements of the key stakeholders.

Keywords

Service dominant logic, shrimp farming, information asymmetry.

Introduction

Digital technologies for agriculture help farmers to reach a wide range of markets and agricultural experts (Banker et al. 2011). However, the strict 'farmers and markets' view of the fisheries and aquaculture sub-sectors has also hampered service exchange *with multiple stakeholders, with multiple criteria with cross-cutting concerns* (Mathisen, Haro, Hanssen, Bjork, & Walderhaug, 2016, p.7). A focal case is shrimp culture, a fast-growing agricultural sub-sector in India. The shrimp supply chain in India is not efficient and is characterized by uncertainty and inefficient exchange of information in different stages spanning supply (hatchery), production (farming), distribution (mainly export) and demand (Vlachos and Malindretos 2019). Digital innovation has embraced Service-Dominant Logic (SDL) to address this restrictive producer-customer categorization for goods exchange (Lusch and Nambisan 2015). SDL reconceptualizes actor to actor exchange using the key concepts of service ecosystems, service platforms and value co-creation as a means to effect service innovation in the digital era. According to this view, a supply chain is a nested service ecosystem (Lusch, 2011). In this context of the growing impact of IT capabilities on service innovation, our study seeks to address the following questions: what are the sources of information inefficiency in shrimp supply chain? How could a service dominant-logic view of shrimp farming supply chain inform digitally enabled innovation in a developing country context?

Prior IS studies on exchange activities in agriculture and fisheries predominantly follow a goods-focused view where the actors exchange specific outputs, predominantly physical, as a result of performing certain activities (E.g.: Banker et al., 2011). However, actors in the shrimp farming supply chain possess a diverse set of resources in the form of skills and knowledge. Understanding supply chain exchanges in fisheries and shrimp farming as the exchange of these resources within a service ecosystem provides a more insightful approach for digitally enabled service innovation (Lusch, 2011, Lusch & Nambisan, 2015). As argued by the proponents of service-dominant logic, "when two actors jointly provide for each other's carbohydrate and protein needs by having one actor specialize in harvesting fish from the oceans and the other specialize in cultivating the soil, the exchange can be considered one of fish for wheat or of the application of fishing skills and knowledge (fishing services) for the application of farming skills and knowledge (farming services)" (Lusch & Nambisan, 2015, p.159). The latter approach will profoundly influence our understanding of service, exchange, resource and value. Despite limited digital infrastructure and resources, transformative services in developing countries have shown their significant impact on economic development. For example, Srivastava and Shainesh (2015) studied the impact of digitally enabled healthcare service delivery provided by two private enterprises in India through the lens of service-dominant logic, shedding light on service innovation in bridging the service divide. Along similar lines, we analyze the shrimp supply chain and farming practices using multiple case studies in two different South Indian states. We draw upon the four meta-theoretical foundations of service dominant logic, *actor to actor network, resource liquefaction and resource density and resource integration (*Lusch and Nambisan 2012) as key dimensions to analyze the case study data gathered from shrimp value chain stakeholders.

Shrimp Farming and Service Dominant Logic View

This section analyzes the literature on digital technologies for shrimp farming and related domains, emphasizing how service ecosystems and digital technologies are linked. We further review service dominant logic and how its premises have been applied to various domains. Subsequently, we develop a broad conceptual framework to analyze actors and their exchanges in shrimp farming using SDL.

Shrimp Farming

Shrimp is the lucrative crustacean species farmed across the world, and currently, Pacific white shrimp (Penaeus Vannamei) is the leading species farmed worldwide, and also in India (Kumaran et al. 2017). India has 1.2 million hectares of brackish water spread across nine maritime states. Shrimp farming adds to 70% of India's seafood in value, hence forming a major component of the fish production system (MPEDA 2015). Penaeus Vannamei farming is expanding in India (FAO 2014) due to the abundance of Specific Pathogen Free (SPF) seeds in the international market. Shrimp, as compared to other meat items, have a low feeding requirement in terms of protein (30 – 35%), a fast gain of weight up to 20g, amenable for high stocking densities and much higher meat yield (65-70%) (Briggs, 2005; Ravichandran et al., 2011). Shrimp has formed one of the major components of India's seafood export for almost two and half decades and has a high potential for foreign exchange earnings. However, the small-scale farmers in India are unorganized and have very little access to scientific knowledge and technologies (Muralidhar et al. 2012). Supply chain actors in shrimp farming predominantly follow a goods-centric mindset. For example, profiling of the shrimp supply chain in the South Indian state of Andhra Pradesh identified stakeholders, their roles and importance in the supply chain (Muralidhar et al., 2012). However, this understanding limits the extent of understanding about resources that various actors have or need and how they are exchanged or further, could be exchanged. This is particularly relevant for operant resources, which consists of specific skills and knowledge (Lusch and Nambisan 2015) possessed by one actor which could also benefit another actor (e.g.: farmer's knowledge about a disease can inform pharmacy. Several studies conducted in countries other than India regarding the digitization of the shrimp supply chain have mainly focused on the development of sensors or GIS systems for monitoring of ponds covering a large areas and, as such, do not cover the supply chain as a whole. For example, Quader et al. (2010) conducted a study on suitable site selection of shrimp farming in the coastal areas of Bangladesh using remote sensing techniques. The study addresses database construction of GIS-based environmental fisheries and analysis of the environmental impact of shrimp culture. Buitrago et al. (2005) studied a single-use site selection technique using GIS, for aquaculture planning in Margarita Island in Venezuela. The study involved the identification of optimum sites for mangrove oyster raft culture based on multi-criteria evaluation using GIS. In the Indian scenario, Karthik et al. (2005) conducted a study on brackish water site selection in Palghar taluk of Thane district of Maharashtra, using remote sensing and GIS. This study demonstrated the potential use of remote sensing, GIS and GPS for aquaculture site selection and planning. The main focus of the study was to identify the potential area for the commencement of sustainable shrimp farming with the help of remote sensing and GIS. Mobile applications like AquaBrahma (http://www.aquabrahma.com/) were developed, which provided services to hatcheries and Agro input suppliers and also provided market price indicators.

Most of these national studies collect data using satellite images. A medium was required to collect ground data from the farmer and combine it with GIS data to develop a prediction model. However, the GIS failed to provide individual pond level data. Moreover, market demand, exporters, disease prediction and alerting were not incorporated in these studies. Jensen (2007) reported that the adoption of mobile phones by marginalized fishermen of Kerala in Southern India increased the welfare of both producers and consumers. Sub-sectors of agriculture like fisheries and shrimp culture remain underexplored in developing countries like India to benefit from potential features and affordances of digital technologies.

Service Platforms in Agriculture

As the concepts of SDL has not been widely applied to aquaculture or shrimp farming, we review the literature on SDL on the parent domain of agriculture. For many centuries' agricultural commodities like rice, wheat, soybeans etc., have been sold through oral auctions. High cost for transportation, inability to get reliable price information and lack of reliable mechanisms to measure the quality of products make the farmers dependent on intermediaries who exploit them (Goyal 2010). Prior studies have shown the impact of digital trading platforms in agricultural commodities (Banker et al. 2011). For example, e-Kutir is social entrepreneurship based in the Indian state of Orissa. e-Kutir evolved in five distinct phases.

Service Dominant Logic

Service-Dominant Logic approaches actor to actor exchange in a supply chain as the exchange of service, which counters the traditional approach of goods-centered exchange..The creative insight in this approach is the opportunity for a detailed understanding of resources possessed by and needed by different actors in a supply chain. SDL reconceptualizes service as a process of using one's resources for someone's value instead of traditional services conceptualization as a unit of output which forms the central theme of service-dominant logic (S-D Logic) (Lusch and Nambisan 2015). The resources used in this perspective are created by integrating existing resources (Vargo & Lusch 2008). The main drivers for service innovation are the users' mandate for new services and executives' aspiration to craft new services for existing markets or find new marketing positions for prevailing services (Damanpour et al., 2009; Mathews & Shulman, 2005). The main key elements in SDL are Ecosystem, Platform and Co-creation as shown in the emergent framework below (Figure 1). In service-dominant logic, actors are not viewed in their dyadic roles of producers and consumers but in a broader sense as actors in a system creating value through service provision and resource integration (Lusch and Vargo 2011). All actors are prospective resource integrators in a system of actors and are potential innovators. Thus, a network-centric perspective is one of the central themes of S-D logic (Barrett et al. 2015). S-D logic draws on the concept of resource liquefaction, which refers to the "decoupling of information from its related physical form or device" (Normann 2001). S-D logic involves the deployment of resources for the benefit of the actors in the network so that the resources can be mobilized quickly for an actor or time or space to attain the desired service. The key issue is with respect to density (Barrett et al. 2015). Maximum density can be attained when the best combination of resources can be mobilized in a particular context (Lusch, Vargo, & O'Brien, 2007; Normann, 2001).

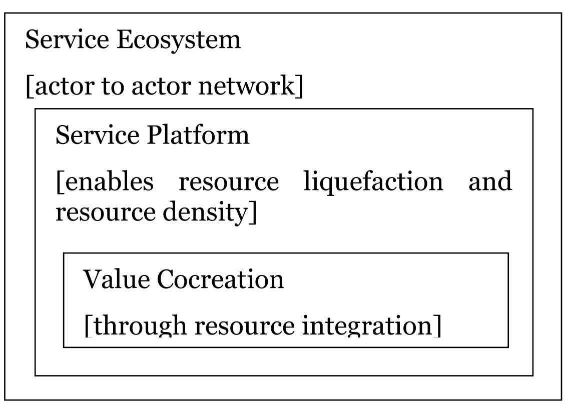


Figure 1. A Theoretical Framework Based on Literature

Research Methodology

The main aim of our study is to identify information gaps in the shrimp supply chain and to develop an SDL view of the system. We chose the case study approach as our study is predominantly conducted in an under-explored domain in IS research. Multiple comparative case studies (Figure 2) were conducted to design and develop our framework (Eisenhardt, 1989; Cavaye, 1996). Purposive sampling with some convenience of access constraints was used to select three case sites. The case study approach: "*tries to illuminate decisions: why they were taken, how they were implemented, and with what result*" (Schramm 1971). The unit of analysis of our case study is the shrimp supply chain. The qualitative nature of this approach therefore allows us to explore the complexity of the decision-making process of each stakeholder in the aquaculture supply chain. Moreover, the method's rich qualitative nature allows for an in-depth understanding of the difficulties faced by the farmers in conducting the harvest and reaching better markets. The comparative case study benefits our research questions are two-fold. First, it allows us to understand a relatively unexplored agricultural subsector from an information system perspective. Secondly, comparative case studies "*enable richer, more accurate and generalizable theorizing*" (Bechky & O'Mahony, 2015 p. 174), suitable for our motivation. The average interview time was about 15 minutes.

Sl. No	Aquaculture organization / Department	Participant role	Area of functioning
1.	Aquaconnect	Chief Executive Officer	Platformarization of aquaculture
2.	ACE Technologies	Product Manager	Aquaculture cold chain (Packaging technology)
3.	XpertSea	Chief Revenue Officer	Smart aquaculture equipment (Specialized in counting equipment)
4.	Salem Microbes PVT Limited	Sales Manager	Digital Technology in Aquaculture
5.	PCI Continental cryogenics	Sales Engineer	Smart dissolved oxygen generator
6.	Das and Kumar	Partner	Instruments and Equipment Manufacturer
7	ABC	Manager	Sea food exporter
8	R8	Professor, Marine Biology	Aquatic animal health
9	R9	PhD, Marine Biology	Aquatic animal health
10	R10	Senior Officer, MPEDA	Aquatic animal health
11	Aquaconnect	Analyst	Platformarization of aquaculture
12	Aquaconnect	Call Manager	Platformarization of aquaculture
13	Aquaconnect	Senior Manager	Platformarization of aquaculture
14	Aquaconnect	Analyst	Platformarization of aquaculture
15-18	Farmers from Tamil Nadu	Owning farm land in Chidambaram	Shrimp farm
19 - 23	Farmers from Kerala	Owning farm land in Kochi	Shrimp farm
24	Technician	Working in farm land	Shrimp farm

Table 1. Key Informant Profile

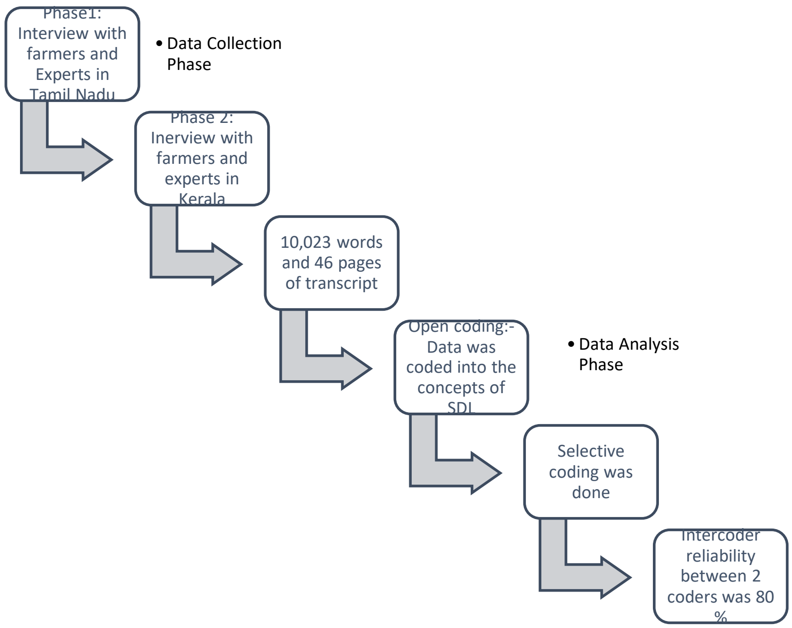


Figure 2. Research Methodology

Shrimp Supply Chain

The interview data collected and analyzed was first used to understand the shrimp supply chain. In both the case studies, farmers were using the traditional method of farming which has major drawbacks. Shrimp cultivation requires an initial investment of about INR 0.9-1 million and the harvest typically goes up to four months. The first phase of the aquaculture supply chain is broodstock production, followed by spawning in the hatchery. The shrimp seedling is grown in the hatchery for about 45 days, following which the post-larvae is transferred from the hatchery to the shrimp farmers.The farmers buy shrimp seedlings in the ratio of 1 lakh shrimp per one hectare as it is considered the optimum amount. As it is impossible to count this large quantum of shrimp manually, the farmers use the traditional approximation method to count the seedling. However, this may result in underestimation of seed counts, which may cause loss to the farmers. Some of the quotes from the farmers as well as the industry experts are as follows:

"The traditional method of counting has about 27% inaccuracy, which may cause huge loss to the farmers" R3 (CIO, Xpert Sea, Canadian Aquaculture technology company)

Seed count is an important parameter as it forms a major part of the cost of the entire cultivation. Hence the traditional method of seed count estimation may not be appropriate. After the seed is brought to the farmland, a typical harvest goes up to three-four months, depending upon the weight gained by the shrimp. The harvesting period requires constant monitoring of ten parameters and weather, dissolved oxygen and feed parameters. The optimal count after harvesting is 30 per kg. If any of the parameters goes wrong, then the entire harvest is lost. If the parameters are not appropriately controlled or the feed intake is not proper, then it may affect the health of the shrimp badly and the entire cultivation may be lost, causing huge setbacks to the farmers. The farmers are now conducting lab experiments weekly in the nearby labs. Technicians (A person who has done his master's in fisheries) are employed to give feed and input parameters. All the parameters, including water quality reports and feed ratio, are written on the paper. This makes it difficult to show proof to the government or other agencies for insurance if the harvest is lost.

"*The farmers would be keeping all the writings as farm-level values, they don't have data in digital format, so it is good for nothing when you have this data imagine what you could do with this data*. R1 (CEO, Aquaconnect, Digital Platform company for aquaculture)

The parameters and the feed amount given etc., are written in notebooks and thus are prone to damage. The farmers in Chidambaram are doing weekly analysis, while those in Kochi are conducting the tests once in two days. The laboratory is nearby and the cost of running tests is low. The traditional method requires constant monitoring, so one or two people are employed day and night to check the farm conditions in both the case sites. However, manual observation may lead to errors and thus loss to the farmers. Some of the sample quotes are given below.

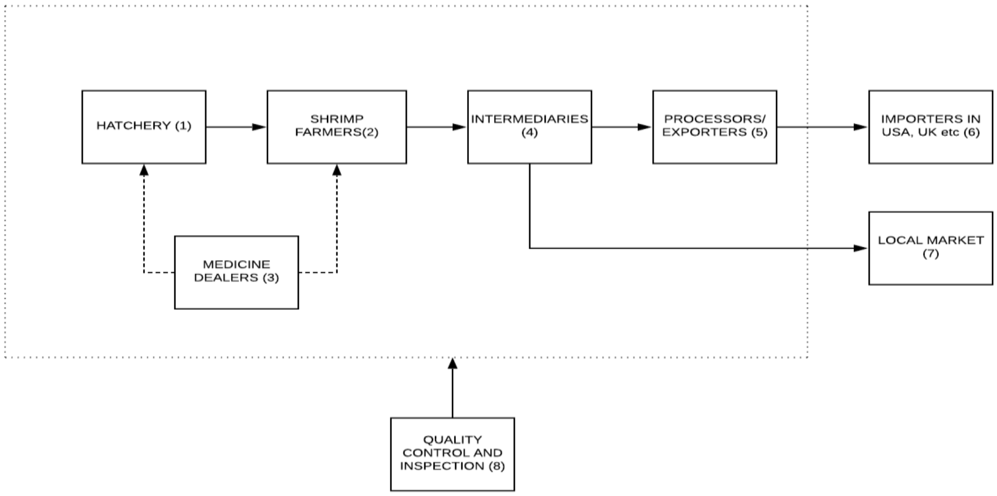


Figure 3. Shrimp Supply Chain that Emerged From the Case Data Analysis

Dissolved oxygen is also an essential component of the water quality parameters and feed ratios. The dissolved oxygen (DO) generator needs a constant electricity supply if the farmers are not using an automatic DO generator as in the traditional method. This results in unnecessary power consumption and an extra cost for the farmers. Moreover, this results in constant monitoring of the electric power supply and switching on the generator when required.

"*I accidentally stepped onto the switch of the machine which produces dissolved oxygen…and the aeration stopped for the entire night, we realized this only after 12 hrs, When some 10-20 shrimps floated dead the next day morning*" R20 (Farmer, Kochi)

If any of the parameters are not at the expected level, farmers tend to use medicines in non-optimum amounts expecting a better yield; however, this may result in rejection by the quality control and inspection unit in the international market, which checks for the medicine content before approving. After the harvest season, the farmers sell the harvest to the available exporter at the accessible market at the given price as they do not have access to a wide variety of markets. Moreover, the intermediaries play a major role in helping the farmers to find the markets. However, in most cases, the intermediaries exploit the farmers, harvesting huge profits.

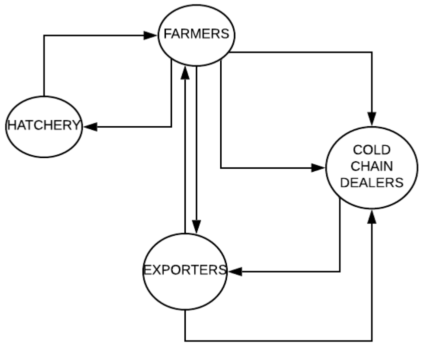
"*The intermediaries connect us to meet up with the farmers and they play a major role in fixing prices*" R7 (Manager, Shrimp Export Company, Kochi).

A Service-Dominant View of the Shrimp Supply Chain

Having analyzed the shrimp supply chain through multiple case studies, we propose a digitally enabled solution framework based on service innovation.

Actor to Actor-Networks

This section explores the case study data to analyze the actor-to-actor network in the proposed digitally-enabled shrimp farming.



The four main actors in the shrimp supply chain are hatchery, farmers, exporters and cold chain logistics. Digitally enabled shrimp farming can help hatcheries improve the counting efficiency, which can help farmers in stocking the right amount. In the current scenario, the farmers find out the best hatchery using word of mouth from other farmers. Cold storage, which can improve the liveliness of the shrimp, is lacking in these areas. The cold chain logistics can retain the freshness of the shrimp for approximately four weeks. This can help the farmer take time to identify a suitable buyer from a range of buyers.

Figure 4. Actor to Actor Networks

"Machine Learning Techniques can improve the efficiency of seedling counting by approximately 21% "

R3 (CEO, XpertSea)

Resource Liquefaction

Sl. no	Value units	Supporting quotes	Operant/ Operand
1	Hatchery seedling quality	"*There is about 27% inefficiency in hatchery seedling quality and counting*" R10	Operand:- Hatchery seedling Operant:- Seedling counting machine
2	Water quality parameters	"*We conduct weekly lab tests to monitor the water quality parameters. Further, we seek the advice of the technicians to get suitable recommendations*" R12	Operand:- Farm water Operant :- Low cost sensor
3	Shrimp growth prediction	"*The best shrimp count is 30 per kg…however, its uncertain…sometime it can increase*" R3	Operand:- Shrimp Operant:- Business Intelligence and Analytics
4	Shrimp disease prediction	"*Sometimes the shrimp gets disease all of a sudden and we are unable to foresee it…we have to wait for the help of an expert to visit the pond and give suitable recommendation*" R4	Operand:- Shrimp Operant:- Business Intelligence and Analytics
5	Suitable market price	"*We export to the immediate available exporter, and the intermediary plays a major role in finding the exporter*" R12	Operand:- Shrimp Operant:- Business Intelligence and Analytics
6	Suitable insurance coverage	"*The risk involved in the shrimp cultivation is huge…therefore we find it difficult to find out suitable insurance policies…moreover we are finding it difficult to convince the insurance agents.*" R15	Operand:- Shrimp Operant:- Business Intelligence and Analytics

Table 2. Resource Liquefaction Parameters

All the actors involved in the shrimp supply chain that we analyzed, the seedling count, feed ratio, water quality parameters and market prices were embedded in the physical matter (writings). However, for information to be useful, it must be collected and stored to be accessed by other stakeholders in the supply chain and perform analysis and make predictions.To understand the information needs of each stakeholder, we first analyze the information flow possible. The farmer needs to feed some initial data into the database, including 1) Hatchery from which the seedling was brought 2) Initial stock of postlarvae and feed 3) Feed providing ratio 4) Price at which the feed was brought. The feed-providing ratio can be updated according to the shrimp's growth (twice in the first month, thrice in the remaining months). Low-cost sensors which can be implemented and checked for error and calibration can be used for data acquisition at every defined time interval (e.g., Parra et al., 2018).

Resource Density and Integration

The four main physical resources needed for cold chain logistics are seedling counting machines, business intelligence and analytic architecture, cold storage parameters and low cost, low error-prone aquatic sensors. The main resource integration agent that emerged from our study is business intelligence and analytics. As depicted in Figure 5, this will be the value unit that will integrate all the remaining components by minimizing information asymmetry.

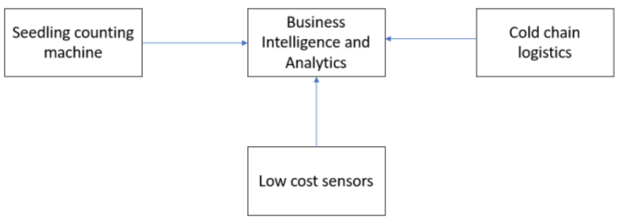


Figure 5. Resource Density

An Information-Centric Architecture for Shrimp Farming Service Platform

Our case studies provided further evidence for inefficient information exchange in shrimp farming actor to actor networks. Our respondents presented evidence of the loss incurred due to the presence of intermediaries. Particularly interesting data points are that of the exporters and farmers, who are equally concerned about the role of the intermediaries. Intermediaries here exploit information asymmetry between stakeholders. The high cost of transportation, lack of reliable price information, and the inability to verify the quality of the products are exploited by the intermediaries (Goyal 2010). In coffee supply chains, Banker et al. (2011) have also empirically investigated the effect of the profit incurred by the farmers by selling their products through a digital platform. Therefore, we propose:

Proposition 1: The effectiveness of actor-to-actor networks in digitally-enabled shrimp farming will reduce the influence of intermediaries.

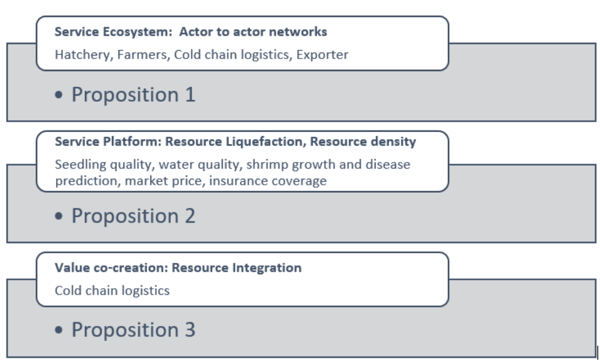


Figure 6. Emergent Framework from Case Data Analyses

The constant acquisition of water quality parameters and other market parameters plays an important role in the efficiency of the digital infrastructure in terms of disease prediction, growth prediction, and resource liquefaction. However, recent advances in digital infrastructure have identified low-cost sensors and fault detection systems in sensors that could be highly useful in developing countries. These data acquisition methods play an important role in anchoring farmers towards effective decision-making. (e.g.: Parra, Sendra, García and Lloret, 2018; Chen, Zhen, Yu and Xu, 2017). Thus, with the combination of data acquisition devices and information processing capacity, the effectiveness of digital infrastructure could be augmented. Therefore, we propose:

Proposition 2: Resource liquefaction through credible data exchange on quality parameters of shrimp farming among farmers, test labs, insurance and credit providers would improve the creditworthiness of shrimp farmers.

Proposition 3: Digitally enabled shrimp farming will improve the effectiveness of decision-making and problem-solving skills of the shrimp farmers than in traditional methods.

Design and deployment of the digital infrastructure by considering all the parameters may be challenging but necessary for the shrimp supply chain's overall profitability and traceability. The service dominant logic view provides a powerful perspective of the underlying networks, resources and value creation through integration, a view that could support digital platform conceptualization for shrimp farming. This research contributes to digital platform design initiatives for the shrimp supply chain and also informs policy initiatives for the betterment of aquaculture.

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