Peruvian fishmeal industry resilience to El Niño Southern Oscillation (ENSO) Events: Implications for industry structure

by

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Abstract

With the recent increase in record-breaking weather events and the inherent susceptibility of the fishmeal industry to temperature fluctuations, the industry dynamics and sustainability of the Peruvian fishmeal sector has gained renewed attention. Among important causes of concern are the cyclical impact of El Niño Southern Oscillation (ENSO) events on productivity and profitability of fishmeal producing firms, long-term structural changes in the industry, and resulting socio-economic consequences. Although distinct risk management strategies have been implemented by industry players and a range of policy initiatives have been introduced by the government over the years, the firms in the Peruvian fishmeal industry remain highly susceptible to the effects of ENSO events. The increased frequency and magnitude of ENSO events over the past decade has forced relatively less resilient firms out of business and has been accompanied by an observable trend towards increased industry concentration. While there is a potential for efficiency gains and economies of scale from increased concentration, policy makers and industry players have concerns about negative social implications from declining numbers of small and medium firms and shifting competitive dynamics in the industry. As a result, policy-makers and industry stakeholders are in the continuous search for effective strategies and mechanisms for enhancing the resilience of individual fishmeal producers and the overall industry to the effects of ENSO events.

The objective of this study is to expand the understanding of factors that affect the resilience of firms to ENSO events in the Peruvian fishmeal industry. The analysis is based on a panel database that combines information from the Peruvian Instituto Nacional de Estadística e Informática (Statistics Institute), Aduanet (Peruvian Customs website), and the Oceanic Niño Index (ONI). The objective is to identify firm characteristics and factors that can potentially enhance the resilience of a firm to the negative impacts of ENSO events. The specific period of study covers the ENSO event that lasted from July 2009 to April 2010. The resilience of individual firms is measured by applying system resilience framework proposed by Barroso et al. (2015). Subsequently, the effect of a range of characteristics on firm resilience is estimated using a fractional response logit method. Among key parameters of interest are the estimated effects of size, experience, location, and participation in government support programs. The results indicate positive relationship between resilience and experience, diversification, access to government subsidy programs, and share of imported inputs. The results also indicate a negative effect of firm size on resilience to ENSO events. The industry and policy implications of the findings are discussed, while highlighting the number of methodological limitations. The overall contribution of this study is twofold. First it presents an application of resilience triangle approach to measuring firm resilience in the context of Peruvian fishmeal industry. Second, it provides new insights on the factors affecting firm resilience to the negative impact of ENSO events. The findings have a potential to inform policy and industry initiatives designed to enhance the industry's ability to cope with negative consequences of ENSO events.

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Finally, I would like to thank all those who for one reason or another I am forgetting and were a fundamental part of my professional development.

Dedication

This project is dedicated to all those angels who watch my steps from heaven, you know who you are.

Chapter 1 - Introduction

The increase in global food demand, driven by urbanization and rising middle class in emerging markets, has been accompanied by the growing demand for animal proteins. Over the last decade, the global consumption of seafood has seen a marked increase (Gandhi and Zhou 2014). One of the main inputs in farmed fish production is fishmeal. It ensures high yields and productivity due to its nutritional attributes such as high amounts of amino acids and high palatability (Jackson 2006). In 2013, world fishmeal production reached the 4.9 million metric tons (MT), with Peru being the major producer and exporter accounting for 1,115,000 MT (22.6%) of production and 849,000 MT of exports (SEAFISH 2016).

After gold, copper, and oil, fishmeal is the fourth largest export product and a source of foreign currency income for Peru (Nolte 2017). According to 2014 data, the Peruvian fishmeal industry is responsible for over 200,000 jobs in fishing and 13,000 jobs in the processing sectors (Christensen et al. 2014). Due to its leading role in the global fishmeal market and the domestic economy, the Peruvian fishmeal industry has always attracted interest from policy makers and agri-food industry players. With the recent increase in record-breaking weather events and the inherent susceptibility of fishmeal industry to temperature fluctuations, the industry dynamics and sustainability of Peruvian fishmeal sector has gained renewed attention.

The Peruvian fishmeal industry is subject to a cyclical impact from El Niño Southern Oscillation (ENSO) Events. Historically, ENSO had a particularly strong impact on Peruvian fisheries during nine distinct periods since 1980. From 2009, the Peruvian government has established measures like Individual Vessel Quotas (IVQs) and fishing seasons depending on the availability of biomass in order to reduce the impacts of ENSO on its fisheries and fish population (Tveteras, Paredes, and Peña-Torres 2011). During the most recent ENSO event from

November 2014 to April 2016, the Peruvian fishmeal industry experienced a 24% drop in production resulting in a 17% drop in exports (SEAFISH 2016). Despite the government efforts to protect the industry, many firms did not survive the shock and the industry experienced a significant structural shift. The analysis of industry concentration dynamics throughout the ENSO shocks indicate a marked increase in concentration based on Four-Firm Concentration Ratio (CR4) and the Herfindhal-Hirschman Index (HHI). This dynamic has forced the policy makers and industry stakeholders to re-evaluate the risk management strategies and programs designed to enhance the industry's resilience to ENSO related shocks.

This thesis contributes to the literature by presenting an application of the system resilience framework to (i) measure the resilience of Peruvian fishmeal producing firms, and (ii) to examine factors affecting firm resilience. System resilience is broadly defined as "…the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks" (Walker et al. 2004, 4). The concept of resilience embraces the fact that every productive system will always be subject to some level of unpreventable vulnerability (Jüttner and Maklan 2011), thereby demanding that the system either endure or adapt for survival (Lindbloom, Shanoyan, and Griffin 2017). The shocks that ENSO causes are not new to the fishmeal industry and to this day firms continue to adapt to counteract them. These adaptations include opening more processing facilities, increasing fishing fleet size, diversifying input and output, or increasing input storage capacity.

Existing studies have focused on the effects of ENSO on fishmeal prices and other commodities as well as the changes in price ratios between fishmeal and substitutes such as soybean meal (Ubilava 2014, 2017), responses of agriculture to information (Chen, McCarl, and Hill 2002), and responses on the availability of different fish species (Elizarov et al. 1993; Asche and Tveterås 2004; Sun et al. 2006) without addressing the impacts it has on performance and management strategies at the firm level. Although the resilience framework has been widely used in different industry contexts, such as the automotive industry, urban infrastructure, and production agriculture (Sheffi 2005; Tierney and Bruneau 2007; Zobel 2010; Carvalho et al. 2011; Pant, Barker, and Zobel 2014; Barroso et al. 2015; Güller et al. 2015; Lindbloom, Shanoyan, and Griffin 2017), literature examining the resilience of agricultural production systems to natural and man-made shocks is still underdeveloped.

1.1 Objectives

The overall objective of this research is to fill the gap in the literature by providing insights on factors affecting the resilience of firms in the Peruvian fishmeal industry to weather related shocks. It seeks to answer the following research question: What factors can potentially enhance the ability of Peruvian fishmeal producers to withstand and recover from the negative impacts of ENSO events? More specifically, the thesis aims to achieve the following three objectives:

1. Develop a quantitative measure of resilience of Peruvian fishmeal producing firms to the effects of an ENSO event;
2. Analyze factors affecting resilience of Peruvian fishmeal producing firms; and
3. Present implications for policy and industry decision makers

The findings have a potential to inform public policies and management strategies designed to mitigate negative impact of future ENSO events.

1.2 Overview of the Resilience Framework

The conceptual framework used in this study is based on the resilience triangle approach. The resilience triangle framework relies on graphical analysis to derive a resilience index that reflects both the impact of the shock on performance and the length of the time to recover (Sheffi 2005; Tierney and Bruneau 2007; Barroso et al. 2015; Lindbloom, Shanoyan, and Griffin 2017). For example, if the vertical axis represents the performance measure which can be affected by the shock and the horizontal axis represents time, then the resilience index reflects the area of a triangle defined by the following three points: (A) the level of performance prior to a shock, (B) the lowest performance level during the shock period, and (C) the post-shock (recovered) level of performance. The area of triangle is inversely related to the resilience. For example, a firm with a larger area of triangle is less resilient (i.e. has a larger drop in performance due to the shock, and a longer recovery period) compared to a firm with a smaller area of triangle.

1.4 Overview of Data and Methods

This study considers the ENSO event from July 2009 to April 2010 as a shock period of interest. Two datasets were used to conduct the analysis. For the analysis of industry concentration dynamics, a dataset was obtained from Superintendencia Nacional de Aduanas y de Administración Tributaria (SUNAT) official database of reports on fishmeal firms' monthly exports. In addition, data from the National Economic Survey were gathered from the Peruvian Statistics Institute, Instituto Nacional de Estadística e Informática (INEI), on financial and production characteristics of firms. They were used for calculating the resilience index of each firm. After calculating a resilience index for each individual firm, a fractional response logit model was used to estimate the effects of different production, marketing, and management characteristics on firm resilience.

1.5 Overview of Results

The estimation results indicate that the experience of the fishmeal processing company, diversification of inputs and outputs, and a level of government support have positive effect on firm resilience. They also indicate that the size of firm assets (buildings, refrigerated storage, etc.) have a negative effect on resilience. It is important to note that the limited sample size did not provide sufficient power for estimating the effects of a squared term for assets. Thus, it remains undetermined whether there exists a certain size at which the relationship between size and resilience turns positive.

1.6 Thesis Outline

The rest of the thesis is organized as follows: the next chapter provides an overview of the fishmeal industry followed by the section presenting the literature on resilience and the resilience framework. Studies of public policies designed to counteract ENSO in fisheries and other agri-business contexts and system resilience are also discussed. The section on data and methods provides detailed explanation of the model, the data, and the variables selected for the empirical analysis. The results section presents key findings and discussion of important implications for policy and industry decisions. Finally, the conclusions section provides a summary of the results, major implications, and recommendations for further research.

Chapter 2 - Background

FAO (2016a) finds that worldwide supply for farmed fish has increased, bringing major implications to the actors involved in the supply chain. Since 2014, human consumption of farmed fish surpassed the consumption of wild-caught fish, and more inputs are being used to produce farmed fish. One of the main inputs in the production of farmed fish is fishmeal. It ensures high yields and productivity due to its nutritional attributes such as high amounts of amino acids and high palatability for fish (Jackson 2006). Since the mid-1900s, Peru has dominated the fishmeal industry, and today it produces more than 40% of the world's total output.

2.1 History of the Peruvian Fishmeal Industry

Until 1939, the Peruvian fishing industry was not operating as an industrialized commercial segment of economy and was characterized by predominantly small-scale subsistence producers (Villanueva 1962). General Oscar Benavides tried to push the development of the industry during his regime (1933-1939) through the protection and the creation of facilities for those with entrepreneurial pursuits, and potential. The first companies that ventured were mainly producers of frozen fish even though locally there was not enough demand for it and they mainly relied on exports (Caravedo Molinari and Gorman 1977).

General Prado came to power in 1939 and was succeeded by General Bustamante in 1945. During both presidencies, the trade relationships between the United States and Peru started to get tighter due to a mutual belief that industrialization and trade between both nations will bring reciprocal well-being (Caravedo Molinari and Gorman 1977). On one side, with hostilities from World War II at its peak, the United States incentivized the industrialization of the Peruvian fishery to supply the Allied Forces with fish, supplementing the affected American fish supply chain (Axelrod 2009). On the other side, the Peruvian government allowed American enterprises to explore the Peruvian natural resources for its exploitation and commercialization (Caravedo Molinari and Gorman 1977). Increasing demand provided a window for new companies to enter the market leading to the growth of the industry that continue through to the end of the war.

The United States was the main destination of Peruvian fish products, but towards the end of WWII this trend was going to change. The USA adopted protectionist measures, such as import tariffs, to revive its local fishing industry (Maldonado Felix and Puertas Porras 2014). To add to the unfavorable market conditions, the Bustamante regime was ended by General Manuel Odría. This represented the end of the protectionist measures adopted to protect exporters, and only those who produced for the local markets would remain protected.

It was not until the beginning of the Korean War that the United States would show interest in Peruvian fish once again. As advantageous prices were present in the world markets, the Odría regime reinstated the beneficial conditions for Peruvian fisheries. Caravedo Molinari and Gorman (1977) found that this shifted the production from 45,000 MT to approximately 113,000 MT in 1952. The end of the Korean War, reintroduced protectionist barriers by the USA, leading to a fall in exports and the need to look for new markets by the Peruvian fisheries (Caravedo Molinari and Gorman 1977).

In the 1950s, seeking to diversify from American markets and looking for uses for the byproducts of their frozen fish production, Peruvian fisheries imported presses from Norway to process fishmeal and fish oil (Iparraguirre Cortez 1968). This gave birth to the Peruvian fishmeal and fish oil industries, in it to the changes in the structure of Peruvian fisheries and leading what is has to become today. This growth was led by the high availability of anchoveta and the rapidly growing international demand for fishmeal. By the 1960s, the Peruvian industry has become the largest fishmeal producer of the world, adjudicating about a quarter of world production (Klarén 2017). In order to protect its fisheries from international exploitation, agreements with Chile and Ecuador were reached, fining or seizing boats that would not respect the agreement (Klarén 2017).

Increasing international demand for fishmeal triggered the opening of more fishmeal facilities, creating the need to stock the facilities with more fish. Fisheries changed from artisanal wooden vessels to iron cask vessels and increased their fleet size. The increase in fleet size brought adverse situations such as overfishing. Overfishing was aggravated when the Peruvian coasts were impacted by ENSO occurrences. ENSO events decreased the amount of anchoveta available in the coasts by increasing Sea Surface Temperatures (SST), which led the government to unsuccessfully try to address the overfishing issue through the establishment of annual fish catches. As a result, some fishmeal facilities moved their production to frozen and canned fish, reducing the world supply of fishmeal (Klarén 2017).

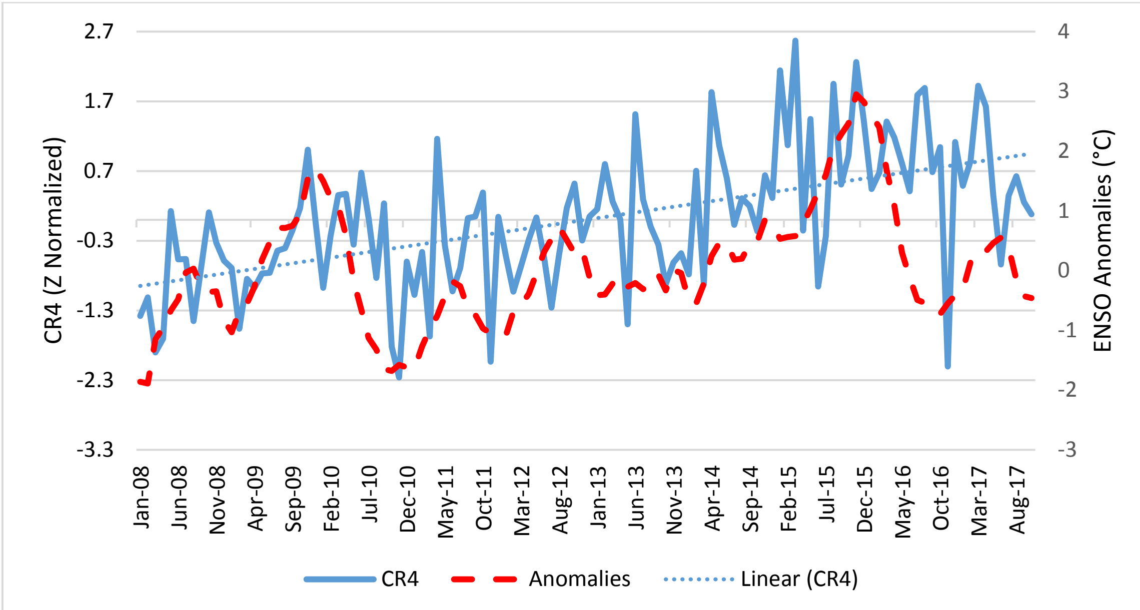
In the 1990s, accessible legislations passed by Peruvian Congress and greater investments boosted Peruvian fishmeal exports (Klarén 2017). The National Peruvian Fishing Company estimates that by 1995, Peru was in charge of 29% (1.8 million MT) of the world's fishmeal, ahead of Chile's 24% (1.6 million MT). However, by April 1997, the world and Peruvian fishmeal industries were struck by one of the strongest ENSO events in history that lasted until May 1998. ENSO decreased the production of fishmeal by 17% in 1997 and 47% in 1998.

The 21st century began with a promising recovery of the fishmeal industry in Peru when production reached 2.4 million MT. These good times did not last for long. The decade was marked by four ENSO events (2002, 2004, 2006, and 2009) that halted the growth of the industry. Concerns about weather events brought tighter fishing regulations and the creation of Individual Vessel Quotas (IVQs) for anchoveta catches. Individual Vessel Quotas were created with the goal of improving the economic, social, and biological situations of the Peruvian fisheries (Young and Lankester 2013). These measures did not stop ENSO negative effect on the production of fishmeal, pushing it to its lowest point in 2014.

By 2015, the fishmeal industry produced 800 thousand MT averaging 1.1 million MT in the past ten years. Exports during this year dropped by 19.6%, representing its lowest point in a decade. Fish extraction represented about 0.8% of the Peruvian GDP divided equally between the extraction sector and a 0.4% in the transformation sector (Ministerio de la Producción 2016). It is uncertain the amount of employment that fishmeal production generates, but OCEANA (2016) reports that about 60,000 people depend on fisheries in Peru. Christensen et al. (2014) estimated that fisheries generated about 232,000 jobs in Peru with 5% dedicated to the fishmeal industry without counting those who are indirectly involved.

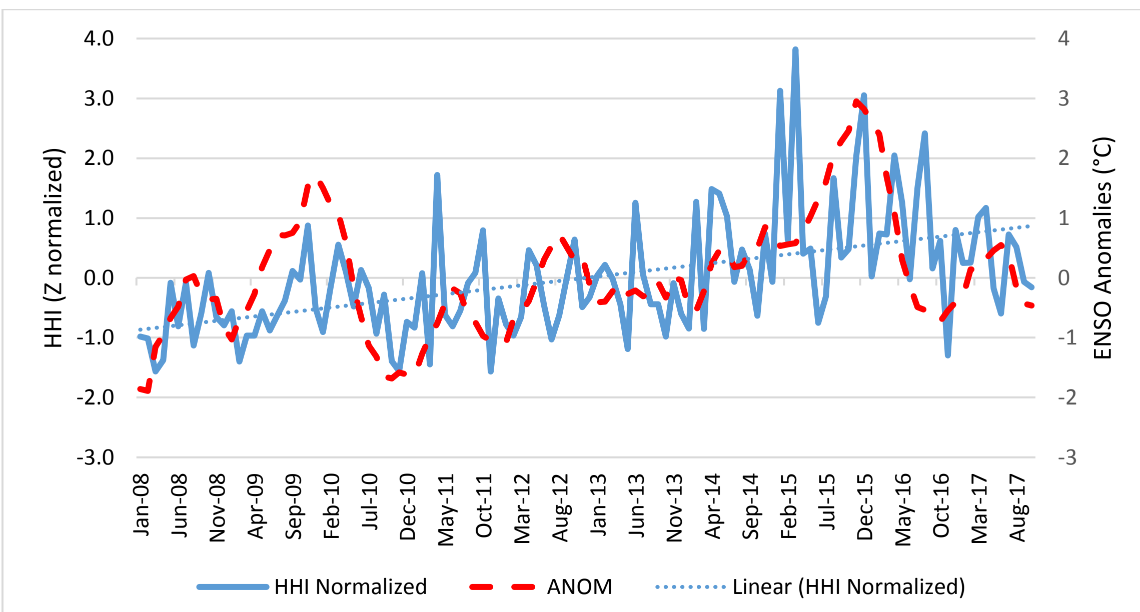
The analysis of historical data shows that the occurrence of ENSO events coincide with the increased concentration in the fishmeal industry. As ENSO anomalies increase over time, the fishmeal industry shows higher concentration (Figure 2-1 and Figure 2-2). During the ENSO 2014, average monthly CR4 reached 76% and average monthly HHI of 2,031.

Figure 2-1. Peruvian Fishmeal CR4 Behavior to Enso Events



Source: Own creation with SUNAT data

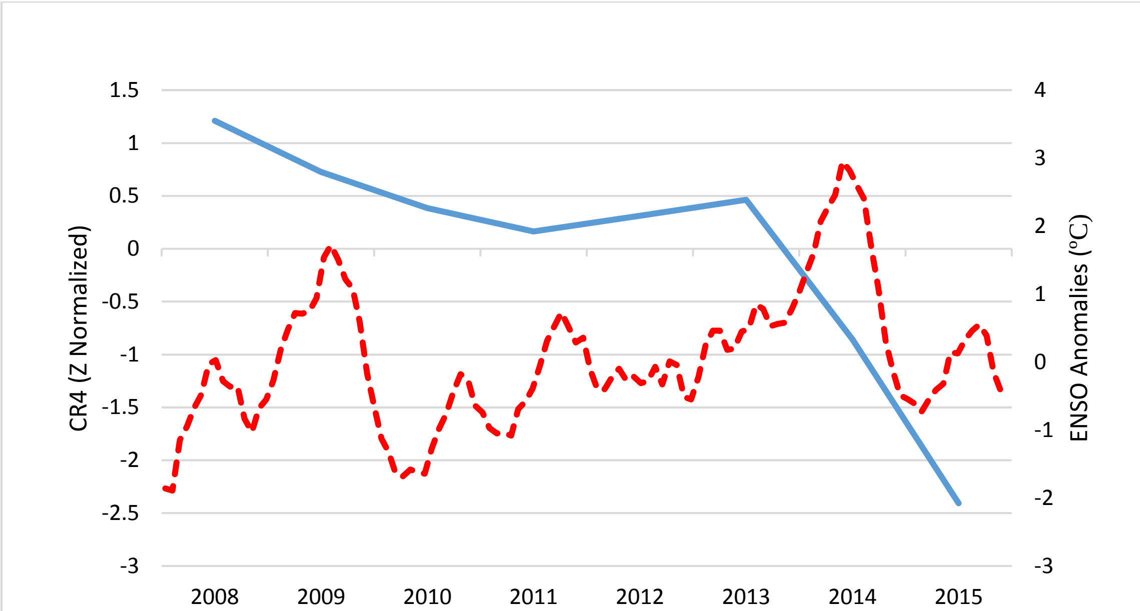
Figure 2-2. Peruvian Fishmeal HHI Behavior to Enso Events



Source: Own creation with SUNAT data

The concentration of the Peruvian fishmeal industry can be compared to what happens to another industry not affected by ENSO events such as the Peruvian copper industry. The Peruvian copper industry is becoming less concentrated over time (Figure 2-3). In addition, during ENSO events, there is not an increase in concentration with the occurrence of an ENSO event.

Figure 2-3. Peruvian copper CR4 during ENSO events.



Source: Own creation

2.2 Peruvian Fishmeal Supply Chain

The year 2014 represented the first year in which aquaculture fish was consumed more than wild-caught fish (FAO 2016a). To sustain the demand for farmed fish it is important that farmed fish diets contain the appropriate amounts of amino acids to maximize the growth of fish. It is fishmeal that guarantees high yields and productivity due to its nutritional attributes such as high amounts of amino acids and high palatability (Jackson 2006). Securing fishmeal supply brings certainty to the growth of the supply of farmed fish. To do this, the fishmeal supply chain needs to be healthy and firm. The production and distribution of fishmeal involves three major participants: fishers, processors, and distributors (Copeinca 2010).

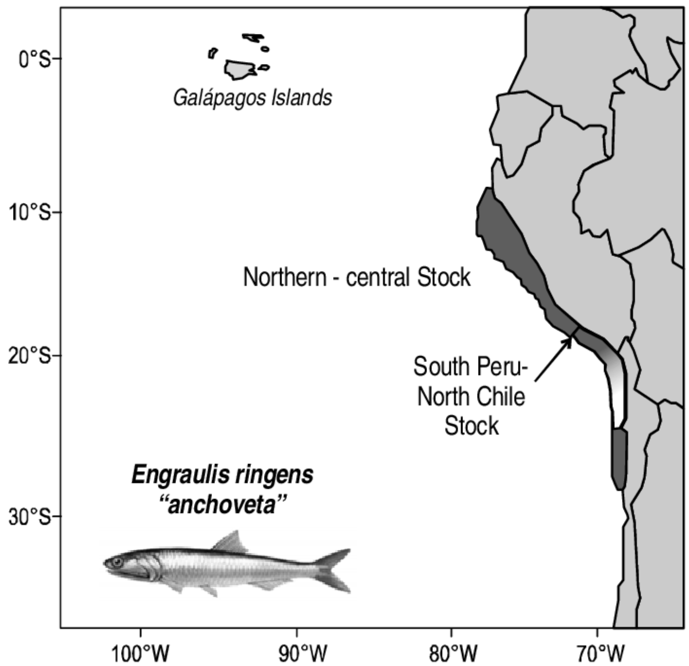
Fishers

Fishmeal is a powder or flour produced from the drying and milling of mainly pelagic species of fish and seafood by-products (Stickney and McVey 2002; SEAFISH 2016). Pelagic species are used to produce fishmeal because of their small or almost non-existent demand for human consumption and large availability. They are found from the surface of the ocean to about 655 feet deep and coexist in large banks, making its fishing beneficial. Examples of pelagic species include the anchovies (also known as anchoveta), sardines, tuna, and mackerel (NOAA 2017b). The most used pelagic species to produce fishmeal are the anchoveta, accounting for 40% of the fishmeal production, followed by the 11% of the by-products generated from herring processing (SEAFISH 2016). For 2013 catches, if by-products were not considered in the production of fishmeal, anchoveta composed 94% of the fishmeal production, and capelin a scarce 4% (FAO 2016b). Fishers are in charge of catching the anchoveta that will be processed into fishmeal.

Most of the anchoveta banks are found near the Peruvian Pacific Coast, and it is considered one of the largest fisheries of the world (

Figure 2-4). The Banco Central de Reserva de Peru (BCRP) reported that on average from 2003 to 2014, Peruvian fisheries landed about 5.6 million MT, with a maximum catch in 2004 of 8.8 million MT. Moreover, BCRP reports that Peru destines more than 90% of its annual catches to the production of fishmeal and fish oil. In addition to the relevance it has to the world production of fishmeal, anchoveta provides about 60,000 jobs in Peru and guarantees the well-being of about 800,000 people that depend on them (OCEANA 2016).

Figure 2-4. Distribution of anchoveta banks along the coasts of Peru and Northern Chile



Source: Perea et al. (2011)

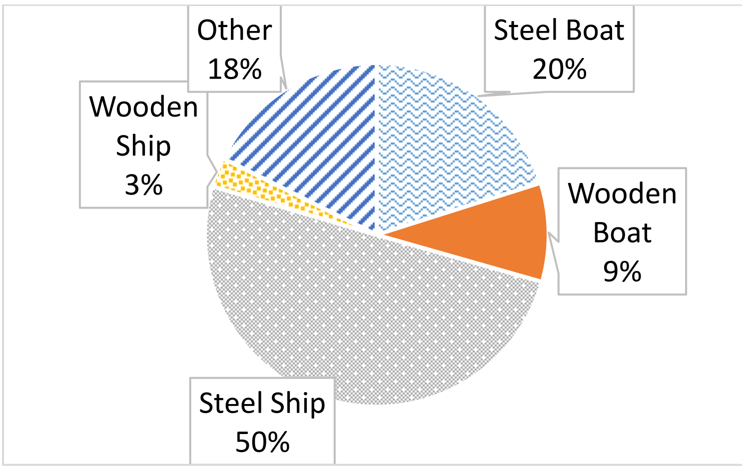
Peruvian anchoveta fishers are distributed all along the Peruvian Coast. Data from Ministerio de la Producción estimates that Port Chimbote alone accounts for about 24% of the anchoveta landings. Other important ports for anchovy landings are Chicama (15.5%), Chancay (9.8%), and Callao (9.1%).

Purse seine vessels[1] made out of different materials are used along the Pacific Coast of Peru to catch anchoveta. The industrial fishery fleet for indirect human consumption is mainly composed by naval steel vessels and wooden vessels. The Annual Survey in 2014 reported that out of the total firms surveyed that develop fishing activities, 50% are steel ships, 20% steel boats, and only 12% are made of wood (Figure 2-5). Steel vessels have the capacity to store

[1] Purse seine vessels are the boats that use a fishing net, also referred as seine, to catch their fish.

between 100 to 850 cubic meters (m^3), while wooden vessels range between 32 and 100 m^3 (Paredes and Gutiérrez 2008). Fleet vessels are usually owned by vertically integrated corporations, while wooden vessels are owned by individual fisherman (Arias Schreiber 2012).

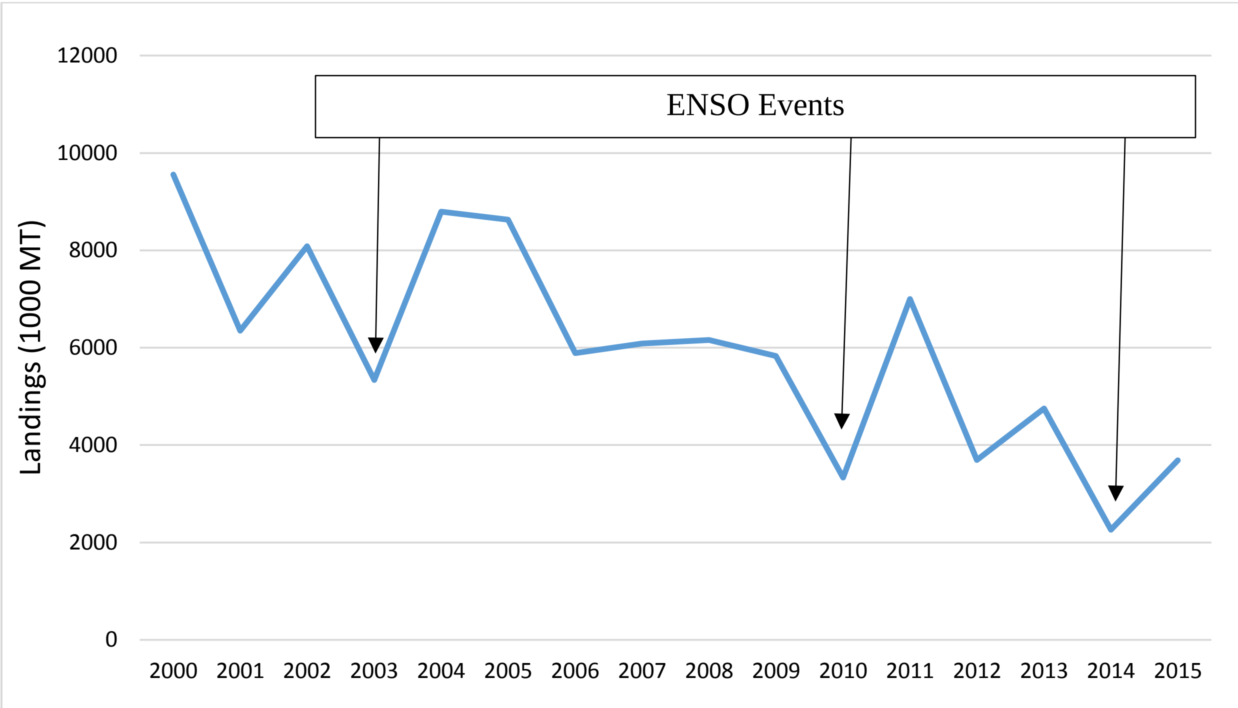
Figure 2-5. Composition of the Peruvian fishing fleet according to the National Economic Survey 2014



Source: Instituto Nacional de Estadística e Informática (2017)

The well-being and productivity of the fishery can be affected by a series of factors such as overfishing and adverse weather conditions (Guy 2016), thereby reflecting the fluctuations of world and national landings (Figure 2-6). Most of the fluctuations suffered by the Peruvian-Chilean Pacific Coast are attributed to the effect of El Niño Southern Oscillation (ENSO). ENSO effects raise Sea Surface Temperatures (SST), thereby reducing the availability of nutrients for anchovies. Peru was affected by an ENSO event in second half of 2009 that lasted until the first third of 2010. According to BCRP, Peru reduced its anchoveta landings destined for industrial use by 5% in 2009 and 46% in 2010 compared to 2008, a Non-ENSO year. This reduction in catches causes a ripple effect to later affect the processing into fishmeal.

Figure 2-6. Anchovy Landings Destined for fishmeal production



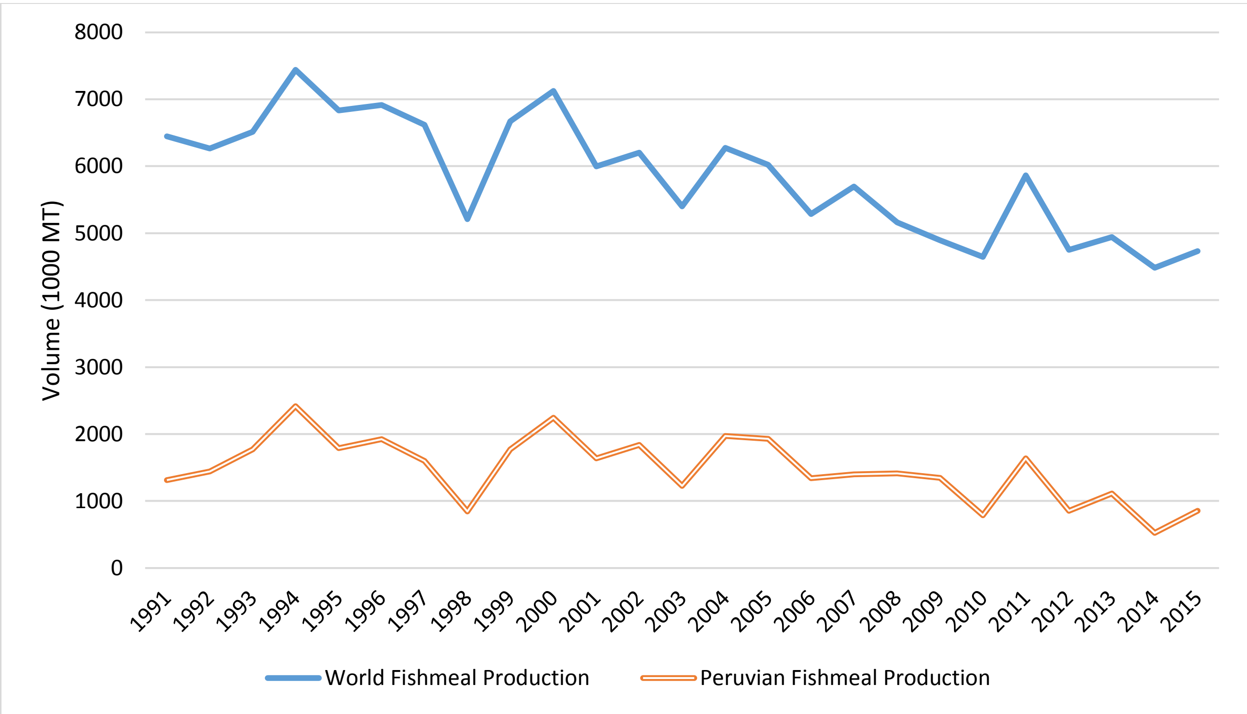
Source: Ministerio de la Producción (2016)

Fishmeal Processors

Evidence shows that the utilization of fishmeal by aquaculture diets is increasing, but it remains important for other sectors as well. SEAFISH (2016) finds that in the 1960s the utilization of fishmeal by aquaculture was almost non-existent, and it was the pig (50%) and chicken (48%) industries that made use of almost all the fishmeal production. Today, 70% of the fishmeal production is destined to aquaculture diets (Jackson 2016), which accounts for the reliance on fishmeal for the proper development and supply of farmed fish. Not only is it important for the aquaculture industry, but Haifeng et al. (2009) find that introducing high quality fishmeal in diets for piglets increases their performance and health conditions.

Contrary to expectations, world fishmeal production has been decreasing since the end of the last century (Figure 2-7). Stronger weather events and legislations have reduced fish stocks and, respectively, thus reduced production from 6.38 million MT in 1990 to 4.73 million MT in 2015. It is during the weather events that the production of the industry has suffered the most in the three decades. ENSO 97-98, 09-10, and 14-15 represent three of the lowest points in the production of fishmeal throughout history where in the last one, the industry reached its lowest production in 25 years.

Figure 2-7. Fishmeal Production in Peru and the World



Source: Ministerio de la Producción (2016)

Individual countries have behaved differently with regards to their fishmeal production, but over the last 25 years, Peru has lead the industry with 852,000 MT produced in 2015 followed by Thailand with 420,000 MT, China with 400,000 MT, Chile with 322,000 MT, Vietnam with 285,000 MT, and the USA with 263,000 MT. Although Peru keeps the lead in fishmeal production, its 2015 fishmeal figures have also been significantly reduced from 1.43 million MT.

Since its early beginnings, the process of making fishmeal has not changed significantly. FAO (1986) describes the process of making fishmeal with different stages, beginning with the reception of the anchoveta in the processing plant, which is later cooked. To remove all the fluids from the cooking process, the cooked anchoveta goes through a press. The solid material is then centrifuged, dried, and finally milled into fishmeal. After cooling, it is either packaged into bags or stored in sheds and silos. The production is later passed on to the distributors.

The cost of opening a fishmeal processing facility can vary according to the installed capacity desired (FAO 1986). Results from 1984 show that the investment of opening a processing plant was around $4.2 million/MT, which in today's dollars would represent a $9.7 million/MT. About 42% of this investment accounted for the fishmeal line. A fishmeal processor's most significant production expenses included marine inputs, accessories and spares, and wages. INEI 2015 survey data revealed that more than half of the total costs of production come from the purchase of marine inputs.

The number of Peruvian fishmeal plants has grown steadily, from 137 in 1999 to 170 in 2015 (Ministerio de la Producción 2016) located along the Peruvian coasts. In 2014, 15% of the Peruvian fishmeal production came from Port Pisco (Ica department) followed by a 14% in Port Callao (Lima department), and a 12% in Port Chicama (La Libertad department). Although most of the production came from Port Pisco, the majority of the fishmeal plants are located in the department of Ancash.

Fishmeal processors rely on the availability of anchoveta in order to take out their production. Most of them have their own fishing fleet to guarantee the availability of their main input, but this does not

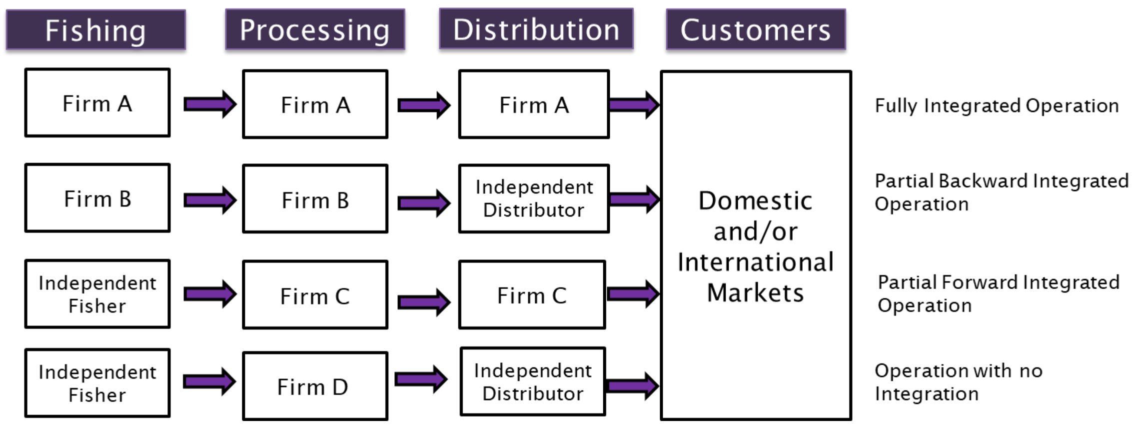
Distributors

After the production of fishmeal, fishmeal processors either sell their production directly to customers or rely on third parties. Little is known about fishmeal distributors due to their share of the market. Third parties include brokers or representatives that either merchandize fishmeal in local markets (about 10%) or distribute it to international markets (about 90%).

In 2015, the major market for the Peruvian fishmeal is China. China imports 75.8% of the Peruvian fishmeal exports followed by Germany 5.89%, Chile 3.39%, and Taiwan 3.38% (Ministerio de la Producción 2016).

The Peruvian fishmeal supply chain is summarized in the three major stages: fishing, processing, and distribution. These stages are in constant interaction among each other. Fishmeal processors have various levels of vertical integration. In some cases, fishmeal processors backward integrate into the fishing activity by owning a fishing fleet and operations to guarantee consistent and reliable supply of input. In other cases, fishmeal processors forward integrate by developing distribution capabilities to increase their involvement in marketing and wholesale activities. Figure 2-8 maps the Peruvian fishmeal supply chain and shows the interactions between its links.

Figure 2-8. Peruvian fishmeal supply chain

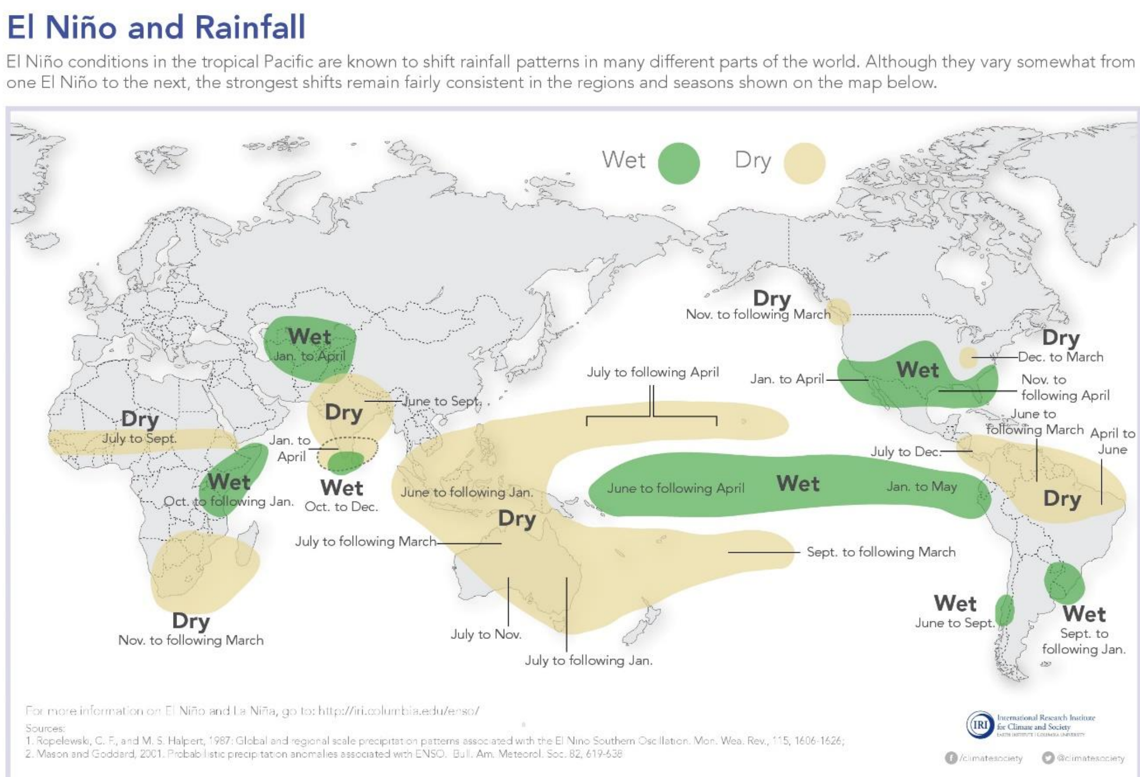


2.3 El Niño Southern Oscillation (ENSO)

When fishermen in the coasts of Peru and Ecuador noticed a reduction on their catches during Christmas time matched with the increase in rainfall and temperatures, they did not know they were facing what we know today as El Niño Southern Oscillation (ENSO). Although different indices for the determination of an ENSO event are used in climatology and climate economics, the Southern Oscillation Index (SOI) and the Oceanic Niño Index (ONI) are the most widely used. The Southern Oscillation Index (SOI) obtains measures on air-pressure from Tahiti and Darwin (e.g. Brunner (2002), Ubilava and Holt (2013), Cashin, Mohaddes, and Raissi (2017)). Despite its usefulness in previous research, the Sea Surface Temperature (SST) in the Niño 3.4 region from the ONI is being applied more regularly in research regarding ENSO (e.g. Hsiang, Meng, and Cane (2011); Hsiang and Meng (2015); Ubilava (2017)), and considering it is a region closer to the Peruvian coasts the SST is a better indicator of an ENSO shock. An ENSO event is determined by NOAA (2017c) when for "five consecutive 3-month running mean of SST anomalies in the Niño 3.4 region is above the threshold of +0.5°C".

The increase in Sea Surface Temperatures (SST) on the eastern Pacific Ocean changes rainfall and temperature. This effect causes multiple teleconnections around the world (NOAA 2017a) (Figure 2-9). In the case of the Peruvian Pacific Coast, and as fishermen stated, it is characterized by an increase in rainfall and temperatures. Also in the Pacific, warm ocean conditions do not allow the upwelling process to develop properly ("Impacts of El Niño on Fish Distribution" n.d.), and plankton is unable to photosynthesize (National Geographic 2015; Drye 2015). Contrary to these effects in the eastern Pacific, El Niño is the cause of droughts in the Atlantic zones of South America and the major western Pacific islands.

Figure 2-9. El Niño effects around the World

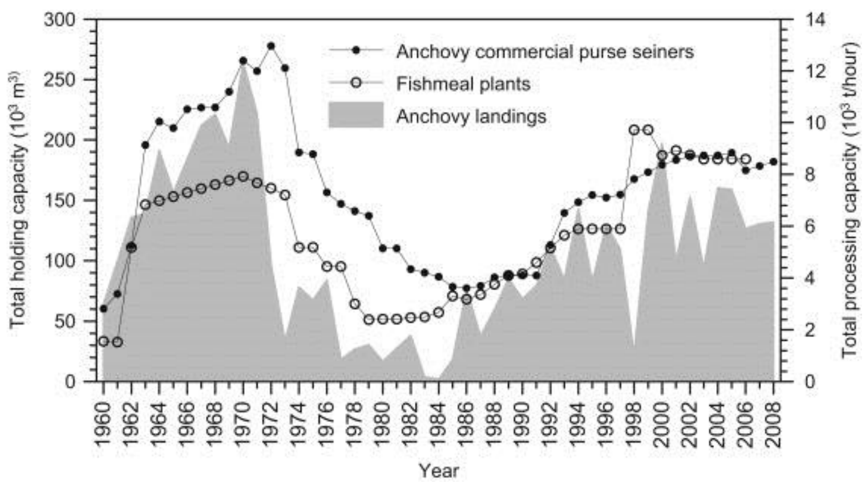


Source: Ropelewski and Halpert (1987); Mason and Goddard (2001); Martins (2012)

Because ENSO occurs primarily due to disturbances in the Pacific, fisheries are the first ones affected by ENSO shocks. When the upwelling process is stopped by warm waters, banks of fish find it hard to find plankton, their main source of food, thus reducing the fish available in the sea that depend on it. Examples of these effects are addressed by Elizarov et al. (1993) on the

Peruvian jack mackerel change on distribution, Asche and Tveterås (2004) on the vulnerability to ENSO of the Peruvian anchoveta and the Chilean jack mackerel, and Sun et al. (2006) on the increase in fishing costs during the ENSO 97-98 shock. The effects are later transferred to industries that depend on fish as their main input. Some of these industries include frozen fish, canned fish, fish oil, and fishmeal. Considering that fishmeal is a great source of income for the Peruvian economy, during ENSO 97-98, welfare losses were estimated to be around the $319.32 million causing long term economic problems for Peru (Sun et al. 2001). Figure 2-10 shows the close relationship between the anchoveta landings, fishmeal plants, and industrial purse seiners.

Figure 2-10. Behavior of the Peruvian anchoveta and fishmeal industry in Peru.



Source: Arias Schreiber and Halliday (2013)

Implications for industry stakeholders and policy-makers

Industry stakeholders should to shape their risk management strategies to survive and recuperate from record breaking weather events such as ENSO. This is particularly true for medium and small fishmeal producers who are not only forced to reshape their strategies, but must also find the resources to cope with the impacts of ENSO, a problem that larger companies might not have. The failure to develop effective risk management techniques to minimize ENSO could lead to exiting the business or losing their market share, indicating their inability to recover. In the case of exiting the market, policy-makers have to find mechanisms to mitigate the environmental impacts, but also they have to be vigilant of the economic and social consequences.

At the industry level, managers have to make optimal decisions when allocating their resources and implementing strategies that not only ensure the survival of their firms, but also their well-being during the shock. Companies that have the resources to do so, increase their storage capacities of either inputs or finished goods.

In the long-run it can be hypothesized that firms with a better position to cope with ENSO will likely increase market share leading to increased consolidation of the industry. However, to determine the certainty of our hypothesis, the resilience framework will be used to determine if the size of the companies affects their capacity to preserve themselves through the El Niño phenomena.

An increase in consolidation brings multiple economic and social side effects. Economically, consolidation can increase the bargaining power of the few fishmeal producers, possibly increasing fishmeal prices and negatively impacting the price of anchoveta catches. Socially, pushing out smaller firms could represent an increase in unemployment especially in fishing communities. Lastly, because of its importance in international trade, the fishmeal industry consolidation can also have policy implications.

Peruvian policy-makers have tried to address the overfishing issue by different means. The installment of total maximum limit of permissible catch in which the Instituto del Mar de Peru (IMARPE) calculates the available anchoveta biomass and establishes a maximum fishing quota. Furthermore, fishing seasons are installed depending on the data available on weather conditions. Additionally, in order to give smaller fishermen the ability to reach the anchoveta banks, individual vessel quotas (IVQs) were created which can be sold to other individuals. Moreover, no industrial vessel can fish within 10 miles off the Peruvian coast. And finally, the prohibition to extract and/or process anchovy specimens with a size smaller than 12 centimeters in length with a maximum tolerance of 10% of the catches. Furthermore, firms have adopted diversification and vertical coordination strategies to cope with the negative effects of ENSO. Although a great field of study, previous researchers have sidestepped due to the lack of available data.

Chapter 3 - Literature Review

The production and economic implications of ENSO events for agriculture and fishing have been widely studied. Policy and strategy initiatives to mitigate these effects differ around the world depending on the impacts that ENSO has in different regions of the world.

With regards to agricultural commodities, Adams et al. (1998) estimated that agriculture in the USA lost between $1.5 to $1.7 billion during the ENSO event from 1997-98. In addition, Hansen et al. (1998) examined the impacts that ENSO has in the southeastern USA on peanut, tomato, cotton, tobacco, corn, and soybean production finding that the event has a strong influence in the behavior of yields. Moreover, Legler et al. (1999), Phillips et al. (1998), Chen and McCarl (2000), and Tack and Ubilava (2013) find that on the majority of the crops, with some exemptions, yields are considerably decreased during ENSO events depending on the regions studied. Political entities have engaged in reducing the impacts of weather events. Chen et al. (2002) investigate the role that providing more detailed information about ENSO events has on the value of agriculture. They find that having more information available on the phases of ENSO "almost doubles the welfare impact" (Chen, McCarl, and Hill 2002). Nadolnyak and Hartarska (2009) examine crop disaster payments in the southeastern US and the impacts caused by weather events including multiple variables representing ENSO. They find that weather events have more impact on the final payment than other social or political variables. In addition, Keil et al. (2006) point out the droughts caused by ENSO in Central Sulawesi, Indonesia. They suggest that policy should focus on improvement of forecasts and facilitating the acquisition of low interest loans.

In the case of fisheries, Elizarov et al. (1993) find important changes in the distribution of jack mackerel in open waters during warm years. Furthermore, Asche and Tveteras (2004) state that Peruvian anchoveta and Chilean jack mackerel stocks are exposed to ENSO events and poor fisheries management. On the Peruvian side, Kroetz et al. (2016) examined the establishment of IVQs to the Peruvian anchovy. They find that profits were increased by 34-41%. With regards to Chile, Peña-Torres et al. (2017) find that Chilean fishermen shifted their fishing strategies to farther south and away from the usual 200 nautical miles. Jimenez-Umaña (2005) proposes that rationalizing fishing efforts can be beneficial for fisheries. Sun et al. (2006) examined the impacts of ENSO to the Taiwanese mackerel purse-sein fisheries. They estimate losses for fisheries around $6.22 million during the ENSO 1997-98. The lack of fish in the sea forced fishermen to spend more time fishing thus increasing their costs. Moreover, they argue that government remunerations to voluntarily reduce fishing efforts in Taiwan have not been very successful. Arias Schreiber (2012) analyzes the development of political measures to ensure the sustainability of the Peruvian anchoveta fisheries, and the further fishmeal production. Legislative measures include exploration of the biomass available in the sea deriving in the establishment of a Total Allowable Catch (TAC) for the north-central and southern regions, fishing seasons based on biomass availability, and closures of fishing seasons for at least three days if more than 10% of landings are below 12 cm of length. Vessels need to have a geo-localization system, and they are only allowed to carry out one fishing trip per day.

This negative effect on anchoveta fisheries transfers on to fishmeal processors in the aspect that they lack the required raw materials for the production of fishmeal and have to purchase them at higher prices, which has implicit social costs. Caviedes (1985) points out the negative effects that ENSO 1982-83 had all over Peru, and due to the lack of fish in the ocean, the Peruvian fishmeal production was stopped, resulting in an increase of the unemployment and crime. Muck (1989) states the dependence of the Peruvian economy on anchoveta catches suggesting that overfishing is one of the main causes of the collapse. He finds that catching anchoveta's predators is a way to solve the issue. Although this could have been a solution, today the Peruvian government only allows anchoveta fishing to be destined for fishmeal. Golnaraghy and Kaul (1995) bring out the importance to have policies that anticipate the effects of ENSO in order to reduce its induced social costs for Peru. They state that during the 1972-73 ENSO, anchoveta catches were reduced significantly thus diminishing the fishmeal production which led to the nationalization of the Peruvian fisheries. Shortly after, an agency for the prediction of ENSO was created. Sun et al. (2001) examined the effects of ENSO on welfare in the international trade of fishmeal. They find that fishmeal exports in Peru and Chile decreased during ENSO 1997-98 by $8.166 million, but was not as harmful as the ENSO 1983 due to cost saving initiatives learned. Chambers (2005) reports that ENSO 1982-83 caused great migration from the fishing areas of Peru to the capital, Lima, finding local governments unaware of the consequences that this population increase can bring. Arias Schreiber (2012) also states that when the TAC has been met, a fishing ban on anchoveta and fishmeal processing are put in place. In addition, fishmeal processing plants are forced to be certified by the Ministerio de la Producción (Ministry of Production) and are not allowed to receive any anchoveta from artisanal or unauthorized vessels.

Along the Eastern Pacific, similar effects of ENSO are described as in Peru. Kane (1999) finds that ENSO in Chile represents excess rains and increase in temperatures. In addition, Cabezas and Vangni (2015) research the role of ENSO on Ecuadorian rainfalls. They find that during strong ENSO events, precipitation increases by 90% in the Ecuadorian coasts.

Despite the efforts to control the ENSO negative effects, the agri-food industry is still resentful to the impacts of ENSO. In order to reduce the impacts, those who are in place of decision-making should have a better understanding on how ENSO impacts the most basic business units. The next chapter addresses multiple ways in which resilience can be measured and previous studies that have used the resilience framework.

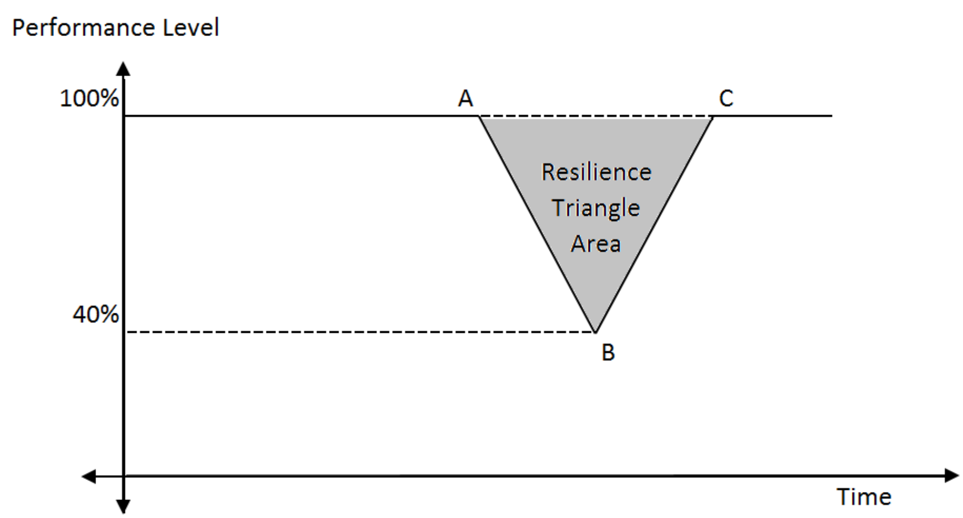
Chapter 4 - Resilience Framework

Definitions of resilience have been used in different fields, including ecology, engineering, rural development, and, lately, in agricultural systems. The concept of resilience was proposed by Holling (1973), who defined it as the ability of an ecosystem to return to equilibrium after being affected by a shock. Walker et al. (2004, 4) broadly defined a system's resilience as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks". Tierney and Bruneau (2007) took resilience to engineering describing it as the ability of a physical system to reduce hazards. In the case of rural development, it was defined by Heijman et al. (2007) as the ability to adapt to exogenous events in order to maintain the same standard of living. Finally, Lindbloom et al. (2017) brought the concept of resilience to agricultural systems and detailed a resilient farm as one that has the capabilities of returning to its normal or improved state after being impacted by a shock. Although definitions vary depending on the field of study, one could say that a resilient fishmeal processor is that who has been shocked by an adverse event and was able to return to operation and performance prior to the shock.

Resilience can be measured using qualitative and quantitative approaches. Qualitative approaches rely on judgment and assessment of industry experts on certain aspects that can be of high impact for the subject in study. Ahern et al. (2006) applies an index-based measure derived from psychometric parameters to determine the psychological resilience in adolescents, and Tippens (2017) interviews and surveys refugees to determine their psychosocial health and resilience. Besides being popular in psychology, qualitative indices have been used to measure the resilience of organizations (Bhamidipaty, Lotlikar, and Banavar 2007; McManus 2008). Furthermore, Nikookar et al. (2014) created a questionnaire with the practices and attributes that a supply chain has and that affects the supply chain resilience, and asked industry leaders to assign a score on those characteristics. Although it is good to know about the perspectives from experts, qualitative methods are constrained to more subjective ideas of resilience.

Quantitative approaches use mathematical model to measure resilience. For example, Bruneau et al. (2003) proposed the resilience triangle framework to measure the resilience of communities to seismic activity on the idea that performance will return to its normal (or improved) level after a shock. They also argue that resilient communities will take a shorter time to recover and/or will not be as adversely affected as those that are not. Figure 4-1 minimum impact on their performance or will take less time to recover. Under this idea, three points are identified: (A) The level of performance prior to a shock, (B) the lowest performance level during the shock period, and (C) the post-shock (recovered) level of performance. Then, the area of the triangle created is calculated to quantify the resilience of each community (Figure 4-1).

Figure 4-1. Representation of the Resilience Triangle



Source: Bruneau et al. (2003), Lindbloom et al. (2017)

Another set of studies apply the resilience triangle to assess the resilience of urban infrastructure, the automotive supply chain, and diversified farms. Tierney and Bruneau (2007) and Pant et al. (2014) examine the resilience of infrastructure to natural disasters using the quality of infrastructure as their performance measure. Additionally, Güller et al. (2015) apply the resilience triangle a supply chain perspective while Carvalho et al. (2011) and Barroso et al. (2015) take it further to review the fulfillment rates of the automotive industry using the same approach. Finally, Lindbloom et al. (2017) exert the resilience triangle to calculate farms resilience and assess the importance of diversification on resilience.

This research tries to contribute to the resilience literature by applying resilience triangle framework to the Peruvian fishmeal industry. It applies the framework to measure resilience at three different levels: industry, firm, and business unit. Net profits are used as a measure of performance. The 2009-2010 ENSO event was selected as a shock period of interest due to its magnitude and the severity of its effect on the industry. The measure of resilience is derived from a graphical representation of the change in net profits during the years 2008 to 2011 where the year 2008 is the pre-shock level and 2011 represents the end of the shock. Then, resilience index is defined as the inverse of the area of the triangle, calculated through the following formula:

$$R_i = \frac{1}{(x_a - x_b) * \left(\frac{y_a + y_b}{2}\right) + (x_b - x_c) * \left(\frac{y_b + y_c}{2}\right) + (x_c - x_a) * \left(\frac{y_c + y_a}{2}\right)} \quad (1)$$

Where R_i is the resilience index for firm i, x_a is the year the shock began, x_b is any year during the shock, and x_c is the post-shock period, y_a is the performance level at year x_a, y_b is the performance level at the year x_b, and y_c is the performance level in the post-shock period (year x_c).

To illustrate the use of Equation 1, consider a hypothetical fishmeal processor “F”. This fishmeal processor obtained in the years 2008 (x_a), 2009 (x_b) and 2010 (x_c) net income in

Nuevos Soles[2] for 1000, 500 and 1000, respectively. The annual net profits in the year 2008 provides a reference on the top performance reached during the shock. As a result, for the year mentioned above, company F has a 100% (y_a) performance in the year 2008, 50% (y_b) in 2009, and 100% (y_c) in 2010. The resilience for hypothetical fishmeal processor F is therefore calculated as follows:

$$R_F = \frac{1}{(2008-2009)*\left(\frac{100+50}{2}\right)+(2009-2010)*\left(\frac{50+100}{2}\right) +(2010-2008)\left(\frac{100+100}{2}\right)} \quad (2)$$

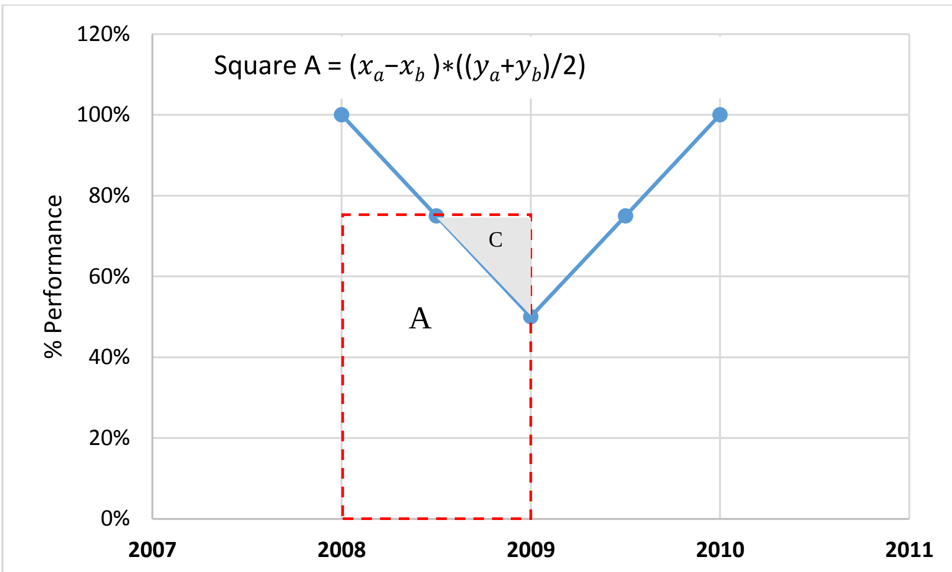
For this example, the area (the denominator) is 50 units thus the fishmeal processor ABC has a resilience index of 0.02.

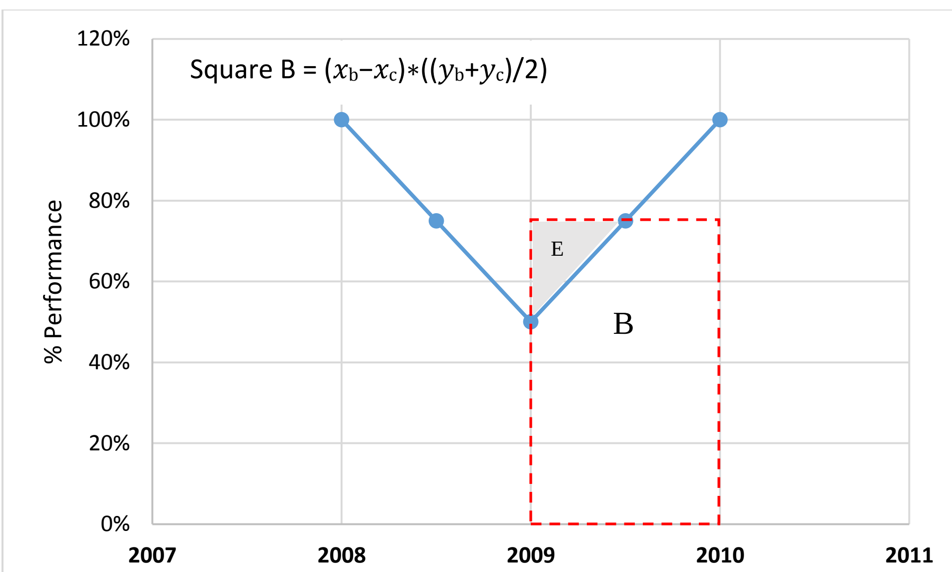
Next, we graphically present how equation 1 is applied to this example through the steps presented in Figure 4-2. Note that the first part of the denominator computes the operation $(2008-2009)*\left(\frac{100+50}{2}\right)$ obtaining the negative area of 75 units belonging to square A in Figure 4-2. Observe that area A includes triangle C. Then, the second part of the denominator computes the operation $(2009-2010)*\left(\frac{50+100}{2}\right)$ obtaining the negative area of 75 units belonging to square B. Notice that square B also includes triangle E. After, the third part of the denominator computes the operation $(2010-2008)(\frac{100+100}{2})$ obtaining the positive area of 200 belonging to the square created by square I. Observe that square I is created by the points (2008,0), (2008,100), (2010, 100), and (2010,0). Lastly, one can proceed to add the three areas previously obtained (-75, -75, and 200) to obtain an area of 50. As the last graph of Figure 4-2 shows, triangles D, C, E, and F are congruent. This means that although the negative areas take

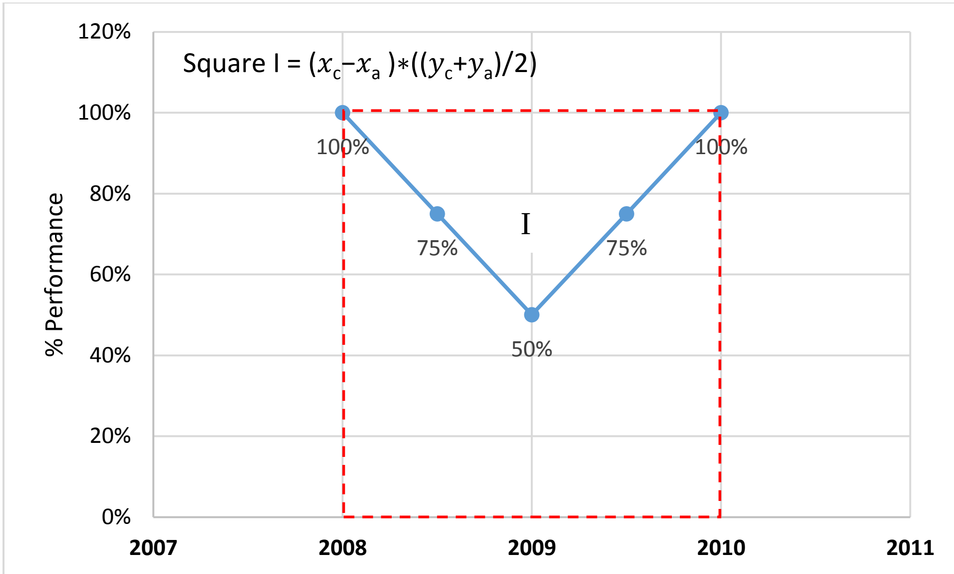
[2] The Peruvian Nuevo Sol exchange to the US Dollar during this study was 2.88 Peruvian Nuevos Soles (PEN) per US Dollar.

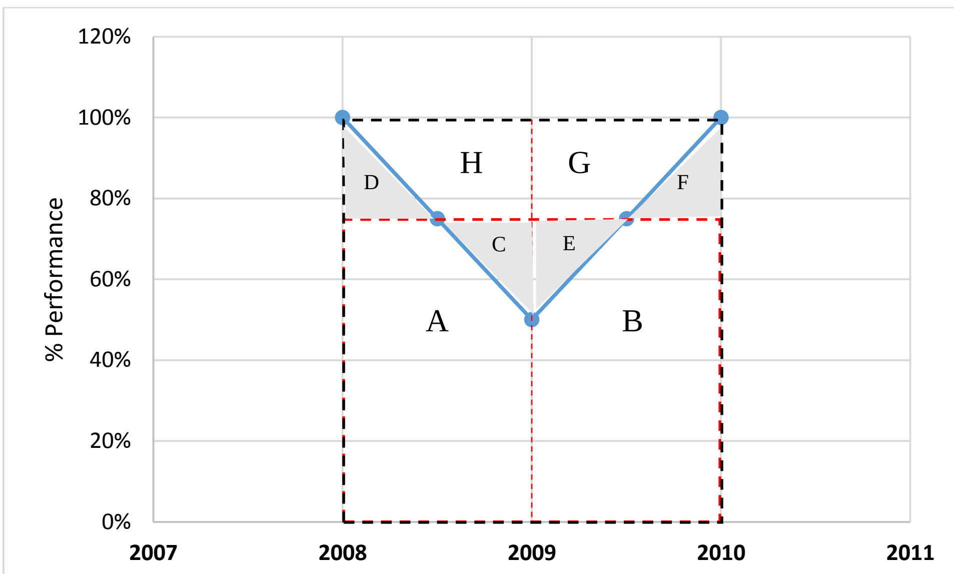
away triangles C and E, these are compensated by keeping the areas of triangles D and F thus providing the area of the original triangle. Then the inverse of the area is obtained to get the resilience index. This means that as firms have a bigger (smaller) area, their resilience index is reduced (increased).

Figure 4-2. Calculating areas for complex triangles



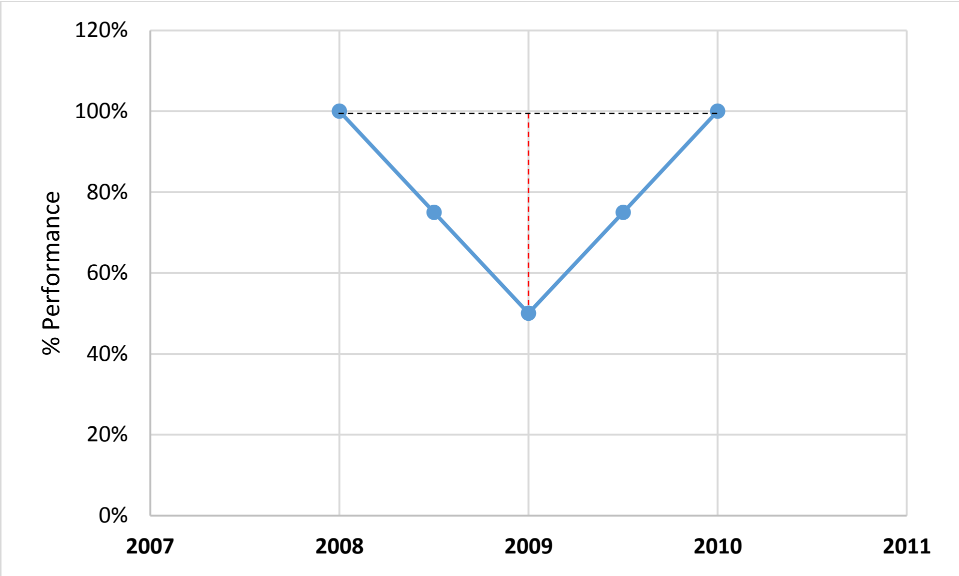






To corroborate this result, the common area of a triangle, $\frac{1}{2} base * height$, can be used. The height of the triangle would represent the difference from 100% to 50%, taking a value of 50%, as the red dotted line in Figure 4-3. The base would be the difference between 2008 and 2010, taking a value of 2 (black dotted line in Figure 4-3). When these values are computed $\frac{1}{2} 50 * 2$, the same result of 50 is obtain, and a resilience of 0.02. Despite the ease to calculate the area of triangles through the common formula, in this study, the formula in equation 4 is more appropriate for complex figures that are not necessarily triangles.

Figure 4-3. Measuring area with the common triangle area formula



Following the concept of resilience, we hypothesize that larger processors should be more resilient to ENSO events because they have more resources to face the ENSO events. Additionally, they can allocate their resources to buy or acquire fishing quotas from other companies that find it more profitable to do so than producing fishmeal. Furthermore, smaller plants are more susceptible to close during ENSO because they are prone to the establishment of fishing bans, established to prevent overexploitation of marine resources, closing their facilities when their fish stocks runout.

Chapter 5 - Data

This study was conducted using an unbalanced panel dataset obtained from two different sources. Data on financial and economic characteristics of the fishmeal producers in Peru obtained from the Instituto Nacional de Estadistica e Informatica (INEI), Peruvian statistics institute, on the National Economic Survey (Instituto Nacional de Estadística e Informática 2017). These results can be found in the microdata section of the INEI webpage (http://iinei.inei.gob.pe/microdatos/). Furthermore, a data set was obtained from ADUANET which is the Peruvian Customs Agency, Superintendencia Nacional de Aduanas y de Administración Tributaria (SUNAT), official database of reports on fishmeal firms' monthly exports. This data was used to measure industry concentration ("Consulta de Declaraciones de Exportacion Definitiva" 2018). In addition, Sea Surface Temperature (SST) in the Niño 3.4 region from the Oceanic Niño Index (ONI) was used to determine the shocks (NOAA 2017c). The ENSO 2009-10 was selected as the shock to be studied. The year 2008 was established as the pre-shock period and 2011 as post-shock period.

National Economic Survey

INEI conducts the National Economic Survey on an annual basis. Firms are divided in two different groups. The first group comprises companies that surpass the 150 Tax Units (532,500 Peruvian Nuevos Soles or about $184,896 USD) in sales. This group of firms are forced to participate in the survey otherwise they receive a fine. The second group is composed of firms that are below the 150 Tax Units. From this second group, a sample is calculated by INEI through the Lavallée-Hidiroglou algorithm to determine the optimal size. After calculating the optimal size, firms are randomly selected to be part of the survey. Failure to complete the form may also result in a financial fine for the establishment. The survey is conducted nationwide through electronic and physical forms. When the forms are returned to the INEI, they are entered in an excel spreadsheet and published as microdata for its public availability. Data is published at two different levels. At the firm level, financial statements, inventory movements, and staff employed are made available. In addition, business unit level data is enabled. This means that data on the fishing and transformation stages are available. At business unit level, similar data as the firm level can be found although information about costs, inputs, and fixed asset movements can also be found.

On the ENSO 2008-2011, 267 firms participated on the survey in the fishing sector during the 2009-2010 ENSO. At the business unit level, 163 fishing units and 228 processing plants completed the survey. Despite the seemingly large number of observations, two main limitations decreased the useful observations used in the analysis. A set of only 59 fishmeal processing plants were part of the survey out of the 154 existing at the shock. Additionally, some of the firms had incomplete data. Also, not all observations were available across all years. Therefore, the panel was unbalanced. The availability of panel data is required for the estimation of the resilience index, and from year to year firms that would not reach the 150 tax units would not be part of the survey. Although still a rich source of time series data, seven fishmeal firms together with 38 fishmeal processing plants met the threshold to be part of the survey during the time period selected. This lead its way to focusing on the business units although summary statistics are presented at all levels.

The Peruvian Ministry of Production reports that 154 fishmeal processing plants are registered for the production of fishmeal. It is worth noting that the figures appearing in this publication are estimates based on data collected from 38 fishmeal processors out of the total reported by the Ministry of Production. These 38 fishmeal processing plants had complete data for all variables and fulfilled the desired characteristics of panel data.

A performance indicator is needed to measure the resilience of each processing plant in the study. As a matter of fact, profits represent a major indicator to determine the well-being of a company, and negative profits can lead to the end of a company. Supported in this reasoning, profits were selected as the performance indicator. Although the top profits during the shocks were selected as the 100% level of performance for the firms, and taken as the reference to determine the performance during the other years of the shock. This was done to avoid bias towards companies that obtained lower profits. The level of performance for each individual fishmeal plant were graphically represented for the 38 fishmeal processing plants to analyze their own resilience triangle. Once the triangles were established, the area for each one of them was calculated using equation 1. The resilience index was thereafter the dependent variable of the empirical model.

5.1 Summary Statistics

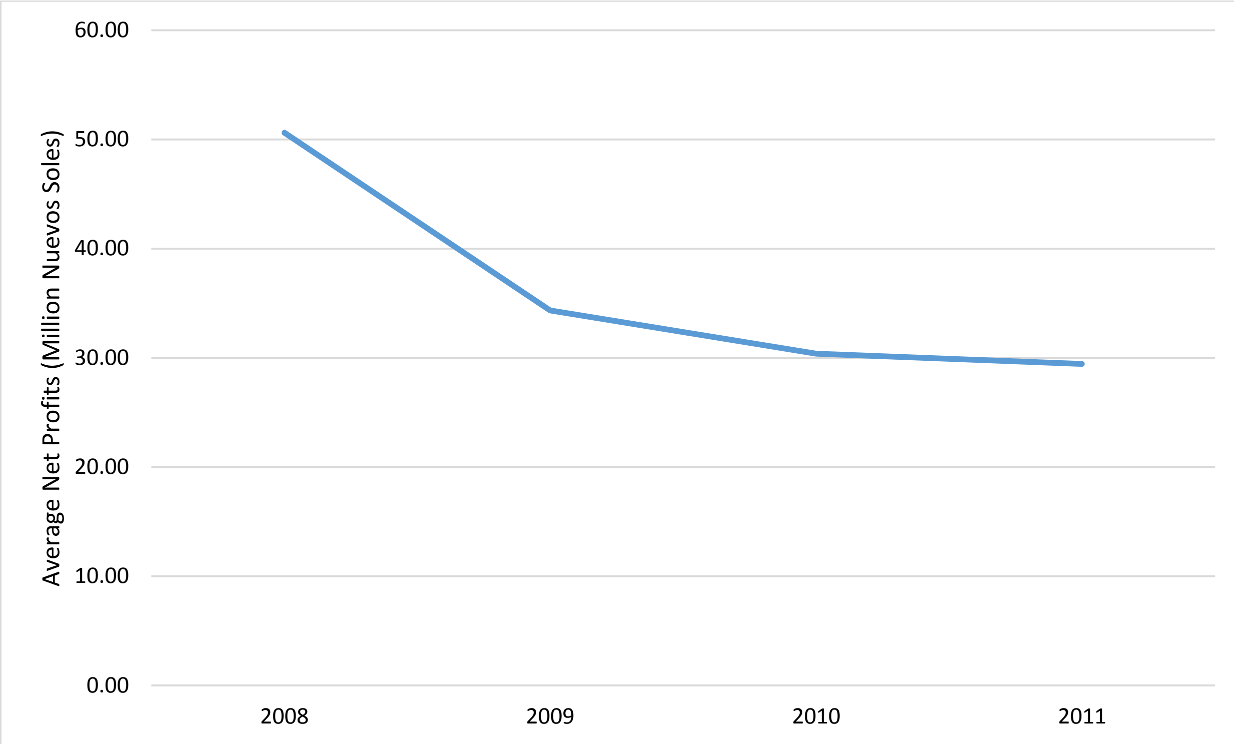
This section reports the results of the summary statistics for the period of the shock which began in 2008 (pre-shock period) and ends in 2011(post-shock period). The values shown below are gathered, at first, for fisheries in general, and later for business units that were part of the survey during the whole shock. The summary statistics analysis was executed using Stata and Excel to corroborate that there were no errors. Note that monetary values are presented in million Nuevos Soles (PEN) deflated to the 2009 Peruvian Consumer Price Index.

Appendix B shows the financial and productive values for the fisheries in Peru. It should be noted that the values were reported by firms themselves in the survey results provided by INEI.

From 2008-11 period, fisheries owned at least 3 vessels to which they commission their fishing activities. An average fishery held at the beginning of the four-year period had 75.456 million PEN (about $26.2 million USD) in fixed assets and ending with 81.812 million PEN ($28.4 million USD) withdrawing 5.806 PEN ($2.0 million USD). An important component of the fixed assets is represented by the machinery used to fish and process the fish, initiating each year with an average of 53.265 million PEN ($18.5 million USD). As mentioned before, not all fisheries included in the survey are considered fishmeal producers. The average firm has 1.534 locations. Despite the importance of other indicators, the mean net profits of a fishery in Peru only reached the 2.732 million PEN ($0.9 million USD) during this period, and some of them operate with losses.

Furthermore, a set of summary statistics and business units are included. Statistics include different characteristics that each processing plant has. Characteristics for monetary values are represented in thousand PEN for a better interpretation. Table 5.1 shows income and expenses of all the fishmeal processors that were part of the survey during the selected shock.

Figure 5-1. Average fishmeal processors net profit.



Source: Instituto Nacional de Estadística e Informática (2017)

In addition, Figure 5-1 shows the impact that ENSO caused on the net profits of the fishmeal processors. During the ENSO 2009-2010, fishmeal processors decreased their net profits from more than 50 million Nuevos Soles in 2008 to less than 30 million in 2011.

Peruvian processors place their products in different markets. Although on average a large part of its products are sold locally, the most important markets are abroad. Of these markets, the main importer of fishmeal is China. As for the sale of by-products, one might think that international markets are not so willing to buy them. Table 5.1 shows how these products, in spite of not being so different, the international markets also represent, on average, a higher volume of sales. In addition, different resources can be identified to generate income. This income can come from the lease of land and various equipment for production.

In terms of expenses, Peruvian companies spent 81,684 million Nuevos Soles (about $28.4 million US Dollars) annually on average in expenses coming from thirds parties. This value, for the most part, is due to the outsourcing of their production. In addition, expenses for leases of land, machinery and other equipment were incurred for 10.141 million Nuevos Soles. In addition, 6.360 million Nuevos Soles per year were paid on average. The grand total of expenses reached 86,027 million Nuevos Soles annually.

Table 5.1 Business unit level summary statistics in the 2008-11 period.

Category	Variable	Mean	2008 Mean	2009 Mean	2010 Mean	2011 Mean
Income						
	National Merchandise Sales	627	463	361	1,076	517
	National Finished Goods Sales	4,834	5,589	4,065	4,179	5,690
	National By-products Sales	799	495	259	426	1,800
	National Diverse Income	1,526	1,360	1,100	2,597	949
	National Leases	61	0.294	54	124	42
	Land Leases	6	0.249	7	1	14
	Merchandise Exports	33	0	0	2	112
	Finished Goods Exports	52,215	47,175	50,814	49,493	58,987
	By-products Exports	642	1,243	217	83	1,198
	International Diverse Income	41	16	80	2	59
Expenses						
	Expenses from Third Parties	7,628	6,601	7,652	6,616	9,187
	Transportation and Storage	1,011	1,484	829	736	1,160
	Outsourced Production	831	868	901	535	1,038
	Leases	326	187	358	266	439
	Publicity	56	113	79	45	14
	Taxes	445	316	535	377	509
	Insurance	212	143	242	202	236
	Total Expenses	9,198	7,920	8,799	8,276	11,179
	Observations	334	57	84	95	98

The resilience triangle framework requires the availability of panel data to be able to calculate resilience for the firms. The lack of panel data on some of the fishmeal processing facilities reduced the amount of fishmeal processing plants that were included in the study. Below we present some of the income (Table 5.2), expenditures (Table 5.3), fixed assets (Table 5.4), and inventories (Table 5.5) statistics. These summary statistics are presented to show in depth the reality of the fishmeal processors in Peru.

Dang et al. (2018) proposed three ways to measure a firm size: total assets, total sales, and market value of equity. Although mentioning the three have advantages and disadvantages, assets represent the resources that the firm has. Resources available can play an important role when coping with ENSO. From the fixed assets section, machinery represents the largest value on average. This machinery is often used for fishmeal, fish oil, preserved fish, and cured fish production. In spite of having the breakdown in the values of the machinery from 2008 to 2010, the data do not present in detail how the value of the machinery was distributed.

Finished goods at the beginning of the year and at the end represent the highest values in inventories. It is important to keep in mind that inventories are also good resources for the generation of income. This can mean that companies that hold larger amounts of inventories can generate income although a fishing ban has been established.

Table 5.2 Selected Peruvian fishmeal processors income statistics in the 2008-11 period.

Description	Mean	2008 Mean	2009 Mean	2010 Mean	2011 Mean
Profit	60,394	55,462	52,770	62,006	73,808
Net sales in Peru	7,507	7,583	6,446	9,168	6,676
Sale of goods in Peru	5,838	6,305	5,218	6,129	5,669
Sale of merchandises in Peru	772	460	402	1,951	163
Sale of finished goods in Peru	4,429	4,787	4,698	4,080	2,865
Sale of by-products in Peru	500	58	118	99	2,001
Diverse income generated in Peru	1,668	1,278	1,228	3,039	1,007
Income for leases in Peru	24	0.433	17	5	87
Land leased in Peru	14	0.390	16	1	42
Subsidies in Peru	242	98	330	292	250
Net sales outside of Peru	60,654	54,890	53,418	60,096	77,276
Sales of goods outside of Peru	60,587	54,890	53,238	60,096	77,183
Sale of merchandises outside of Peru	0.155	0	0	1	0
Sale of finished goods outside of Peru	60,053	54,890	53,238	60,032	74,763
Sale of by-products outside of Peru	497	0	0	63	2,246
Diverse income generated outside of Peru	67	0	179	0	93
Observations	152	38	38	38	38

Table 5.3 Selected Peruvian fishmeal processors expenditure statistics in the 2008-11 period.

Variable	Mean	2008 Mean	2009 Mean	2010 Mean	2011 Mean
Third Party Expenses	6,291	6,071	5,817	5,691	7,878
Transportation and Storage (Freight, transportation and warehouse expenses)	1,052	1,318	735	804	1,418
Mail and Telecommunications (phone, cable, fax, etc)	90	114	95	80	68
Production commissioned to third parties	466	367	526	379	619
Maintenance and repairs	577	276	578	849	609
Lease expenses	227	210	245	210	247
Electricity, water, and gas expenses	1,066	1,071	1,009	850	1,394
Publicity, publications, and public relations	56	92	92	10	23
Taxes	529	335	642	491	676
Insurance	203	182	198	201	235
Total Expenses	7,767	7,011	7,094	7,257	10,144
Observations	152	38	38	38	38

Table 5.4 Selected Peruvian fishmeal processors fixed assets summary statistics in the 2008-11 period.

Variable	Mean	2008 Mean	2009 Mean	2010 Mean	2011 Mean
Initial land	4,595	4,120	4,953	4,165	5,265
Initial buildings	8,471	7,453	8,994	7,705	10,017
Initial machinery	37,314	32,157	38,568	37,436	41,950
Total initial fixed assets	56,953	49,161	57,357	55,589	67,680

Final land	4,917	5,072	5,019	4,390	5,245
Final buildings	9,811	9,383	8,820	8,914	12,649
Final machinery	41,692	40,648	37,648	37,482	53,090
Total final fixed assets	60,639	59,903	57,239	59.032	67,680
Observations	152	38	38	38	38

Table 5.5 Selected Peruvian fishmeal processors inventories summary statistics in the 2008-11 period.

Variable	**Mean**	**2008 Mean**	**2009 Mean**	**2010 Mean**	**2011 Mean**
Initial finished goods	8,104	7,171	8,433	11,283	4,947
Initial by-products	244	9	416	420	106
Initial products in process	17	48	10	9	0
Initial Raw materials	161	166	128	241	97
Initial packaging materials	381	409	435	378	284
Initial diverse supplies	1,637	1,988	1,471	1,222	1,917
Initial inventory to be received	14	2	8	38	8
Final finished goods	10,300	9,399	10,846	4,358	18,018
Final by-products	466	98	958	89	775
Final products in process	35	80	9	46	0
Final raw materials	123	62	259	64	105
Final packaging materials	377	449	392	390	255
Final diverse supplies	1,217	49	1,244	1,603	1,653
Final inventory to be received	56	8	14	192	2
Observations	152	38	38	38	38

Once the shock period was established, the processing plants that had panel data available were selected for further study. Although the number selected was 38, this represents more than 20% of the total population. In addition, Table 5.6 shows a wide range on the refrigeration and buildings assets averaging 1.2 million and 7.4 million Nuevos Soles, respectively. In the sample selected, an average of 11 million Nuevos Soles was kept in inventories at the end of the year 2008, and processing plants were importing on average a 0.002% of their total consumption for the same year. On the expenditure side, transportation and storage represented on average 1.3 million Nuevos Soles. In the years in business, on average the processing plants have spent 16 years in business with the oldest dating 63 years and the youngest 1 year.

Table 5.6 Selected processing plants summary statistics.

	# Obs	Mean	Std. Dev.	Minimum	Maximum
Refrigeration (1000 PEN)	38	1,239	3,563	0	15,364
Buildings (1000 PEN)	38	9,383	8,359	244	39,543
Inventory (1000 PEN)	38	11,380	8,675	195	32,403
% Imported Raw Materials	38	0.002	0.008	0.000	0.047
Transportation and Storage (1000 PEN)	38	1,318	2,931	0	11,544
Years of Experience	38	16	12	1	63
Vertical Integration	38	0.763	0.431	0.000	1
Diversification	38	0.395	0.495	0.000	1
North-Central Region	38	0.868	0.343	0.000	1

Vertical coordination and diversification are among other strategies used by fishmeal producers. From the sample, 76% of the fishmeal processors own a fleet to develop fishing activities. In addition, 39% of the fishmeal processors produce other types of products that are not only fishmeal. These products can be fish oil, frozen fish, or canned fish. Although they also depend on fishing, they are not constrained to the anchoveta fishing.

Additionally, Table 5.7 shows the average resilience index computed for the 38 processing plants included in the study. The resilience index for the 38 Peruvian fishmeal processing plants during the shock selected was 0.177. Although there are no other shocks to compare the resilience with, one can assume that economies of learning have caused a positive effect in the resilience of fishmeal producers to ENSO events. These economies of learning can be a representation of what Sun et. al. (2001) found with the implementation of better cost saving initiatives.

Table 5.7 Fishmeal processing plant R_i results

	2009-2010 Shock
Mean	0.177
Std. Dev.	0.363
Observations	38

Once the resilience index of the different fishmeal processors has been calculated, one can proceed to find a model that includes the variables that help predict the resilience of the business units.

Chapter 6 - Empirical Analysis

One of the objectives of this study was to estimate the effect of fishmeal processors' characteristics on their resilience to ENSO events. After calculating the resilience index and establishing the measure of size to be buildings and refrigeration assets, the econometric model is specified to estimate the effects of the size of processing plants on resilience. The resilience index measures the ability of firms to recover from shocks. This ability is hypothesized to be a function of $Size_i$ in this research. The theoretical equation supporting this is presented in equation 3. is the measure of size selected for processing plant i, and X_{ij} are other control variables that may also affect the resilience of fishmeal processors.

$$R_i = \alpha + \beta_1 Size_i + \beta_j X_{ij} + \varepsilon_i \qquad (3)$$

Where R_i is the resilience index of the processing plant, and $Size_i$ are the monetary value of refrigeration and building assets for processing plant i, and X_{ij} are other control variables that may also affect the resilience of fishmeal processors.

While different authors use different estimation methods for the factors influencing Ri, we chose to use fractional response logit. An OLS is the most common way to think about addressing the issue (e.g. Lindbloom et al. (2017)). Another set of papers on resilience literature use probit (e.g. Tesso et al. (2012)) and logit (e.g. Cohen et al. (2016)) regression models to estimate the factors that affect resilience. Although all models have advantages and disadvantages in predicting the resilience, using probit and logit fractional response regression models better suit this study. As a result, a fractional response logit model was used to determine the factors that affect the resilience of fishmeal processing plants. This model was used due to the nature of the resilience index of taking values equal to or greater than 0 and equal to or less than 1, and an OLS may have predicted values outside of the [0,1] range.

With regards to the measurement of size, different measures can be adopted to determine the size of a firm. As mentioned before, Dang et al. (2018) determine three ways (assets, sales, and market value of equity). They add that in the absence of these three indicators, other measures such as the number of employees, total profits, or net assets can be used. Hart and Oulton (1996) assert that using the different indicators depends more on the availability of data rather than on the advantages and disadvantages any indicator could have. Results for this model using fixed assets (refrigeration and buildings), total sales, and number of employees as the measurement of the size of the processing plant through probit and logit fractional response regression are shown in Appendix C. Although a good first step to check on relationships between the size variables and the resilience index, it would be a mistake to conclude based on these results. Consequently, other variables have been specified in the model to avoid falling into an omitted-variables bias.

Control variables are included in the model to take into consideration other factors that can affect the resilience of a processing plant. The control variables were categorized in capital, experience, government aids, and other characteristics that can help in the recovery process. Capital variables are the financial means by which a firm can face the adverse situations of ENSO. Also, some expenditure firms have can make them more resilient than other firms. Additionally, more experienced firms could have developed economies of learning from previous ENSO events that make them more resilient, but it can also be argued that their technology is not as efficient as new technology used today for the processing of fishmeal. Despite the importance of the industry to the national economy, not many fishmeal processors receive government aids that can help producers recover from ENSO due to the understanding from the government perspective that it is an industry that can recover itself from ENSO events.

Furthermore, firms' characteristics that could help in coping with ENSO occurrences are vertical coordination, diversification, and the location of the firm. In general terms, our model follows the general idea described by equation 4.

$$R_i = f(\beta, \delta, \theta, \rho, \gamma, \varphi) \qquad (4)$$

Where R_i is the resilience index, β is the size measure selected, δ are the capital measures selected, θ are expenses characteristics, ρ are non-monetary characteristics, γ is the experience in years at the beginning of the shock, and φ are the government aids provided to firms expressed by the subsidy received.

Next, variables that fall within the categories mentioned above were chosen to know if the size of the fishmeal processing plants influence their resilience index during the El Niño phenomenon.

To represent the categories mentioned before, independent variables used in equation 4 and equation 5 were chosen based on economic theory and literature on resilience. In addition, available data to represent them in the model was considered.

The first step for determining the model was the selection of the measure for size. Previous literature on different fields have used assets as their measure of size. For example, Singhvi and Desai (1971) research the quality of corporate financial disclosure using total assets as their measurement of size. Shehata (1991) examined company's size to determine their accounting methods. At first, he considered using total sales as a proxy of firms' size, but when capitalizing and expensing research costs, he defines total assets as the measure for size. In this case and from this point on, this study considers building assets and refrigeration assets as measures of size. Buildings represent the monetary value of the installations that each fishmeal processing plant has. In addition, monetary value of the refrigeration assets was included in the model because the usage of this type of assets can serve as a risk management practice for the storage of fish. Based on economic theory, one would expect that larger firms should perform better through ENSO events. However, one can argue that the size of the processing plants can affect their resilience either positively or negatively. An analogy of a tree can explain this reasoning. When a strong wind affects a tree, those trees with bigger roots and thicker trunk can be more resistant to the wind, but also will have a larger crown and less flexibility making them more likely to break compared to trees with a narrower, more flexible trunk and smaller crown. The trees with narrow trunks can be analogues to small fishmeal processors that when there is shortage of fish don't underutilize their installed capacity as a large processor might. Furthermore, the assets in refrigeration can be very beneficial when there is high availability of fish. When the availability of fish is diminished by ENSO events, firms can incur high expenses on refrigeration that may be counterproductive.

Furthermore, the inventory and percentage of imported raw materials consumed were selected. The inventory value indicates how much available resources a firm has for processing or selling in order to generate income. The percentage of imported raw materials indicates the level of input diversification. This is because as the local resources become unavailable for the production of fishmeal, fishmeal processors can increase reliance on international markets for input procurement. These processing plants can be importing a wide range of raw materials such as chemicals or extracts from other marine species. It is prudent to think that companies with higher inventories at the beginning of the event and with higher percentage of imports will experience higher values on their resilience index. In addition, variables about expenses in transportation and storage were included although uncertain about which direction these expenses will take.

In addition, firm's characteristics such as vertical integration, diversification, and the region in which they are located were included in the model as dichotomous variables. Diversification stands for the fact that fishmeal processors can use their installed equipment in the processing of other products such as fish oil, frozen fish, or canned fish. In theory, a processing plant that has the ability to switch to the production of another product that is not as reliant on anchoveta or fish vulnerable to ENSO would be more resilient. In the case of location, the Peruvian fisheries are divided in two regions, North-Central and Southern regions. Fisheries above the 16th parallel South up to the border with Ecuador are considered part of the Northern region, otherwise they are part of the Southern region. Those stationed in the North-Central region are expected to show more resilience to ENSO events because of the policies such as establishment of quotas and fishing season. In the case of the Southern region, it is shared with Chile and agreements about the quotas have not been reached. Also, Chilean fishing can have an effect on resilience for the processing plants in this region.

Finally, a dummy variable for those firms who received subsidies was included. Subsidies can be a great aid for the processing plant during an ENSO event, and it is included in the model. Although not many firms receive subsidies, it is an important source of resources to increase the resilience of a firm. The possibility of correlation between subsidies and size was explored, but not correlation was found between refrigeration and building assets and subsidies.

Despite including the variables mentioned before in a first model, the variables for inventory, transportation and storage, vertical coordination, and the North-Central Region were not significant. Hence, the following model was specified:

$$R_i = \alpha + \beta_1 Ref + \beta_2 Build + \delta_2 ImpRM + \gamma_1 Exp_i + \rho_2 Divdum + \varphi_1 Subdum_i + \varepsilon_i \quad (5)$$

To account for the law of diminishing marginal utility on the size of the firms, two more models were specified adding squared terms for the refrigeration and buildings:

$$R_i = \alpha + \beta_1 Ref_i + \beta_2 Build_i + \beta_3 Ref_i^2 + \beta_4 Build_i^2 + \delta_1 Inv_i + \delta_2 ImpRM_i + \theta_1 T\&S_i + \gamma_1 Exp_i + \rho_1 VCdum_i + \rho_2 Divdum_i + \rho_3 NC_i + \varphi_1 Subdum_i + \varepsilon_i \qquad (6)$$

The model specified in equation 7 does not include the non-significant variables identified in the model presented in equation 4.

$$R_i = \alpha + \beta_1 Ref + \beta_2 Build + \beta_3 Ref_i^2 + \beta_4 Build_i^2 + \delta_2 ImpRM + \gamma_1 Exp_i + \rho_2 Divdum + \varphi_1 Subdum_i + \varepsilon_i \qquad (7)$$

Results and discussion for the models specified are provided in the next chapter.

Chapter 7 - Results and Discussion

As a preliminary test, different models were used to define the approximate relationship between the resilience index and the size measurements proposed. As mentioned before, these results should be interpreted with caution because of the limitations due to small sample size. Appendix C show how the direction of the resilience index will depend on the measurement of size used. As mentioned before, the measure selected was Refrigeration and Buildings considering both can be proxies of the resources that the processing plants have to withstand the shock.

As one of the objectives of this study was to analyze factors that affect the resilience of fishmeal processors in Peru, the variables mentioned in the section before were regressed on the Resilience index using fractional response logit regression. It was expected that both measures for firm size, inventory, % raw materials imported, experience, vertical coordination, and diversification will have a positive impact on the resilience index.

The results in Table 7.1 show that not all coefficients are significant. However, the results from the model in equation 4 indicate that holding all other factors constant, the inventory, and transportation and storage together with the dichotomous variables for vertical coordination and the North-Central region have no statistical effect on the resilience index. On both models, the coefficients for refrigeration and buildings are negative, indicating that smaller firms are more resilient. The resilience index is reduced by a factor of 8.57x10-8 when refrigeration increases by 1 Nuevo Sol with a 95% confidence. Additionally, buildings also have a negative effect on the resilience index. An additional unit of buildings decreases the resilience by a 1.72x10-8 with a 99% level of confidence. The magnitudes of the coefficients can be interpreted as small changes in the resilience index. Even though they seem like small changes in resilience index, when compared to profits, the results can determine the survival of a business unit, depending on each individual case. Despite results showing that smaller firms are more resilient, it would be presumptuous to recommend a downsizing strategy to all of the processing plants without considering the results from the quadratic regressions.

Table 7.1 Regression results for the effect of processing plants size and characteristics on resilience

	Dependent Variable: R_i			
VARIABLES	Coefficient	Marginal Effect	Coefficient	Marginal Effect
Size				
Refrigeration Assets	-1.09e-06**	-8.57e-08*	-1.02e-06*	-8.16e-08*
	(4.48e-07)	(4.48e-08)	(5.63e-07)	(4.86e-08)
Buildings Assets	-2.18e-07***	-1.72e-08***	-1.97e-07***	-1.58e-08***
	(7.79e-08)	(6.03e-09)	(7.06e-08)	(5.29e-09)
Capital				
Inventory	-2.88e-08	2.27e-09		
	(5.78e-08)	(4.35e-09)		
% Imported raw materials	346.6**	27.31*	324.8*	26.07
	(153.1)	(14.94)	(194.1)	(16.53)
Expenses				
Transportation and Storage	2.77e-07	2.19e-08		
	(4.01e-07)	(3.31e-08)		
Experience				
Years of experience	0.0827**	0.00652*	0.0833**	0.00669**
	(0.0357)	(0.00338)	(0.0350)	(0.00330)
Government Aids				
Subsidy (Yes=1)	28.31***	2.231***	29.11***	2.337***
	(5.481)	(0.739)	(7.116)	(0.797)
Other Characteristics				
Vertical Integration (Yes=1)	-0.368	-0.0290		
	(1.088)	(0.0838)		
Diversification (Yes=1)	4.445***	0.350*	4.730***	0.380***
	(1.358)	(0.104)	(1.360)	(0.0967)
North-Central (Yes=1)	1.399	0.110		
	(1.112)	(0.109)		
Constant	-5.108***		-3.855***	
	(1.363)		(1.006)	
Observations	38	38	38	38

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Likewise, results suggest that increasing the percentage of imported raw materials would increase the resilience of a fishmeal processor. These results behaved as expected considering that the processing plants that have built channels to import their raw materials are more resilient during the shock. Although fishmeal producers are not only importing marine raw materials, it could be said that they have created import channels that allow them to stock up the necessary raw materials when needed. Imported raw materials can easily be incorporated to their production, thus making them more resilient in comparison to the processors that rely only on local raw materials. To the firm level, having these competencies developed over time can mean a less stressful transition through ENSO events. At the government level, facilitating the imports of raw materials can be the solution for producers to develop the adequate mechanisms to import the required resources during ENSO.

In the like manner, although a small percentage of fishmeal processors receive aids from the government, this aid could be helpful for the fishmeal processors. Table 7.1 shows the high significance of subsidies on the resilience index. These results should motivate a change from the government side on the allocation of resources for fishmeal producers considering the importance of the industry. One can think of increasing aid, but other ways such as improved forecasts, and easing some tax measures can also help.

Moving forward to processors' strategies, firms that are diversified are likely to be more resilient than the firms that are not at a 99% level. For firms, this means that having other ways to generate income is beneficial to withstand the negative effects that ENSO events bring. For further research, it would be interesting to use different methods to identify the levels of diversifications and its effects on resilience such as the ones used by Lindbloom et al. (2017) on Kansas farms. Furthermore, the fact that vertical coordination is not significant could mean that firms are able to guarantee a certain catch while the resources are available, but this capability is superfluous when there are not sufficient marine resources becoming an unnecessary expenditure. Going back to the tree analogy, vertically coordinated firms can be strong in good times, but not flexible enough to generate income from other products.

With regards to experience, the increase in experience has a positive effect in the resilience of the Peruvian fishmeal plants. These results agree with what Sun et al. (2001) expressed. They mention how the El Niño phenomenon of the 1997-98 phenomenon had less effect on Peruvian fishmeal exports compared to the 1982 phenomenon due to better cost saving initiatives implemented over time. This may imply that despite the greater intensities of El Niño events, fishmeal producers are learning from past experiences and may be more resilient.

Although location had a positive effect on resilience, it was not statistically significant. This result can be an indicator that the policies implemented in the two different regions for the protection of fishing banks should be reviewed more in depth. At the same time, a deeper analysis of its true impact on the Peruvian fishmeal industry is recommended.

Two previous models show significant negative values for refrigeration and buildings but conclude that the fishmeal industry will become more resilient by downsizing can be wrong. The economic theory implies that it is likely there is a certain optimal size (in terms of physical assets) ensuring maximum resilience, so called minimum resilience scale equivalent to minimum efficiency scale. This can be analyzed by including squared terms. Results for models in equations 6 and 7 include squared terms to estimate the point at which the relationship between scale and resilience turns positive. The addition of squared terms reduces the significance of the refrigeration coefficient although maintaining it with the same sign (Table 7.2). Buildings maintain the same sign and significance level as models previously specified. In addition, the squared terms are not significant. These results could indicate that the sample by itself might be having some effect on the results. As the nature of the source of the data dictates that only firms that exceed the 150 tax units are part of the survey and only 38 firms are part of the study, the results might be only showing the negative side of the quadratic curves.

With the addition of quadratic terms to the model, an evident loss of power is shown due, once again, to the small data sample. Despite the limitations, smaller firms seem more resilient for this sample, and the diversification suggests it is a better strategy to coping with ENSO events. Furthermore, the years of experience are significant and positive. This indicates that more experienced firms may have built economies of learning due to experiences from past ENSO events. Additionally, the more experienced fishmeal processors have learned how to use their installed capacity for the production of other goods thus also demonstrating that diversification plays an important role.

Figure 7-1 and Figure 7-2 show the skewness to the right on both variables which could be the reason why both coefficients are negative.

Table 7.2 Regression results for the effect of resilience including squared terms.

	Dependent Variable: R_i			
VARIABLES	Coefficient	Marginal Effect	Coefficient	Marginal Effect
Size				
Refrigeration Assets	-7.98e-08	-5.89e-09	-3.29e-07	-2.51e-08
	(-7.37e-07)	(5.37e-08)	(7.76e-07)	(5.62e-08)
$(\text{Refrigeration})^2$	-2.03e-13	-1.50e-14	-1.50e-13	-1.14e-14
	(1.38e-13)	(1.24e-14)	(1.55e-13)	(1.32e-14)
Buildings Assets	-4.83e-07***	-3.57e-08**	-3.84e-07**	-2.93e-08***
	(2.07e-07)	(1.45e-08)	(1.51e-07)	(1.05e-08)
$(\text{Buildings})^2$	1.07e-14	7.87e-16	8.55e-15	6.52e-16
	(7.88e-15)	(5.47e-16)	(5.96e-15)	(4.22e-16)
Capital				
Inventory	3.73e-08	2.75e-09		
	(7.05e-08)	(5.22e-09)		
% Imported raw materials	1,013**	74.79	834.2	63.62
	(504.5)	(47.97)	(606.8)	(53.24)

Expenses				
Transportation and Storage	5.19e-07	3.83e-08		
	(4.54e-07)	(3.49e-08)		
Experience				
Years of experience	0.0852***	0.00629**	0.0775**	0.00591**
	(0.0324)	(0.00267)	(0.0311)	(0.00279)
Government Aids				
Subsidy (Yes=1)	46.29***	3.418*	46.27**	3.528*
	(14.42)	(1.611)	(19.28)	(1.911)
Other Characteristics				
Vertical Coordination (Yes=1)	0.00695	0.000513		
	(1.198)	(0.0885)		
Diversification (Yes=1)	5.476***	0.404*	5.378***	0.410**
	(1.300)	(0.109)	(1.365)	(0.123)
North-Central (Yes=1)	1.277	0.0943		
	(1.182)	(0.103)		
Constant	-5.566***		-3.825***	
	(1.461)		(1.129)	
Observations	38	38	38	38

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Despite not being significant, the effectiveness of having differences in the fishery protection policies established between the North-Central zone and the Southern zone should be reviewed more in depth. In the legal framework, laws should look for better ways to preserve the and avoid the overexploitation of the marine resources. In the case of international legislations, more strengthening bilateral agreements between Peru and Chile should be sought in order to regularize fisheries in their border areas so that both countries can benefit from better fishing conservation practices.

Figure 7-1. Refrigeration assets per firm.

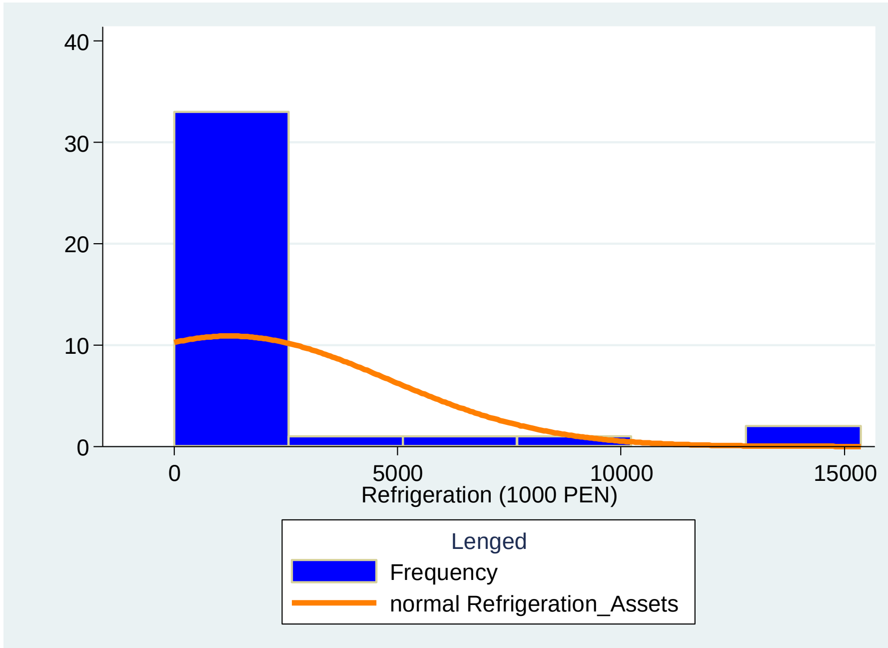
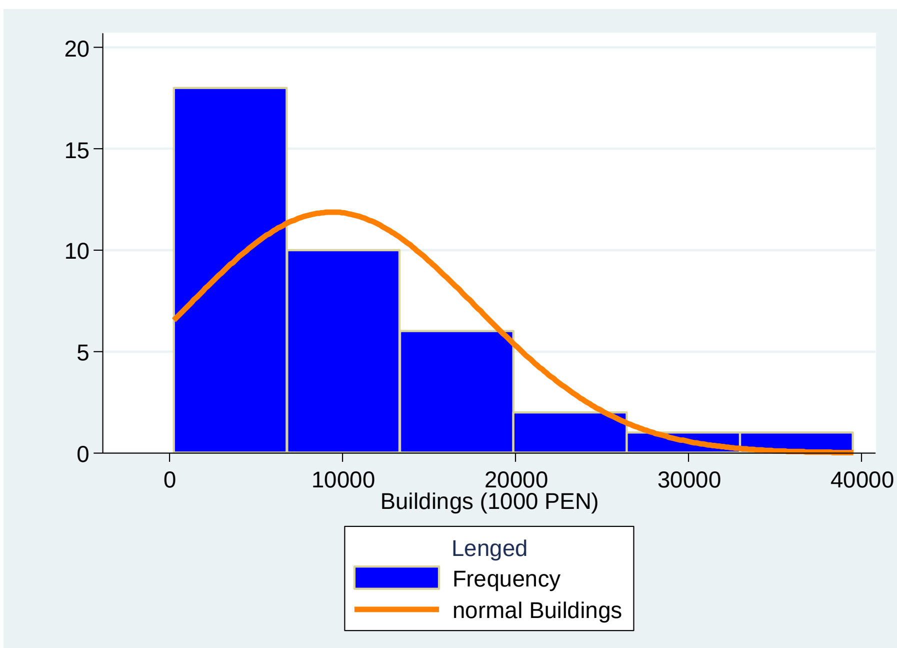


Figure 7-2. Building assets per firm.



For the fishmeal industry, results obtained for the four models indicate that growing is not the only factor that can be important, but also knowing how to grow. Investing in refrigeration and buildings can make a company very well fit for the Non-ENSO events by providing the adequate installed capacity for the processing of fishmeal when the supply of fish is abundant. In addition, becoming vertically coordinated means that fishmeal processors are increasing their size by claiming ownership of a vessel fleet. Although this strategy can be beneficial during abundant times, it could be interpreted that having such a large amount of assets makes them more vulnerable because they are less flexible. With this in mind, diversification becomes a better strategy when coping to ENSO. Those firms that combine a diversification strategy can utilize their installed capacity during scarcity, and put it to work in the manufacturing of other products that in fact can come from non-anchoveta sources.

As more data becomes available and better methods to measure resilience are developed, new approaches can be tested and the analyses can be refined. The availability of more data could help for a conclusive analysis on the exact openness of the quadratic models and its inflection points thus providing a better understanding on how large it is beneficial to be, and how much should be invested in refrigeration. Despite the data limitations, the models presented provide a valuable insight of an industry that has not been given the importance it deserves in economic climatology, and that can cause such a ripple effect on global agri-food production.

Chapter 8 - Conclusions

The objective of this paper was to fill the gap in the literature by providing insights on factors affecting the resilience of firms in the Peruvian fishmeal industry to weather related shocks. More specifically, the thesis (i) developed a quantitative measure of resilience of Peruvian fishmeal producing firms to the effects of an ENSO event; (ii) analyzes factors affecting resilience of Peruvian fishmeal producing firms; and (iii) presents implications for policy and industry decision makers. This is accomplished by applying the resilience framework in conjunction with a unique panel data on the fishmeal industry in Peru. The resilience triangle approach is adapted from previous research done by Lindbloom et al. (2017) and Barroso et al. (2015). Following this approach, the resilience of 38 fishmeal processing plants distributed along the Peruvian Pacific Coast is calculated during the ENSO event that took place from mid-2009 and ended in mid-2010.

The estimation results indicate that the experience of the fishmeal processing company, diversification of inputs and outputs, and a level of government support have positive effect on firm resilience. They also indicate that the size of firms' assets (buildings and refrigerated storage) have a negative effect on resilience. It is important to note that the limited sample size did not provide sufficient power for estimating the effects of a squared term for assets. Thus, it remains undetermined whether there exists a certain size at which the relationship between size and resilience turns positive. The results imply that diversification of inputs and outputs plays a more relevant role in resilience than vertical integration in the context of the Peruvian fishmeal industry.

Government aids can be beneficial when coping with ENSO events. As a firm receives a subsidy from a government agency, fishmeal processors can acquire resources that they did not have readily available. These resources may not only represent a lump sum of money, but also tax concessions or reductions in interest rates to acquire loans more easily as a measure against natural disasters. In the case of sea mandates and legislatures, two different regions are established along the Peruvian coasts. Although from a government stand point the results could mean to immediately help the industry, from a strategy perspective this might not be the best way to deal with ENSO events. Properly, firms by themselves should find risk management strategies that help them cope with ENSO events.

Peruvian laws establish a division of the North-Central Region and the Southern Region on the 16th parallel South. Although no statistical significance was found, results show that difference in legislations on both regions are making fishmeal processors in the North-Central Region more resilient to ENSO events than their parts in the Southern Region. This legislation in the North-Central Region has focused on the protection and sustainability of fisheries leading to better results. This implies that Peruvian legislatures should push for similar laws to be established for the Southern region taking into account the local characteristics of each region. Moreover, when in difficulty, government agencies must be vigilant to measures in which El Niño could be predicted more accurately and have contingency plans for all levels of the value chain that may be affected.

As weather becomes a greater concern and fishmeal is reliant on it, both the fishmeal producers and policy-makers should focus on developing those capabilities in fishmeal producers that increase the resilience of the fishmeal industry as a whole. For fishmeal producers this may involve increasing input and output diversification. For policy-makers, implementing adequate regulations at the height of the situation, targeted on improving the development of the industry and focused on a better management of hydro-biological resources would mean not only an increase in production and profits but also the assurance of long-term industry perseverance. This will help not only to maintain existing jobs but also to create new jobs thus generating well-being and prosperity for the communities that depend on fishmeal exports, and reducing other negative social impacts.

8.1 Recommendations for Further Research

Multiple recommendations for further research stem from this study. First, as INEI publishes the data from the 2017 annual economic survey, the same framework could be used to measure the resilience of fishmeal processors during the most recent ENSO 2014-2016 event. This event is one of the longest lasting events in the last decade, and is being considered one of the strongest event in the current century. Moreover, it is possible that different performance measures would affect the resilience index for each firm. Furthermore, to the extent that the data allows it, a study comparing the resilience of fishmeal processors during similar ENSO events should be conducted. This would grant fishmeal processors a more accurate perspective on their strategies to ENSO events. On the policy side, policymakers would understand the beneficial effects their policies established over time for the fishmeal industry, and provide empirical evidence on the new measures that should be taken to cope with ENSO events. In addition, these policies could help in the development of legislatures that promote the sustainability of marine life.

The models provide a strong insight on the influence of the importance that the government could have on the resilience index. Although for further research, the amount of subsidies a processing plant received instead of a binary variable could be presented in order to estimate the extent at which they are beneficial when coping with ENSO. Likewise, other variables that include other supports from the government can be included. This would equip policy-makers with intuition of marine regulations that can reduce the imminent concentration of the industry.

Finally, with the availability of more data, more variables should be included in the model. These variables can include other management strategies not included in the models presented. In addition, variables on expenditures and specific inventories can be introduced, as data permits it. These variables would allow for the proper estimation of the allocation of resources of the fishmeal processors and its effects to coping with ENSO.

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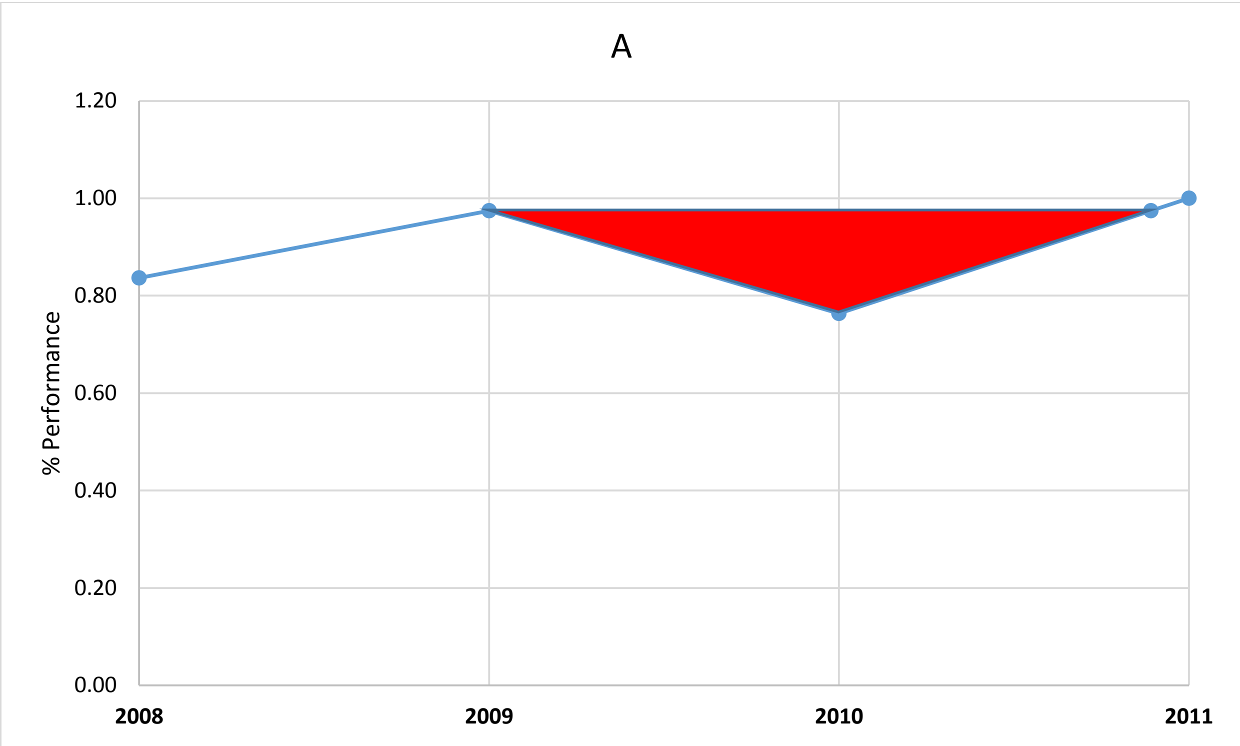
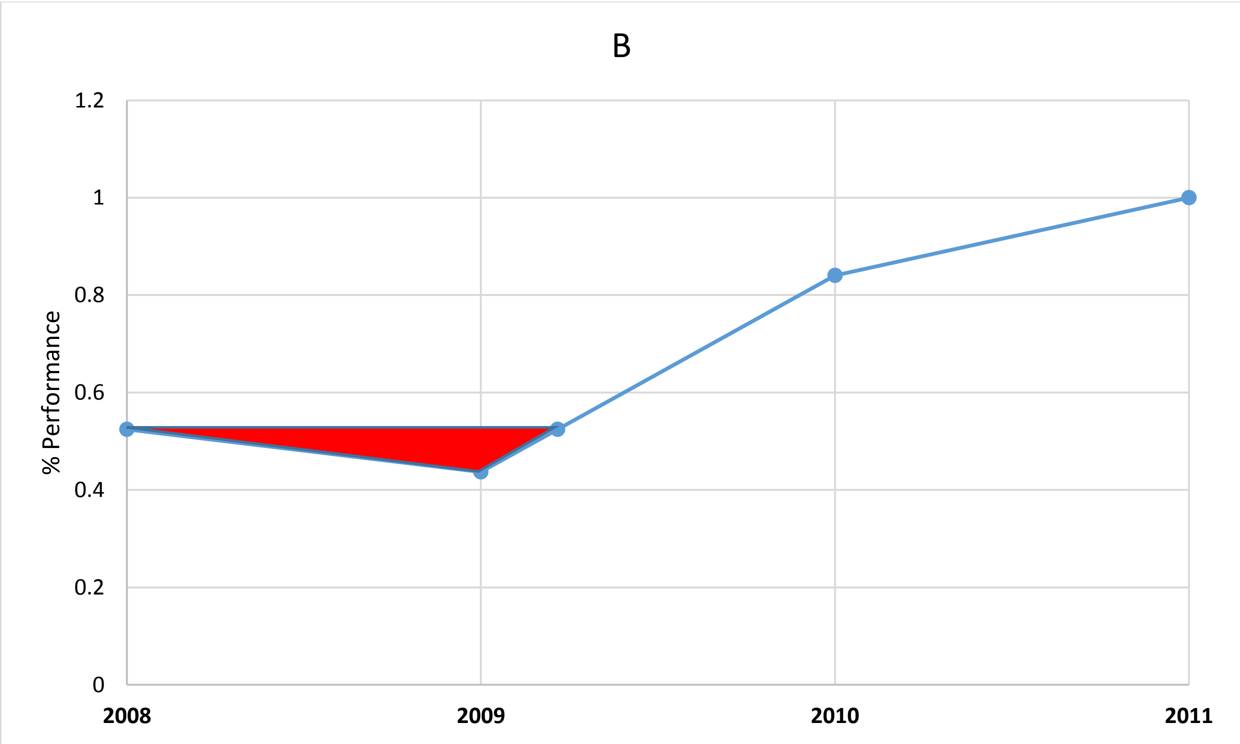
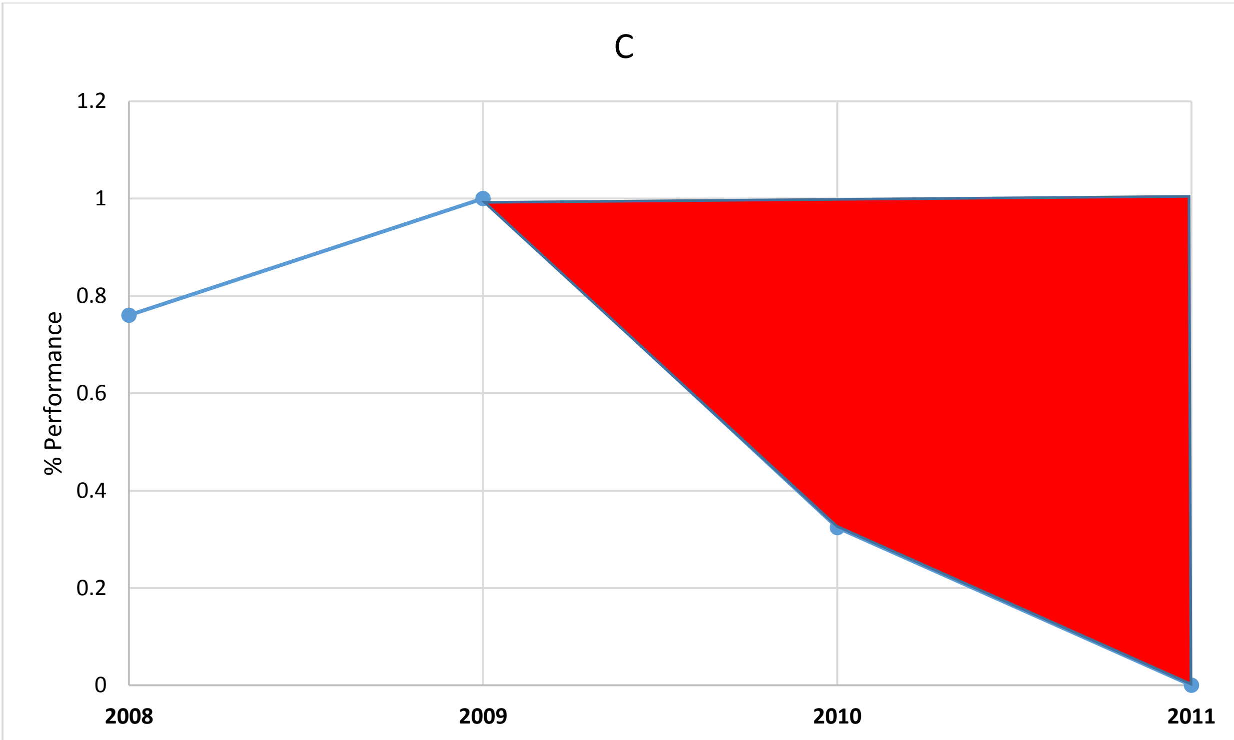
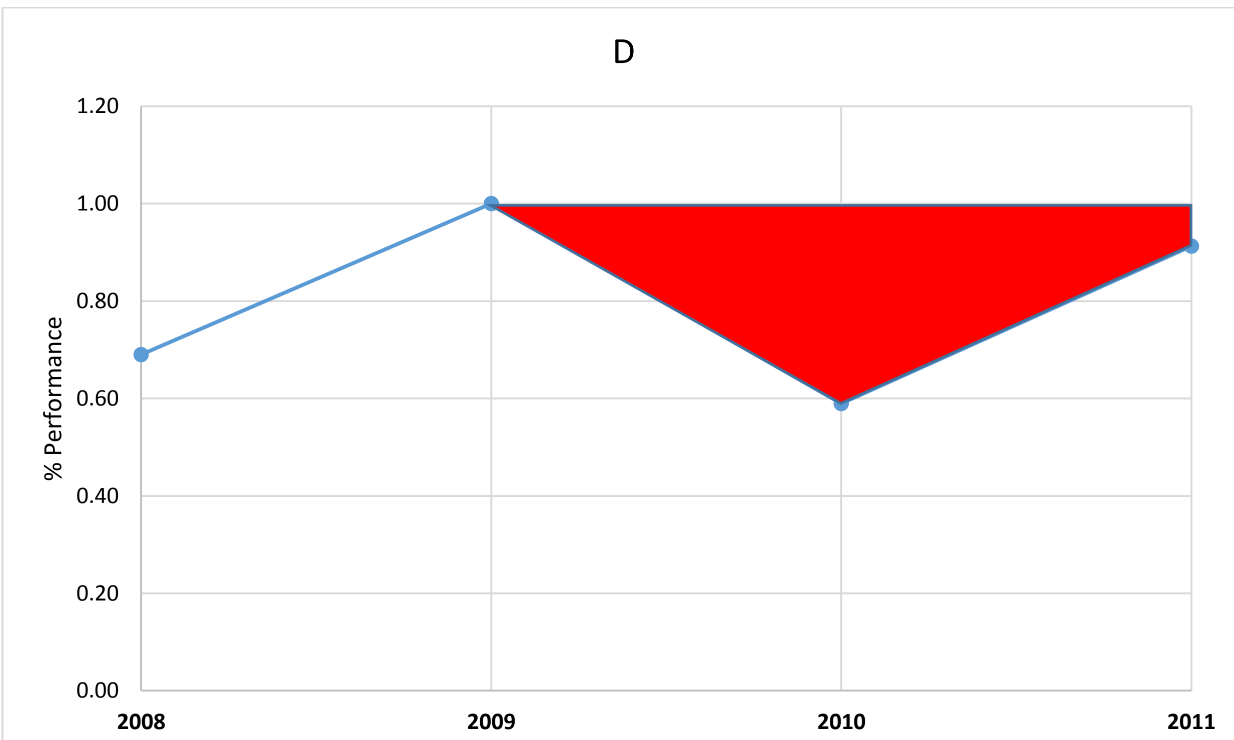
Appendix A - Fishmeal Processors Profit Graphs

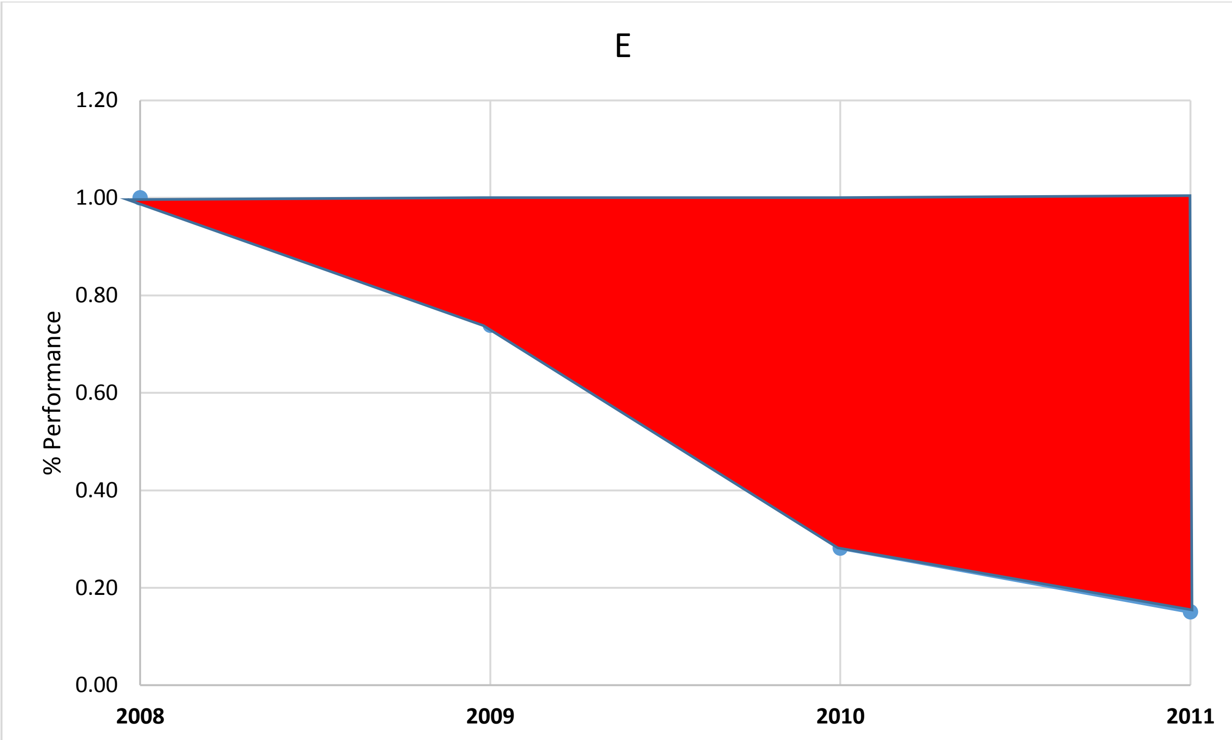
The red areas in the chart were the areas computed to calculate the resilience index for each fishmeal processor.

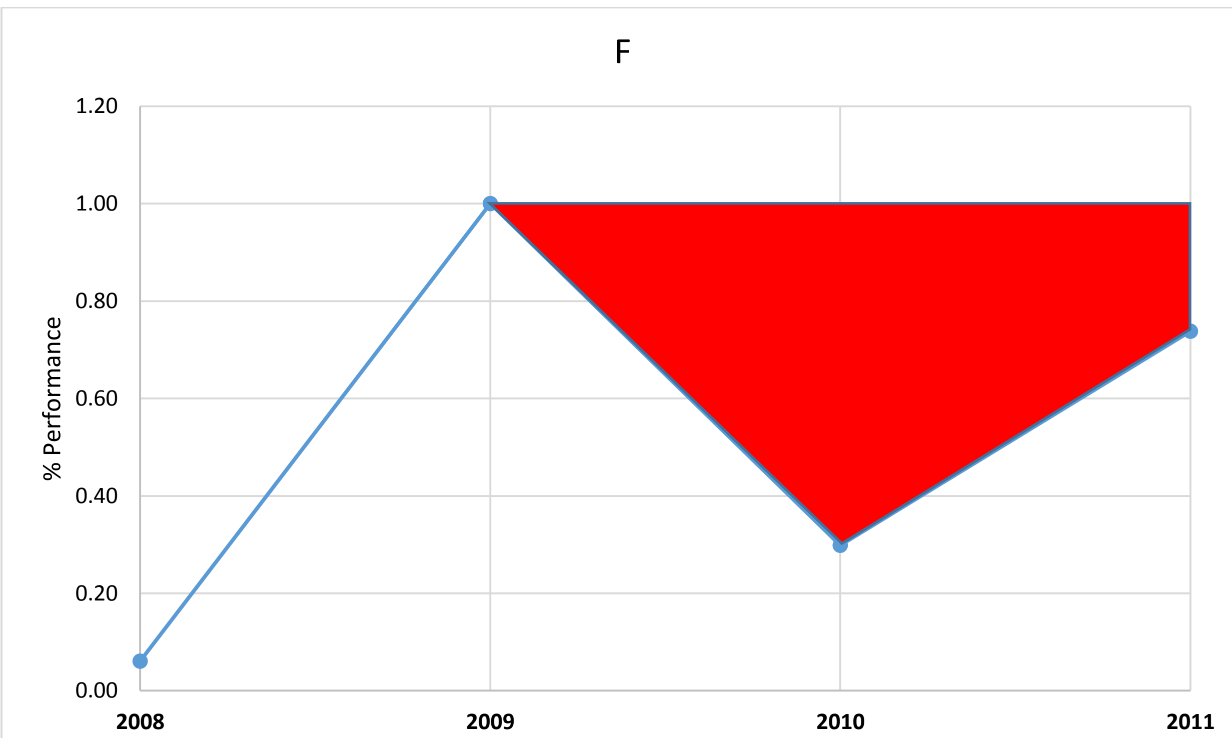





C
1.2
1
0.8
0.6
0.4
0.2
0
% Performance
2008
2009
2010
2011


D
1.20
1.00
0.80
0.60
0.40
0.20
0.00
% Performance
2008
2009
2010
2011


E
% Performance
1.20
1.00
0.80
0.60
0.40
0.20
0.00
2008
2009
2010
2011


F
% Performance
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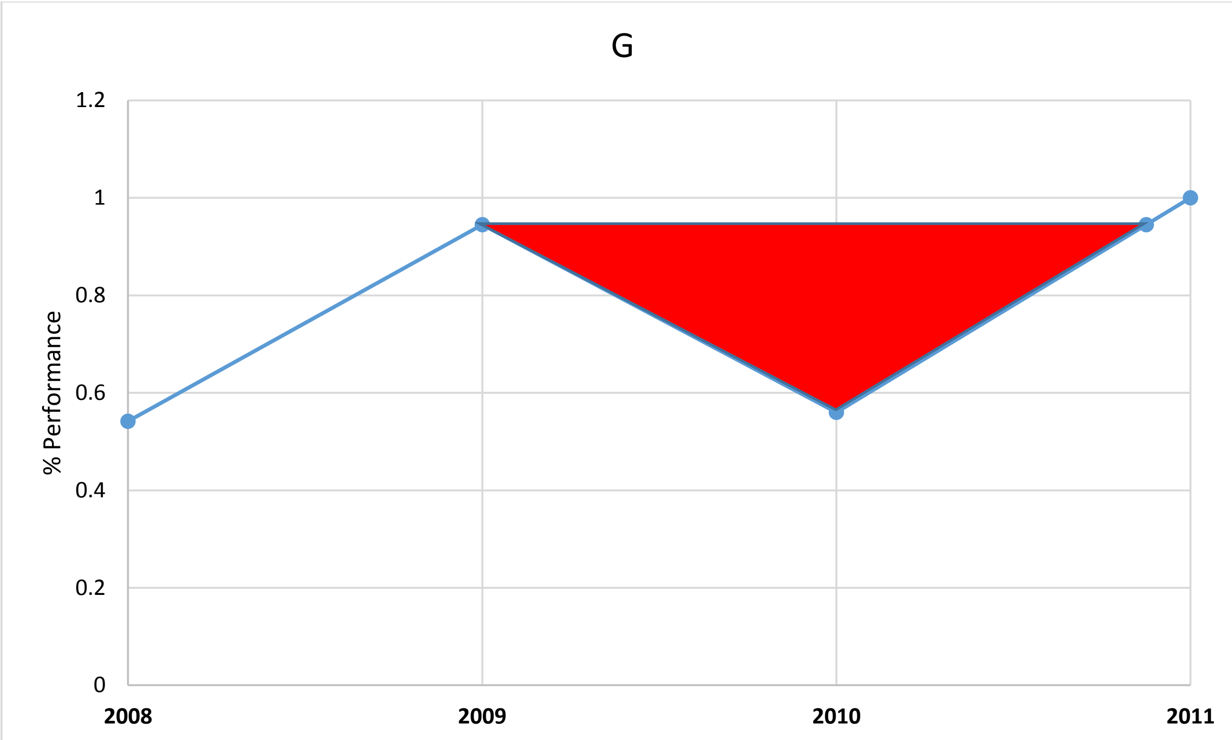
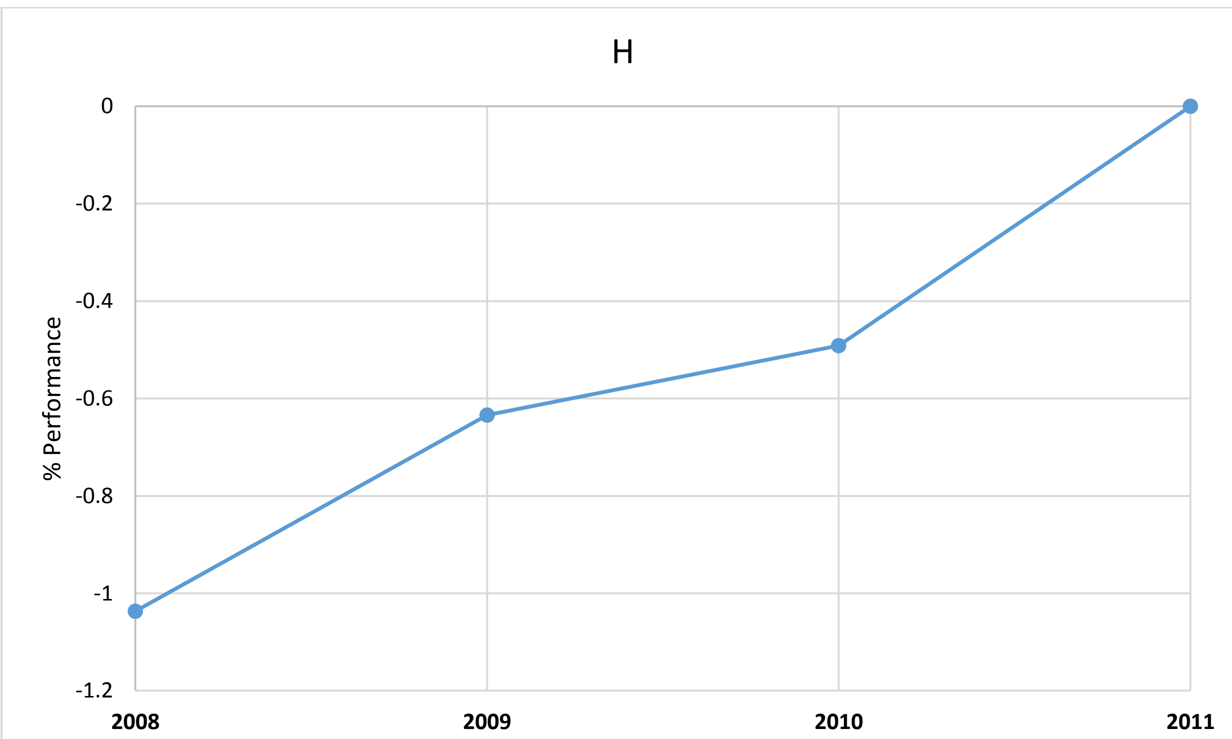
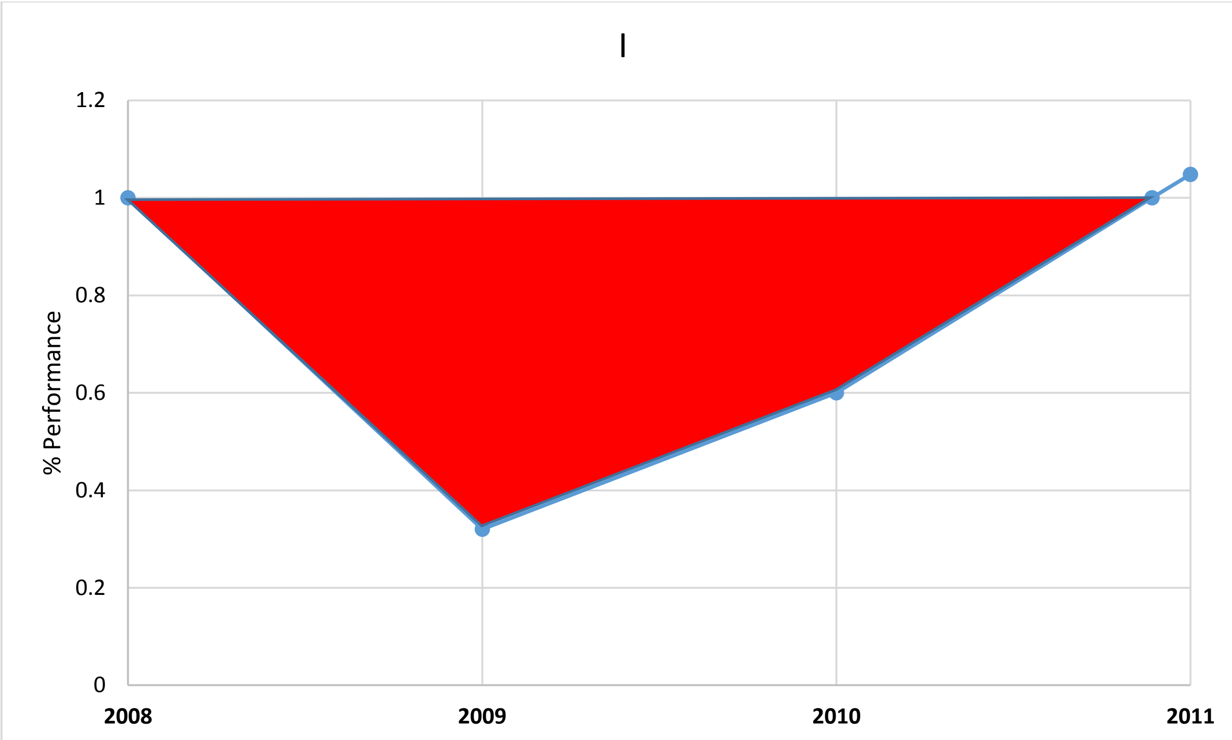
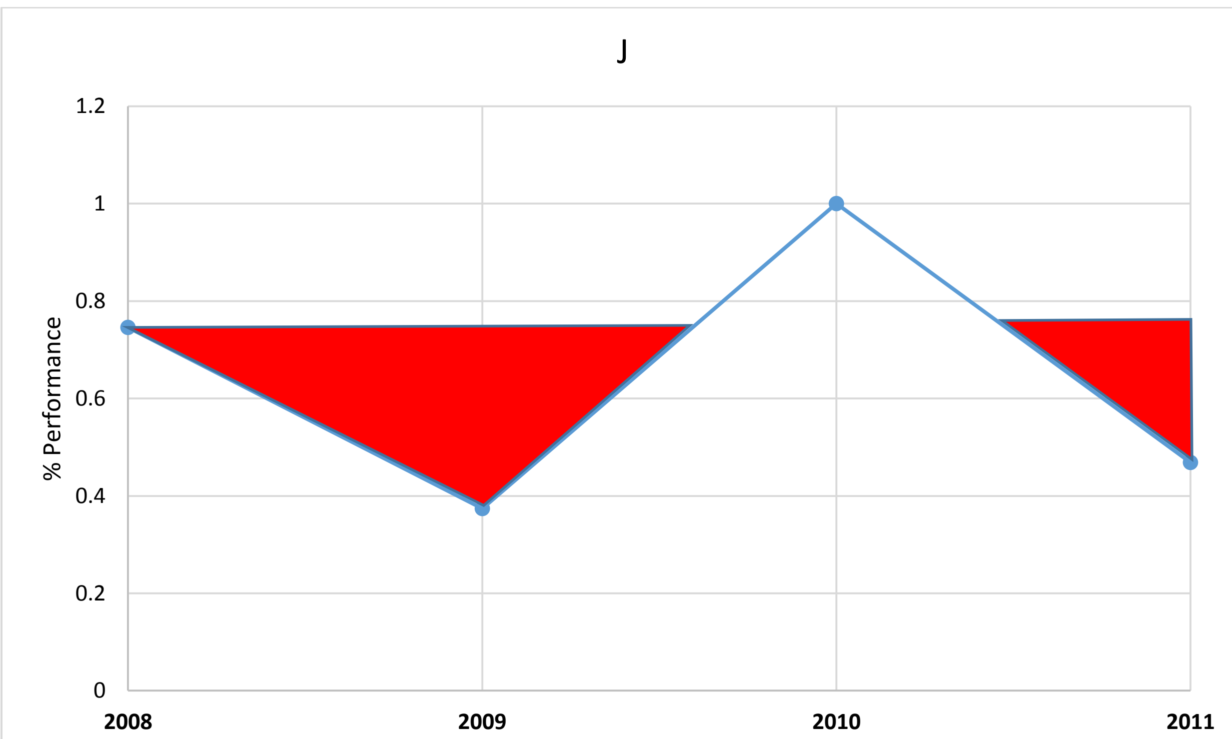
1.00
0.80
0.60
0.40
0.20
0.00
2008
2009
2010
2011

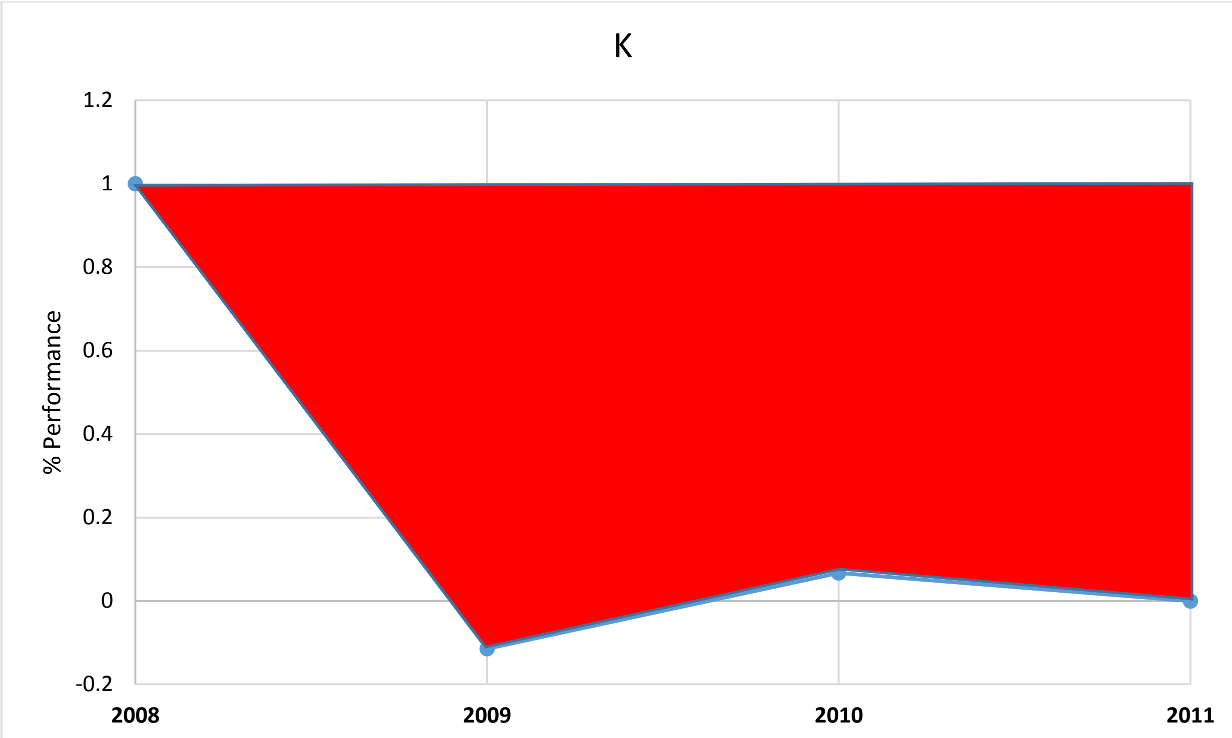




*Closed in the middle of 2011. Considered to have a 0 score in the resilience index.


I
% Performance
1.2
1
0.8
0.6
0.4
0.2
0
2008
2009
2010
2011


J
% Performance
1.2
1
0.8
0.6
0.4
0.2
0
2008
2009
2010
2011


K
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1
0.8
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0.4
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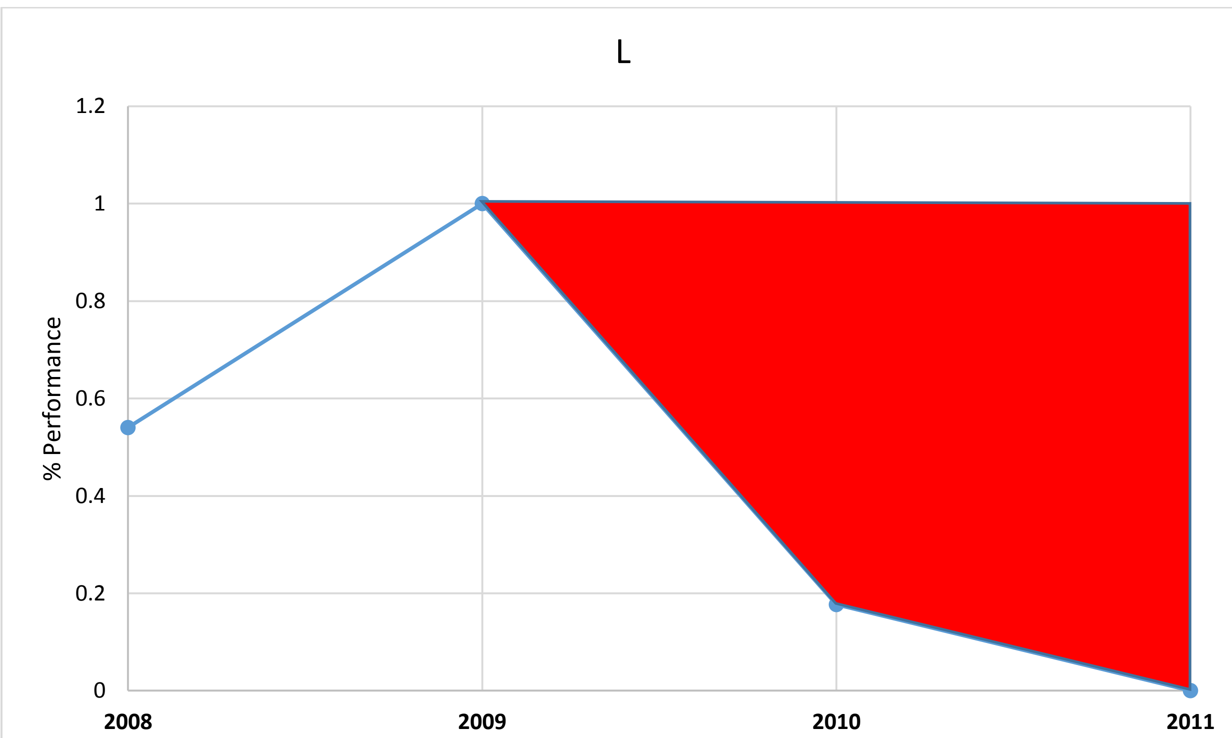
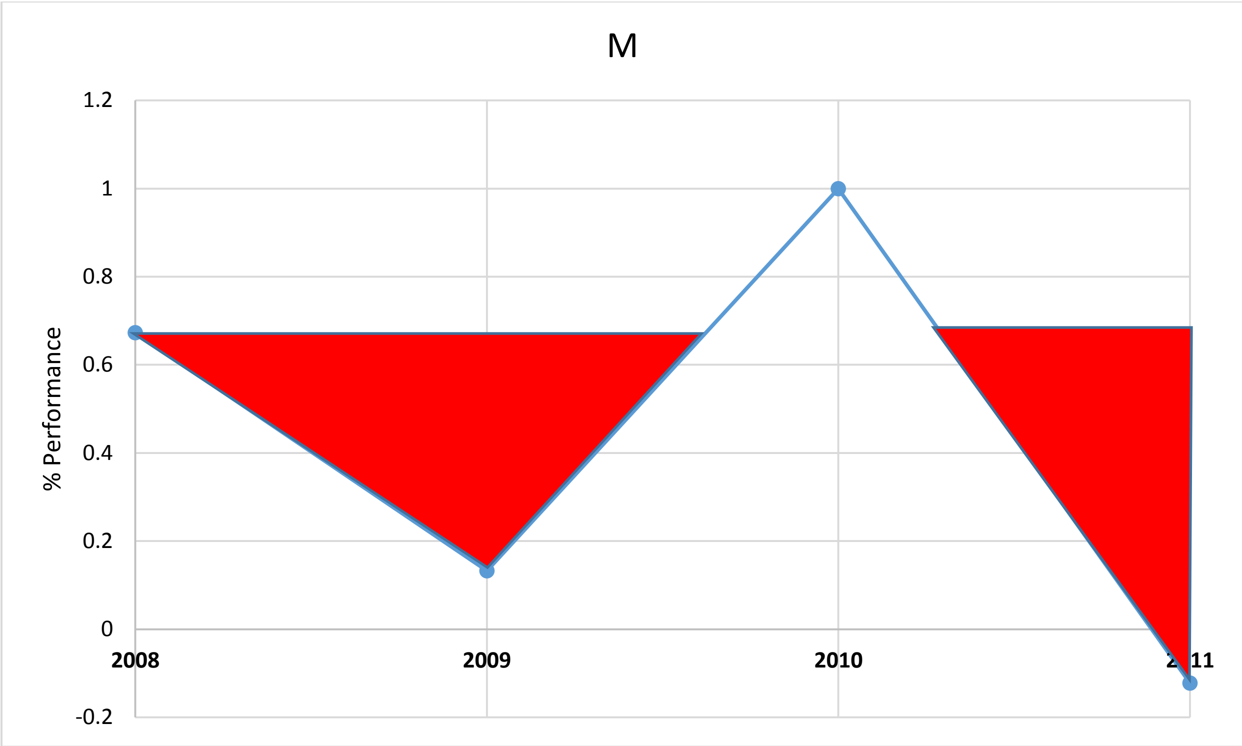
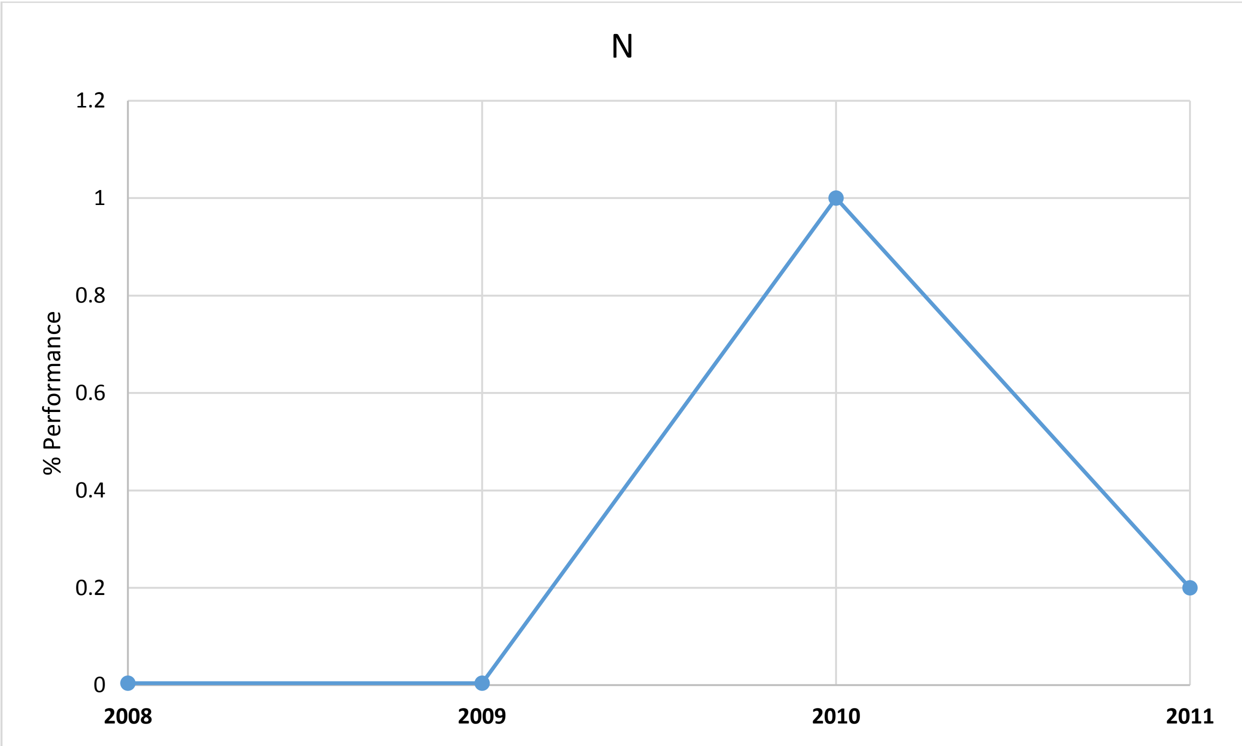
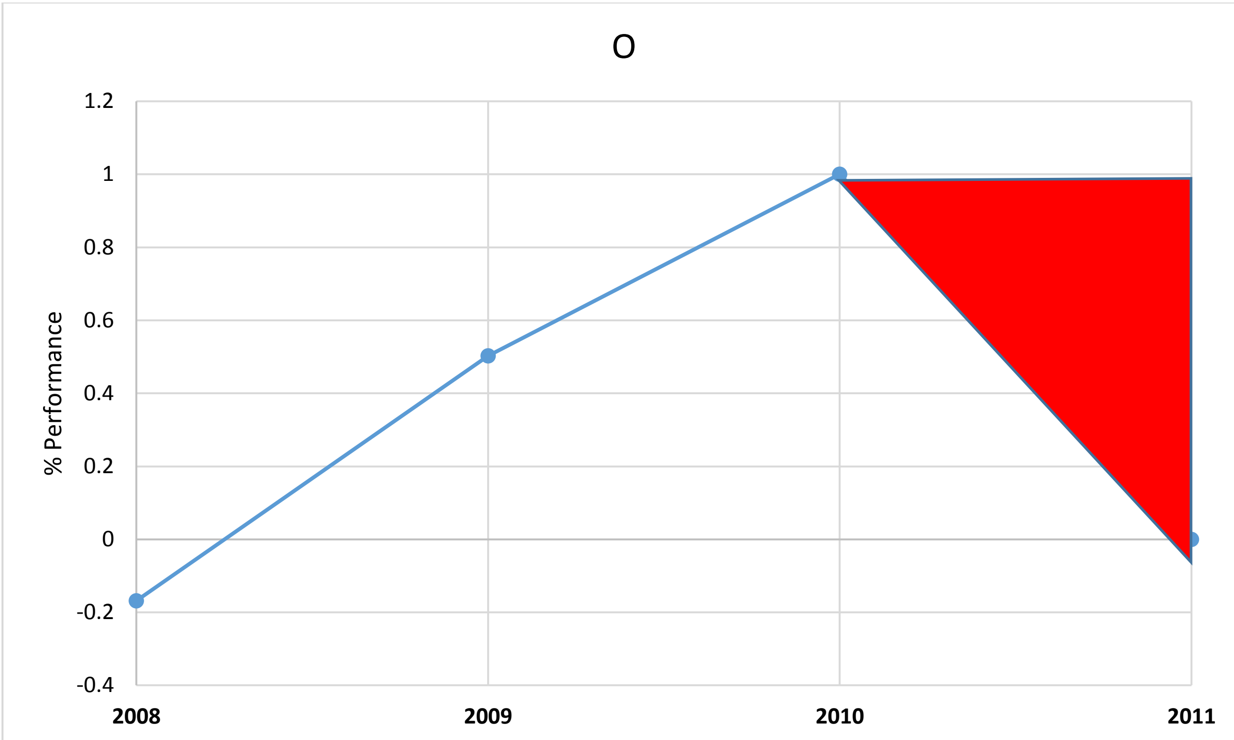
0
-0.2
% Performance
2008
2009
2010
2011

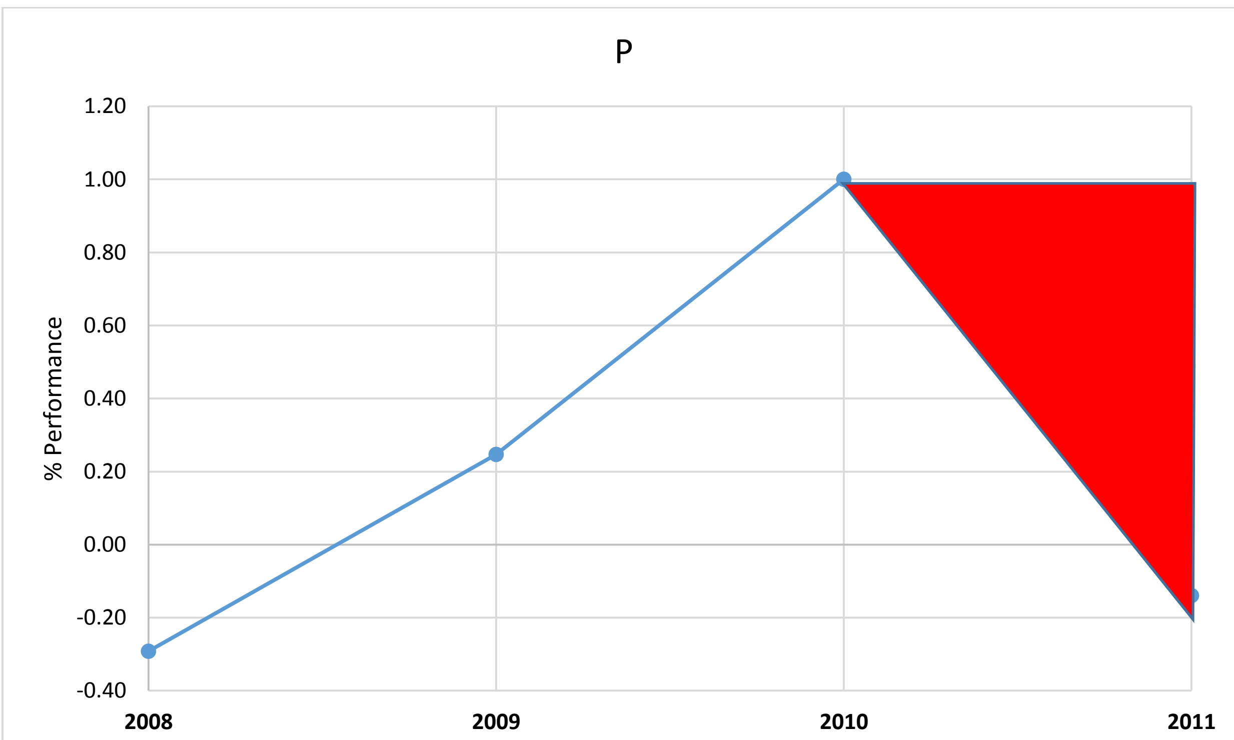

L
1.2
1
0.8
0.6
0.4
0.2
0
% Performance
2008
2009
2010
2011

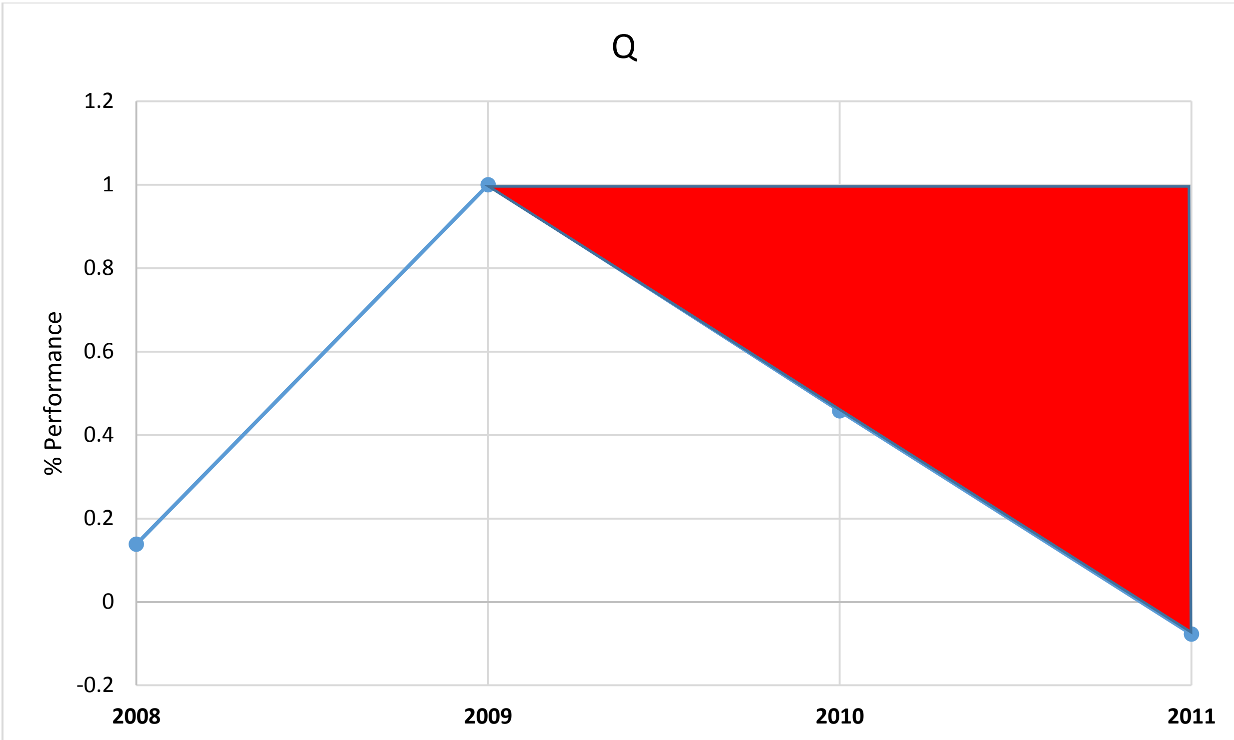


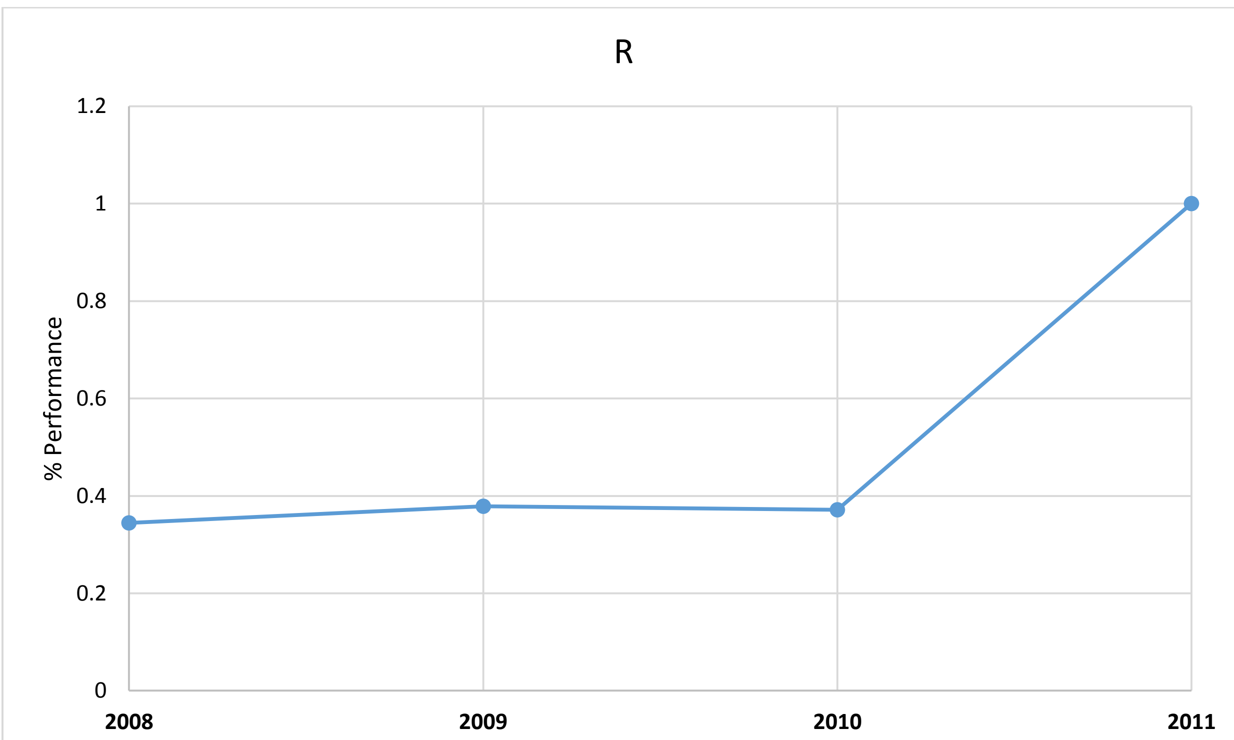


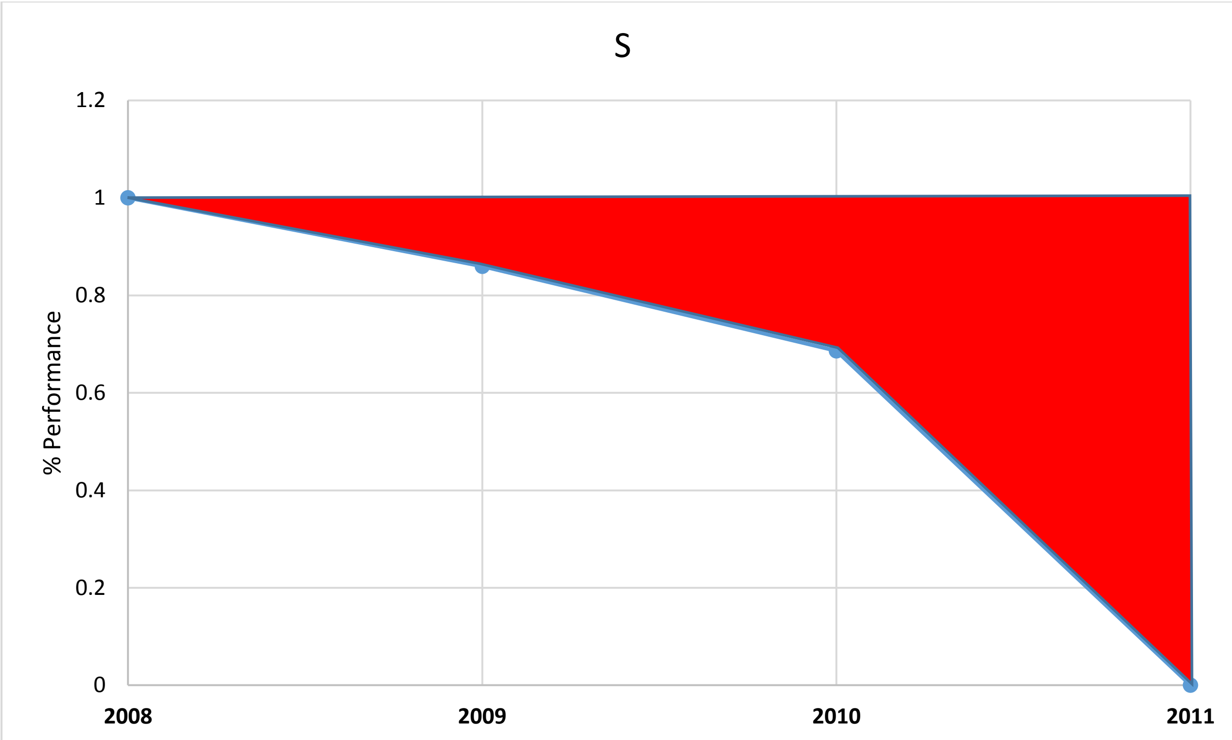
*Considered with 0 resilience because operating with losses.

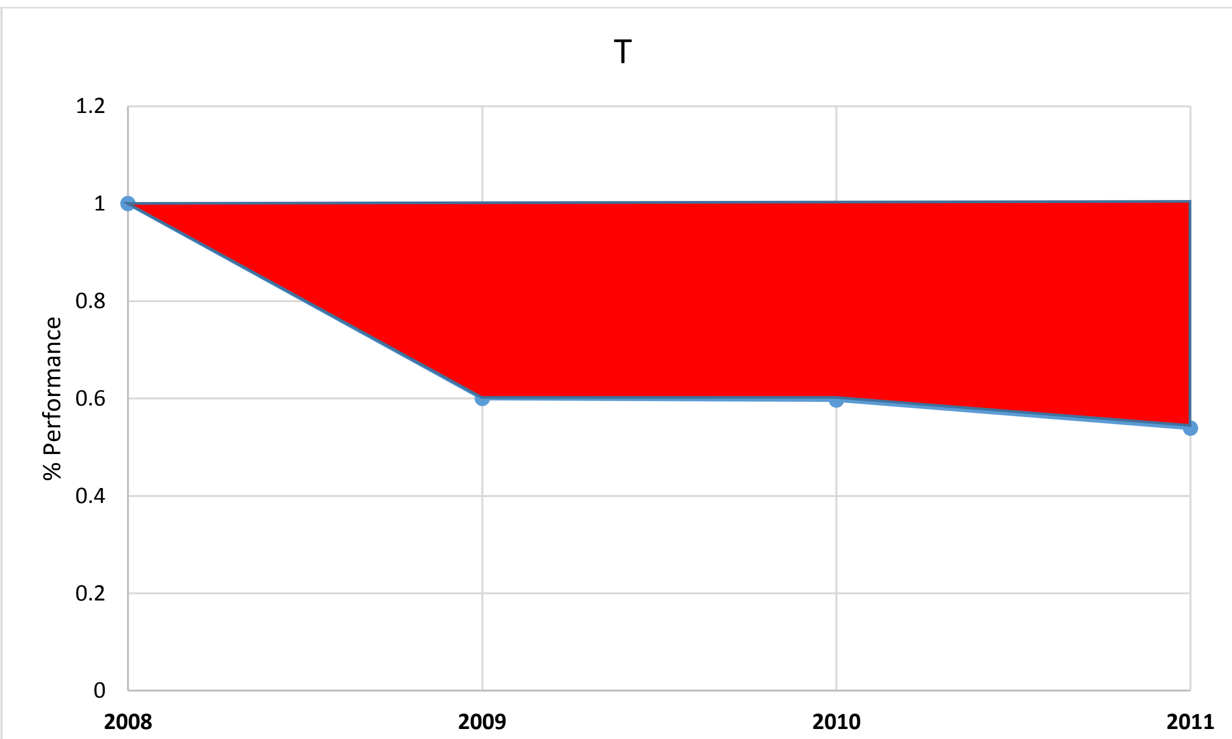

O
% Performance
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
2008
2009
2010
2011

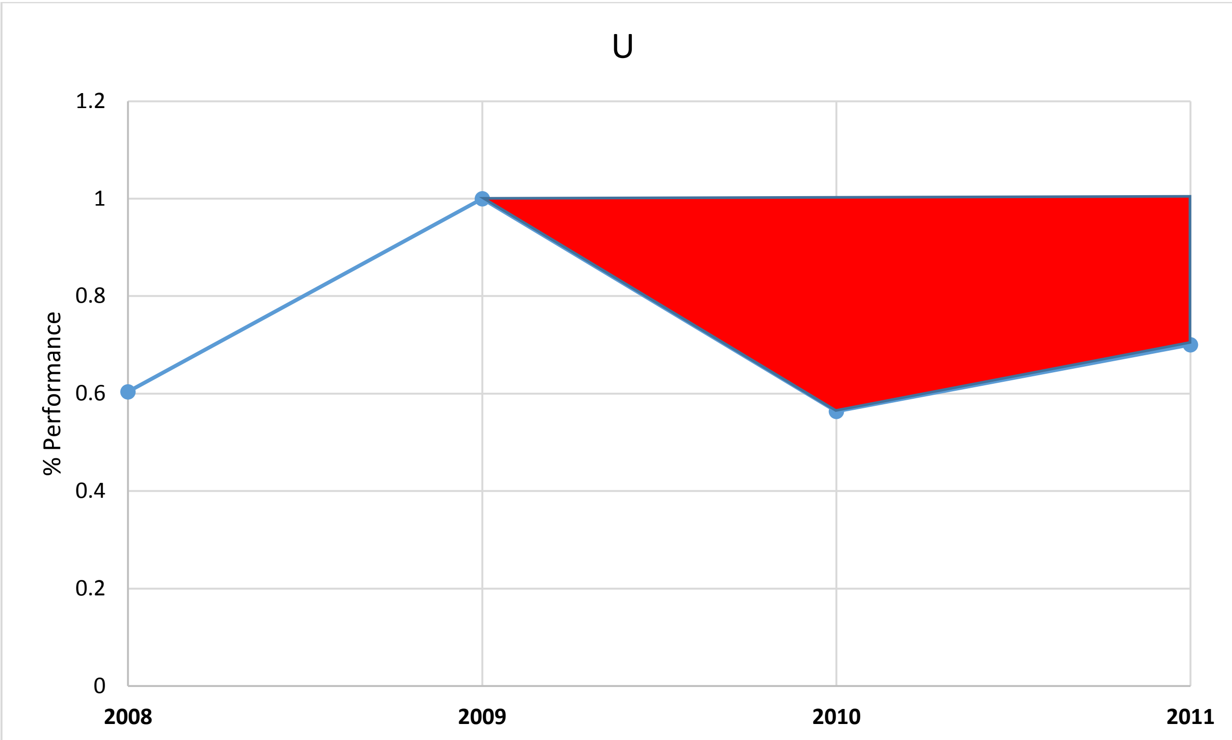

P
% Performance
1.20
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
-0.40
2008
2009
2010
2011


Q
% Performance
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
2008
2009
2010
2011


R
% Performance
1.2
1
0.8
0.6
0.4
0.2
0
2008
2009
2010
2011


S
1.2
1
0.8
0.6
0.4
0.2
0
% Performance
2008
2009
2010
2011


T
1.2
1
0.8
0.6
0.4
0.2
0
% Performance
2008
2009
2010
2011


U
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0.8
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0.4
0.2
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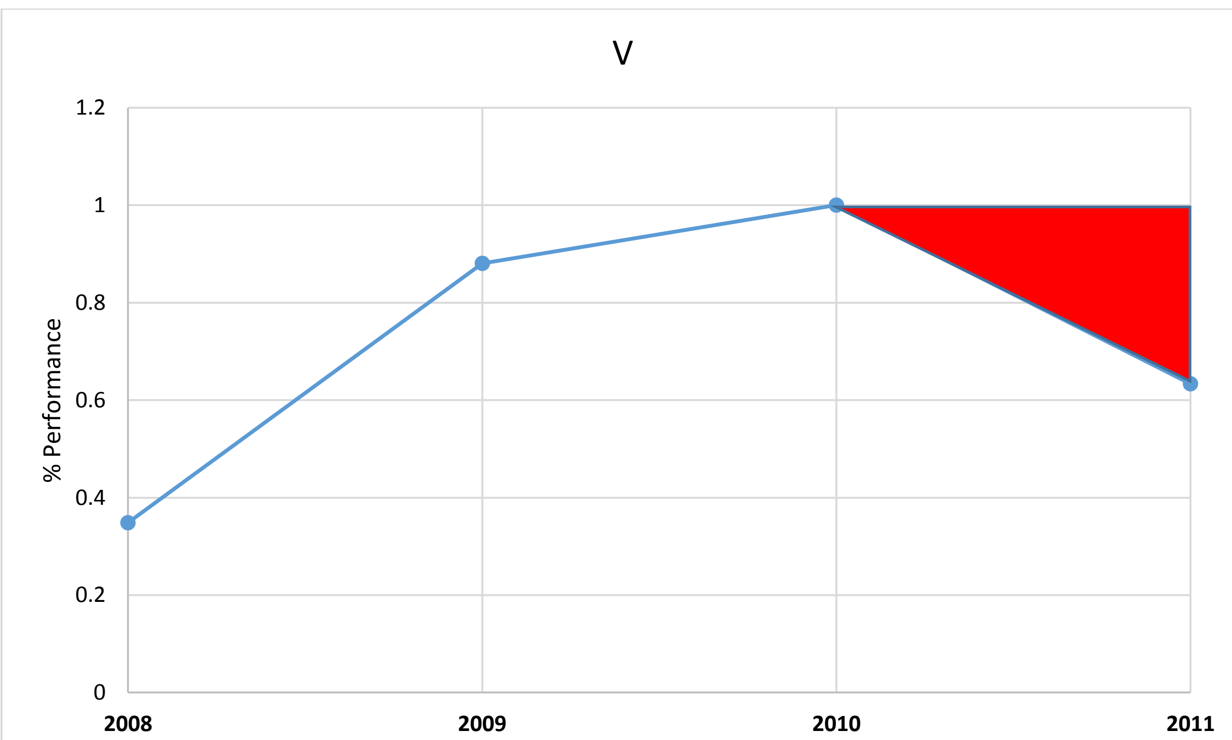
% Performance
2008
2009
2010
2011


V
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0.4
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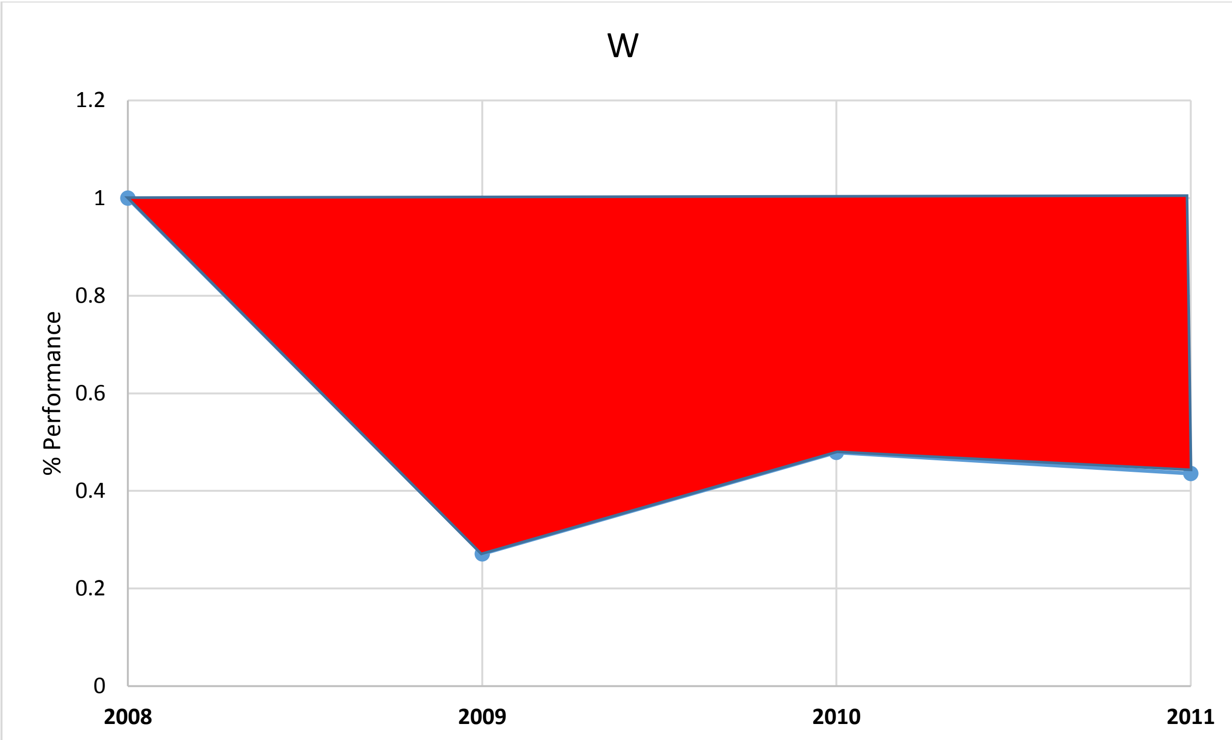
% Performance
2008
2009
2010
2011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0.4
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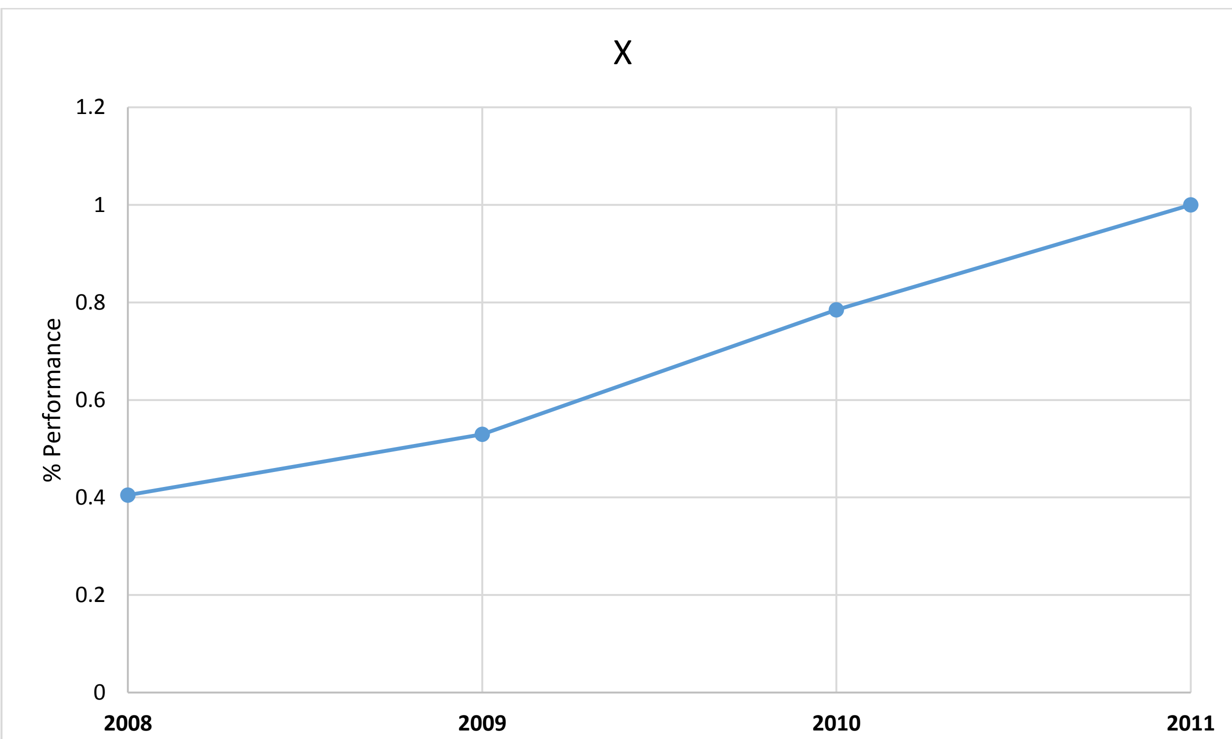
% Performance
2008
2009
2010
2011


X
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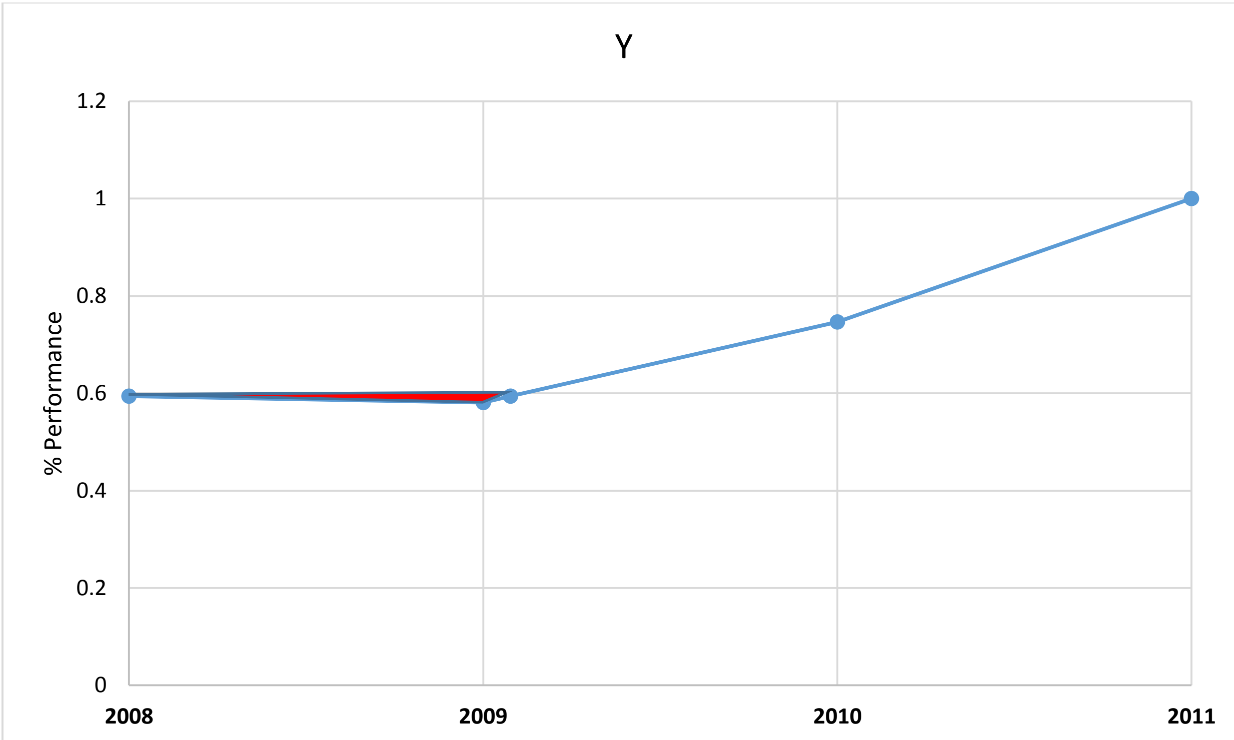
0.4
0.2
0
% Performance
2008
2009
2010
2011


Y
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0.8
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0.4
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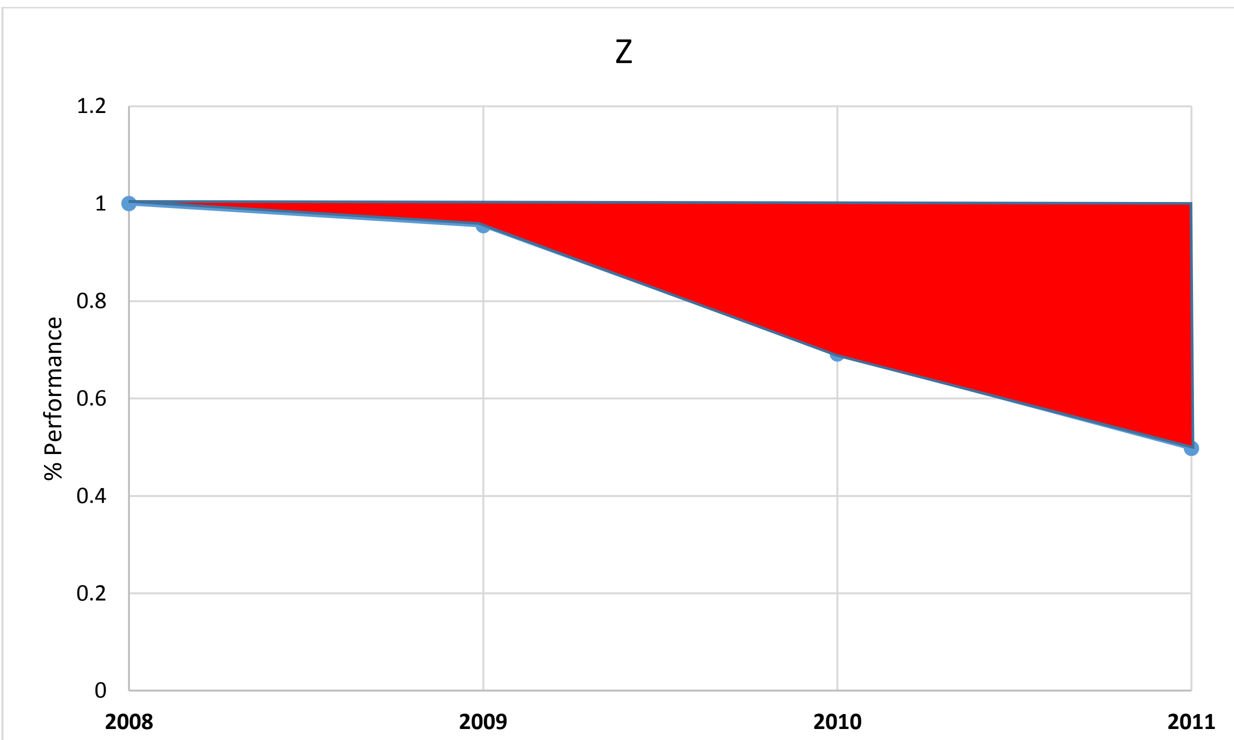
0
% Performance
2008
2009
2010
2011


Z
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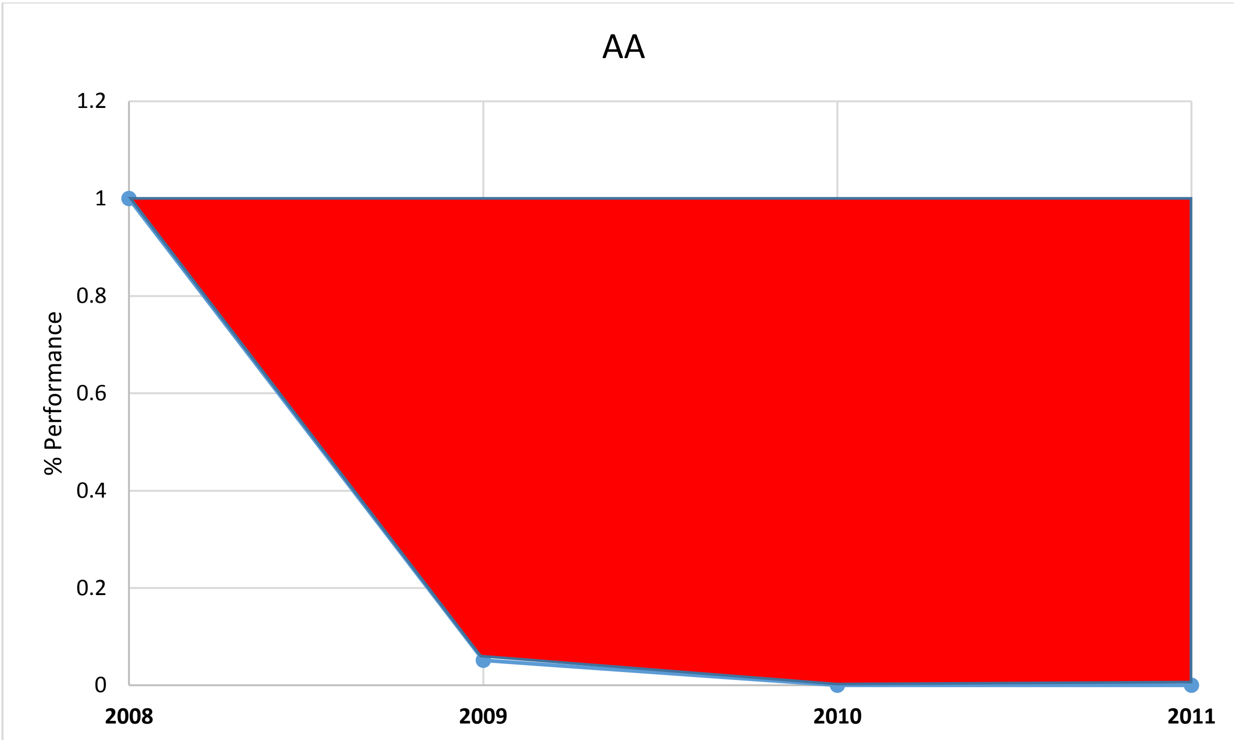
0.6
0.4
0.2
0
% Performance
2008
2009
2010
2011


AA
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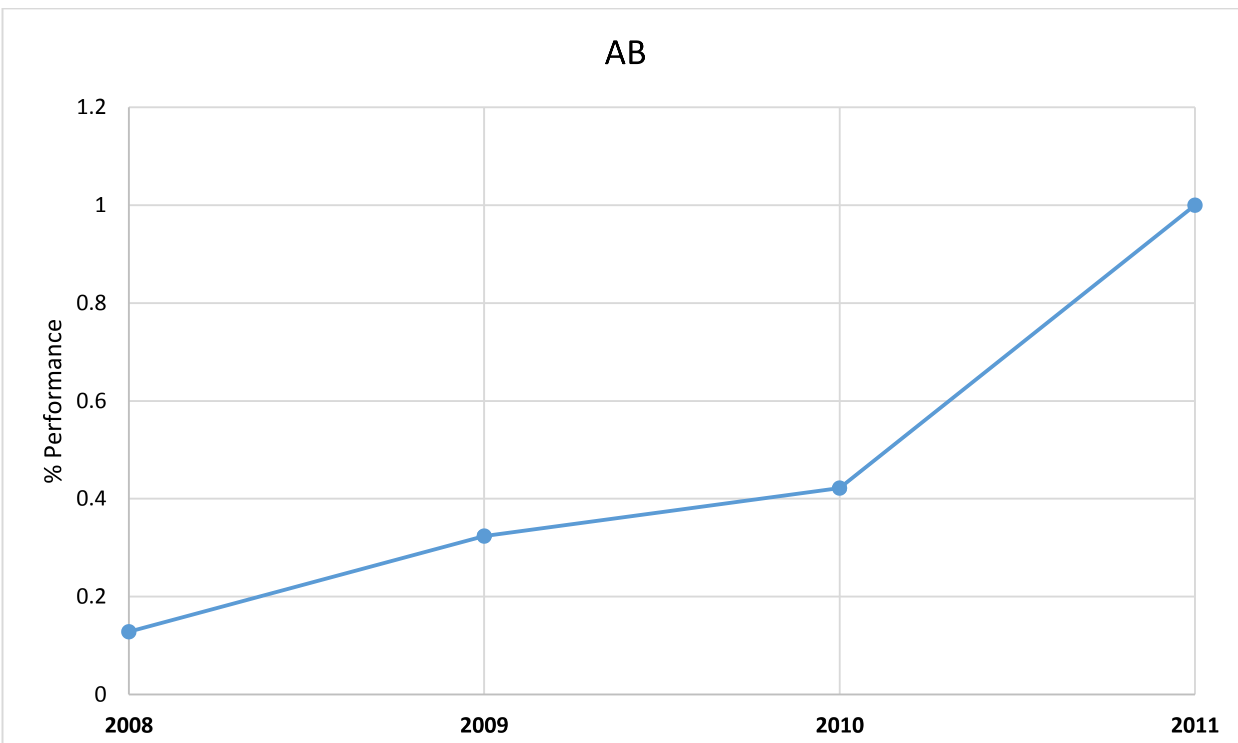
% Performance
2008
2009
2010
2011


AB
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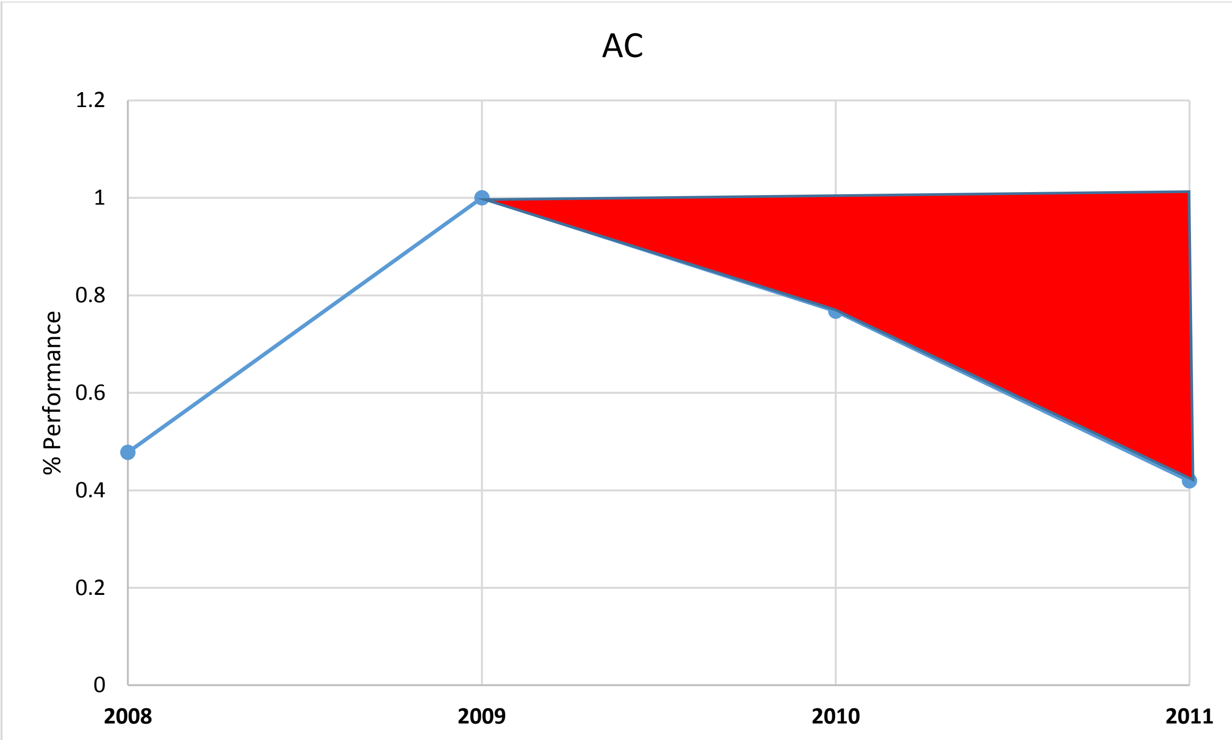
0.8
0.6
0.4
0.2
0
% Performance
2008
2009
2010
2011


AC
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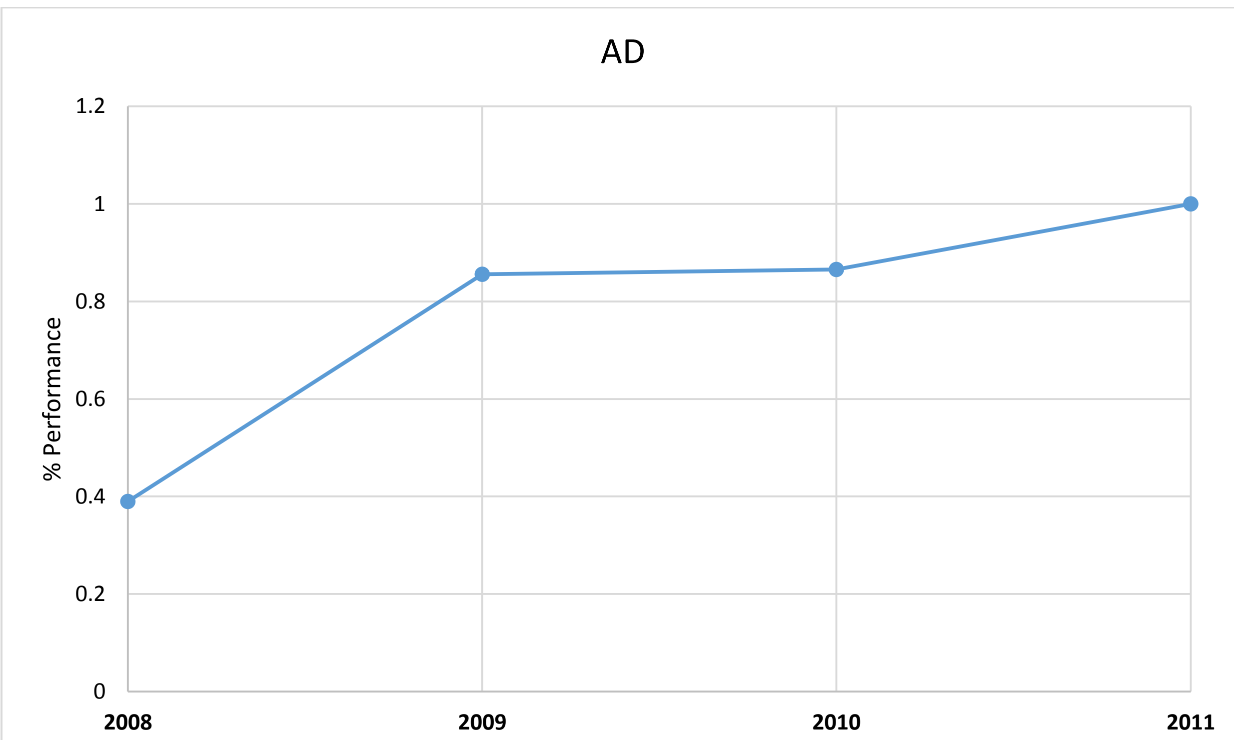
0.8
0.6
0.4
0.2
0
% Performance
2008
2009
2010
2011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0.4
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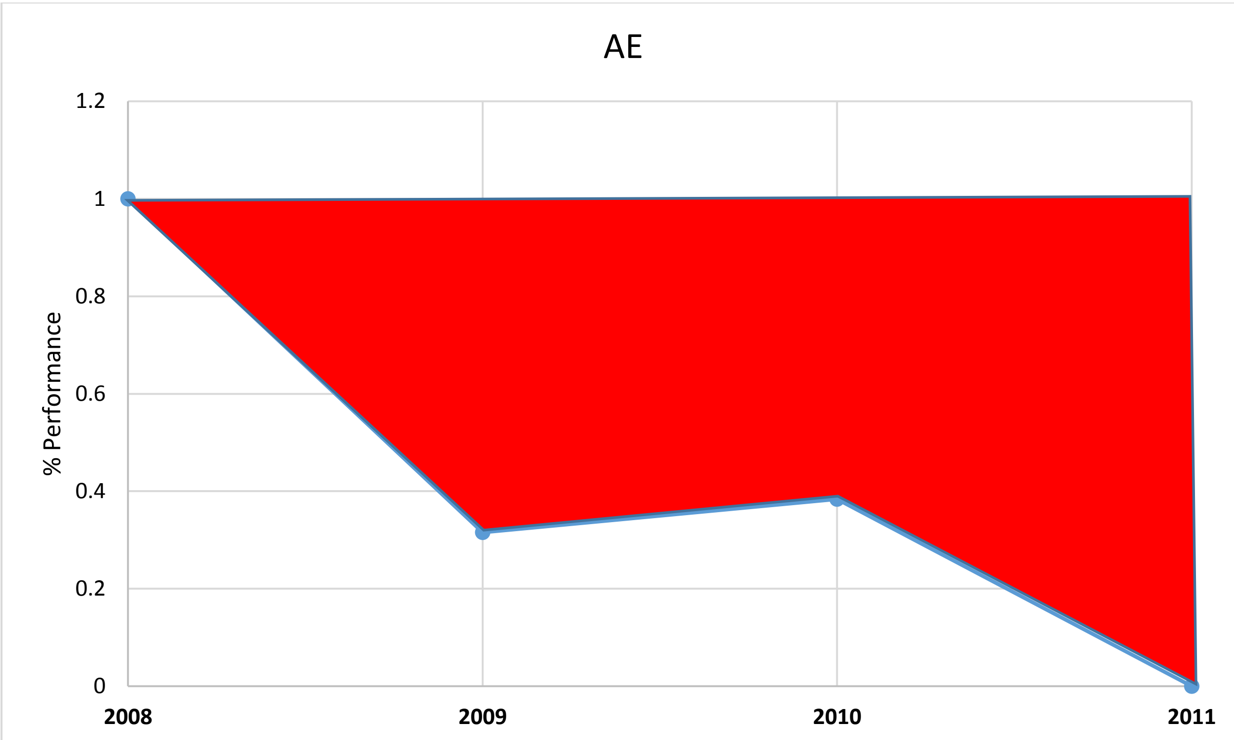
% Performance
2008
2009
2010
2011



AE
% Performance
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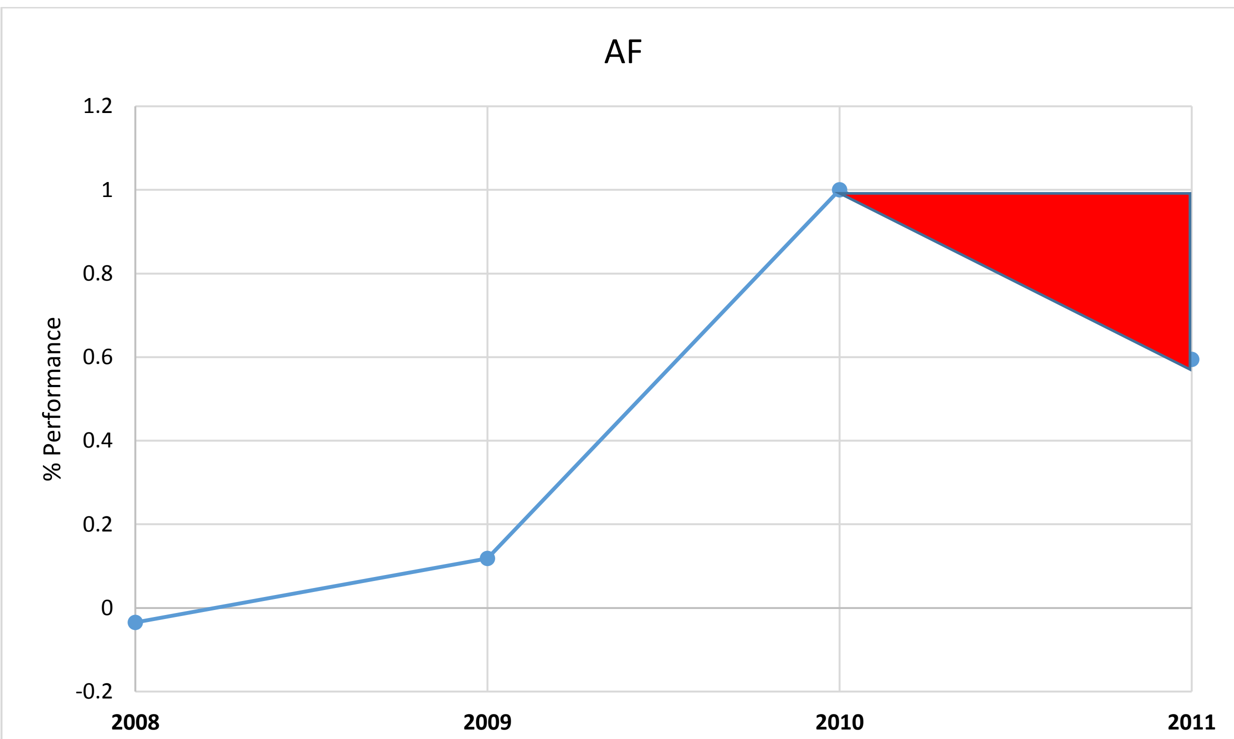
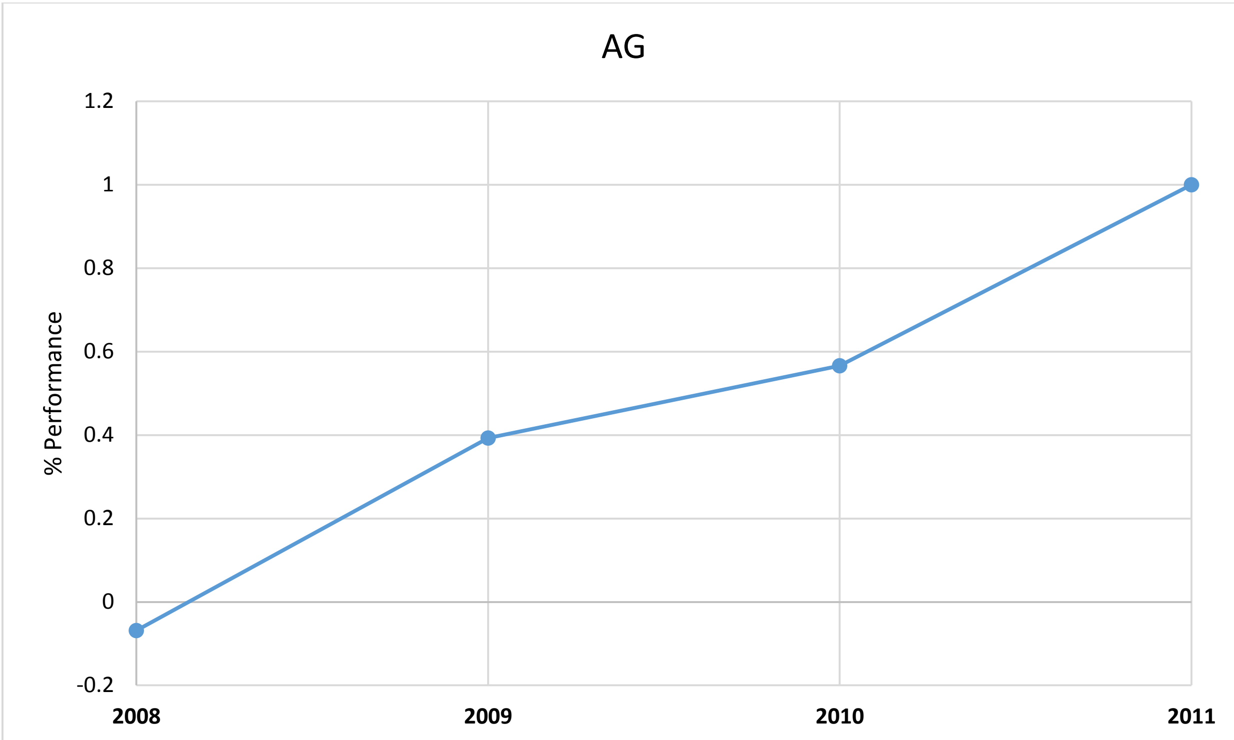
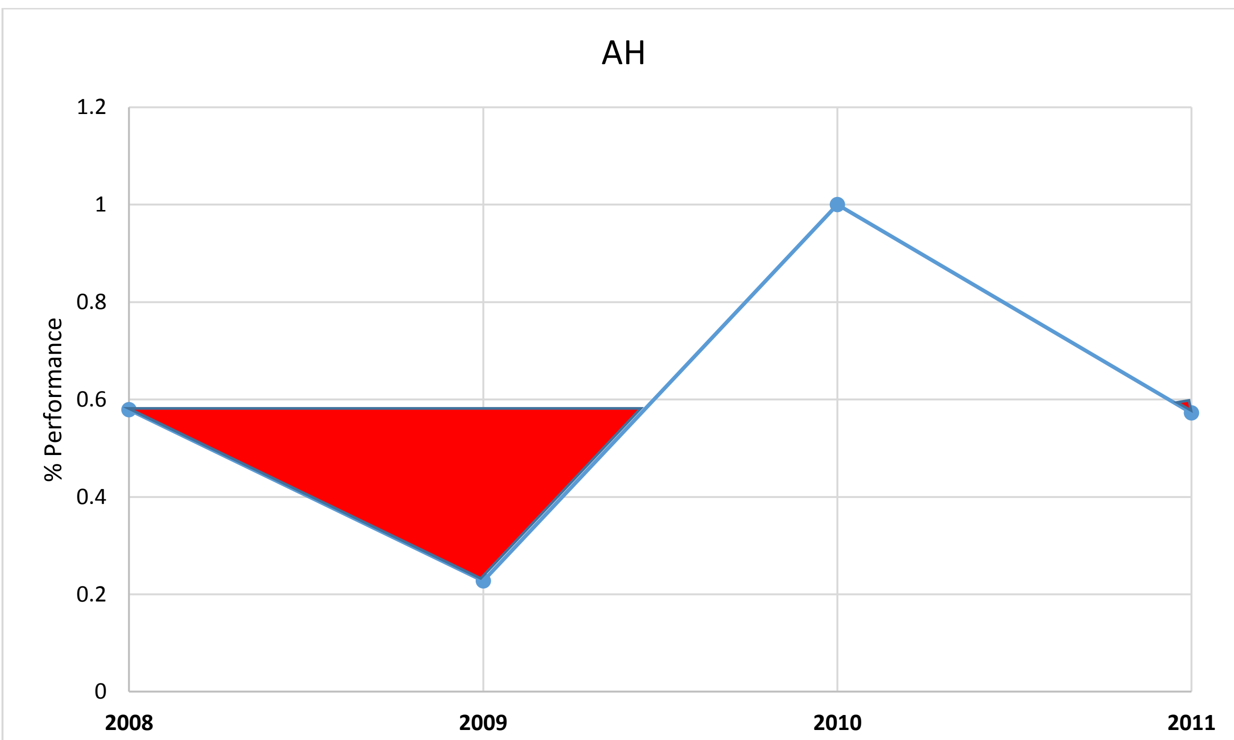
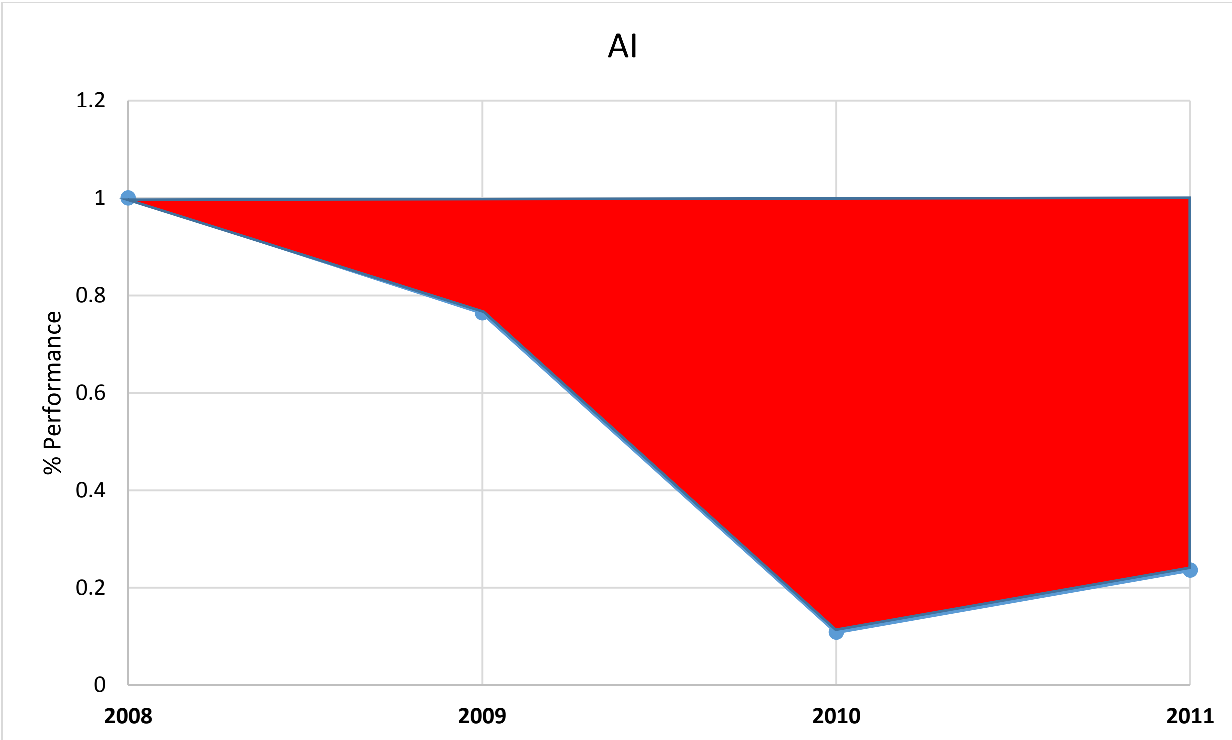
1
0.8
0.6
0.4
0.2
0
2008
2009
2010
2011

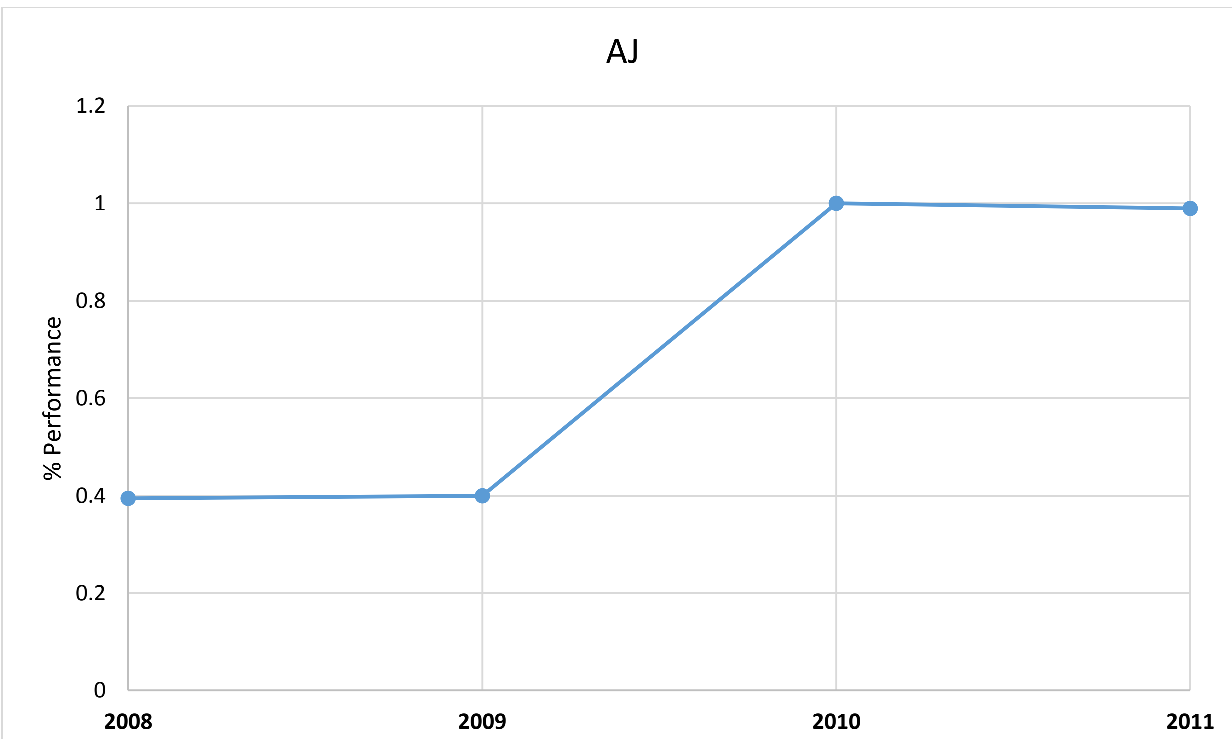


AF
% Performance
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
2008
2009
2010
2011


AG
% Performance
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
2008
2009
2010
2011


AH
% Performance
1.2
1
0.8
0.6
0.4
0.2
0
2008
2009
2010
2011


AI
1.2
1
0.8
0.6
0.4
0.2
0
% Performance
2008
2009
2010
2011


AJ
1.2
1
0.8
0.6
0.4
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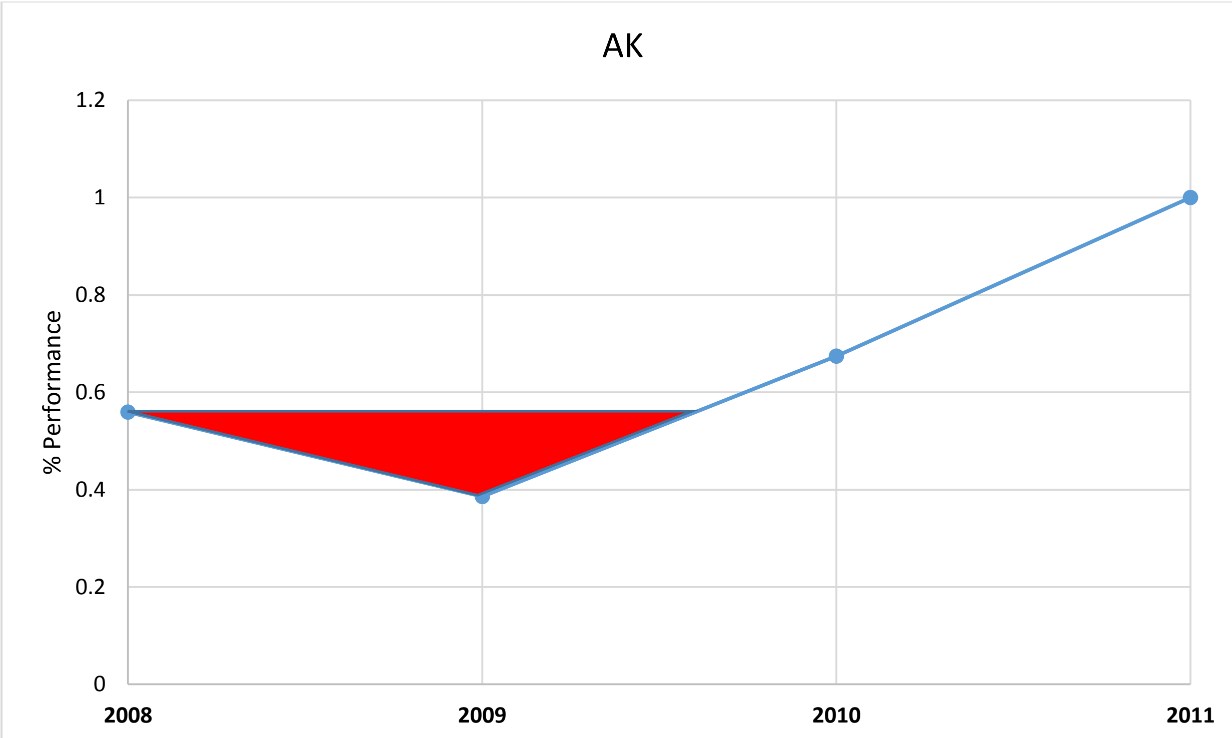
% Performance
2008
2009
2010
2011


AK
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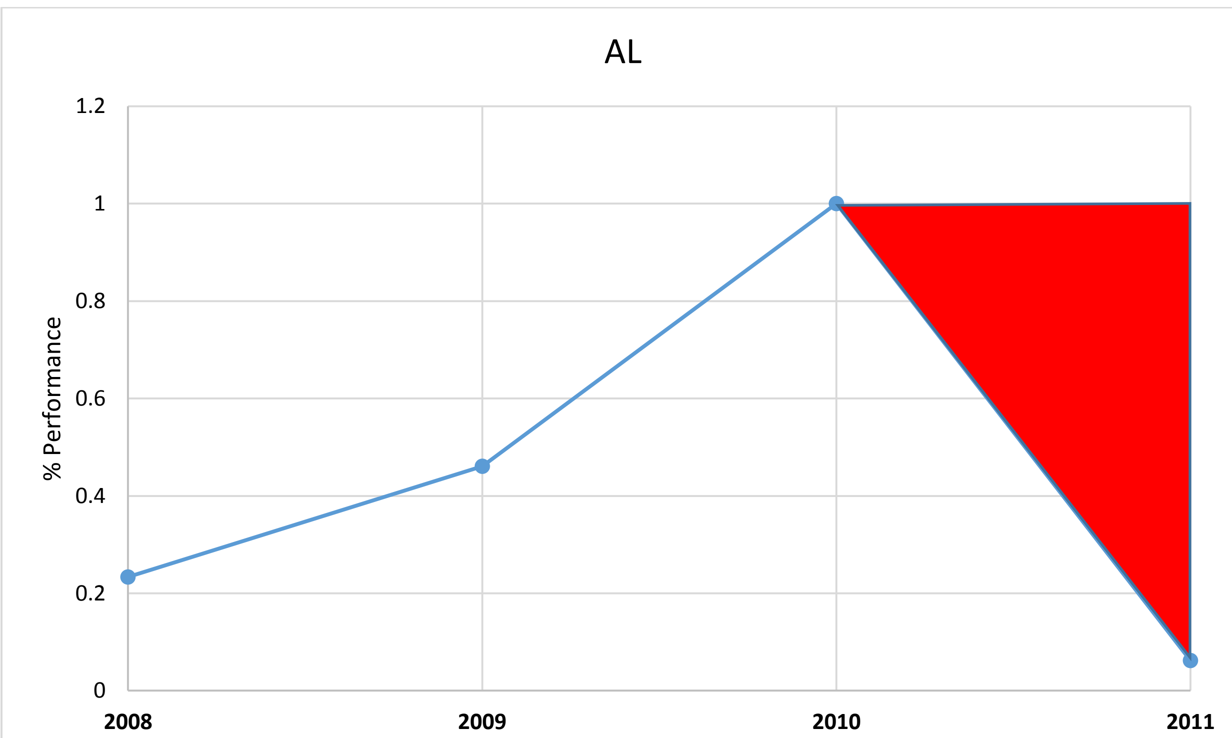
0.8
0.6
0.4
0.2
0
% Performance
2008
2009
2010
2011


AL
1.2
1
0.8
0.6
0.4
0.2
0
% Performance
2008
2009
2010
2011

Appendix B - Fisheries Summary Statistics

Peruvian fisheries summary statistics in the 2008-11 period.

Variable	Mean	2008 Mean	2009 Mean	2010 Mean	2011 Mean
Number of Locations	1.534	1.363	1.265	1.427	2.186
Vessels	3.111	2.593	2.944	3.427	3.483
Net Profit	2.732	0.259	2.485	1.240	7.590
Fishmeal Facilities	0.534	0.407	0.438	0.618	0.695
Cash and Equivalents	2.847	1.838	2.279	2.891	4.542
Current Assets	22.274	15.408	18.032	21.801	35.196
Non-Current Assets	64.630	50.500	51.018	66.889	94.341
Total Assets	86.904	65.908	69.050	88.690	129.537
Overdrafts	0.881	0.803	1.072	0.770	0.815
Current Liabilities	24.724	17.554	22.403	18.434	41.761
Non-Current Liabilities	24.788	19.511	16.438	32.253	33.017
Equity	37.392	28.843	30.209	38.004	54.758
Production	52.649	42.619	38.523	45.897	89.143
Initial Land	2.681	2.121	2.223	2.826	3.686
Initial Buildings	5.140	3.179	4.075	5.935	7.596
Initial Machinery	53.265	36.955	45.129	62.724	69.555
Initial Fixed Assets	75.456	47.739	57.626	79.657	121.813
Added Land	0.411	0.337	0.247	0.600	0.496
Added Buildings	0.726	0.683	0.342	0.530	1.510
Added Machinery	7.056	6.123	4.814	2.187	16.435
Added Fixed Assets	13.045	9.240	7.414	6.846	31.300
Withdrew Land	0.123	0.140	0.145	0.077	0.128
Withdrew Buildings	0.184	0.226	0.241	0.050	0.216
Withdrew Machinery	2.925	3.064	1.959	1.846	5.317

Withdrew Fixed Assets	5.806	4.498	2.981	3.196	13.833
Final Land	2.969	2.318	2.326	3.349	4.054
Final Buildings	5.761	3.694	4.288	6.548	8.890
Final Machinery	57.087	40.505	48.802	60.392	80.673
Final Fixed Assets	81.812	52.482	62.060	79.773	139.280
Observations	524	113	162	131	118

Appendix C - Exploratory Regression Models

Simple models results

Simple Fractional Response Probit			
	Dependent Variable: R_i		
VARIABLES	Coefficient	Coefficient	Coefficient
Refrigeration	8.63e-08		
	(5.70e-08)		
Buildings	-6.53e-08**		
	(3.15e-08)		
Total Sales		-9.09e-10	
		(1.66e-09)	
Average Employees			0.000272
			(0.00139)
Constant	-0.533	-0.874***	-0.967***
	(0.352)	(0.270)	(0.303)
Simple Fractional Response Logit			
Refrigeration	1.59e-07*		
	(9.56e-08)		
Buildings	-1.32e-07*		
	(6.89e-08)		
Total Sales		-1.66e-09	
		(3.17e-09)	
Average Employees			0.000466
			(0.00234)
Constant	-0.785	-1.441***	-1.607***
	(0.624)	(0.481)	(0.532)
Observations	38	38	38

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1