Adoption and Diffusion of Improved Fish Processing Technology on Household Income: A case of Elmina Community in Ghana using System Dynamics Thinking

Evans Anane

Thesis

Submitted to the Department of Geography

In Partial Fulfilment of Requirements for the Degree of

Master of Philosophy in System Dynamics

System Dynamics Group

University of Bergen

August 2020

Abstract

The main purpose of the study was to find out the adoption and diffusion of improved fish processing technology in Elmina, Ghana. In order to achieve this main objective, four (4) research questions were asked or specific objectives were set. Are there already existing fish processing technologies available in the study area? What is the rate of adoption of the newly introduced fish processing technology? What factors constitute the adoption of the improved fish processing technology? What impact of potential policies can help stimulate adoption? In order to achieve these objectives, a system dynamics approach was used where the abbreviation P'HAPI was used in addressing this research. Description of the social system for problem development and qualitative analysis and the use of simulation techniques for qualitative analysis in order to improve the strategy of system structures and control rules was the two main techniques used in the model building process. Secondary data and semi-structure interviews were used in the data collection process for the model. Sensitivity and behavioural analysis were performed to assess the validity and usefulness of the model to serve as a basis for policy analysis. Two (2) major policies were used in the model. It includes sensitization of fish processors on the benefits of improved fish processing technology or oven and training on the operations of the improved fish processing oven. The key findings include two (2) major fish processing oven in the locality, namely Chorkor oven and Morrison oven. The average adoption rate after before the potential policies was 2 people per year and after the policies was 10 people per year from the simulation results. The study came out with four (4) factors which includes, Acceptability in the improved and local oven, Knowledge on the improved and local oven, relative profitability and affordability of the improved fish processing oven. Finally, as the fish processors are sensitized on the improved fish processing oven, acceptability in the improved oven increases which leads to an increase in adoption rate as shown in the simulation results. When fish processors' knowledge and training on improved fish processing oven are up to date, adoption rate increases, the quality and quantity of fish being processed increases because of the adoption of the improved oven which lead to a higher price of processed fish and eventually an increase in the income of the household.

Dedication

This dissertation is dedicated to the Sacred Heart of Jesus, Immaculate Heart of Mary and Saint Philomena.

Acknowledgement

To begin with, I would like to thank the Lord almighty for the gift of life and good health granted to me to successfully bring my study in Norway to an end. I am extremely grateful to the Most High for also granting me the opportunity to study at the University of Bergen, Norway.

Secondly, I would like to express my profound gratitude to my supervisor, Prof. Birgit Kopainsky for her advice, support, intuitive comments, motivation and guidance from the start to the end of the thesis even in the midst of COVID-19. I vividly remember our numerous discussions on skype during the lock down. Again, I am thankful to all the professors, teaching assistants at the Systems Dynamics Society of the University of Bergen, for their useful contribution, suggestion on my thesis and also teaching to become a system dynamist. I would like to thank my classmates and colleagues especially Simon Peter Muwafu for his time dedication, constructive criticism during our discussions on skype.

I am extremely grateful to the major stakeholders specifically, the project coordinators at the Sustainable Fishery Management Project (SFMP) by the USAID, the Central and Western Fishmongers Improvement Association, Ghana (CEWEFIA) and the Fishery Commission (FC), Ghana for the data within the shortest possible time and insightful information with regard to the model building.

Finally, I would like to thank my family for their love, care and support right from the start of the preparations to leave home to Norway. To my parents, Mr Kwabena Anane Agyekum and Madam Monica Kusi, my brother Eric Anane, my sister Millicent Anane, my Auntie and her husband, Mr and Mrs Takyi-Prah, I appreciate your love, care, support and prayers. May the good Lord bless you. I am grateful to all my friends, relatives and loved ones especially Samuel Amakye, Kwame Adarkwa and Mr. Kwabena Asare, for their love, care, support and above all prayers throughout my study. I am enormously grateful to a special brother, Rev. Raphael Amoah Addae OP, and finally to my love, Karen Kwarteng for their love, care, encouragement and prayers.

Table of Contents

List of Abbreviations

FC……………………………. Fishery Commission

USAID………………………...United States Agency for International Development

SFMP…………………….........Sustainable Fisheries Management Project

MoFAD……………………… Ministry of Fisheries and Aquaculture Development

CEWEFIA…………………… Central and Western Fishmongers Improvement Association

List of Figures

CHAPTER ONE

GENERAL INTRODUCTTION

1.1 Background Information

Fish contribute around 18% of the total animal protein consumption in the world (FAO, 2017). Fish plays a major role and comprises the major source of animal protein consumption in Ghana, with marine fish contributing to about 80% of the total fish production (Plahar, Nti, & Steiner-Aseidu, 1997). In Ghana, the annual per capita consumption of fish is around 25 kg which is a little bit more than the world's average which is about 20 kg (FAO, 2016). Fish is highly preferred and also the cheapest source of animal protein in Ghana. Nearly 75% of the total annual catch in the country is locally eaten. Fish intake constitutes about 60% of animal protein consumptions by Ghanaians (Sarpong, Quaatey, & Harvey, 2005) and is higher than the world's average.

Over the last couple of years, overfishing adversely affects the economic wellbeing of affected fishing communities that totally depend on fishing and fishing related activities for their livelihood (FAO, 2014). The large quantities of different species of fish caught throughout the major season are preserved by one of several traditional processing techniques to avoid excessive wastage of fish (Nerquaye-Tetteh, 1989).

Fish that has been caught from the ocean ought to be processed quickly because of enzymatic and microbial developments which deteriorate fish quality after death. After 12-20 hours fish that has being caught starts to spoil and brings unfriendly taste, smell and texture liable to the size and type of the fish species, lessening consumer acceptability for that fish species, and if is not eaten fresh as soon as it is caught, then it should be processed or smoked for use in future or store frozen to prevent post- harvest losses (Obodai, Muhammad, Obodai, & Opoku, 2009).

Fish processing in Ghana can be generally categorized into traditional and modern. Traditional fish processing methods include smoking, drying, salting, fermenting and combinations of these four (4) as modern fish processing methods include canning and freezing (Nunoo, Asiedu, Kombat, & Samey, 2015). This study is focused primary on smoked fish processing in Elmina. Traditional fish processed products such as smoked fish, dried and salted fish are mostly purchased by the typical Ghanaian because of good taste and also cheaper to patronise. Fish smoking is the most practised processing technology in Ghana. Some fish and fishery products are also commodities for the export business (With the neighbouring countries, internationally with the European Union mainly, UK, France, Spain, and the Netherlands) apart from the local intake. Large quantities of quality and healthy traditional smoked fish that are consumed and also exported to the international markets in Europe and USA for the Diasporas from West Africa, Ghana is part of those countries (Failler, Beyens, & Asiedu, 2014). Practically, almost all species of fish available in the country can be smoked. Fish smoking is traditionally done by women in coastal towns and villages, groups/ associations, and inland fishing communities particularly along the shores of Lake Volta in Ghana. This is also not new in most sub-Saharan African countries (Ali Ahmed, Dodo, Bouba, Clement, & Dzudie, 2011).

Most experts agree that many fisheries around the world are in serious crisis. There is also wide agreement that something needs to be done to reduce the problem (Pauly et al., 2002). Fishery resources in Ghana are under pressure due to high demand for fishery products, poverty, population growth and particularly lack of alternative livelihood options. Like most developing countries, such as Ghana, fisheries have been observed to “rhyme with poverty” as a result of lack of alternative livelihoods (Béné, 2003). However, according to (Ofori-Danson, Sarpong, Sumaila, Nunoo, & Asiedu, 2013), the dependency on fish and fishery products for livelihood and poverty reduction in Ghana cannot be taken for granted. Therefore, there is the need to provide alternative livelihoods to increase income of the people in the coastal areas which fish smoking. Although Fish smoking has been in the Coastal areas, but these women make less income out of it because of the processing technology used and also less value addition to the fish which can increase the price. This can be done by increasing the life span of the fish and also adding value to it to increase the price. The fish processing technology introduced recently in Ghana is called “Ahotor” oven. “Ahotor” is a twi word from one of the Ghanaian Language meaning “Comfort”. The Ahotor oven was developed by SNV Ghana under Sustainable Fisheries Management Project (SFMP) to improve on the quality and competitiveness of smoked fish through the use of a clean smoking technology. Sustainable Fisheries Management Project (SFMP) was a five-year USAID funded project which started in 2015 with the objective of rebuilding marine fisheries stocks and catches through adoption of responsible fishing practices. The project was a Feed the future initiative and contributes to the Government of Ghana's fisheries development objectives and United States Agency for International Development’s (USAID's) Feed the Future Initiative. Coastal Resources Centre (CRC) leads the implementation of SFMP with a consortium of local and international partners and MoFAD and FC (Ministry of Fisheries and Aquaculture Development and the Fisheries Commission).

The Ahotor oven was designed as an improvement over the existing Chorkor smoker which was developed in the early 70's. The Ahotor oven was developed as part of efforts to strengthen on the post-harvest fish value chain by the Sustainable Fisheries Management Project (SFMP), have a sustainable fishery where there would less catch to reduce over fishing and finally develop an oven that is more efficient to reduce the amount of fish that ought to be processed to be able to generate income. The project was promoting the Morrison oven which was an improvement on the Chorkor oven until the development of the new oven or technology. (Etsra & Avega, 2018).

Research findings by (C. A. Nti, Plahar, & Larweh, 2002, p. 105) indicates that "majority of the women into fish processing are now economically empowered by the adoption of the improved technology. Some of the women own properties such as buildings, boats and fishing nets to sponsor fishermen on their fishing trips, so they can purchase the fish from them. They also performed most of the responsibilities of men, namely supporting the family financially and paying the children's school fees."

This indicates that if the improved fish processing oven is been adopted by fish processors, specifically women, then it can lead to an increase in their income.

The new oven is an improvement over the existing Chorkor oven to make it easier for adoption. Some of the early adopters have indicated that, it is less profitable. Unfortunately, this has not been the case, as there are very few fish processors in Elmina who have been able to adopt the technology. Some of reasons cited per the interview with some fish processors in the locality and review of literature include, affordability the improved technology and also lack knowledge on the use of the improved technology upon discussion with these fish processors. The study sort to find answers to the lower or the declining nature in adoption.

1.2 Reference Mode of Behavior

A report from (Owusu, Addo, & Kent, 2019) indicated that as of 2018, only 113 ovens had been constructed, including 74 built with full cost covered by the project. The remaining 39 was fully covered by fish processors themselves without any subsidy or support from the project.

As of 2019, 306 Ahotor ovens were constructed in Ghana with the support of SFMP and 214 with the support of the FC Post-Harvest Unit with funding from the World Bank West Africa Regional Fisheries Project. Only 15% (76/520) of Ahotor ovens were constructed without a subsidy of 88% or more and remaining 75% was covered fully by the project.

The number of adopters covering the fully cost of the technology themselves decreases over years.

Comments from (Etsra & Avega, 2018) on the review of the Ahotor oven in Ghana, revealed that the number of adopters who purchased the oven without any subsidy or support from the project implement were declining. compared to the total population of fish processors in the locality. However, there is more value added to the fish to increase the life span which then increases the price for fish processed and finally increase income of women involved in fish processing. This finally reduced poverty in the Coastal areas and also create alternative source of livelihood. Although there are a lot of fish processors in Elmina but comparing the number adopted the improved technology over the years to that of the population of fish processors is intriguing and ought to be studied.

Despite the strong economic potential of the Ahotor oven, the clear health and environmental benefits as well as the appropriation and promotion of this new technology by the Fishery Commission, a critical mass of early adopters required to drive diffusion of the innovation reduced gradually than originally anticipated (increasing). The decreasing trend of adopters covering the full cost of the oven themselves without a subsidy or support from the project is indicated in figure 1.1. The values presented in figure 1.1 is for the locality (Elmina) alone out of the national values (Ghana).

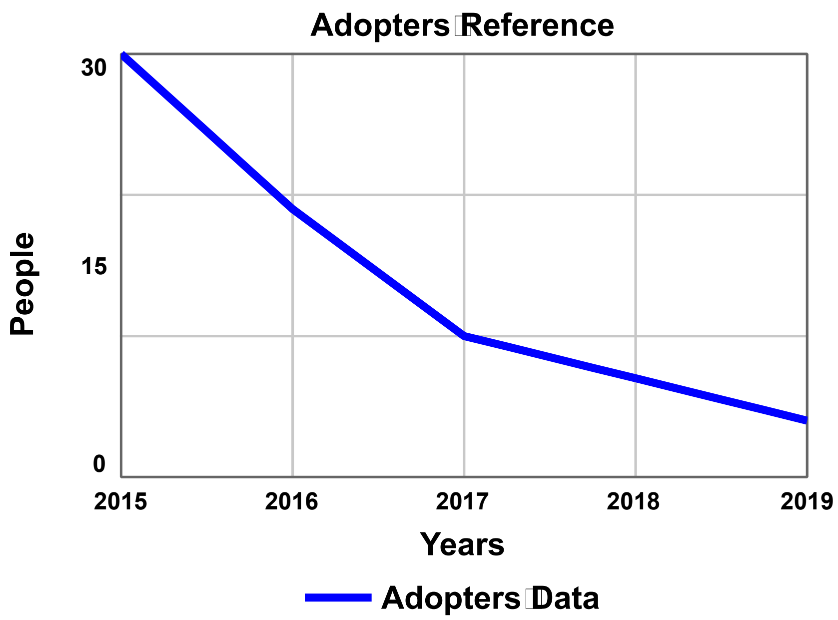


Figure 1.1: ***Reference Mode of Behavior for Adopters covering full cost of improved oven in Elmina, Ghana.***

1.3 Research Methodology

The research methodology used for this study is system dynamics approach. This is used in identifying and solving problem in all fields of study. System Dynamics Developments as indicated by (Wolstenholme, 1982) addresses how the method can be used as a two-step procedure using system analysis relevant over a wide range of social systems and also to be able to provide methodology in identifying problem, analysis and implementation. The two steps include, description of the social system for problem development and qualitative analysis and the use of simulation techniques for qualitative analysis in order to improve the strategy of system structures and control rules.

By the means of tools of Systems Dynamics (causal loop diagrams (CLD) and quantitative modelling) this study seeks to appreciate the process of decision-making from a more holistic perspective. Decision-making intuitions may provide evidences to the long-standing question of why technology-related assistance has in a lot of instances unsuccessful to take root in most parts of the developing world (A Ahmed, 2004).

1.3.1 Research Questions

It is against this background that the study seeks to answer the following questions in no particular order.

- Are there already existing fish processing technologies available in the study area?
- What is the rate of adoption of the newly introduced fish processing technology?
- What factors constitute the adoption of the improved fish processing technology?
- What impact of potential policies can help stimulate adoption?

1.3.2 Research Objectives

The main objective for the study is to assess the impact of adoption of improved fish processing technology on household income as a source of alternative livelihood in the coastal areas apart from fishing using social system thinking approach.

Specifically, the study seeks to achieve the following objectives.

- To identify the indigenous fish processing technologies available in the study area.
- To identify the adoption rate of the Ahotor (Comfort) oven fish processing technology.
- To identify the factors influencing adoption of the Ahotor (Comfort) oven fish processing.
- To evaluate the impact of potential policies to stimulate adoption

1.3.3 Elmina as a case study

Elmina, which is located in the Komenda Edina Eguafo Abrem (KEEA) municipality, is about 6 km west of Cape Coast, the regional Capital. Fishing activities in Elmina dates as far back as the 1400‘s where fishing activities were basically for domestic purposes and to feed slaves (Aheto et al., 2012). The Elmina fishing harbour is the third largest fish landing site in Ghana after the two major harbours (Tema and Sekondi harbours). The fisheries activities at Elmina are largely artisanal whilst those of Tema and Sekondi are mostly concerned toward semi-industrial and industrial fishery. Even though Elmina is dominated by artisanal fisheries, it contributes about 15% of the country's total fish output (Elmina & Strategy, 2015). Elmina being a cosmopolitan area boast of receiving migrants from other places who migrate in pursuit of job opportunities in the fisheries industry (T. Koranteng, 2012). Therefore, Elmina do not contribute significantly to the local livelihoods and economy of Elmina, but to the larger extent the national fisheries GDP. Being a historic fishing community where fishing dates back to the 1400s, the Elmina fish landing harbour which is constructed along the bank of the Benya lagoon offers a very good landing site for all types of canoes and small semi-industrial boats involved in traditional fisheries. Furthermore, the Elmina 2015 (Elmina & Strategy, 2015) reveals that about 75% of the estimated population of Elmina derive their livelihood directly from fishing or other activities that depend on it such as processing and trading of fish and building of canoe. Apart from the fishing potentials, it also serves as a very important olden city, which is well known for its role in the famous slave trade and served as home to the largest slave castle in Ghana (Asiedu-Addo, 2013).

Therefore, Elmina justifies as being the best area especially for this research which is concentrated on adoption of improved fish processing technology.

1.3.4 Data Collection Tools and Techniques

A mixed method research strategy was used in the study given both quantitative and qualitative nature of the specific objectives of the research. Secondary data and semi-structure interviews were used in the data collection process.

Some of the data to quantify the model was collected from the Fisheries Commission in Ghana, Ministry of Fisheries and Aquaculture Development. Expert Interviews were conducted with Project Coordinators at the Coastal Resources Centre (CRC) leading the implementation of the Sustainable Fisheries Management Project (SFMP) funded by the USAID, Leaders and some members of Central and Western Fishmongers Improvement Association (SEWEFIA). Some consumers were also interviewed on the quality of processed fish.

The expect interviews gave a leading and relevant information in building the model especially with regards to the adoption of fish processing technology.

1.3.5 Data Analysis

Validation test was carried out whereby the model was subjected to series of test to assess its usefulness and whether is robustness or not. The major focus was on causal relationship and outcome of the behavioural feedback mechanism and also the interaction between income of the fish processors and; adoption of the improved fish processing or smoking oven processes. Scenario runs from the valid model with behaviour analysis also were carried out.

1.3.6 Research Ethics

This section explains the research ethics as prescribed in (Denscombe, 2012) guide for research proposals. All the interviewee and respondent in this research participated on a private and voluntary basis. Under no circumstances were the participants given gift or whatsoever to take part in the research. The Information provided was transparent and timely as possible within practical boundaries. It was made clear to the participants that the research attempts to serve the community and also obtaining a master's degree and; that the findings would help in the capacity building of the society and the world at large (Elmina & Strategy, 2015).

1.4 Organization of the Study

The study is organized into six (6) chapters namely, General Introduction, Literature Review, Model Conceptualization, Validation of the Model and Sensitivity Analysis, Model Behavior and Policy Analysis, and Findings and Recommendation.

Chapters one (1) describe the general introduction which includes the background information, problem statement, reference mode of behaviour, research questions, objectives and methodology.

Chapter two (2) entails the literature review on Ghana's fishery sector, fish smoking or processing sector, methods of fish processing in Ghana, factors that contributes to the adoption of improved fish processing technology and impact of adoption of improved fish processing methods. Chapter three (3) gives the model description and conceptualization.

Chapter four (4) discusses the model validation and sensitivity test performed in the model. Chapters five (5) gives a detailed analysis of the model behavior and also a leverage point for policy analysis to achieve a desired behaviour. Chapter six (6) which is the final chapter discusses the conclusions, findings from the study and recommendation for further studies.

CHAPTER TWO

LITERATURE REVIEW

2.1 An Overview of Ghana's Fisheries Sector

The fishing industry in Ghana mainly consists of the marine sector, the inland (freshwater) sector and coastal lagoons. In 2013, about 2,98,000 tonnes made up total capture fisheries production, inland fisheries comprise of 24% (90,000 tonnes) mostly based on Lake Volta, the largest human-made lake in Africa (FAO, 2017). In Ghana, the fisheries sector contains a diverse and range of fishing activities, extending from subsistence to semi-industrial and to industrial fisheries. Usually, rivers, lakes, coastal lagoons, shallow seas and offshore waters are where fish are caught (FAO, 2017). However, marine fishing, lagoon fishing, lake Volta, other freshwater fisheries, aquaculture, and imports of fish are the six different sources of domestic fish supply while the industrial, semi-industrial and artisanal sub-sectors are the primary fishing operations in Ghana (FAO, 2017).

Ghana's waters contain a total of 485 fish species, out of which 347 represent 72% and belong to 82 families caught in the coastal waters (FAO, 2017). Also, 17 cephalopod species and 25 crustacean species are found in 5 families and 15 families respectively in Ghana's territorial waters (FAO, 2017). Ghana's waters harbour an extensive variety of fish species such as pelagic and demersal fisheries resources which make up to the national catch; grunt, sea bream, tilapia, herring, mackerel, Cape hake, barracuda and tuna consist of the marine catch profile (FAO, 2017). Also, the small-scale sector provides 70 percent of the total fish production, and in the fishery value chain, 60 percent of the women gain employment (FAO, 2017). The gross domestic product (GDP) in the fisheries sector contributes 4.5 percent; agriculture on the other hand contributes 12 percent GDP and workforce 10 percent GDP.

2.2 An Overview of Ghana's Smoking Fishery Sector

In Ghana, the smoked fishery sector plays a key role in terms of creation of jobs, income generation, food security and foreign exchange earnings assisting in the sustainability of the Ghanaian economy (Asiedu, Failler, & Beygens, 2018). About seventy percent to eighty percent of the fish smoked are locally consumed (Asiedu et al., 2018) . In Ghana, the fish species that are usually processed by smoking include catfish (*Clarias spp*), herring *(Sardinella aurita, Sardinella moderensis),* mackerel *(Scomber spp),* anchovy *(Anchoa guineensis)* and tuna *(Thunnus albacores, Katsuwonus pelamis)* (FAO, 2017) but inland species are *Chrysichthys spp, Tilapia spp, Lates spp, Synodontis spp, Hydrocynus spp, Cyprinus carpio* and marine species include *Sphyraena spp, Caranx spp, Penaeus spp* as cited in (Asiedu et al., 2018).

The smoked fish business is predominately dominated by women, whose economic activities in the fish processing sector has become very crucial considering the low levels of income by most women in Ghana (K. A. Koranteng, 1993).

The Smoked fish processing is categorized in two forms, the “dry hot smoke” and the “wet hot smoke”. The dry hot smoke uses heat to removes moisture and cooks the fish; and the wet hot smoked only applies smoke to the fish, and this smoke is adequate to manage the outside spoilage of the fish (Anon., 2007). Wet hot smoked fish last for 3 days after smoking in 40-50 percent moisture content for about 2 hours; whilst Dry hot smoked fish last for about 9 months after smoking for about 10 to 15 percent moisture content for about 18 hours (Anon., 2007).

2.3 Methods on Fish Processing in Africa

According to researchers, there are different fish processing methods used by fish processors in Africa to reduce post-harvest losses which sometimes stands at 40 per cent of the entire catch (Adeyeye & Oyewole, 2016; Okomoda & Alamu, 2003). Notable among methods use by the fish processors are smoking, salting, drying, frying, fermenting, chilling and freezing (Adeyeye & Oyewole, 2016). These methods though effective have its own shortfalls, hence the need for the adoption of improved preserving methods (Adeyeye & Oyewole, 2016). According to Adeyeye and Oyewole (2016) fish smoking is the most dominant of all the tradition method of fish processing in Africa. An estimated 80 per cent of the fish catch and consume are process with smoking technique. There are different kinds of smoking techniques use for preservation depending on the available resources (Okomoda & Alamu, 2003; E. L. Okorley, Zinnah, Kwarteng, & Owens, 2001). Traditional ovens, round mud and kilns are well known ovens use for fish smoking in Africa. Notwithstanding, the dominance use of these ovens it has been revealed that the lack of regulatory mechanism over the drying rate sometimes results in either under or over drying, as well as an exposure of the fish dust, flies and some contaminated elements (Akinola, Akinyemi, & Bolaji, 2006). Other studies have also reported on health risk possessed by the smoking (Adeyeye & Oyewole, 2016), yet it is still the most preferred preservation method among coastal fishing communities. Among the reason cited for the preference for the use of mud oven for fish smoking and preservations are the availability of local materials, examples firewood, sand and knowledge in building such ovens (Adeyeye & Oyewole, 2016; Akinola et al., 2006; C. Nti, Quaye, & Sakyi-Dawson, 2002).

2.4 Women & division of labour in Africa setting

Studies have shown that both men and women play a significant role in fishing and fish processing. However, the gender role ascribed for women and men within the African settings make either women or men dominant in an aspect of the fish value chain (Megbowon et al., 2010). While men are dominant in using the canoe to catch fish from the water bodies, it is well known that women are also dominant in the fish processing activities (Megbowon et al., 2010; E. Okorley & Kwarten, 2000)**.** That is not to say women do not take part in capture fishery. Indeed, Megbowon et al. (2010) reported in their study that women partake in both capture fishery and processing fishing in Nigeria. Yet, the division of labour in the African setting seems to popularise the narrative that asserts that fish processing is an activity for women and fish capture is for men. In Africa, gender roles are instilled in children right from the childhood. Girl child is train to become a good 'domestic manager', in that she will be responsible for performing all domestic chores while in her husband's home. Thus, she is responsible for cooking, sweeping, washing and many other things in the house. This has resulted in more women becoming dominant in performing domestic activities. Boy child on the other hand is train to be more outgoing, courageous, independent and provider. They are expected to show leadership qualities and involve in public activities instead of doing domestic chores(Amakye, 2019; Amos-Wilson, 1999; Williams, 2001). This has resulted in the non-recognition of some of the activities women perform in the public sphere of which fish capture is one of them. Among the women in the fish processing activities, it is noted that old women are dominant in fish processing in Africa. Adeyeye and Oyewole (2016) found that over 56 per cent of women in fish processors are old women. Additionally, the study found that only 51 per cent have primary school education with 38 per cent without education. Given the statistics and findings of the studies mentioned above, it is obvious that women especially the old women are the most dominant in traditional fish processing. That notwithstanding some young women also participate in the fish processing activities.

2.5 Factors that contribute to the adoption of improved fish processing methods

Different studies have explored factors that contribute to the adoption of improved fish processing methods. Since the adoption of improved processing methods impact on the income and the wellbeing of the people involved. In the study " the evaluation of traditional solar fish drying system technology towards enhancing fish storage in Nigeria", Akinola et al. (2006) reveals among other findings that the availability of materials for the making of the improved processing equipment's contributes to the adoption of such improved methods. (Hall, 2011), insisted that the available of materials is not enough factor for the adoption of improved fish processing technology. He added that access and knowledge as well as evidence of the positive impact of the improved fish processing method is key to its adoption. Similar to these findings Odediran and Ojebiyi (2017) in the study "Awareness and adoption of improved fish processing technologies among fish processors in Lagos State, Nigeria" reported several reasons why those involved in fish processing do not adopt the improved fish processing methods. Key among them were lack of access to improve technology, high cost of the new technologies, unavailability of the improved technology, lack of extension services from the agriculture development, high risk in adopting such technologies due to inadequate technical know-how and the believe that the improved technology is not superior to the existing traditional ones. In Ghana, E. L. Okorley et al. (2001) studied the production constraints and training needs of women involve in fish processing activities in the Central region of Ghana. The study found that most women do not adopt the improved processing methods. Two major reasons were cited for the non-adoption of the improved fish processing technologies are lack of funds to acquire the new technologies and high cost associated with the adoption of improved technologies. Lack of knowledge on the improved fish processing methods was cited as the third reason for the low adoption of these methods (E. L. Okorley et al., 2001). In similar vein, C. A. Nti, Plahar, W. and Larweh, P. (2002) reported from their study that the availability, access to materials and the knowledge of the improved processing message contribute significantly to the adoption of improved fish processing methods. Thus, the availability of funds alone cannot contribute to the adoption of the improved fish processing method, however, other factors like the availability and access to the materials and techniques in operating the improved technologies are also essential for its adoption.

2.6 Impacts of the adoption on improved fish processing methods on household income

C. A. Nti, Plahar, W. and Larweh, P. (2002) used participatory rural appraisal and survey to study the impact of the adoption of improved fish processing technology on household income, health, and nutrition in Ghana. The study reported that the adoption of improved fishing processing technology has positive impact on income and health status of the fish processors. The study reported that there is positive income improvement in the household resulted from increases in the quality and quantity of output, price per unit out and profits. Again, the study further revealed a reduction in eye problems and headache because of the reduction in the exposure to smoke and heat. Akangbe, Bankole, Ajibola, Fakayode, and Animashaun (2013) also found that fish processors in northern Nigeria prefers the improved processing technology to the old smoking methods. The study cited increases in processors income and the flexibility with the use of the improved methods as the reasons for such adoption. Boohene and Peprah (2012) found from the study in Ghana that the adoption improved fish processing methods increase income, investment opportunities and other socio-economic conditions of households. It also affirms that health hazards experiences while processing fish through the traditional methods has reduced due to the safety of the improved methods. The review of the literature above seems to conclude that the adoption of improve fish processing technologies has a positive impact on health and economic status of the fish processors. That notwithstanding, some of the studies pointed out the low rate of adoption, indicating that there are some impediments that needs to be addressed to ensure that more processors adopt the improved technologies.

2.7 Definition of Adoption and Diffusion

Adoption of technology has been studied by a lot of diffusions of innovation theories. The most effective and instrumental has been the one by (E. Rogers, 1995) indicating the adoption of innovation as a life-cycle consisting of five classes of adopters: innovators (these are people who are ready to take risk and try new things as well), early adopters (this class of adopters are people who are eager to adopt the technology but does it carefully and on a slower pace), early majority (people who are careful but ready to accept change more quickly than the average), late majority (these are people who doubt the use of new ideas or products and only when a lot of people start using it), and laggards (these are traditional and old-fashioned people, slow to revolution and analytical towards new ideas, will only adopt or try them if the new ideas have become the order of the day).

Diffusion is different from Adoption as the former is the process whereby new product or technology is spread among users while the latter deals with the internal decision process on individual basis (Mahajan & Peterson, 1979; E. M. Rogers & Shoemaker, 1971).

This theory just like the Bass diffusion model (Bass, 1969) sees technology spread as the consequence of two main factors; which include, innovation which refers to the desire of people to try out new technologies, and imitation which refers to the influence of those that have tried out a technology in drawing in others who have not yet tried this technology to trying and using it. The innovation adoption curve developed by (E. Rogers, 1995) therefore seems to suggest that trying to quickly and massively convince a lot of people of a new idea, product is useless. For innovation to diffuse through a society in order to make impact and also for a lot people to start showing or accepting to use, it takes time for the early adopters to convince or advertise to the people who are yet to adopt.

2.8 Hypothesis

- Fish processors confidence and acceptability of the improved processing oven influence its adoption.
- Adoption of the improved oven increases the quality of the processed fish and also increases the price as well, which finally increases the profit compared to the local oven.
- The cost of the improved oven limits or prevents some fish processors to adopt.
- Fish processors without knowledge or training on the improved oven is less likely to adopt. That is Knowledge on the improved oven will significant effect on adoption of the improved oven.

CHAPTER THREE

MODEL CONCEPTUALIZATION

3.1 Introduction

This chapter thoroughly discusses the basic structure of the model and also give details on the conceptualization. Again, the chapter focuses on the explanation on the assumptions used in the building of the model. Further explanation on the major factors fish processors consider before deciding to adopt the processing technology, that is acceptability of the improved technology, knowledge and affordability of the technology. It also gives explanation on the comparison traditional and improved technology.

3.2 Model Conceptualization

The model was conceptualized in one locality along the coastal area in Ghana where fish smoking or processing is a major livelihood activity. The name is Elmina and is located in the Central region of Ghana and also the capital of the Komenda/Edina/Eguafo/Abirem (KEEA) *Municipality.*

Model conceptualization is the first step in operationalizing one's idea behind the concept of a particular study (Sterman, 2002). The adoption of improved fish processing technology depends on how fishmongers evaluate the new oven and act on the evaluations.

The main structure representing the explanatory model of the actual system is described below. This assessment can be described as simple structure with a stock of non-adopters, and adopters, with the rate of adoption linking the non-adopters to the adopters and non-adoption rate that links back the adopters to the non- adopters. Adopters' and non- adopters' impact on the diffusion process are quantified as the number of total fish processors or smoker's population in Elmina using the improved fish processing technology (Ahotor oven), that is the number of fish processors processing fish using the improved technology and the number of fish processors using the local oven (Figure 3.1). In the model, only the Ahotor oven is considered as the improved technology in the context of this research.

Diffusion and Adoption research emphasis on some perceived gains of innovations and has documented numerous cases in which local cultural practices and beliefs apply control over which innovations are adopted (Stone et al., 2007).

C. Nti et al. (2002) reported from their study that the availability, access to materials and the knowledge of the improved processing message contribute significantly to the adoption of improved fish processing methods. Thus, the availability of funds alone cannot contribute to the adoption of the improved fish processing method, however, other factors like the availability and access to the materials and techniques in operating the improved technologies are also essential for its adoption.

The acceptability of the improved oven and acceptability in the local oven stocks represent one of the factors or social norms fish processors consider before adopting the improve oven. Fish processors adopt processing technology based on the level of acceptance in their locality. Market, consumer and producer acceptability is one of the factors that affect the rate of adoption (C. Nti et al., 2002).

Dominant to the explanatory model is the stock of Acceptability in improved oven with a net flow of change in acceptability. This is the faith that the adopters have shown in improved processing technology. It is how the people have come to accept the improved processing technology usage.

Fish processors have certain social, cultural and traditional beliefs on improved technology which takes time before fully accepting the improved fish processing technology. Fish processors adopt processing technology based on the level of acceptance in their locality. Market, consumer and producer acceptability is one of the factors that affect the rate of adoption (C. Nti et al., 2002).

That is whether fish processors have faith in the new technology and also whether the newly introduced technology doesn't compromise on their social believes as well. This has been the case as fish processors copy other fish processors on the blind regardless of whether that particular innovation was successful or not. These fish processors only adopt just because their colleague fish processors have adopted and using the technology.

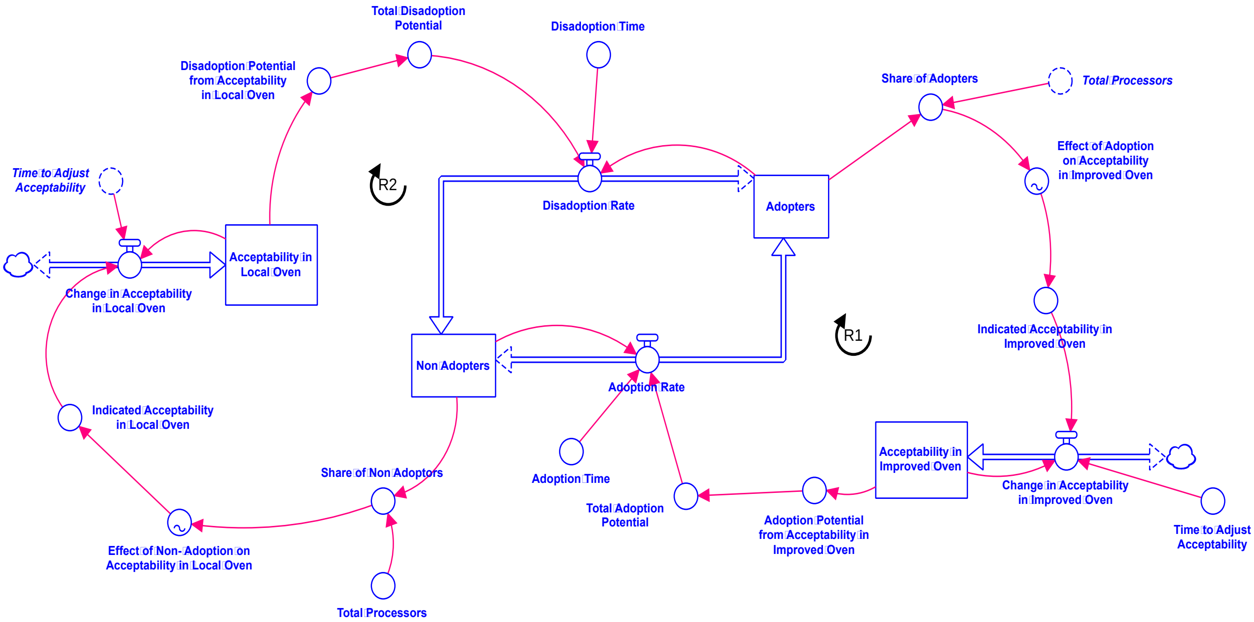


Figure 3. 1: The Acceptability in the Improved and Local Processing Oven

The link between the stock of adopters and the acceptability in improved oven forms a reinforcing loop (R1). This reinforcing loop locks the system into local oven or strengthens adoption of the improved oven. On the other hand, the dis-adoption rate is determined by a reinforcing loop (R2).

The adoption rate is determined or influenced by the total adoption potential consisting of acceptability in the improved technology, knowledge on the improved oven, affordability of the improved oven and relative profitability. Affordability depends on the cost of the improved technology and profit or savings made from fish processing. Profit is determined by the operational cost on fish processing and the revenue made from fish processing. Fish processors then saves some of the profit over time and this will enhance the affordability of the improved oven.

The acceptability on the improved oven depends on the change of the acceptability. This change depends on the indicated acceptability, the stock of acceptability itself and the time to adjust acceptability. This is the reinforcing feedback loop

Individual learning improves the fish processors' ability to implement the new technology and to make better decisions about improved seed. This brings about knowledge on the improved oven. Hall (2011), insisted that the available of materials is not enough factor for the adoption of improved fish processing technology. He added that access and knowledge as well as evidence of the positive impact of the improved fish processing method is key to its adoption Early adopters can help teach the potential adopters on the operation of improved oven. This can help potential adopters to adopt and also improve on their knowledge by learning from the adopters. Again, experience comes into play in terms of the knowledge and operation of the processed oven. The link from adopters, adopters share depends non -linearly on the indicated knowledge through to the stock of knowledge on improved oven, to total adoption potential and finally back to adopters. The stock of Knowledge on the improved oven depends on the change in knowledge on improved oven which is also influenced by the indicated knowledge of improved oven (Figure 3.2).

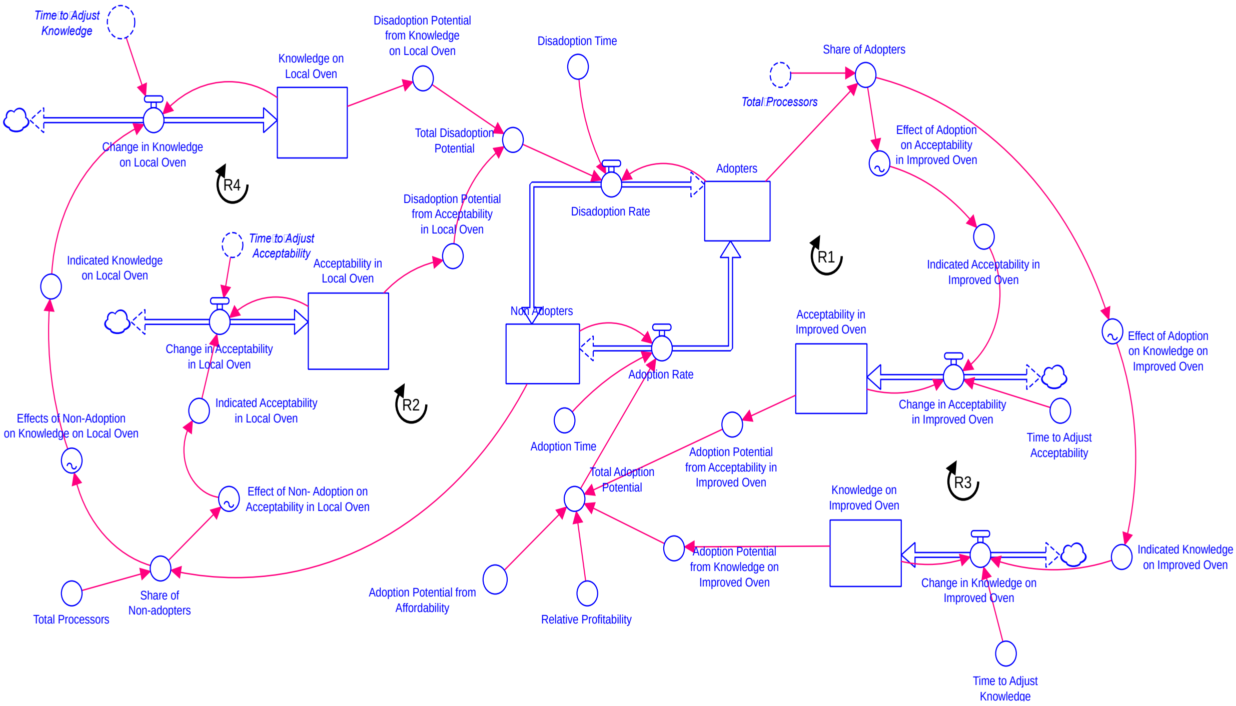


Figure 3. 2: Knowledge on Improved and Local Processing Oven

The reinforcing loops (R3 and R4) determines the knowledge on the improved and the existing local processing oven. The link between adopters and knowledge on improved oven forms reinforcing loop (R3) and also the link between non-adopters and knowledge on local oven forms the reinforcing loop (R4).

Fish processors can only afford the cost of the improved oven through savings over time. The savings is directed towards the buying of the oven and is influenced by the savings rate which is dependent on the income from the fish processing business after all the expenses and household expenses. This income is from the sales of the processed fish from locally processed fish. The savings over the years link to oven affordability and then to adoption potential from affordability and finally links to the stock of adopters (Figure 3.3).

Profit made from locally processed fish over the years by fish processors is estimated by deducting the cost of fish processed locally and revenue from locally processed fish. This is not the entire household income but only the income from fish processed locally by the fish processors.

The money fish processors save after the household expenses and also after reinvesting into the fish processing business. This is where the savings towards the purchase of oven comes from. The household relies on this savings for unforeseen circumstances over the years. It also serves as a reserve for the household in times of need.

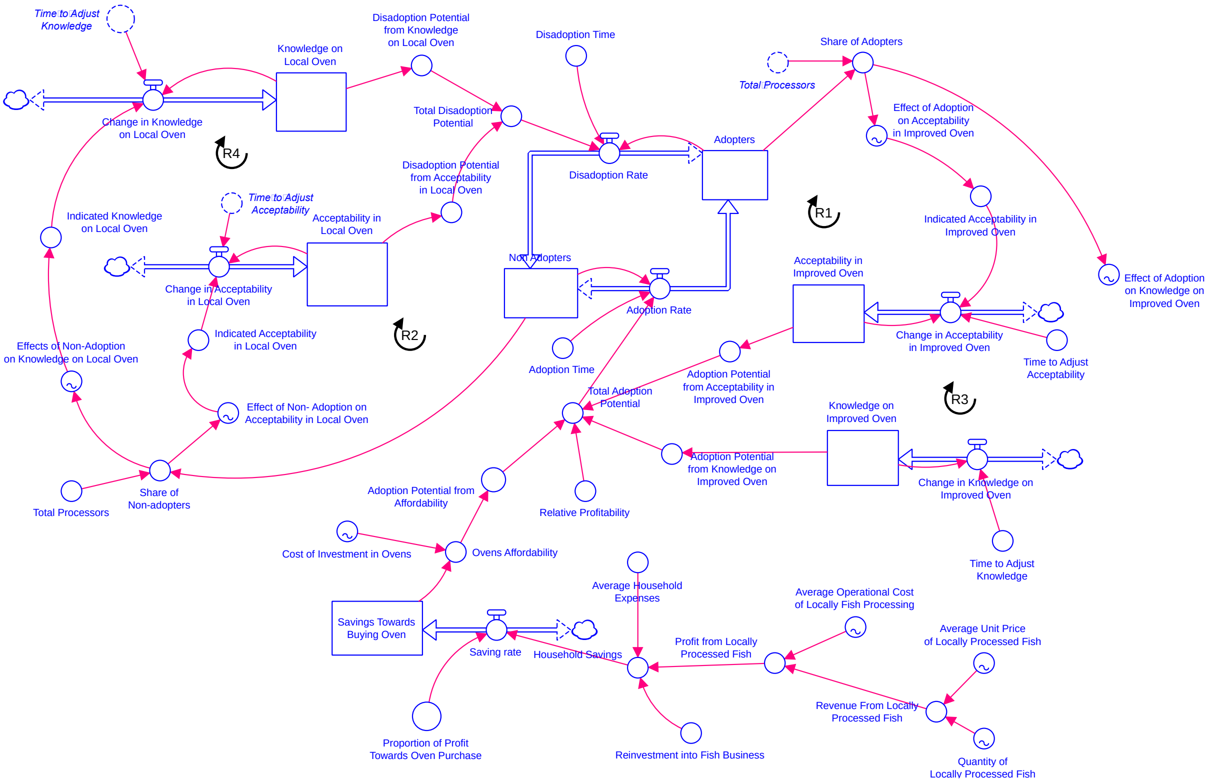


Figure 3. 3: Affordability Structure

Fish processors ability to afford the improved processing oven depends on their savings behaviour. How fish processors can save proportions of the income realized from the sales of the processed fish. This can only be realized after the household expenses and other expenses have been deducted from the income.

As this proportion increases, the savings towards buying oven increases over the years. As this proportion increases, fish processors will be able to save a reasonable amount over the years. This proportion is influenced by the household savings. Higher household savings, with a higher proportion of profit towards oven buying, will definitely increase the savings towards buying oven over time. This will enhance the affordability of the oven.

CHAPTER FOUR

MODEL VALIDATION AND SENSITIVITY ANALYSIS

4.1 Introduction

Model validation is an important and at the same time controversial aspect of any model-based methodology in general, specifically system dynamics (Barlas, 1996).

This Chapter is very important when using system thinking or dynamics method of study. It talks about the robustness of the model and also how it represents the reality. That is establishing a greater confidence in the model in terms of the kind of data used and its sources.

4.2 Internal Validity

The methodology used in this research serves as a strong and good justification for the internal validity of the model. The fish processors and key members of the fish processing communities in the study area were engaged in discussions to come at the justification for this model. Key stakeholders and informants were interviewed (Fishery Commission, agriculture departments) to strengthen the researcher's knowledge of the real system. The research also made use of Some Secondary data from reliable international and national data centres and reports. Where both primary and secondary data were not available in relation to the study, estimations were drawn from studies and reports similar to this research topic. The data integration used in the model makes it solid framework for researching on this topic.

4.3 External Validity

This is form of validation is conducted to test the robustness and confidence in the model. As contained in (Senge & Forrester, 1980), model validation is a process of establishing confidence in the soundness and usefulness of a model. Similarly, (Barlas, 1996) presents model validity as making known the usefulness of the model taking into consideration its purpose. (Barlas, 1996) stated that the main objective of system dynamics model validation is to determine the validity of the structure of the model.

"Thus, the general logical order of validation is, first to test the validity of the structure, and then start testing the behavior accuracy, only after the structure of the model is perceived adequate" (Barlas, 1996, p. 188). (Barlas, 1996). Logical order includes direct structure test, structure-oriented behaviour test and bahavior pattern test. The first two tests (direct structure and structure-oriented behavior) deals with the structure of the system whiles behaviour is about the bahavior of the system.

4.3.1 Direct Structure Test

Direct structure checks the validity of the structure of the model by comparing it directly with knowledge about the structure of the real system and includes having each relationship exclusively and also comparing it with the knowledge about the real system which includes no simulation (Barlas, 1996).

Direct structure test consists of empirical test, theoretical test and implementation methods. Empirical test includes structure confirmation test and parameter confirmation test. On the other hand, theoretical test consists of direct extreme-condition test having sub tests of dimensional consistency test and boundary adequacy test (Barlas, 1996; Senge & Forrester, 1980). These tests are explained in the subsequent sectors.

Structure Confirmation Test

This test is conducted to make sure the model replicates the theory about the real system. Upon the review of literature and theories on the adoption and diffusion of fish processing technology, discussions with some fish processors, experts and other key informants and finally the researcher's conclusion, the structure of the model is valid.

The factors affecting adoption of fish processing technology including knowledge in the improved oven, acceptability of the improved oven, affordability of the improved and relative profitability have been modelled in the system.

Again, the relationship between fish processors income and their ability to adopt the fish processing technology is also modelled in the system with the addition of the affordability structure. Also, fish processors propensity to save for some years in order to afford the processing technology is indicated in the model.

Parameter Confirmation Test

This is the second direct test and it basically deals with the evaluation of both conceptually and numerically of constant parameters and the knowledge of the real system (Senge & Forrester, 1980).

Base on this, the model passes the parameter confirmation. This is because all parameter values were estimated upon fish processors answers and responses, existing literature and some data specifically to the municipality. Also, in situations where data were not available, estimation was used based on national and international data in relation to the research topic. The numerical values used in the estimation for the effects in the model are solidly based on literature by (Kopainsky, Tröger, Derwisch, & Ulli-Beer, 2012) showing trust building (which in this case fish processors acceptability on the improved oven) and knowledge improvement depends nonlinearly on the area cultivated with improved (the number of fish processors using the improved fish processing).

Finally, the model documentation at the appendix shows the sources used in the calibration of the model. This helps verify the parameter confirmation test in the model.

Direct Extreme- Condition Test

This test is an equally important test done to evaluate the validity of the model equations when subjected to extreme conditions by assessing the acceptability of the resulting values against the knowledge of what would have happen under a related condition in real life (Senge & Forrester, 1980).

The parameter, proportion of profit towards oven purchase was subjected to extreme condition test. When there was no proportion (zero proportion), the adoption potential from affordability was zero, the adoption rate was zero and finally the stock of adopters was also zero. This proportion of the profit from the sales of processed fished is allocated or save for some years to facilitate the fish processor to purchase the improved processing oven. The figures (4.1,4.2 & 4.3) below shows the base run and the extreme condition

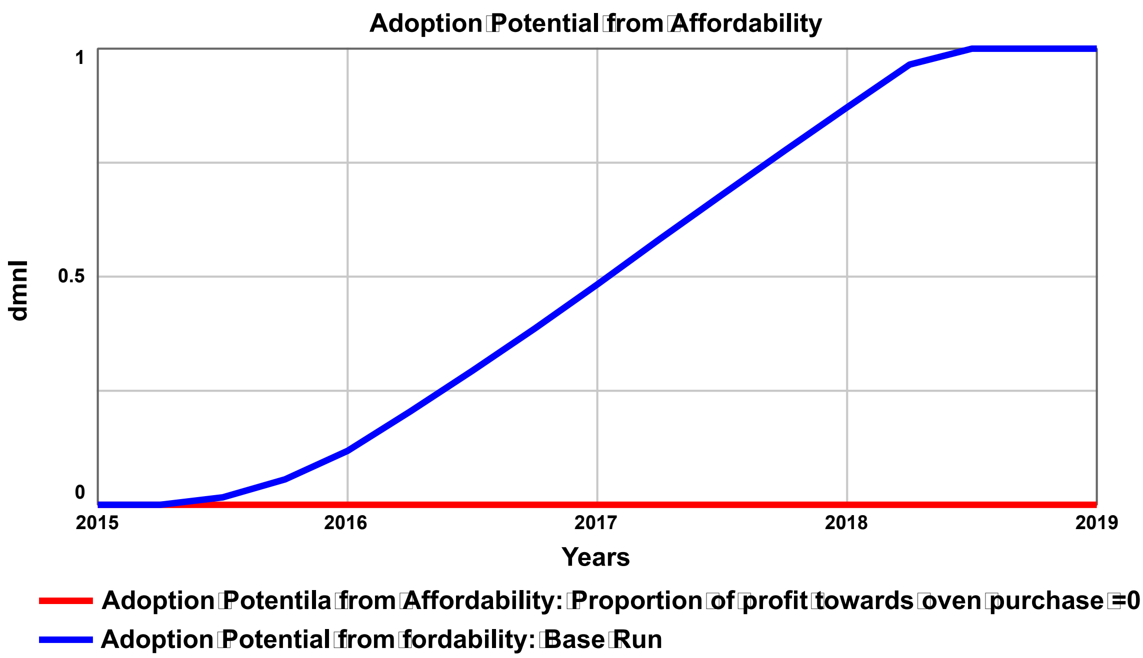


*Figure 4. 1**: Extreme Condition test of proportion of profit towards oven purchase on adoption potential from affordability***

From figure 4.1, when there was zero or no proportion towards oven purchase, the adoption potential from affordability was zero. Meaning there was no adoption since fish processors couldn’t save some of the profit made from the sales of processed fish. On the other hand, it is been realized that with a 25% (Base run) proportion of income towards the purchase oven, fish processors were able to afford the oven.

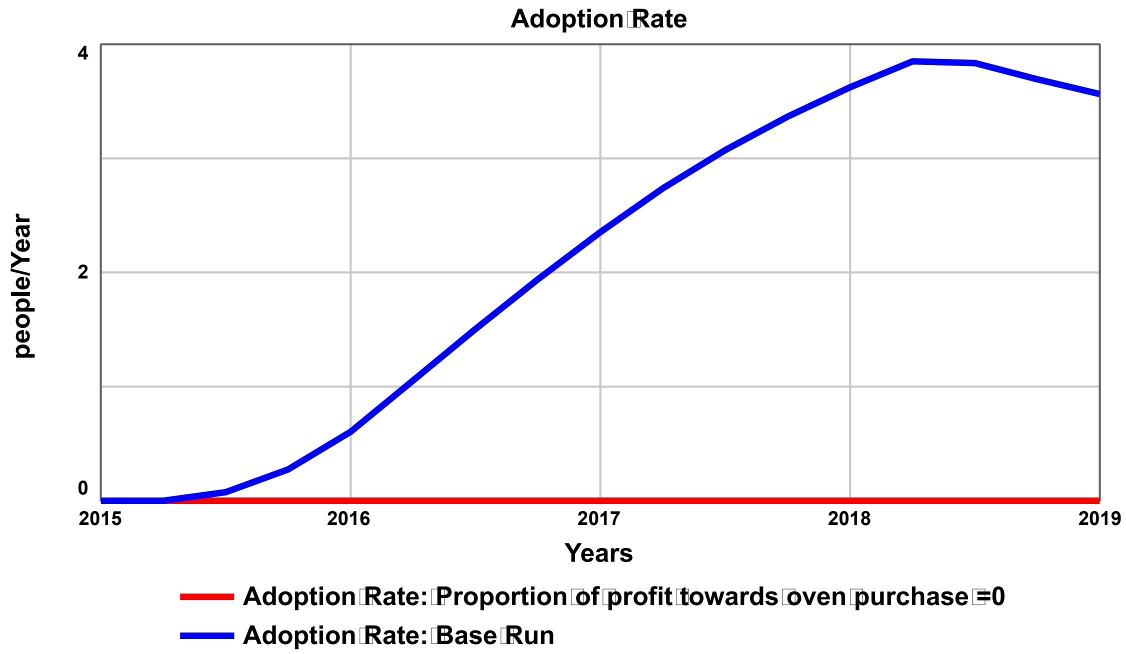


*Figure 4. 2**: Extreme Condition test of proportion of profit towards oven purchase on adoption rate***

This is similar to the affordability potential, when there was zero proportion from profit or income towards oven purchase and 25% proportion of profits saved towards oven purchase. The adoption rate increases when there was proportion of profits being saved towards the buying of the oven.

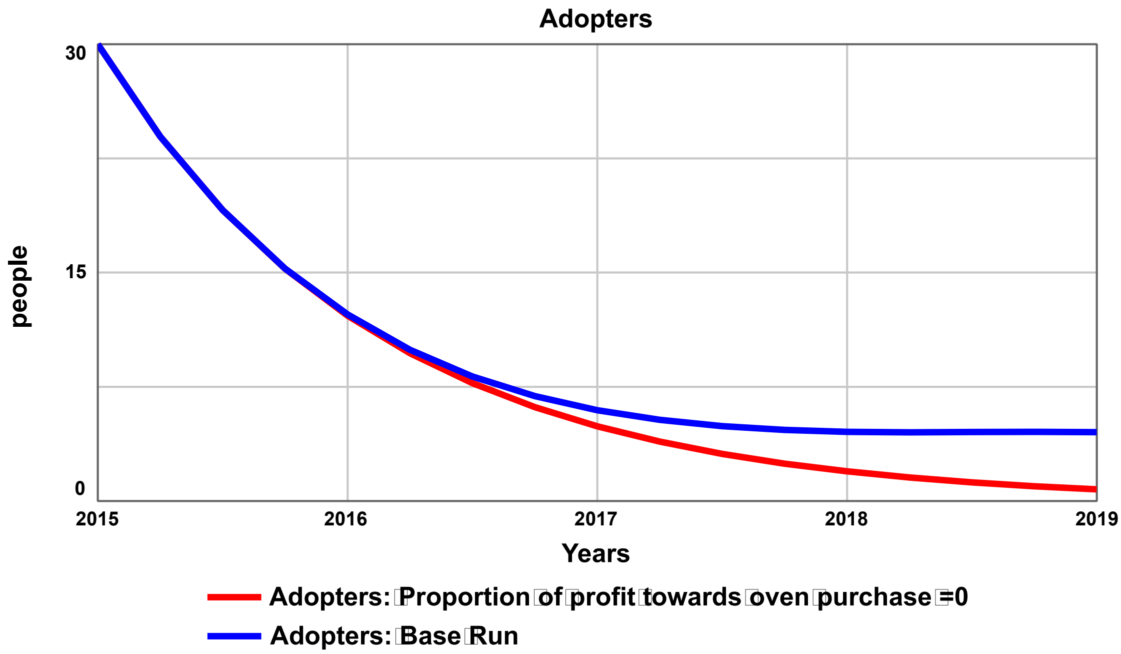


Figure 4. 3: ***Extreme Condition test of proportion of profit towards oven purchase on adopters***

Adoption increased as indicated in figure 4.3 with 25% of profits saved over the years towards oven purchasing.

4.3.2 Structure Oriented Behavior Test

Structure-oriented behavior tests, indirectly evaluate the validity of the structure, by applying some behavior tests on model-generated behavior patterns (Barlas, 1989; Senge & Forrester, 1980). This kind of test involve simulation and can also be extended to the whole model as well as to secluded sub-models of it (Barlas, 1996). Under this, only one (1) was conducted, behaviour sensitivity test.

Behavior Sensitivity Test

Behavior Sensitivity Test determines the parameters in the model which are very sensitive and also finding out whether the real system would display similar highly sensitive to the corresponding parameters.

In this regard, some parameters in the model were placed under highly extreme conditions to determine whether these parameters are highly sensitive. The following parameters were tested. It includes; Adoption time, Time to adjust Acceptability, Time to adjust Knowledge, Proportion of profits towards oven purchase, Initial values of Acceptability and Knowledge of improved oven and Relative Profitability.

Adoption Time

The average adoption for processors to start adopting the technology is 1 year. The adoption time was tested by some adjustment using minimum and maximum values. The results are shown in figure 4.4 depicting the behaviour of the model (the most important variables). Adoption time of 0.5, 1, 1.5, 2 and 2.5 was used in the testing process.

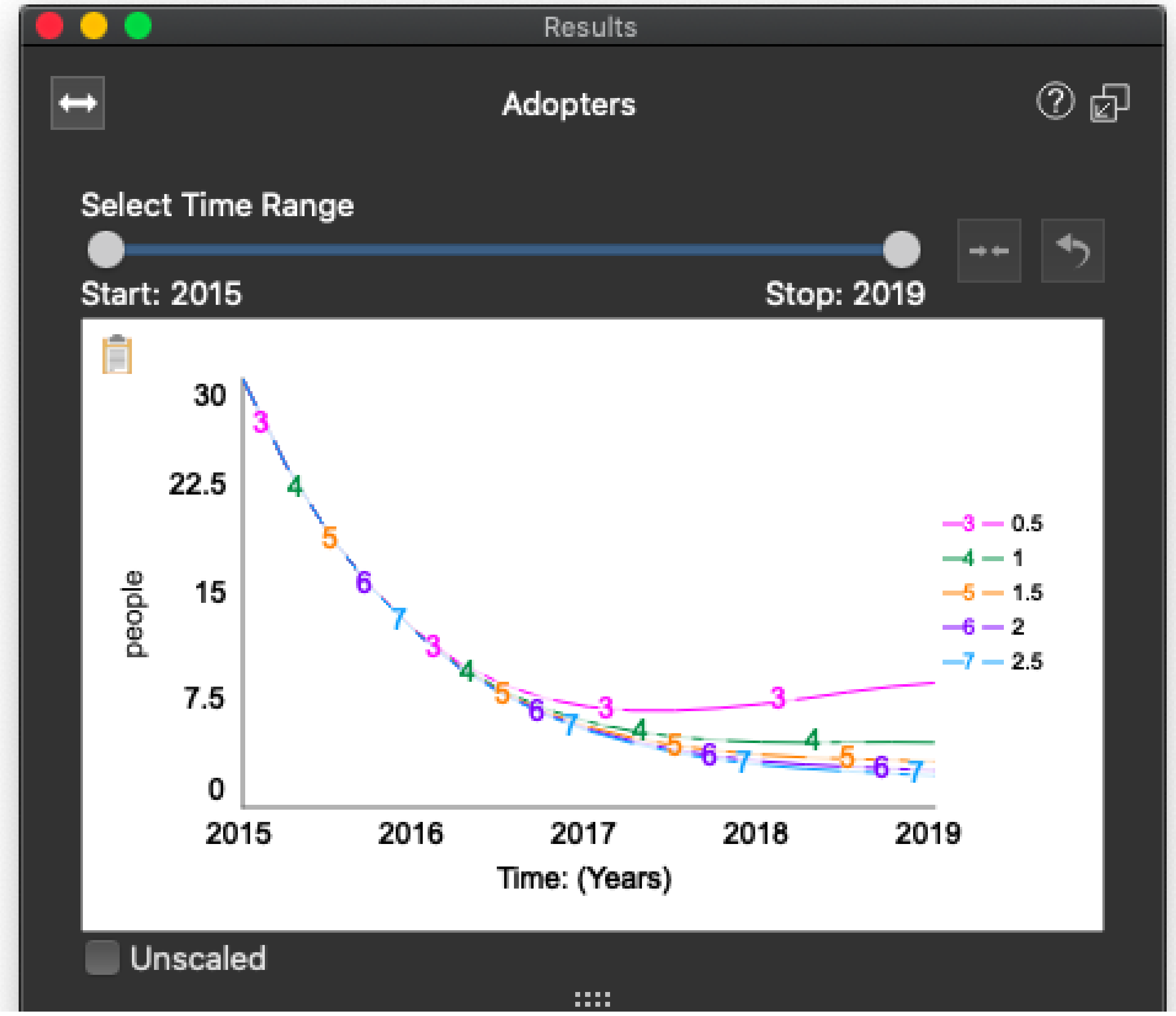


*Figure 4. 4: **Adopters stock using adoption time***

As shown in the graph, as the adoption time increases from 0.5 to 2.5, adopters decreases until 2017 and then, some increases, and others continue to decrease.

Adoption time less than one- year makes adopters stock decreases and later increases. This behaviour happens because adoption time affects the adoption rate. The rate of adoption increases as the adoption time is less than one year. Adoption rate is also affected by the non-adopter's stock as well. The adopters' stock decreases and after 2017, increases with adoption time of less than one year. Even though, the dis-adoption rate decreases, but it later increases with a less than one-year adoption time. Finally, the non-adopter's stock. increases. Adoption time more than one- year decreases until 2019. The behaviour makes sense because, realistically, adoption of a fish processing technology needs more than half a year for some adoption to take place.

Time to Adjust Acceptability

This is the time it takes for fish processors to come in terms with the fish processing technology. That is the time it takes to get rid of some social, cultural and traditional beliefs attached to the fish processing technology before adoption takes place. On the average, it takes three (3) years for a fish processor to fully accept the improved processing technology. The acceptability time is adjusted from less than three (3) and more than three (3) years. This adjustment affects the stock of acceptability of improved oven, total adoption potential, adoption rate and adopters' stock. The results of Acceptability stock for improved oven and Adopters stock are shown in figure 4.5 and 4.6

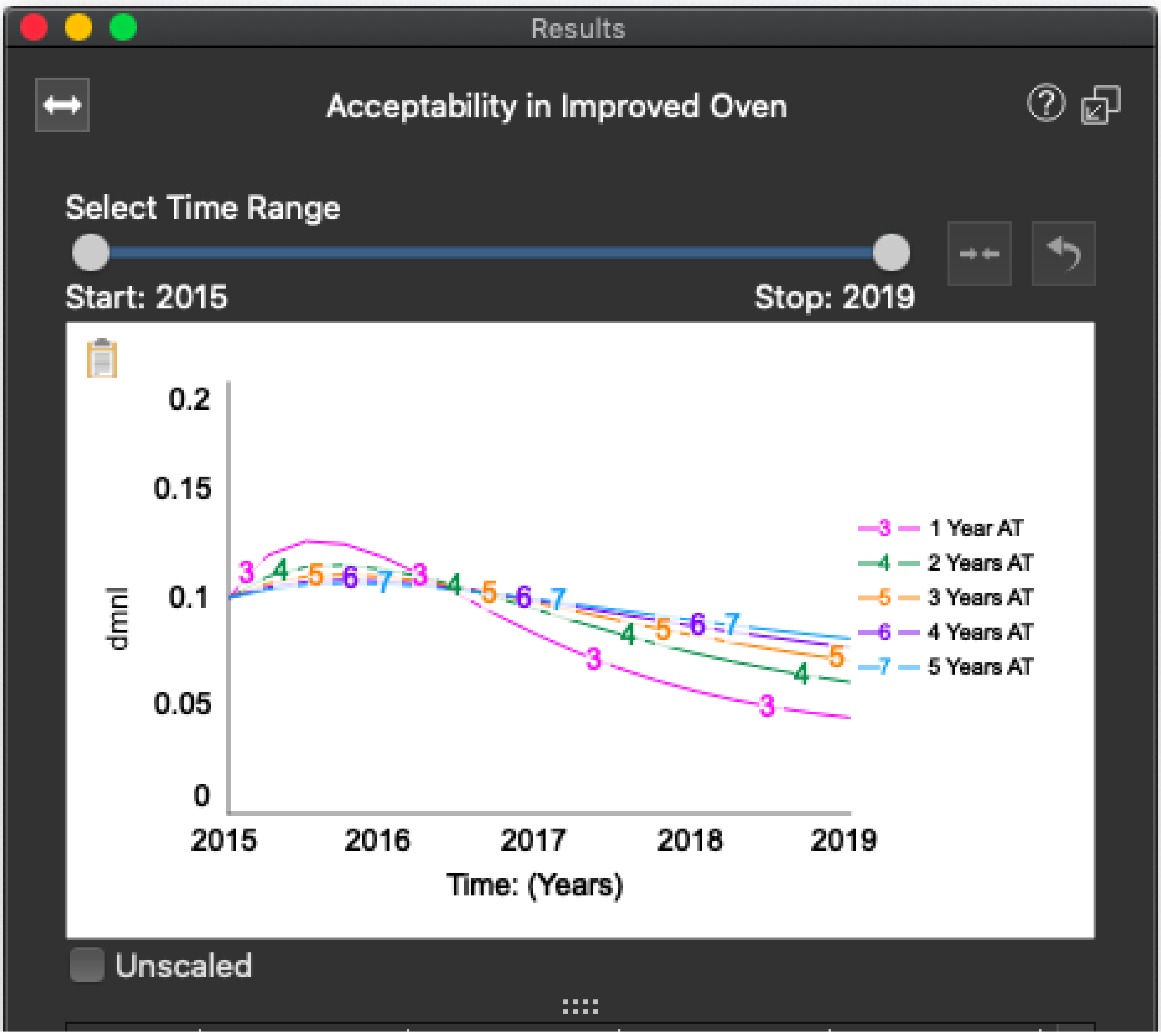


*Figure 4. 5: **Acceptability in improved oven using time to adjust acceptability***

Acceptability time of less than Three (3) years decreases the acceptability in improved oven stock rapidly while the acceptability time of more than Three (3) years decreases the aceeptability in improved oven gradually. The oberved behavior happended because, time to adjust acceptability affects the change in acceptability. This change in acceptability is determined by the indicated acceptability, the acceptability stock iteself and the time to adjust acceptability. The change in acceptability increases from negative to zero because the indicated acceptability is less than the accetability stock. Again, the indicated acceptability is influenced by the share of adopters, which decreases. The change in acceptability affects the acceptability stock (decreases), the adoption potential (decreases) and finally reduces the adopters. This makes sense because, it takes more time to fully accept a technology and also to get rid of the cultural and other social beliefs. Acceptability time of three (3) years decreases in a more steady state compared to the other time.

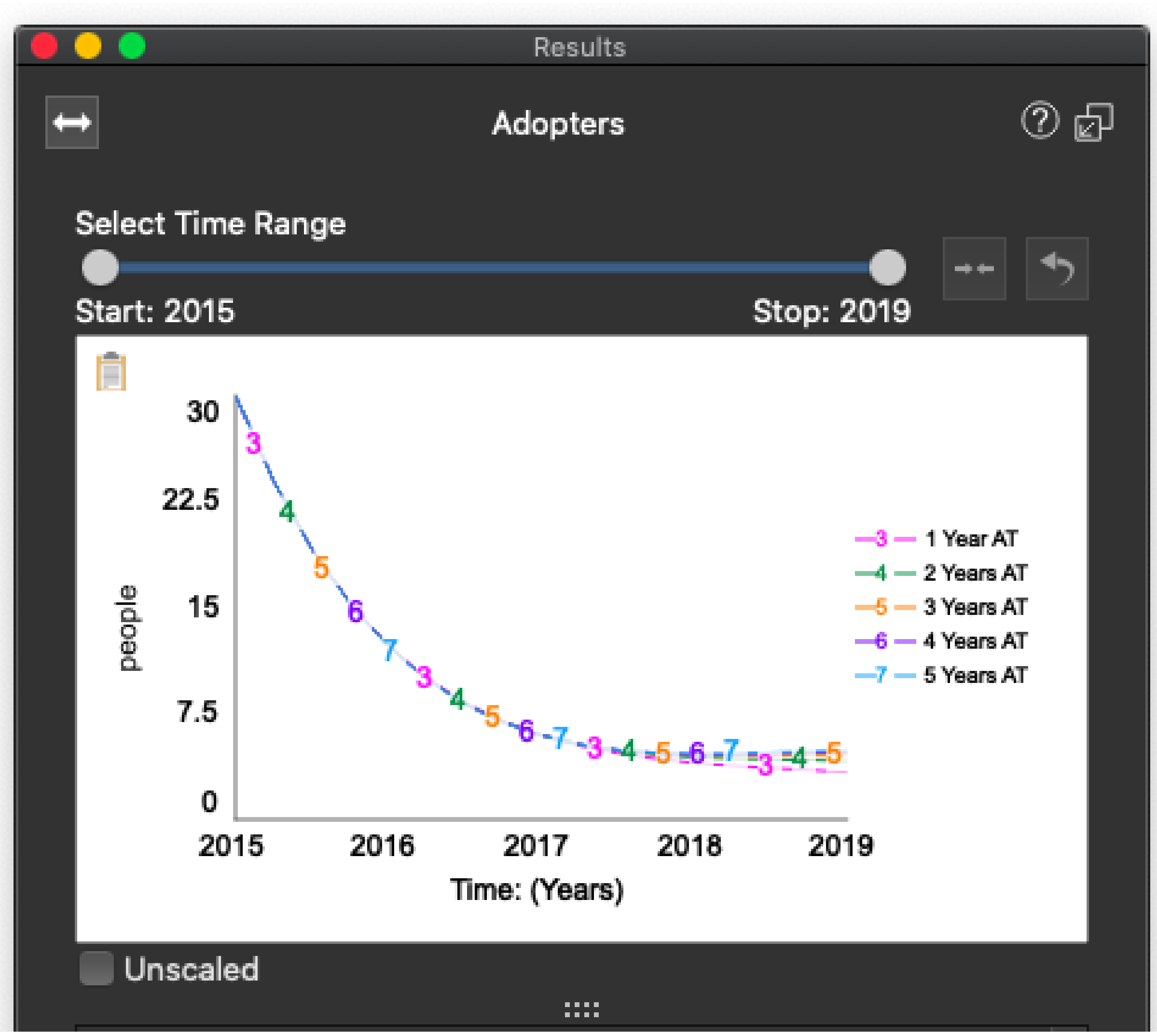


*Figure 4. 6: **Adopters stock using time to adjust acceptability***

Time to Adjust Knowledge

This is one of the exogenous variables in the model when adjusted, affects the stock of knowledge on improved oven, total adoption potential, adoption rate and finally adopters. The time used for the testing purposes ranges from one (1) to five (5) years. This will help to know how robust the model is to some adjustment in the knowledge time. The results of the stock of knowledge of improved oven and adopters are shown in figure 4.7 and 4.8.

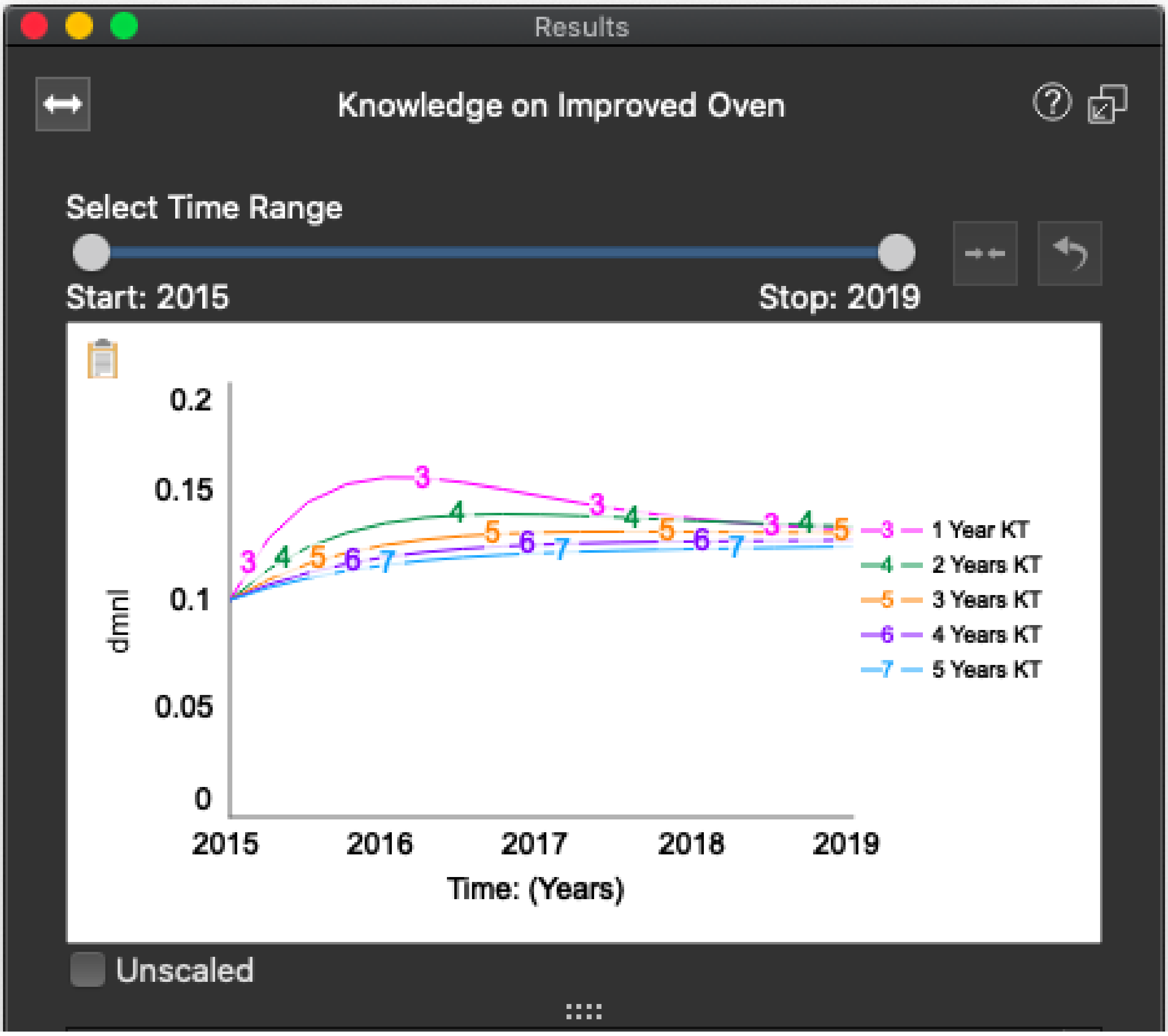


*Figure 4. 7: **Knowledge on improved oven using time to adjust knowledge***

Knowledge time of less than three (3) years increases until 2016 and later decreases the stock of knowledge on improved oven compared to the knowledge time of more than 3 years. It takes more time for the non-adopters to learn from the adopters and also share with the potential adopters.

Adopters on the other hand, decreases either with knowledge time of more than three (3) years or less than three (3) years. This also makes sense as it takes more time to learn from the adopters and have some knowledge on the operation of the processing technology or improved oven.

The reason behind the observed behaviour is that, time to adjust knowledge affects the change in knowledge. The change in knowledge is determined by the indicated knowledge (goal), the knowledge stock and the time to adjust the knowledge. The share of adopters which influences the indicated knowledge deceases, so the indicated knowledge also decreases. The knowledge stock which is influenced by change in knowledge increases in the early until 2016 and later decreases. The knowledge stock influences the total adoption potential, the adoption rate and a little influence on the adopters.

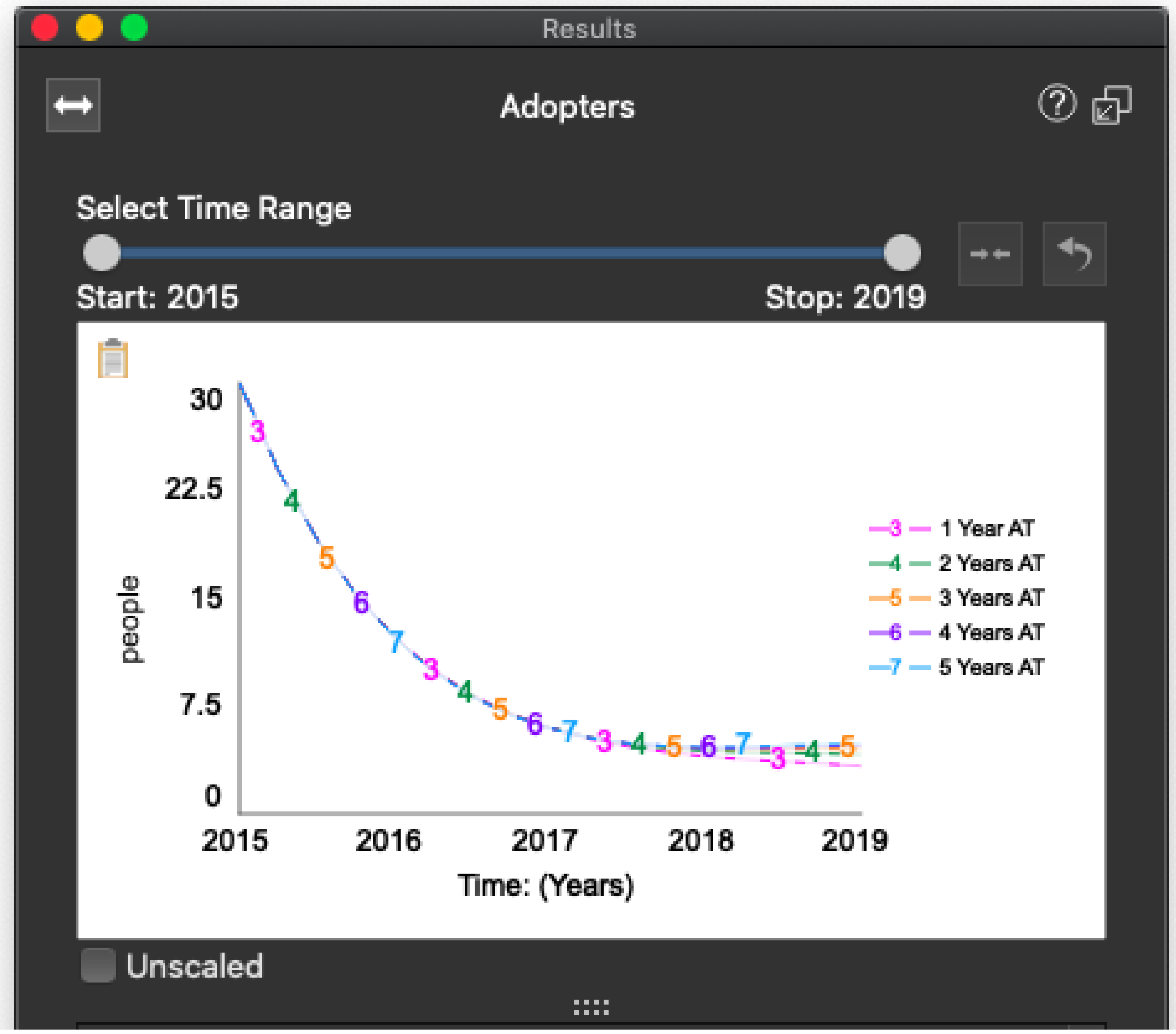


*Figure 4. 8: **Adopters stock using time to adjust knowledge***

Proportion of Profits Towards Oven Purchase

This is the part of the profit directed towards the purchase of the oven over time. As this proportion increases, the higher the savings, which increases the affordability of the oven by fish processors. An adjustment in the proportion will affect the savings, affordability of the oven, total adoption potential, adoption rate and adopters. Only the graphs of savings, affordability and adopters will be shown.

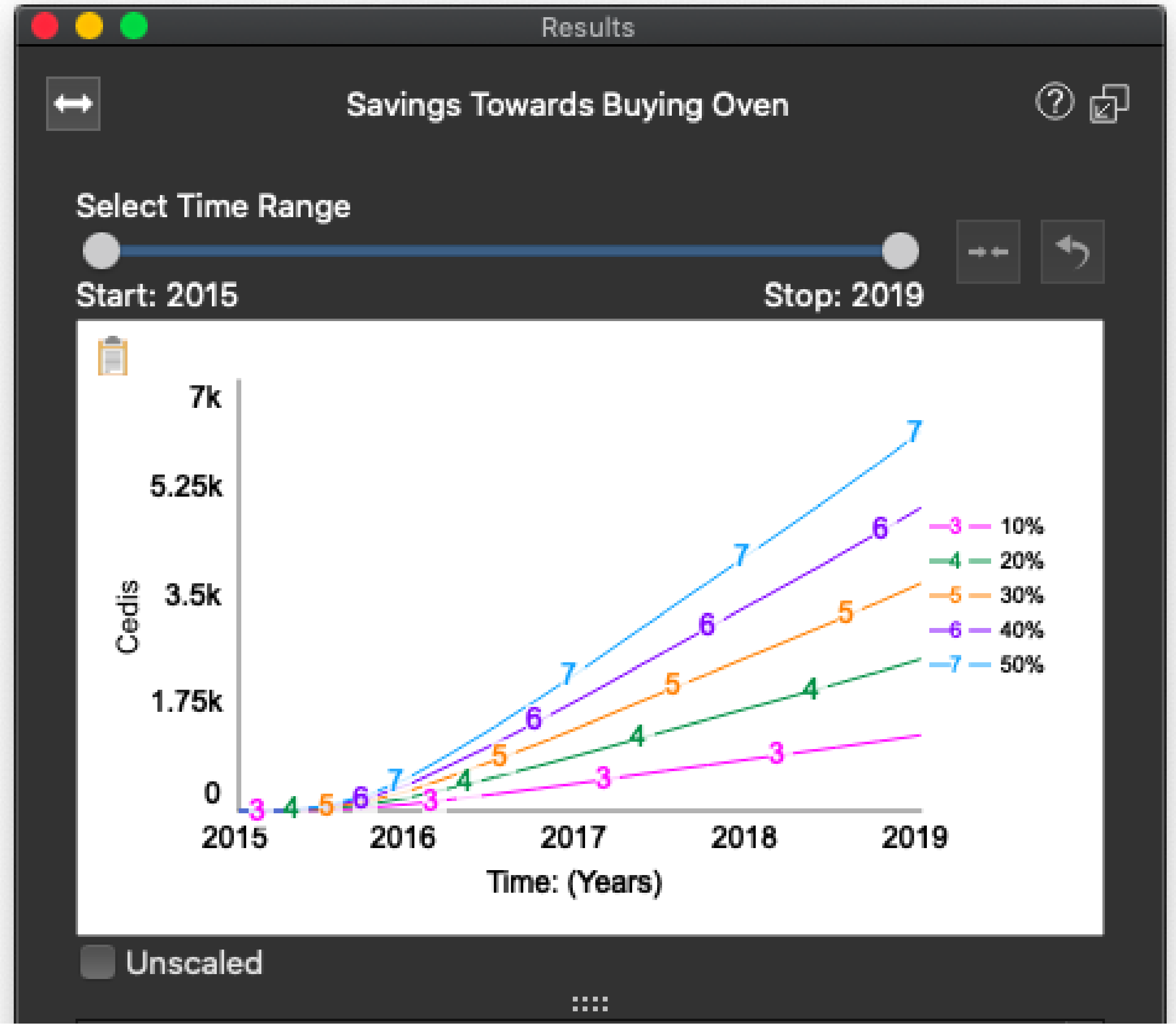


Figure 4. 9: ***Stock of savings towards buying oven***

An increase in the proportion of savings towards buying oven will mean, the savings stock will increase and eventually fish processors can afford the improved processing oven. The proportion is influenced by the profit or money left after household expenses and reinvestment into the fish processing business. The higher the household expenses, the lower the proportion and finally the lower the savings towards buying the oven.

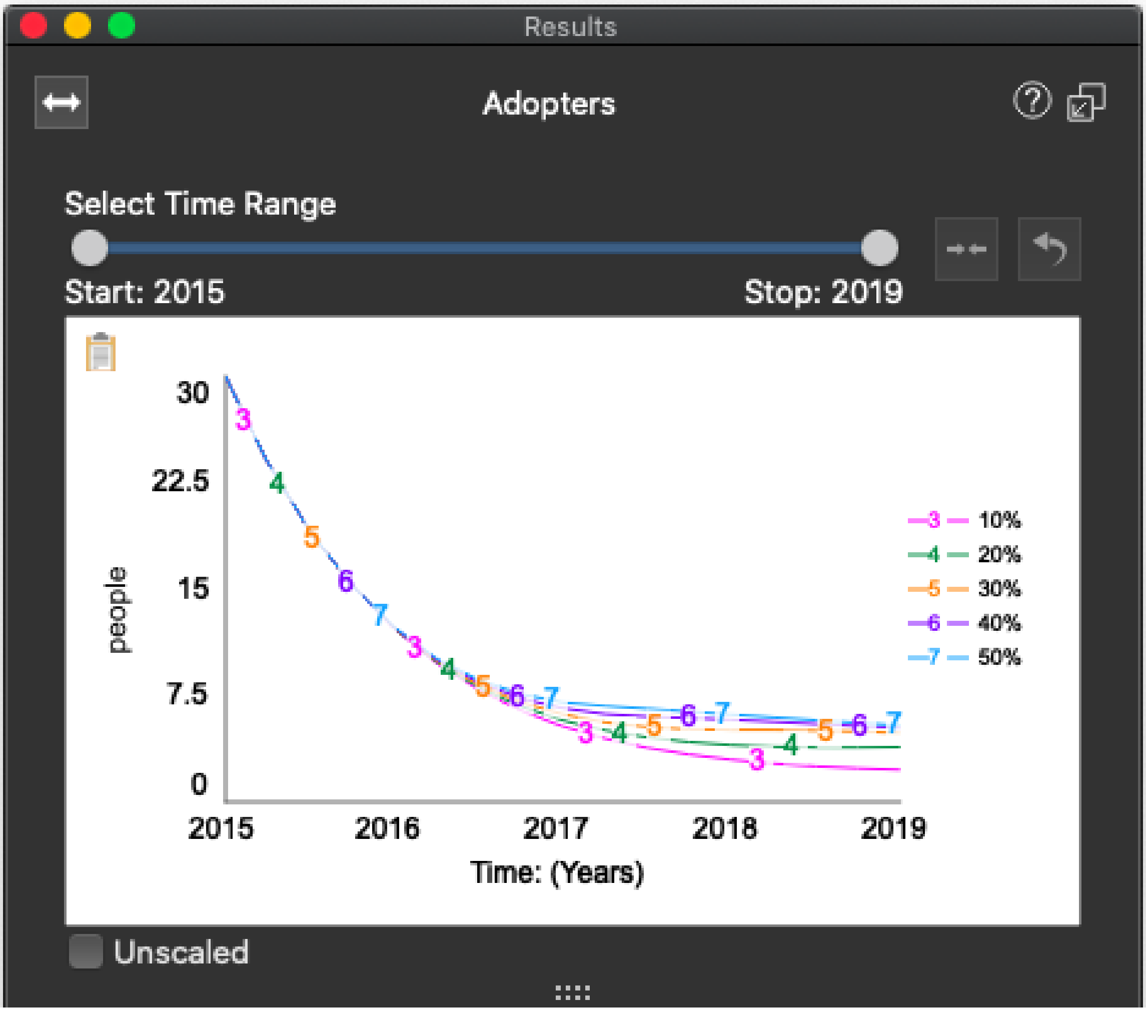


*Figure 4. 10: **Adopters stock with proportion of profit towards oven buying***

An increase in the proportion of savings towards purchasing oven, will mean more savings towards purchasing of the oven, fish processors will be able to afford the processing oven. Adoption potential from acceptability will increase because of the increase in affordability, so as the total adoption potential. The adopter's stock will decrease but after 2017, higher proportions more than 10% (0.1) will decrease slowly. There is sharp decrease until 2017 because the savings towards buying of the oven takes a little time for it to pile up before fish processors can start purchasing the oven and use it.

Relative Profitability

The fourth attribute added to the adoption potential is relative profitability. This variable is exogenous to the model. A Value of relative profitability from one (1) to five (5) was used in the testing process.

As the relative profitability increases from 1 to 5, total adoption potential increases which then increases the adoption rate but finally decreases adopters' stock. The lower the relative profitability, the faster the adopters decreases. That is, as there is a lower profit margin in the improved oven compared to the local oven, the adoption (adopters' stock) decreases. Figure 4.11 and 4.12

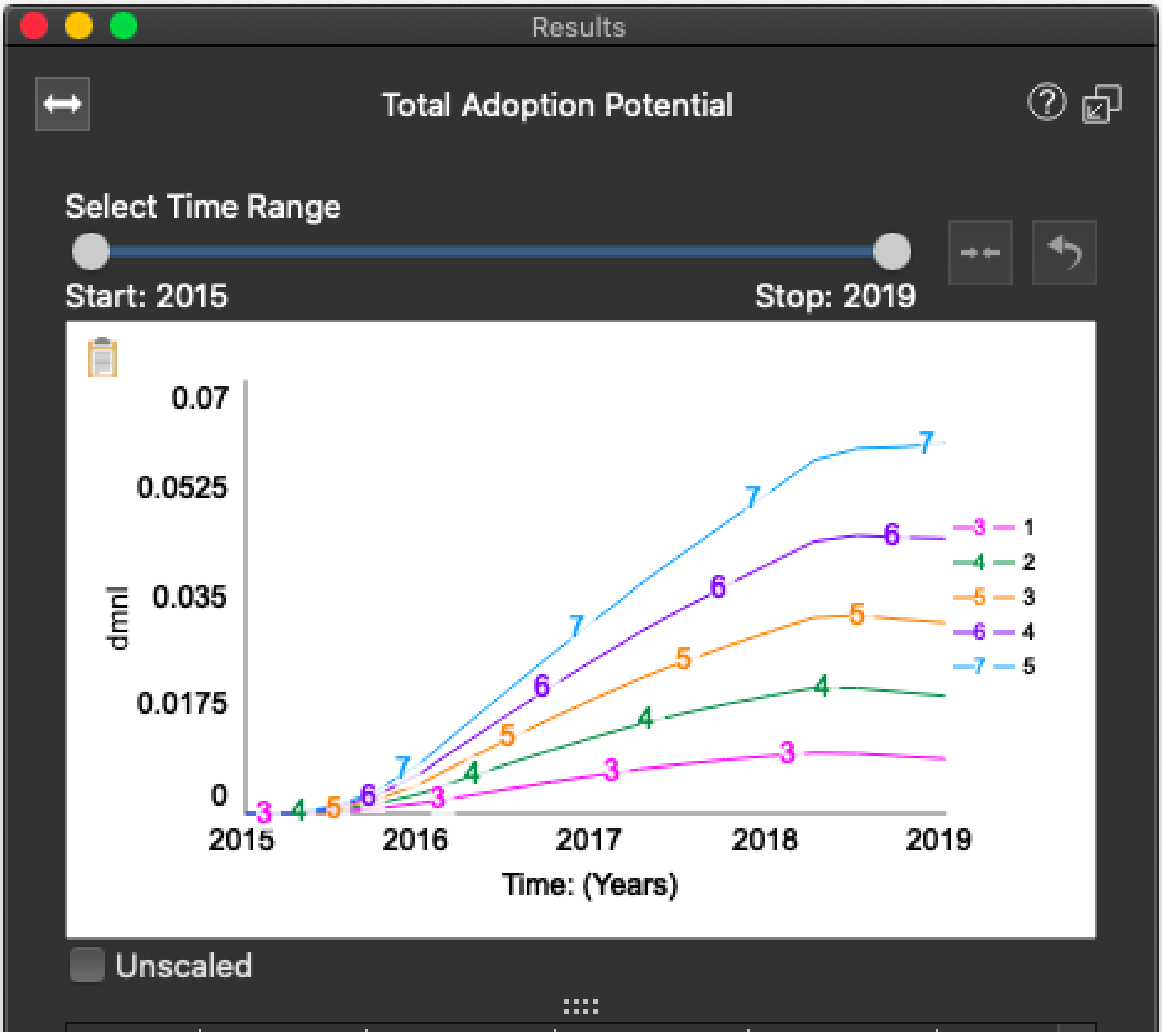


*Figure 4. 11**: Total adoption potential using relative profitability***

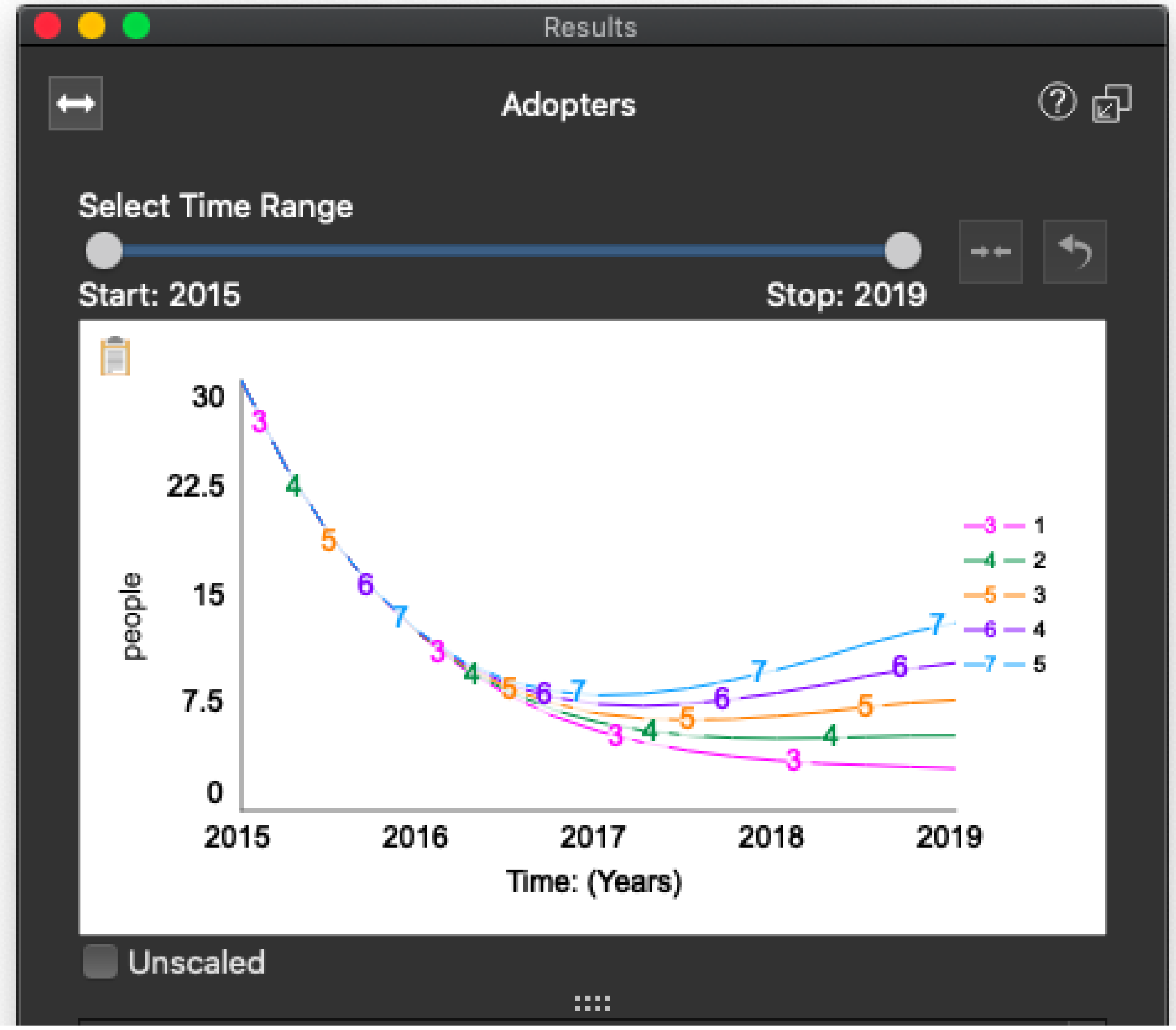


*Figure 4. 12: **Adopters stock using relative profitability***

4.3.3 Behavior Pattern Test

Pattern Behavior test helps to unravel out if the model would depict the same behavior upon calibration with different values. The Initial values of Acceptability in Improved Oven and Knowledge on Improved oven was tested in this regard.

Initial Value of Acceptability in Improved Oven

The initial value of acceptability in improved oven was very sensitive to the model. Initial values of stock determine how and where the stock starts. A less value will start-out less and vice versa. It determines the initial level of acceptability of the improved oven by the fish processors before adoption takes place. Whether an increase or a decrease in the initial value in this case will mean that the acceptability stock will decrease depending on the level it starts out. This is because, adoption potential from acceptability is dependent on the acceptability stock, so a decrease in the acceptability stock will definitely decrease the adoption potential from acceptability. This will increase the total adoption potential and the adoption rate, but the adopters decrease because of the decrease in the dis-adaption rate which eventually lead to the increase in the non-adopters. Figure 4.13 and 4.14 depicts the behavior pattern of Adopters and Acceptability in Improved oven stocks.

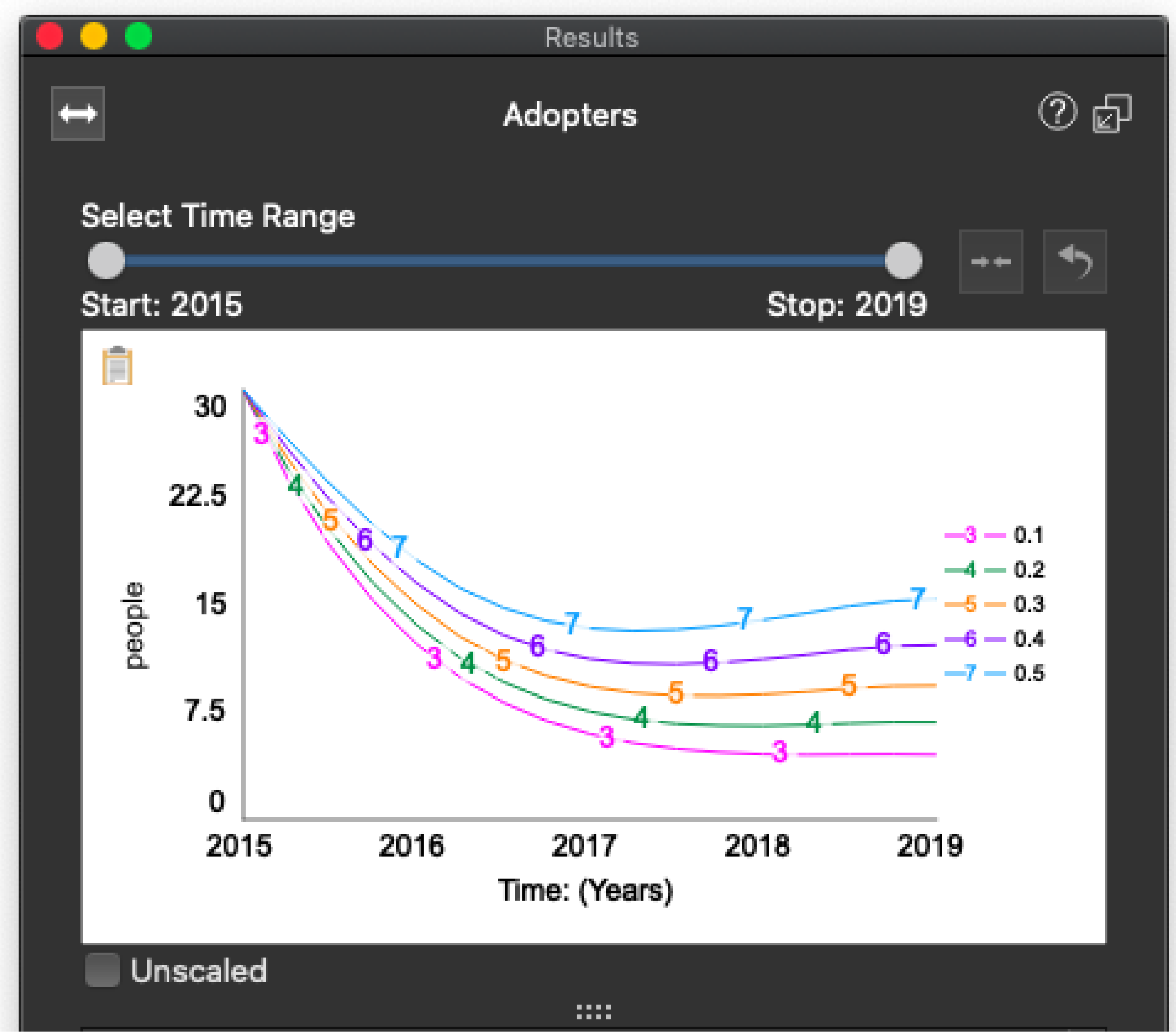


*Figure 4. 13**: Adopters Stock with initial values of Acceptability in Improved Oven***

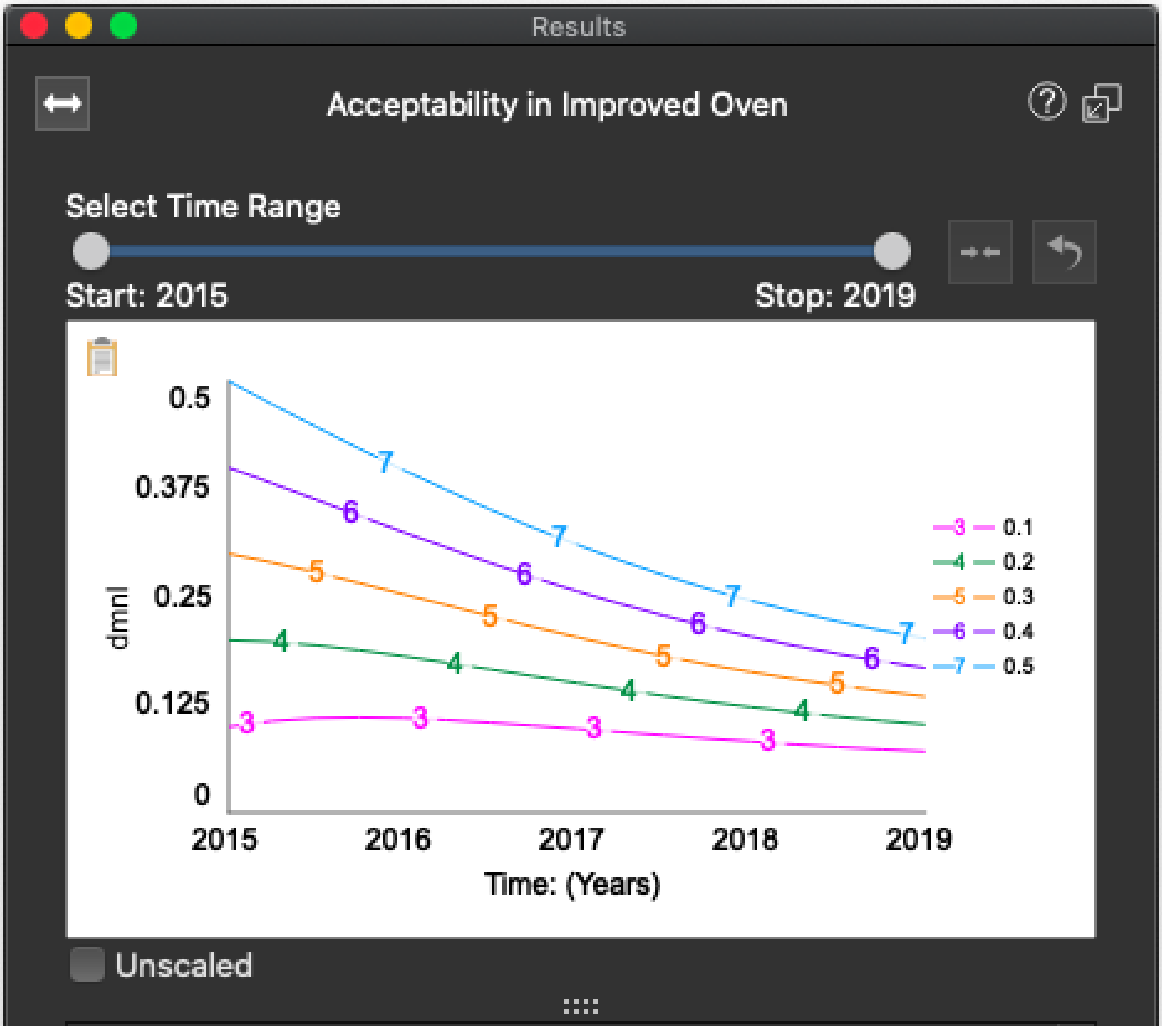


Figure 4. 14: ***Stock of Acceptability in Improved Oven***

Initial Value of Knowledge on Improved Oven

The initial value of knowledge on improved oven was tested with some values starting from 0.1 to 0.5. As it can be seen in the stock of knowledge on improved oven, initial value of less than 0.2, increases the stock (knowledge on improved oven) whiles initial value of more than 0.2 decreases the stock (knowledge on improved oven). This happens because, the share of adopters decreases, as the effect of adoption on knowledge also decreases, which tend to decrease the indicated knowledge. Since the stock of knowledge on improved oven is more than the indicated knowledge, the change in knowledge decreases. Adoption potential from knowledge goes down because the knowledge on improved oven which drives it decreases. As the adoption potential from knowledge makes Total Adoption Potential increases and also Adoption rate but adopters stock decreases rapidly, as the initial value decreases from 0.1 to

0.5. Figure 4.15 and 4.16 depicts the behavior pattern of Adopters and Knowledge on Improved oven stocks.

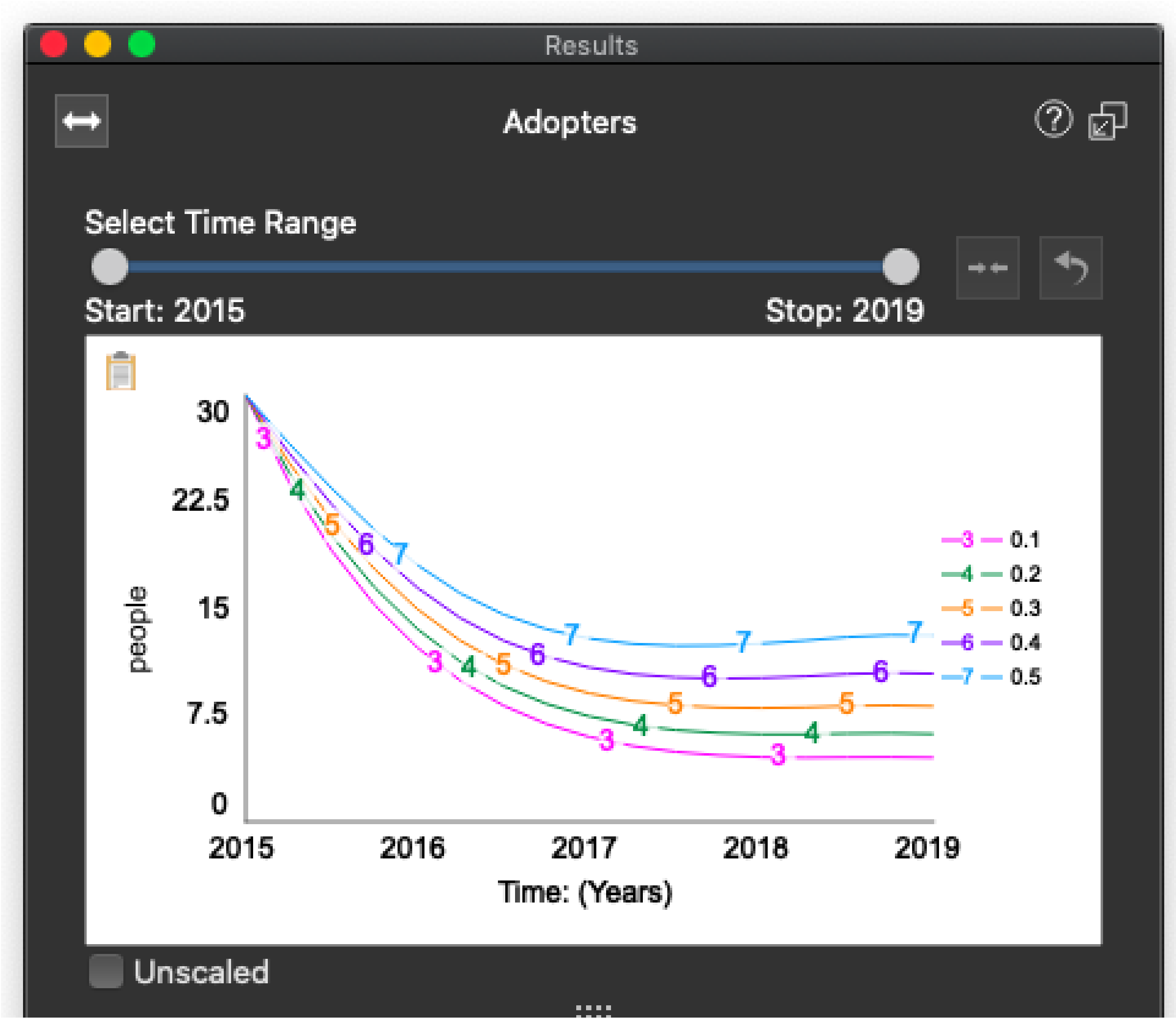


*Figure 4. 15**: Adopters Stock with initial values of Knowledge on Improved Oven***

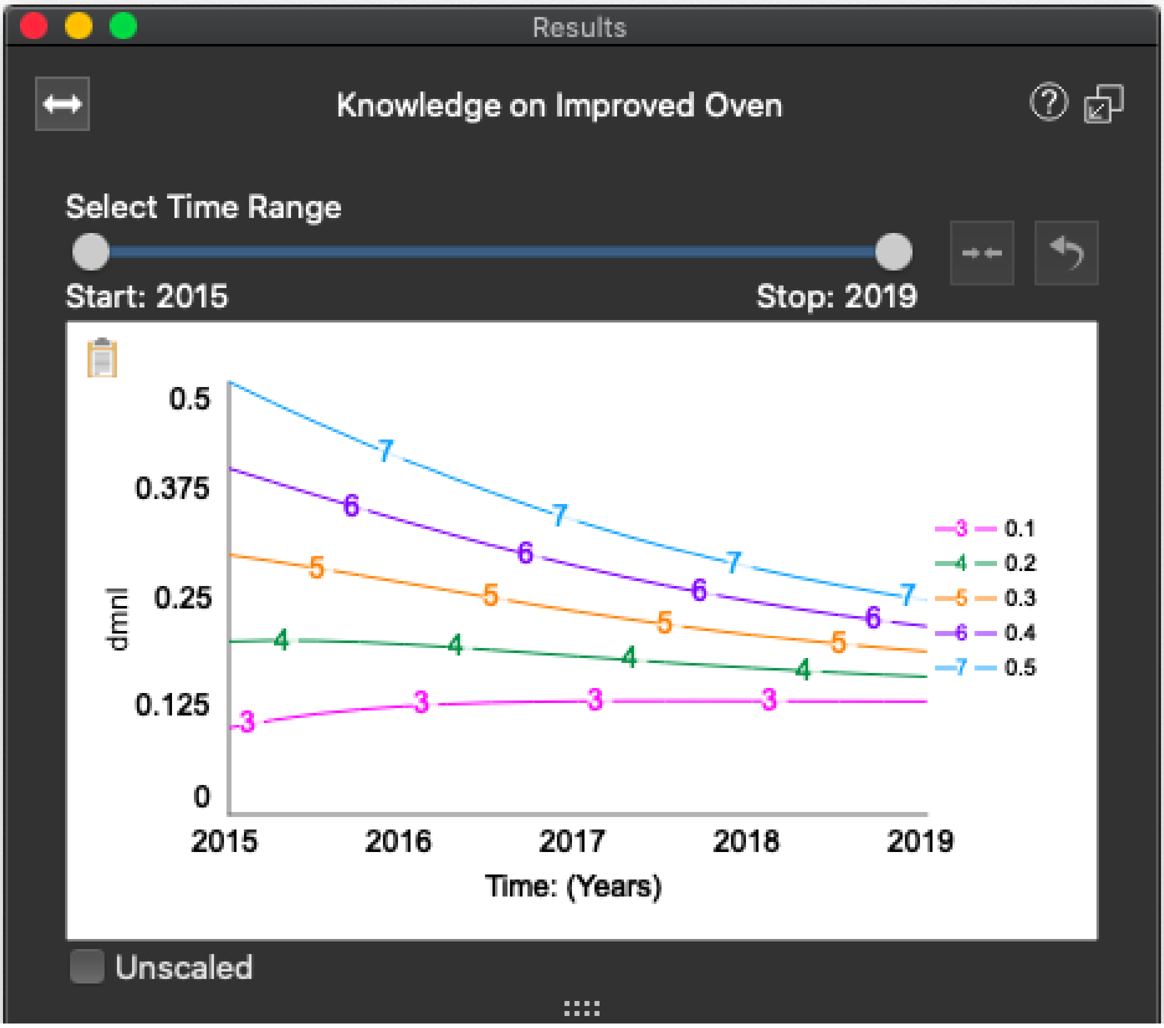


Figure 4. 16: ***Stock of Knowledge on Improved Oven***

4.4 Conclusion

The above results discussed confirm that the model is very robust and valid. The direct structure test shows that the reason behind the model behaviour is solid and useful. Also, the structure-oriented behaviour test confirms the validity of the structure of the model.

In conclusion, the validity of the model for this study is valid and acceptable representation of the real system, helpful for the purposes and finally gives permission for policy analysis.

CHAPTER FIVE

MODEL BEHAVIOR AND POLICY ANALYSIS

5.1 Introduction

This Chapters discuss about the behavior of the explanatory model based on the data used in adjusting the model and also policies that could help get a desired behavior of the system.

5.2 Simulation results

Some results of very important variables in the model after simulation run were used in the model behavior analysis. These includes Adopters, share of adopters, Acceptability in improved oven, Knowledge on improved oven, ovens affordability, savings towards oven buying and Total Adoption Potential.

5.2.1Base run results

This is the results of the explanatory model based on the data used. That is the results with the business as usual. In other words, the problem continues until something happens.

Adopters

The model behavior with respect to adopters and that of the reference mode of behavior (Adopters reference) were compared. The reference adopter which was the reference mode of behavior for the study as seen in figure 5.1 was compared with adopters in the model.

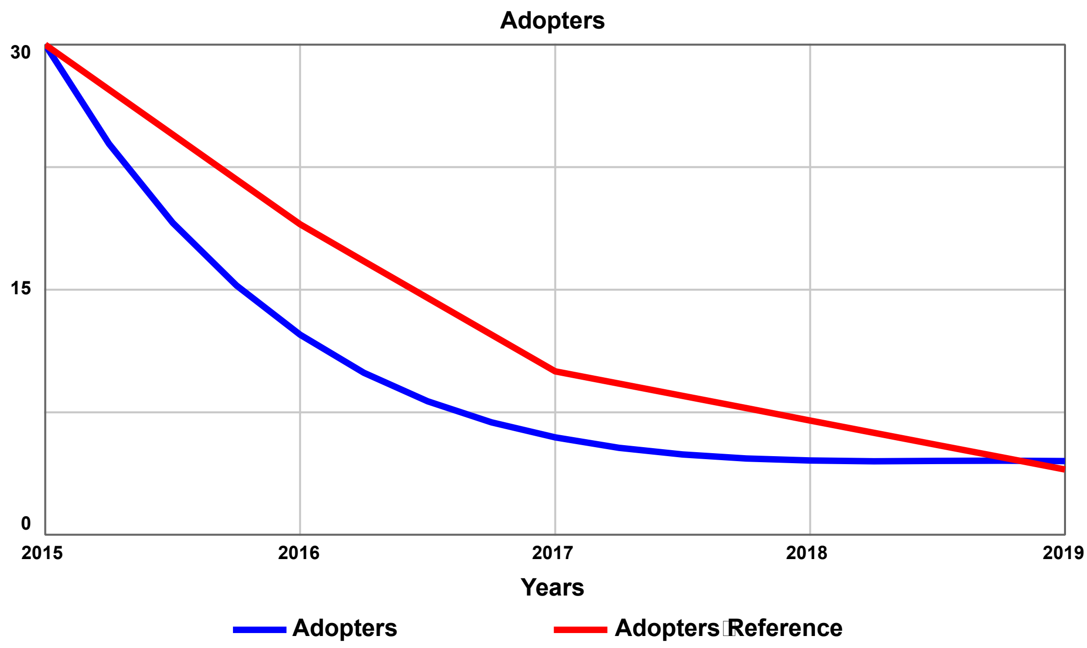


Figure 5 1: ***Base run results for Adopters stock***

Comparing the behavior of the model to that of the reference mode of behavior indicated that the adopters decreases from 2015 to 2019. The reference adopters were fish processors who have been able to afford and adopted the improved fish processing oven themselves without any subsidy or help from the project implementors. The simulated behavior was able to follow the trend of the reference behavior but however it was not a 100% perfect fit. This was because fish processors in the locality have not accepted the improved processing oven. The second reason was less knowledge on the operation of the improved oven. The third reason cited was that fish processors were unable to afford the improved oven and finally, the fish processors were not earning enough using the local fish processing oven in order to afford the improved processing oven which was very high in cost (relative profitability).

Share of Adopters

This the number of fish processors who adopted the improved oven out of the potential adopters or the total population of the fish processors in the locality. Figure 5.2 demonstrates the share of adopters compared to the non-adopters share.

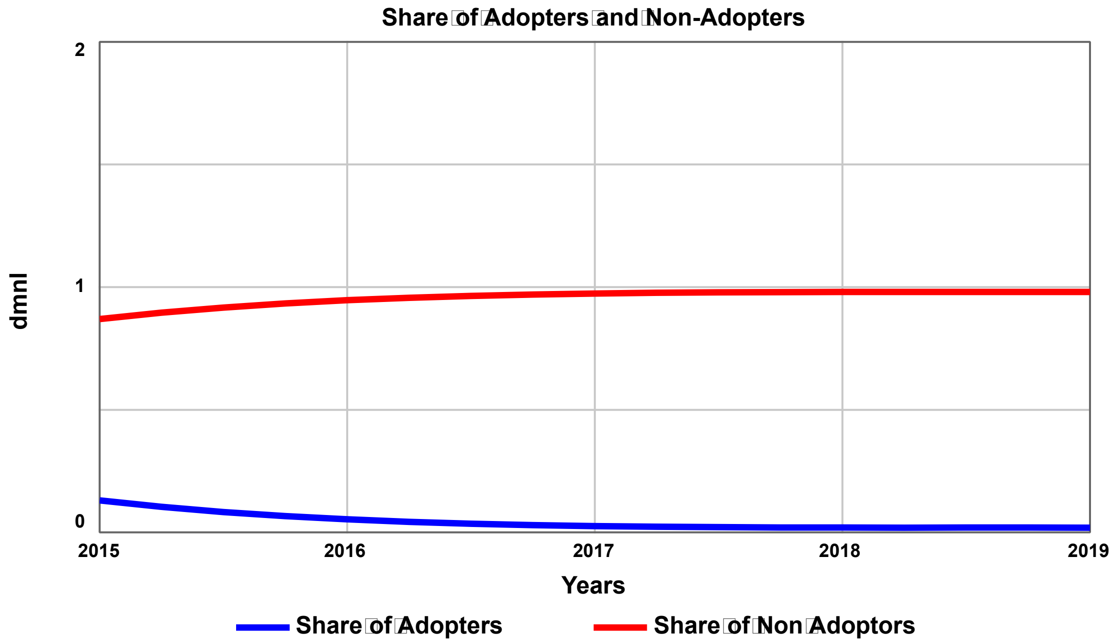


*Figure 5.2**: Comparison of Share of Adopters and Non-Adopters***

As it can be seen in figure 5.2, the share of adopters decreases from 2015 to 2017 and stabilizes at 0.1 until 2019 whiles the share of non-adopters increases from 2015 to 2017 and stabilizes until 2019. The reason behind the observed behavior between the two (Share of adopters and non-adopters) was that adopters share was dependent on the adopters' stock and that of the entire population of fish processors. Here, since the adopters decreases, the share of adopters will also follow similar behavior, thereby decreasing over the years. The share of non-adopters on the other hand increased and was because the non-adopters increases over the years in the business as usual. Also, the share of non-adopters was dependent on the non-adopters, that is as the non-adopter's stock increase, so will the share of non-adopters increase.

Acceptability in Improved Oven

Acceptability in improved oven was one of the factors which affected the adopted and diffusion of the improved oven. As fish processors in the locality have not come to accept the improved oven. Most of the fish processors still uses the local oven with reasons such as cultural and social norms. Figure 5.3 shows the level of acceptability of the improved oven by the fish processors in the study area.

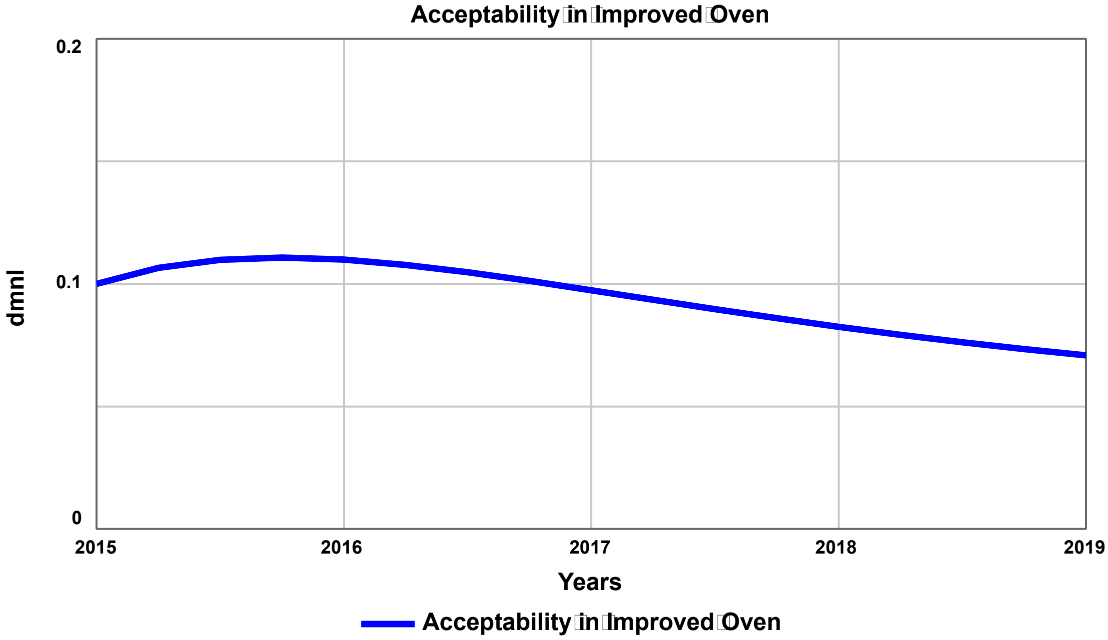


*Figure 5.3**: The Level of Acceptability in Improved Oven***

The acceptability level in the improved oven decreases over the years with an initial acceptability level. As the share of adopters decreases, the effect of adopters on the acceptability of improved oven also decreases. The indicated acceptability which was the goal for the acceptability decreases leading to a decrease in the change in acceptability and finally a decrease in the acceptability in improved oven. The adoption potential from acceptability in improved oven also decreases. This indicated clearly that fish processors are yet to accept the improved oven in the locality and that some needs to be done. This was because, fish processors acceptability in the local oven increased and their cultural beliefs and social norms concerning the improved oven or technology needs to be addressed.

Knowledge on Improved Oven

The second important factor influencing adoption was knowledge level on the operation of the improved oven by fish processors. There was a limited knowledge in operating the improved processing oven and that should this continue, adoption of the improved oven will also continue to decrease. Figure 5.4 illustrates the level of knowledge on the operation of the improved oven.

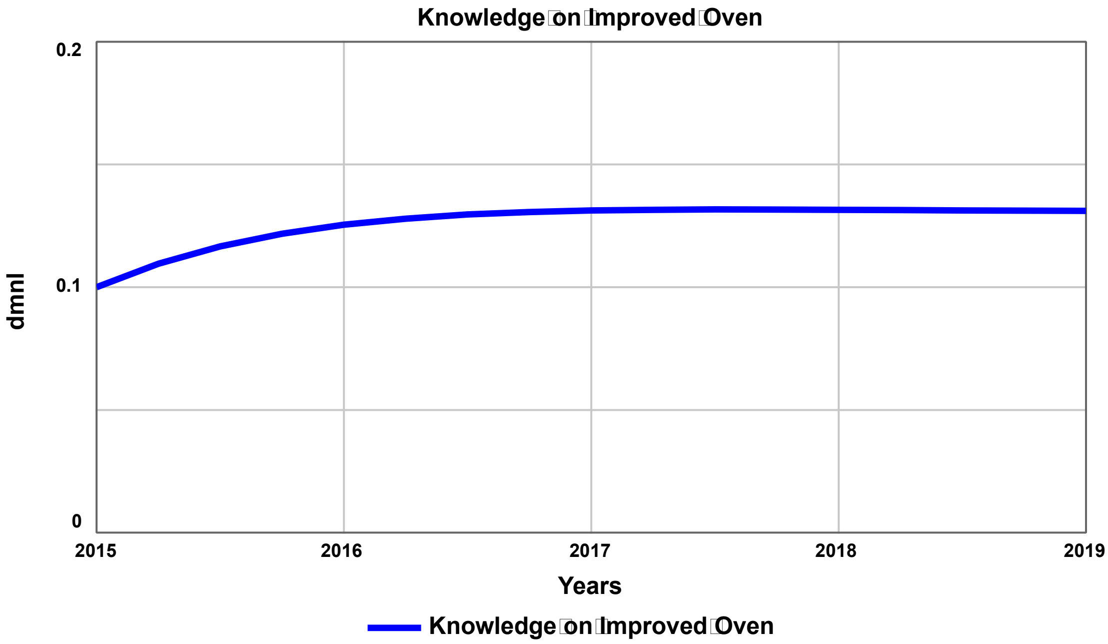


Figure 5 4: ***Knowledge level on Improved Oven***

The level of knowledge on the improved oven increased from 10% to 13%. This means the level of knowledge on the improved oven was limited. The reason for the slight increase was that since the operation of the improved oven was not 100% different from the local oven, fish processors with experience in using the local oven have some level of knowledge on the improved oven. This improved oven is an enhancement or improvement on the local or already existing oven.

The share of adopters also has influence on the knowledge level through the effect of adopters on the knowledge on improved oven. As the effect decreases the change of knowledge which is the difference between the indicated knowledge and the knowledge over an adjusted time, decreases leading to an increase and later stabilizing in the knowledge on improved oven. The adoption potential from knowledge on the improved oven depicts the same behavior of the knowledge on improved oven.

Ovens Affordability

This was to determine the affordability of the oven by fish processors. That is whether fish processors can afford the cost of the oven. Since fish processors cannot afford the cost, they save towards buying the oven from profit gained in processing the fish for some years. Oven affordability is thereby influenced by the cost of investment in ovens and the amount of savings towards buying of the oven. Figure 5.5 shows the affordability level of the oven from 2015 to 2019.

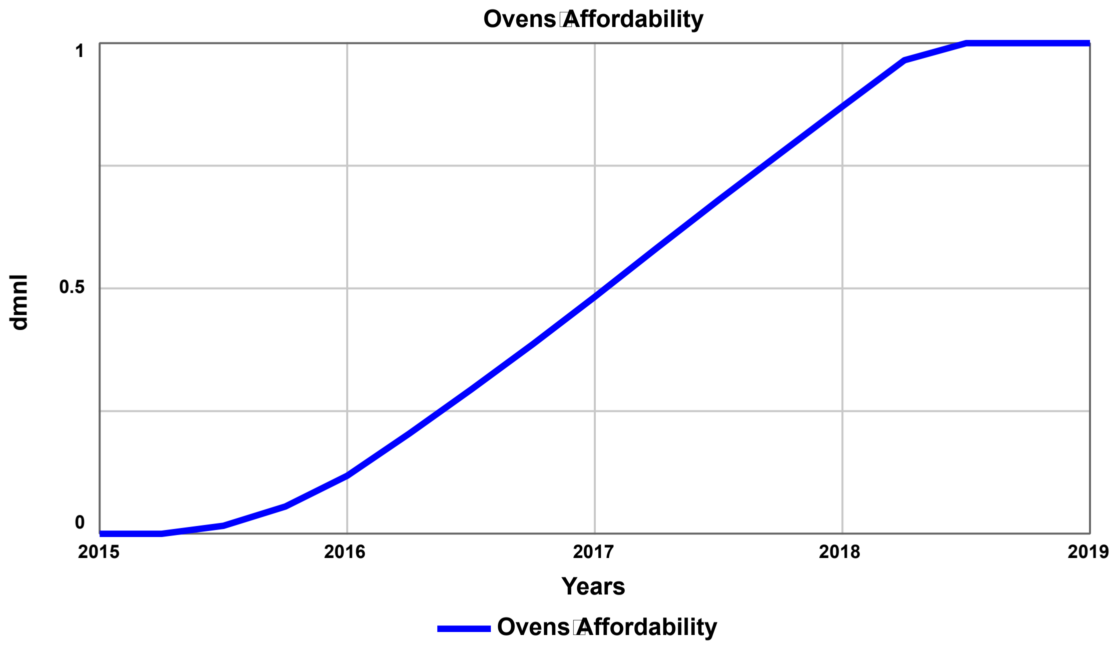


*Figure 5.5**: Ovens Affordability Level***

With the business as usual scenario, one can only afford when the person starts saving for some years from the profit gained from sales of processed fish. It can be seen that; fish processors start to be able to afford the oven 100% from 2018. That is after 3 years of savings towards purchasing of the oven.

Savings Towards Buying Oven

This was the amount of money saved over the years towards buying of the oven. It was determined by the savings rate which was dependent on the proportion of profit towards oven purchase and the household savings. With the business as usual scenario, fish processors can completely get the total amount of money to purchase the oven from 2018 which is 3 years of savings using 25% proportions of profit towards oven purchase. This is indicated in figure 5.6.

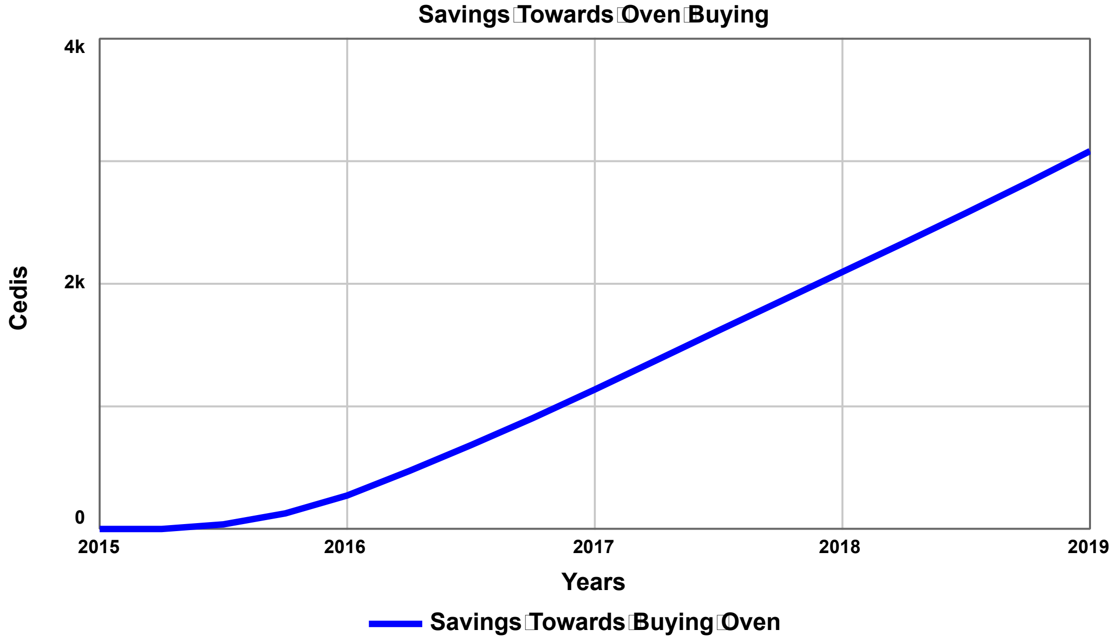


*Figure 5.6****: Savings Level Towards Oven Buying***

Since the cost of oven changes over time (continue to increase) and not fixed, the savings also continue to increase until a fish processor is able to afford or purchase it. Affording the oven alone does not guarantee an increase in adoption. Even though the affordability of the oven reached 100% after 2018, adoption still continue to decrease meaning there are other factors (knowledge and acceptability of the improved oven) that influences adoption as well. The final cost in 2019 was Ghs 3100 per oven.

Total Adoption Potential

This was the combination of all the factors that come into play to influence or affect the adoption and diffusion of fish processing technology. Figure 5.7 shows the total adoption potential from all the four (4) key factors which includes acceptability of improved oven, knowledge on the improved oven, relative profitability and ovens affordability.

The adoption potential from all the factors combined was 15% from the base run. This means that the little knowledge on the improved oven based on the experience in using the local does not guarantee a higher percentage of adoption. Also, 100% ovens affordability based on savings by fish processors could not influenced a higher percentage of adoption.

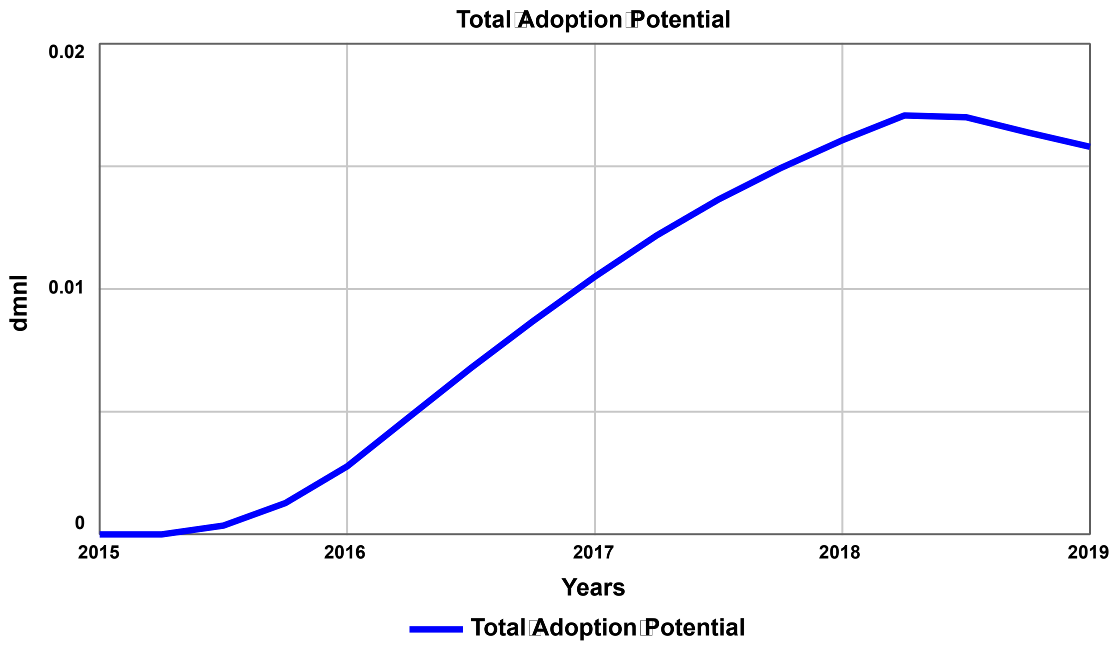


Figure 5.7: ***Total Adoption Potential Level***

In conclusion, the base run results represented the problem at hand and there should be some polices in order to get a reasonable adoption of the technology by fish processors. This then leads to the policy analysis section.

5.3 Policy Analysis

This is the last part in this chapter. It deals with the policy options that would help reduce the problem at hand. From the explanatory model, it was clearly shown that, adoption of the improved oven was decreasing over the period. The leverage point for the policy options include organising sensitizing and awareness workshops targeted at increasing the acceptability of the improved oven within the Municipality. The second option for policy was to provide training on the operation and improved methods of processing fish using the improved oven in order for fish processors to gain more knowledge and add up to the already existing expertise in fish processing.

5.3.1 First Policy Option: Sensitizing and Awareness Creation Workshops on the Improved Oven

From the sensibility analysis, an increase in the acceptability of the improved oven increases the adoption level. Fish processors have some cultural and social beliefs towards new technology and that if these beliefs are reduced, the acceptability level in the improved oven would increase. Because majority of the fish processors within the locality have not come to accept the improved oven or technology, it becomes very difficult to get appreciable numbers to adopt leading to a proper diffusion.

A policy seeking to increase the awareness and acceptability of the improved oven would increase the adoption. With a 28% input in sensitizing and 2 years interval, adoption grew to 51 people out of 230 people as shown in figure 5.8. This clearly indicates that sensitizing workshops in every two years would go a long way to influence adoption of the improved oven. This would also boost fish processors confidence in the improved oven and also spread it to other fish processors within the locality (word of mouth).

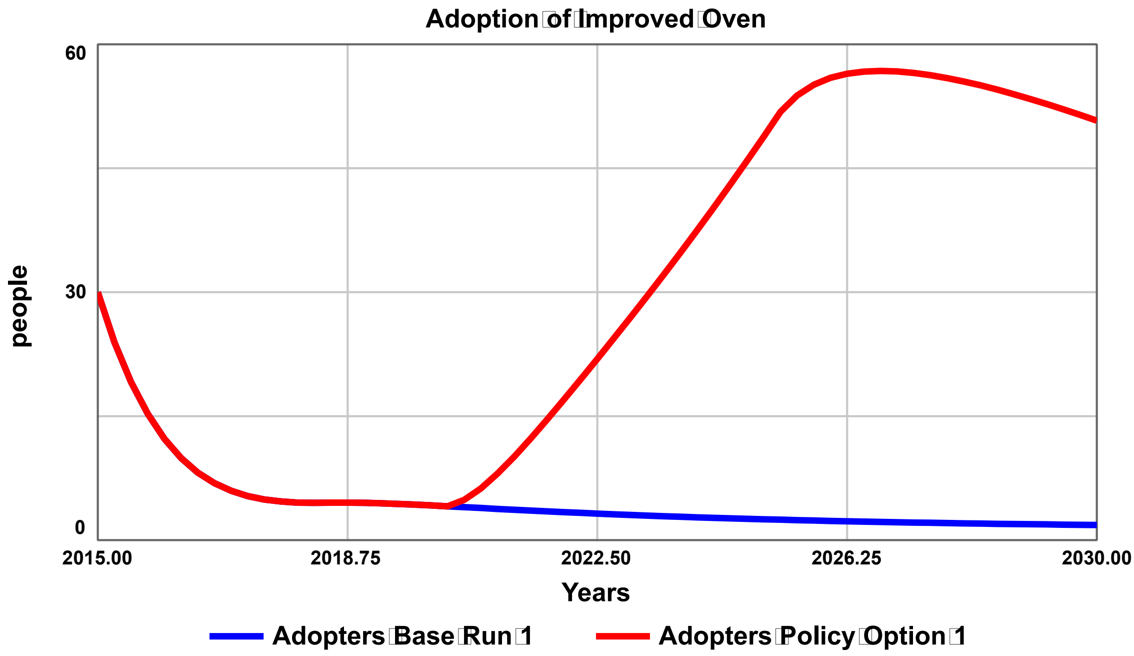


Figure 5.8: ***Comparison of Adopters Base Run with Policy Option 1 (with 28% Sensitizing input at every 2 years)***

Comparing the base run and after adding of policy option 1 (Sensitizing policy), adopters increased from 4 people to 51 people.

5.3.2 Second Policy Option: Training on the Operations and Usability on the Improved Oven

The second policy option was to provide training to fish processors which would increase their knowledge on the improved oven. Fish processors lack knowledge on the operations of the improved oven. A policy option leverage to increase fish processors knowledge would help increase processor's income by getting increased prices for the quality and increased quantity of processed fish. With an increase in knowledge on the existing knowledge on local oven, adoption would increase at some level. Figure 5.9 compares the base run and policy option 2 where there is slight increase in adopters.

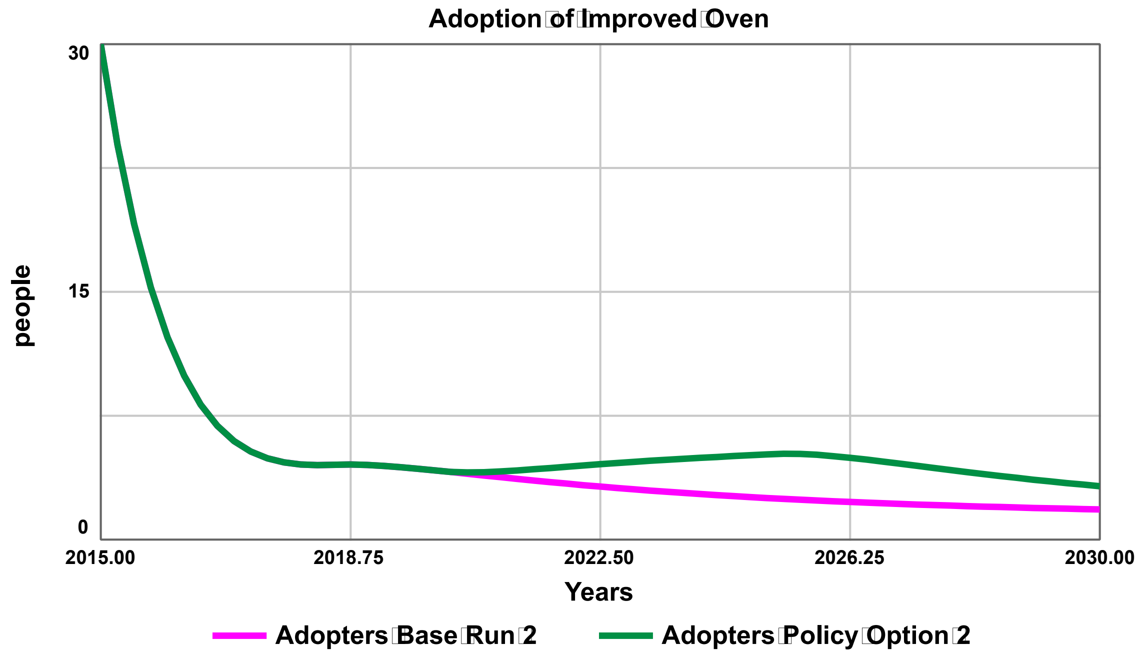


*Figure 5.9**: Comparison of Adopters' Base Run and Policy Option 2 (with 5% Training Input at 2 years Interval)***

With an increase in knowledge on the improved oven, fish processors can help teach and share this knowledge to other fish processors within the locality. Implementation of this policy would increase adoption of the improved oven (adopters) as seen in figure 5.9.

5.3.3 Combination of Policy Option 1 and Policy Option 2

With a combination of the two policy options, adopters increased to 135 people out of 230 people representing 59% as demonstrated in figure 5.10. What this means is that, for an adoption of the improved oven to be effective, all the two policy options should be placed together in order to observe effective implementation.

It can be concluded that based on the behavior analysis and policy options, there is a justifiable conclusion that for an effective and increased adoption of improved fish processing oven, acceptability of the improved oven and knowledge on the improved oven were very important and also formed the leverage point for the informed policies. The remaining two factors (ovens affordability and relative profitability) played an equally important role as leaving them out would not have been possible for achieving the increment in adoption.

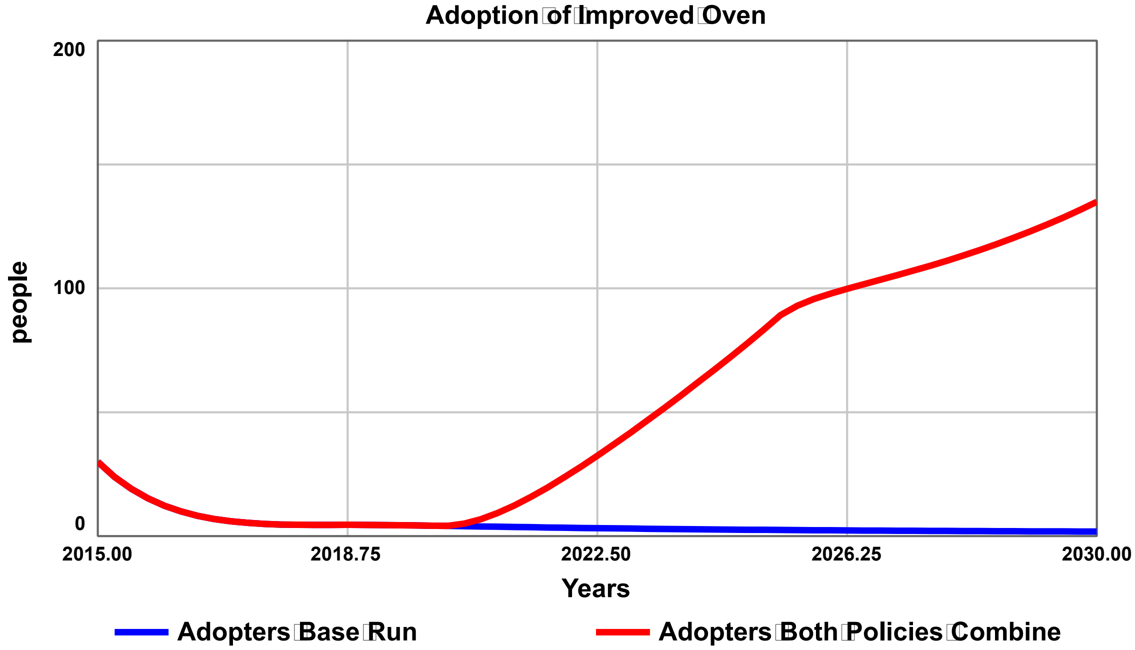


Figure 5.10: ***Comparison of Adopters Base Run with Combination of Policy and 2***

CHAPTER SIX

FINDINGS AND RECOMMENDATION

6.1 Introduction

This chapter discusses the final conclusions and findings of the research. It basically talks about the answers to the research questions in chapter one or the objectives of the research. Recommendations for further studies is also mentioned in this chapter as well.

6.2 Findings

Based on the interview with the fish processors and key stakeholders in the fish processing industry, it was found out that there were two (2) major fish processing oven in the locality, namely Chorkor oven and Morrison oven. This answered the research question or objective one.

Secondly, the average adoption rate before the potential policies was 2 people per year and after the policies was 10 people per year from the simulation results. This indicates that before the policies, the average adoption rate was significantly low and after the policies, it was increased. This answered the research objective or question two (2).

The third objective was to investigate the factors that influence or affect adoption of the improved fish processing oven. The study came out with four (4) factors which includes, Acceptability in the improved and local oven, Knowledge on the improved and local oven, relative profitability and affordability of the improved fish processing oven. All the factors affected adoption in its own way and the best came out from all the four combined based on the simulation results from the model.

Finally, as the fish processors were sensitized on the improved fish processing oven, acceptability in the improved oven increases which leads to an increase in adoption rate as shown in the simulation results. When fish processors' knowledge and training on improved fish processing oven are up to date, adoption rate increases, the quality and quantity of fish being processed increased because of the adoption of the improved oven which lead to a higher price of processed fish and eventually an increase in the income of the household.

6.3 Recommendation for further Studies

The purpose and validity of the model for this research could have replicated the reality of the system very well if some additional boundaries within the system were modelled endogenously. This include a comprehensive modelling of the quantity of processed fish from the original source of production be it from the fish stock or aquaculture. An extensive modelling of the income and expenses of the household could also be done to show the dynamics of the system, specifically in terms of the proportions of income saved towards purchasing of the oven and also proportions invested back into the fish processing business.

References

Adeyeye, S., & Oyewole, O. (2016). An overview of traditional fish smoking in Africa. *Journal of Culinary Science & Technology, 14*(3), 198-215.

Aheto, D. W., Asare, N. K., Quaynor, B., Tenkorang, E. Y., Asare, C., & Okyere, I. (2012). Profitability of small-scale fisheries in Elmina, Ghana. *Sustainability, 4*(11), 2785-2794.

Ahmed, A. (2004). Challenges of agricultural technology transfer and productivity increase in the Sudan. *International Journal of Technology, Policy and Management, 4*(2), 136-150.

Ahmed, A., Dodo, A., Bouba, A., Clement, S., & Dzudie, T. (2011). Influence of traditional drying and smoke-drying on the quality of three fish species (Tilapia nilotica, Silurus glanis and Arius parkii) from Lagdo Lake, Cameroon. *Journal of animal and Veterinary Advances, 10*(3), 301-306.

Akangbe, J., Bankole, Y., Ajibola, B., Fakayode, S., & Animashaun, J. (2013). Adoption of smoking chokor for fish processing in Kwara state. *Russian Journal of Agricultural and Socio-Economic Sciences, 15*(3).

Akinola, O., Akinyemi, A., & Bolaji, B. O. (2006). Evaluation of traditional and solar fish drying systems towards enhancing fish storage and preservation in nigeria: Abeokuta local governments as case study.

Amakye, S. (2019). *Breaking the glass ceiling: experiences of women leaders in private corporate organisations in Ghana.* The University of Bergen,

Amos-Wilson, P. (1999). Some issues concerning women in senior management: a case study from Ghana. *Public Administration and Development: The International Journal of Management Research and Practice, 19*(3), 219-229.

Asiedu, B., Failler, P., & Beygens, Y. (2018). Ensuring food security: an analysis of the industrial smoking fishery sector of Ghana. *Agriculture & Food Security, 7*(1), 38.

Asiedu-Addo, S. (2013). Fishing at Elmina. Graphic Online. Available at:
. doi:Available at:
http://www.graphic.com.gh/news/general-news/9228-fishing-at-elmina.html

Barlas, Y. (1989). Tests of model behavior that can detect structural flaws: demonstration with simulation experiments. In *Computer-Based Management of Complex Systems* (pp. 246-254): Springer.

Barlas, Y. (1996). Formal aspects of model validity and validation in system dynamics. *System Dynamics Review: The Journal of the System Dynamics Society, 12*(3), 183-210.

Bass, F. M. (1969). A new product growth for model consumer durables. *Management science, 15*(5), 215-227.

Béné, C. (2003). When fishery rhymes with poverty: a first step beyond the old paradigm on poverty in small-scale fisheries. . *World Develpment, 31*(6), 949-957.

Boohene, R., & Peprah, J. A. (2012). Correlates of revenue among small scale women fish processors in coastal Ghana. *Journal of Sustainable Development, 5*(10), 28-39.

Denscombe, M. (2012). *Research proposals: A practical guide: A practical guide*: McGraw-Hill Education (UK).

Elmina, & Strategy. (2015). Building on the Past to Create a Better Future; A document prepared by the Komenda-Edina-Eguafo-Abrem (KEEA) District Assembly for the Elmina Cultural Heritage and Management Programme; KEEA District Assembly: Elmina, Ghana,.

Etsra, H., & Avega, B. (2018). Documentation of the Pains and Gains of the Ahotor Oven Improvement Process. *The USAID/Ghana Sustainable Fisheries Management Project (SFMP). Narragansett, RI: Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island and SNV Netherlands Development Organisation. GH2014_ACT235_SNV.*

Failler, P., Beyens, Y., & Asiedu, B. (2014). Value chain analysis of the fishery sector in Ghana. *Mission Report, Trade Capacity Building Project for Ghana, UNIDO/MOTI TCB Project, Accra, Ghana*, 106.

FAO. (2014). The State of World Fisheries and Aquaculture: Opportunities and challenges, 209. Food and Agriculture Organization of the United Nations, Rome.

FAO. (2016). The State of World Fisheries and Aquaculture. Contributing to food security and nutrition for all. Rome.

FAO. (2017). The future of food and agriculture—trends and challenges.

Hall, G. M. (2011). Preservation by curing (drying, salting and smoking). *Fish processing sustainability and new opportunities*, 51-76.

Kopainsky, B., Tröger, K., Derwisch, S., & Ulli-Beer, S. (2012). Designing sustainable food security policies in sub-Saharan African countries: how social dynamics over-ride utility evaluations for good and bad. *Systems Research and Behavioral Science, 29*(6), 575-589.

Koranteng, K. A. (1993). Marine fishery resources of Ghana's coastal zone. Structure and dynamics of demersal assemblages on the continental shelf and upper slope of Ghana, West Africa.

Koranteng, T. (2012). The Vulnerability of Elmina Fisher- folks to HIV/AIDS

Contagion.

. *Journal of Biology, Agriculture and Healthcare, 2*(4).

Mahajan, V., & Peterson, R. A. (1979). First-purchase diffusion models of new-product acceptance. *Technological Forecasting and Social Change, 15*(2), 127-146.

Megbowon, I., Adewolu, M., Ozor, P., Ayo-Olalusi, C., Okunade, O., Mojekwu, T., . . . Kolade, O. (2010). Role of women in fisheries and fish processing: a global view.

Nerquaye-Tetteh, G. (1989). Extension of Research Results to End-users: Success Stories and Failures–a Case Study of the FAO/Chorkor Smoker. In: FRI Project Report. Food Research Institute, Accra.

Nti, C., Quaye, W., & Sakyi-Dawson, O. (2002). Evaluation determinants for effective adoption of an improved fish-processing technology in Ghana-Research and Development Notes. *Ghana Journal of Agricultural Science, 35*(1), 177-184.

Nti, C. A., Plahar, W. A., & Larweh, P. M. (2002). Impact of adoption in Ghana of an improved fish processing technology on household income, health and nutrition. *International Journal of Consumer Studies, 26*(2), 102-108.

Nti, C. A., Plahar, W. and Larweh, P. (2002). Impact of adoption in Ghana of an improved fish processing technology on household income, health and nutrition. International Journal of Consumer Studies, 26 (2), pp. . *26*(2), 102-108.

Nti, C. A., Quaye, W., and Sakyi-Dawson, O. (2002). Evaluation determinants for effective adoption of an improved fish-processing technology in Ghana-Research and Development Notes. . *Ghana Journal of Agricultural Science, 35*(1), 177-184.

Nunoo, F., Asiedu, B., Kombat, E., & Samey, B. (2015). Sardinella and Other Small Pelagic Value and Supply chainof the fishery scetor, Ghana. *The USAID/Ghana Sustainable Fisheries Management Project (SFMP). Narragansett, RI: Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island and Netherlands Development Organisation. GH2014_ACT044_SNV.*

Obodai, E., Muhammad, B., Obodai, G., & Opoku, E. (2009). Effect of Fuel wood on the Quality of Smoked Freshwater Fish Species Sold in Tamale Central Market, Northern Region, Ghana. *Ethiopian journal of environmental studies and management, 2*(2).

Odediran, O., & Ojebiyi, W. (2017). Awareness and adoption of improved fish processing technologies among fish processors in Lagos State, Nigeria. *Research Journal of Agriculture and Environmental Management Vol, 6*(3), 046-054.

Ofori-Danson, P. K., Sarpong, D. B., Sumaila, U. R., Nunoo, F., & Asiedu, B. (2013). Poverty measurements in small-scale fisheries of Ghana: A step towards poverty eradication. *Journal: Current Research Journal of Social Sciences, 5*, 75-90.

Okomoda, J., & Alamu, S. (2003). Application of participatory rural appraisal (PRA) techniques in the verification of fisheries data and trend on Lake Kainji.

Okorley, E., & Kwarten, J. (2000). Women and agro-processing in Africa: a case study of the state of women in fish smoking in the central region of Ghana. *Bulletin de l'APAD*(19).

Okorley, E. L., Zinnah, M. M., Kwarteng, J. A., & Owens, M. (2001). *Production constraints and training needs of women in fish processing in the Central Region of Ghana.* Paper presented at the 17th Annual Conference on Emerging Trends In Agricultural and Extension Education, Baton Rouge, Louisiana. Abstract retreieved from http://www. aiaee. org/attachments/article/1370/pa35. pdf.

Owusu, D., Addo, O. J., & Kent, K. (2019). Lessons Learned Essay - Post Harvest USAID/Ghana SFMP.

Pauly, D., Christensen, V., Guénette, S., Pitcher, T. J., Sumaila, U. R., Walters, C. J., . . . Zeller, D. (2002). Towards sustainability in world fisheries. *Nature, 418*(6898), 689-695.

Plahar, W., Nti, C., & Steiner-Aseidu, M. (1997). *Fish consumption patterns in Ghana and fish quality at household level.* Paper presented at the Proceedings of a Workshop Organized by Artisanal Fish Processing and Applied Project.

Rogers, E. (1995). Diffusion of innovations, edition of the Free Press. *The fourth*.

Rogers, E. M., & Shoemaker, F. F. (1971). Communication of Innovations; A Cross-Cultural Approach.

Sarpong, D. B., Quaatey, S. N., & Harvey, S. K. (2005). Food And Agriculture Organization Of The United Nations (FAO).

Senge, P. M., & Forrester, J. W. (1980). Tests for building confidence in system dynamics models. *System dynamics, TIMS studies in management sciences, 14*, 209-228.

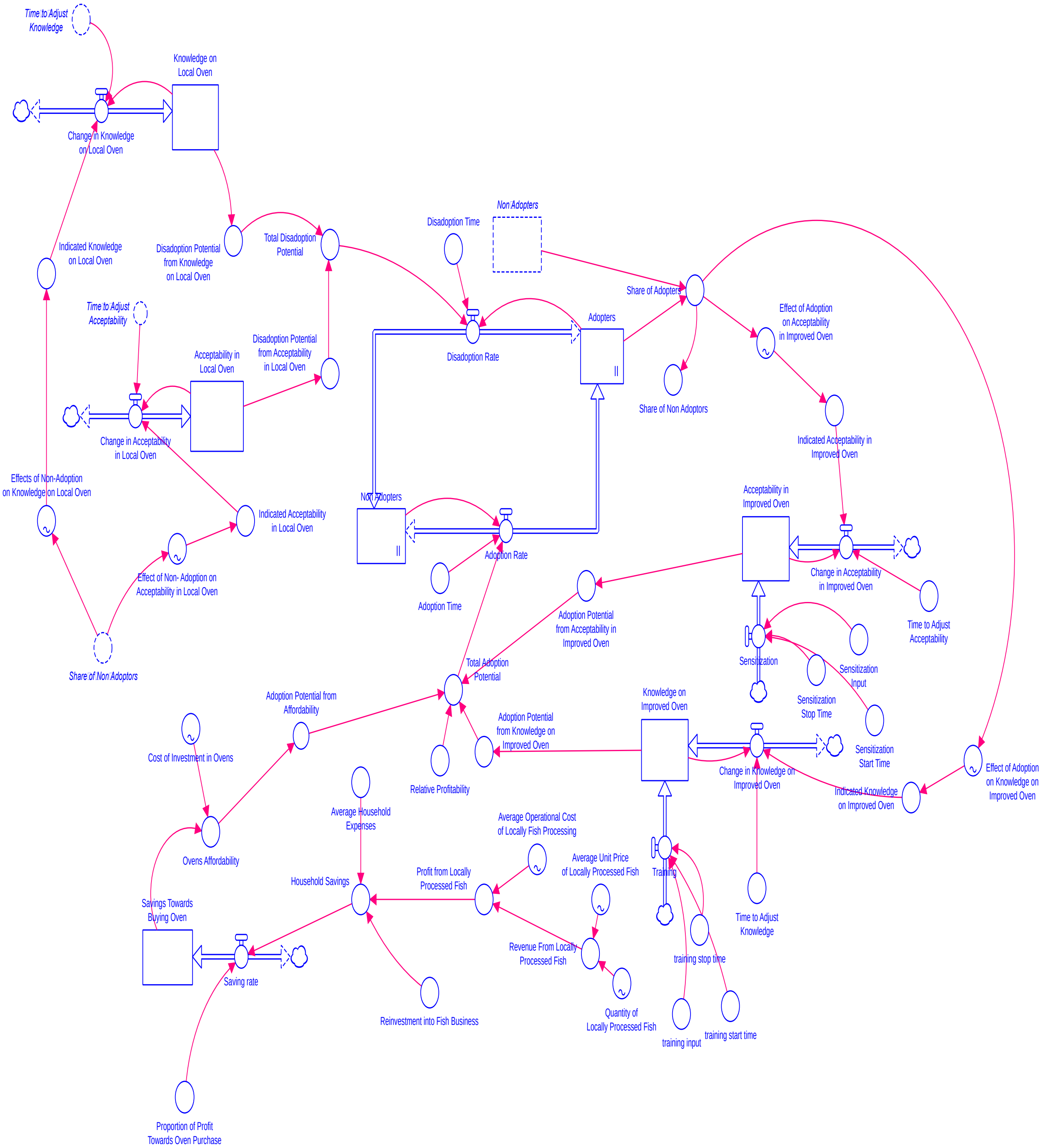
Sterman, J. (2002). System Dynamics: systems thinking and modeling for a complex world.

Stone, G. D., Brush, S., Busch, L., Cleveland, D. A., Dove, M. R., Herring, R. J., . . . Shah, E. (2007). Agricultural deskilling and the spread of genetically modified cotton in Warangal. *Current anthropology, 48*(1), 67-103.

Williams, S. B. (2001). Economic potentials of women in small-scale fisheries in West Africa.

Wolstenholme, E. F. (1982). System dynamics in perspective. *Journal of the Operational Research Society, 33*(6), 547-556.

Appendix 1: Overview of Simulation Model



Appendix 11: Model Documentation

Variable	Formulation and Comments	Units	Source
Acceptability in Improved Oven	Acceptability_in_Improved_Oven(t) = Acceptability_in_Improved_Oven(t - dt) + (Change_in_Acceptability_in_Improved_Oven + Sensitization) * dt This is the faith that the adopters have shown in improved processing technology. It is how the people have come to accept the improved processing technology usage.	dmnl	(C. A. Nti, Quaye, W., and Sakyi-Dawson, O., 2002)
Change in Acceptability in Improved Oven	Change_in_Acceptability_in_Improved_Oven = (Indicated_Acceptability_in_Improved_Oven Acceptability_in_Improved_Oven)/Time_to_Adjust_Acceptability This is the rate at which the acceptability in the improved fish smoking technology changes.	Per year	
Sensitization Input	Sensitization = STEP (Sensitization_Input, Sensitization_Start_Time)- STEP (Sensitization_Input, Sensitization_Stop_Time) This is where fish processors are given more information on the improved fish processing to create awareness and also build acceptability as well.	Per year	
Acceptability in Local Oven	Acceptability_in_Local_Oven(t) = Acceptability_in_Local_Oven(t - dt) + (Change_in_Acceptability_in_Local_Oven) * dt This is the faith that non- adopters have shown in the local processing technology. It is how the people have come to accept the local processing technology usage and not willing to change	dmnl	(C. A. Nti, Quaye, W., and Sakyi-Dawson, O., 2002)
Change in Acceptability in Local Oven	Change_in_Acceptability_in_Local_Oven = (Indicated_Acceptability_in_Local_Oven-Acceptability_in_Local_Oven)/Time_to_Adjust_Acceptability This is the rate at which the acceptability in the local fish smoking technology changes	Per year	
Adopters	Adopters(t) = Adopters (t - dt) + (Adoption_Rate - Disadoption_Rate) * dt This is the number of fish processors using or who have adopted the technology (Comfort Oven) for	People	

	smoking or processing of fish in the study area over the years.		
Adoption Rate	Adoption_Rate = (Non_Adopters*Total_Adoption_Potential)/Adoption_Time The rate of adopting the improved technology at specific period of time by fish processors.	People/year	
Dis-adoption Rate	Disadoption_Rate = (Adopters*Total_Disadoption_Potential)/Disadoption_Time The rate at which fish processors, who are not adopting the improved processing technology. This is affected by several factors.	People/year	
Knowledge on Improved Oven	Knowledge_on_Improved_Oven(t) = Knowledge_on_Improved_Oven(t - dt) + (Change_in_Knowledge_on_Improved_Oven + Training) * dt This is level of knowledge fish processors have in the improved technology and can be used by the fish processors without any complications or having the requisite technical-know-how. That is how fish processors have come to feel comfortable with its usage without any problem with the operations of the improved oven as one adopts.	dmnl	Hall, G. M. (2011)
Change in Knowledge on Improved Oven	Change_in_Knowledge_on_Improved_Oven = (Indicated_Knowledge_on_Improved_Oven-Knowledge_on_Improved_Oven)/Time_to_Adjust_Knowledge The rate at which the knowledge on the usage of the technology changes over time.	Per year	
Training	Training = STEP (training_input, training_start_time)-STEP (training_input, training_stop_time) Addition of knowledge on improved fish processing technology to fish processors	Per year	
Knowledge on Local Oven	Knowledge_on_Local_Oven(t) = Knowledge_on_Local_Oven(t - dt) + (Change_in_Knowledge_on_Local_Oven) * dt This is the extent of knowledge processors have in the local technology which can be used by the	dmnl	Hall, G. M. (2011)

	fish processors without any complications. That is how fish processors have come to feel comfortable with its usage without any problem with the operations of the local oven.		
Change in Knowledge on Local Oven	Change_in_Knowledge_on_Local_Oven = (Indicated_Knowledge_on_Local_Oven-Knowledge_on_Local_Oven)/Time_to_Adjust_Knowledge The rate at which the compatibility of the local oven and how fish processors are familiar with its usage changes over time.	Per year	
Non-Adopters	Non_Adopters(t) = Non_Adopters(t - dt) + (Disadoption_Rate - Adoption_Rate) * dt {NON- The number or percentage of fish processors who are using the traditional method of fish smoking or processing. In other words, the percentage of fish processors who have not adopted the technology (Comfort Oven) for fish processing	People	
Savings Towards Buying Oven	Savings_Towards_Buying_Oven(t) = Savings_Towards_Buying_Oven(t - dt) + (Saving_rate) * dt This is the amount of money saved over the years by fish processors directed towards buying the improved processing oven. This will help fish processors to be able to afford the cost of the oven.	Cedis	
Savings Rate	Savings_rate = Household_Savings*Proportion_of_Profit_Towards_Oven_Purchase This is the rate at which savings directed towards the buying of oven.	Cedis/year	
Adopters Data	Adopters_Data = GRAPH(TIME) (2015.000, 30.0), (2016.000, 19.0), (2017.000, 10.0), (2018.000, 7.0), (2019.000, 4.0) Data on the number of fish processors or smokers adopting the improve oven from 2016 to 2019	People	The USAID/Ghana Sustainable Fisheries Management Project (SFMP) and Central and Western Fishmongers Improvement Association, Ghana (CEWEFIA) 2019 Report

Adoption Potential from Acceptability in Improved Oven	Adoption_Potential_from_Acceptability_in_Improved_Oven = Acceptability_in_Improved_Oven The adoption potential because of the quality and processor acceptability of the improved oven. This is assessed by the fish processors.	dmnl	
Adoption Potential from Affordability	Adoption_Potential_from_Affordability = Ovens_Affordability The proportion of adopters adopting because of the affordability of the oven. That is fish processors gaining adequate profit and saving to be able to purchase the improve fish processing oven.	dmnl	
Adoption Potential from Knowledge on Improved Oven	Adoption_Potential_from_Knowledge_on_Improved_Oven = Knowledge_on_Improved_Oven The potential of adopting the technology because of the level of knowledge of fish processors have in the technology. That is how fish processors can operate the technology without any complications.	dmnl	
Adoption Time	Adoption_Time = 1 This is the average time for adopters to decide whether to adopt.	year	Interview with Fish Processors, 2020
Average Household Expenses	Average_Household_Expenses = 3270 Income from fish processing spent on the household of the fish processor over the years. Average household expenses for a typical year is used in this model.	Cedis/ year	Interview with Fish Processors, 2020
Average Operational Cost of Locally Fish Processing	Average_Operational_Cost_of_Locally_Fish_Processing = GRAPH(TIME) (2016.000, 11600), (2017.000, 12850), (2018.000, 15780), (2019.000, 21000) This is the average expenses made by fish processors who are still using the local oven. It includes all expenses made during the fish processing period. That is purchase of the fresh fish up to sales.	Cedis/year	Interview with some members of the Central and Western Fishmongers Improvement Association, Ghana (CEWEFIA), 2020
Average Unit of Locally Processed Fish	Average_Unit_Price_of_Locally_Processed_Fish = GRAPH(TIME) (2015.000, 12.00), (2016.000, 14.00), (2017.000, 15.50), (2018.000, 17.00), (2019.000, 20.00)	Cedis/kg	Interview with some members of the Central and Western Fishmongers

	This is the average price of a unit of fish processed over the years.		Improvement Association, Ghana (CEWEFIA), 2020
Cost of Investment in Ovens	Cost_of_Investment_in_Ovens = GRAPH(TIME) (2016.00, 2300), (2020.66666667, 2550), (2025.33333333, 2800), (2030.00, 3150) The cost in purchasing the improved fish processing oven over the years.	Cedis	USAID/Ghana Sustainable Fisheries Management Project (SFMP) Implementers
Dis-adoption Potential from Acceptability in Local Oven	Disadoption_Potential_from_Acceptability_in_Local_Oven = Acceptability_in_Local_Oven The proportion of non- adopters adopting because of the quality and consumer acceptability in local or traditional oven.	dmnl	
Dis-adoption Potential from Knowledge on Local Oven	Disadoption_Potential_from_Knowledge_on_Local_Oven = Knowledge_on_Local_Oven The potential of non-adopting the technology because of the lack of technical-know-how fish processors are with the local oven. That is how fish processors can operate the local oven without any complications.	dmnl	
Dis-adoption Time	Disadoption_Time = 1 This is the adjusted time for non-adopters to decide whether not to adopt or adopt at a particular point in time.	Year	
Effect of Adoption on Acceptability in Improved Oven	Effect_of_Adoption_on_Acceptability_in_Improved_Oven = GRAPH(Share_of_Adopters) (0.000, 0.019), (0.250, 0.325), (0.500, 0.598), (0.750, 0.865), (1.000, 0.971) The effect of Adopters trust in improved processing technology over the years.	dmnl	(Kopainsky et al., 2012)
Effect of Adoption on Knowledge on Improved Oven	Effect_of_Adoption_on_Knowledge_on_Improved_Oven = GRAPH(Share_of_Adopters) (0.000, 0.115), (0.250, 0.306), (0.500, 0.631), (0.750, 0.875), (1.000, 0.938) This is how the level of knowledge on the improve oven affect the adoption of the improved fish processing technology.	dmnl	(Kopainsky et al., 2012)

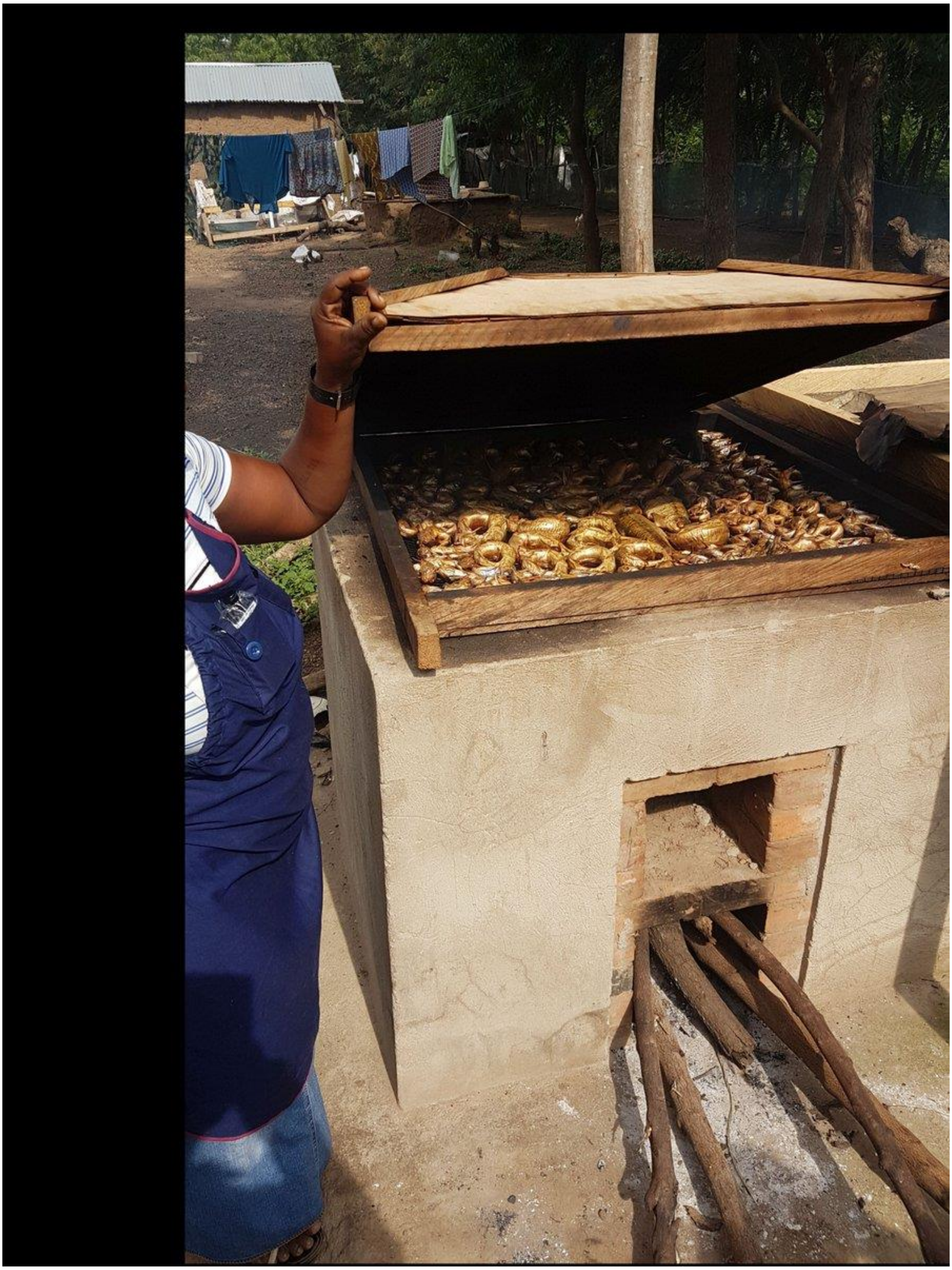
Effect of Non-adoption on Acceptability in Local Oven	Effect_of_Non-_Adoption_on_Acceptability_in_Local_Oven" = GRAPH(Share_of_Non_Adoptors) (0.000, 0.060), (0.333333333333, 0.150), (0.666666666667, 0.780), (1.000, 0.920) This is how non-adoption of the local fish processing technology affects its acceptability.	dmnl	(Kopainsky et al., 2012)
Effects of Non-adoption on Knowledge on Local Oven	Effects_of_Non-Adoption_on_Knowledge_on_Local_Oven" = GRAPH(Share_of_Non_Adoptors) (0.000, 0.120), (0.250, 0.309), (0.500, 0.621), (0.750, 0.860), (1.000, 0.950) This is how non-adoption of the local fish processing technology affects the level of knowledge processors have on the local oven.	dmnl	(Kopainsky et al., 2012)
Household Savings	Household_Savings = MAX (0, Profit_from_Locally_Processed_Fish-(Reinvestment_into_Fish_Business+Average_Household_Expenses)) The money fish processors save after the household expenses and also reinvesting into the fish processing business.	Cedis/year	
Indicated Acceptability in Improved Oven	Indicated_Acceptability_in_Improved_Oven = Effect_of_Adoption_on_Acceptability_in_Improved_Oven This is the goal of the faith or trust in improved processing technology	dmnl	
Indicated Acceptability in Local Oven	Indicated_Acceptability_in_Local_Oven = "Effect_of_Non-_Adoption_on_Acceptability_in_Local_Oven" This is how the fish processors would like to stay or continuing with the local processing of fish and how they have come to accept it	dmnl	
Indicated Knowledge on Improved Oven	Indicated_Knowledge_on_Improved_Oven = Effect_of_Adoption_on_Knowledge_on_Improved_Oven This is how the fish processors wish to be able to use or get familiar with the improved processing technology.	dmnl	

Indicated Knowledge on Local Oven	Indicated_Knowledge_on_Local_Oven = "Effects_of_Non-Adoption_on_Knowledge_on_Local_Oven" This is how the fish processors wish to be able to use or get familiar with the local oven.	dmnl	
Initial Acceptability in Improved Oven	Initial_Acceptability_in_Improved_Oven = 0.1 The extent of acceptability by fish processors adopting the improved oven over the years and is used to initialize the model	dmnl	(Kopainsky et al., 2012)
Initial Acceptability in Local Oven	Initial_Acceptability_in_Local_Oven = 1-Initial_Acceptability_in_Improved_Oven The level of acceptance by fish processors using the local oven over the years. This is used to initialize the model	dmnl	(Kopainsky et al., 2012)
Initial Knowledge on Improved Oven	Initial_Knowledge_on_Improved_Oven = 0.1 The extent of knowledge by fish processors adopting the improved oven over the years. This is used to initialize the model.	dmnl	(Kopainsky et al., 2012)
Initial Knowledge on Local Oven	Initial_Knowledge_on_Local_Oven = 1-Initial_Knowledge_on_Improved_Oven The level of knowledge by fish processors using the local oven over the years. This is used to initialize the model.	dmnl	(Kopainsky et al., 2012)
Ovens Affordability	Ovens_Affordability = MIN (1, Savings_Towards_Buying_Oven/Cost_of_Investment_in_Ovens) This is to determine whether fish processors can afford the cost of investment of the oven. This is determined by calculating the profit from fish processing and the cost involved in purchasing the oven over the years.	dmnl	
Profit from Locally Processed Fish	Profit_from_Locally_Processed_Fish = Revenue_From_Locally_Processed_Fish-Average_Operational_Cost_of_Locally_Fish_Processing This is the profit made from locally processed fish over the years by fish processors. This is estimated by deducting the cost of fish processed locally and revenue from locally processed fish.	Cedis/year	

Proportion of Profit Towards Oven Purchase	Proportion_of_Profit_Towards_Oven_Purchase = 0.25 This is the proportion of household savings directed towards the purchasing of oven. As this proportion increases, the savings towards buying oven increases over the years.	dmnl	
Quantity of Locally Processed Fish	Quantity_of_Locally_Processed_Fish = GRAPH(TIME) (2015.000, 1260), (2016.000, 1327), (2017.000, 1322), (2018.000, 1375), (2019.000, 1450) The quantity of processed fish by fish processors over the years.	Kg/year	Interview with some members from the Central and Western Fishmongers Improvement Association, Ghana (CEWEFIA), 2020
Reinvestment into Fish Processing Business	Reinvestment_into_Fish_Business = 500 This is the amount of money which fish processors reinvest into the fish processing business after gaining some profits. This is not done by every fish processor, but some processors do it upon interviewing them	Cedis/year	Interview with some fish processors, 2020
Relative Profitability	Relative_Profitability = 1.7 This is the comparative of profit from fish locally processed and that of the fish processed using the improved processing technology.	dmnl	
Revenue from Locally Processed Fish	Revenue_From_Locally_Processed_Fish = Quantity_of_Locally_Processed_Fish*Average_Unit_Price_of_Locally_Processed_Fish This is the amount of money generated from the sales of processed fish over years.	Cedis/year	
Share of Adopters	Share_of_Adopters = Adopters/(Adopters+Non_Adopters) The proportion of adopters out of the total population of fish processor or smokers in the area.	dmnl	
Share of Non-adopters	Share_of_Non_Adoptors = 1-Share_of_Adopters UNITS: dmnl Time_to_Adjust_Acceptability = 3	dmnl	

	This is the time at which the acceptability of improved fish processing or smoking technology last. It can be adjusted depending on the adopter.		
Sensitization input	Sensitization_Input = 0.28 This is the effort to put in place to increase the awareness for fish processors to accept the improved oven	dmnl/year	
Time to Adjust Acceptability	Time_to_Adjust_Acceptability = 3 This is the time at which the acceptability of improved fish processing or smoking technology last. It can be adjusted depending on the adopter	year	
Time to Adjust Knowledge	Time_to_Adjust_Knowledge = 3 This is the time at which fish processors can adjust to the level of knowledge of improved fish processing or smoking technology. It can be adjusted depending on the adopter.	year	
Total Adoption Potential	Total_Adoption_Potential = (Adoption_Potential_from_Knowledge_on_Improved_Oven*Adoption_Potential_from_Acceptability_in_Improved_Oven*Adoption_Potential_from_Affordability*Relative_Profitability) This is the overall adoption from all the adoption potential of improved fish processing technology.	dmnl	
Total Dis-adoption Potential	Total_Disadoption_Potential = (Disadoption_Potential_from_Acceptability_in_Local_Oven*Disadoption_Potential_from_Knowledge_on_Local_Oven) This is the overall non-adoption from the three-adoption potential of local fish processing technology.	dmnl	
Training Input	training_input = 0.05 This is the effort put in place to increase and also add unto the existing knowledge on the improved oven	dmnl/year	

Appendix 111: Images of the "Ahotor Oven" or Comfort Oven



An overview of the Ahotor oven

Source: USAID Sustainable Fishery Management Project

Section of the USAID officials and some fish processors inspecting the Ahotor oven with smoked fish in Elmina.
Source: USAID Sustainable Fishery Management Project

Some fish processors receiving some training from Central and Western Fish Mongers Improvement Association under the SFMP by USAID.

Source: USAID Sustainable Fishery Management Project

Some fish processors in the Elmina Municipality with the improved oven with fish on it.
Source: USAID Sustainable Fishery Management Project.