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IMPACT OF EL NIÑO ON PROFITABILITY OF PERUVIAN FISHING AND AGRO-INDUSTRIAL COMPANIES: MITIGATION OF CLIMATE RISKS

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ABSTRACT

The objective of the research is to analyze and explain the impact of the climate phenomenon "El Niño" on the financial profitability of Peruvian fishing and agroindustrial companies, as well as the mitigation of climate risks through the adoption of financial options. The research, which is quantitative and explanatory in nature, is based on the identification of factors affecting the profitability of these companies between 2010 and 2022. The results show the negative impact of "El Niño" on the profitability of the companies, highlighting the need to mitigate these effects through financial options, ensuring business sustainability and the food security of the Peruvian population. In conclusion, the climate phenomenon "El Niño" has a significant negative impact on the financial profitability of Peruvian fishing and agroindustrial companies. This phenomenon emphasizes the urgency of adopting mitigation strategies, such as financial options, so that companies can adapt to climate risks. Implementing these measures not only favors business sustainability but also ensures continuity in production and contributes to food security, strengthening the sector's resilience against extreme climate events.

Keywords: climate risks, profitability, financial options, resilience.

Code JEL : G13, M21, Q14, Q54

INTRODUCTION

The El Niño phenomenon is a recurrent climatic event that affects various regions of the world, especially the equatorial Pacific area. In the case of Peru, its impact is significant due to the country's geographic and climatic characteristics, which make it vulnerable to the effects of this phenomenon. El Niño is characterized by an anomalous increase in sea surface temperature in the equatorial Pacific, which disrupts global weather patterns and causes a series of climate changes, such as excessive rainfall, droughts, high temperatures, and extreme weather events.

In Peru, El Niño has been responsible for various natural disasters over the past few decades, such as floods, landslides, and droughts, which have severely affected agriculture, fishing, infrastructure, and, in general, the country’s economy. The regions most affected by El Niño are the northern and central coast of the country, where intense rainfall and disruptions in marine ecosystems have a direct impact on agricultural and fishing production.

Historically, the most severe El Niño events, such as those in 1982-1983 and 1997-1998, left deep scars in local communities, key economic sectors, and public policies. These events have motivated scientific and academic research to understand their effects and develop mitigation strategies against climate risks, ranging from preventive measures to adaptations in productive sectors, because according to Stern (2014) the effects of climate change have impacts on physical, biological and human systems.

The El Niño events (FEN) that Peru has experienced over the last 40 years have been widely studied by national and foreign academics. In this regard, Galarza and Kamiche (2012), in their study on the assessment of the impacts of FEN on the regional economy of Piura, Lambayeque, and La Libertad in northern Peru, examined the phenomena that occurred during the 1982-1983 and 1997-1998 periods. In their research, they concluded that 80% of the physical damage affected agriculture and fishing in the

northern region of the country, while the remaining 20% was distributed in the southern region. Additionally, they stated that 42% of the damage was caused by excessive rainfall, and the remaining 58% by drought.
The importance of studying and understanding El Niño lies in the increasing frequency and intensity of these events, which demands a comprehensive approach to face the impacts of this climatic phenomenon and ensure the country's resilience to future El Niño events.

Furthermore, Velasquez et al. (2024) studied the impact of the 2017 “El Niño Costero” phenomenon that occurred in the Pirua region, causing calamitous havoc on agriculture and the quality of life of the population, due to the absence of contingency measures and resources for the replacement of all affected infrastructure. The research analyzes the impact of the 2017 El Niño Costero phenomenon in the región.
The importance of studying and understanding El Niño lies in the increasing frequency and intensity of these phenomena, which requires a comprehensive approach to addressing the impacts of this climate phenomenon and ensuring the country's resilience to future El Niño events.

STATE OF THE ART

Economists Black and Scholes (1973) published the options pricing model, which is known as the Black & Scholes Model, marking the beginning of a wave of advancements in the development of derivative products. Initially, these were applied to financial engineering: investments in underlying financial assets, which later led to the creation of derivatives for portfolio insurance of financial assets and commodities, and eventually the emergence of climate risk insurance, now known as climate derivatives. For their significant contribution to the field of Financial Economics, economists Robert Merton and Myron Scholes were awarded the Nobel Prize in Economics in 1995.

Brocket et al. (2005) studied weather derivatives, identifying them as a relatively recent type of financial product developed to manage weather risks. The development of weather derivatives represents one of the recent trends toward the convergence of insurance and finance. In the article, they provide an overview of weather risks, weather derivatives, and the weather derivatives market, and examine the pricing of weather derivatives in an incomplete market, the effectiveness of standardized weather derivative coverage, as well as optimal weather coverage considering basis risk and credit risk. Stern (2014) addressed the economics of climate change, focusing on the impacts of temperature and precipitation variations on the economy.

Hull (2021), a professor of Derivatives and Risk Management at the University of Toronto in Canada, wrote the text Options, Futures, and Other Derivatives, Global, where he discussed everything related to Options Theory, which forms the foundation for the application of derivatives as risk insurance instruments. Cruz et al. (2010) and Juárez y Sánchez (2012) developed analytical modeling of derivatives for climate risk management in Colombia. Hilpisch (2015), in his work Derivatives Analytics with Python, focused on machine learning modeling and forecasting for climate risk management with the support of artificial intelligence resources.

Rubio & Roig (2017) studied the global impacts of climate change on livestock production, the contribution of livestock production to climate change, and specific adaptation and mitigation strategies for climate change in the livestock sector. Viet et al. (2024), in their analysis of risk management and private debt contracts, applied weather derivatives, highlighting the significant financial implications of coverage through climate derivatives.

Bems and Aydin (2021) argue that, since climate derivatives have parameters and rules similar to classic financial derivatives, it is possible to use the same pricing approaches for both financial and climate derivatives. Chavas et al. (2019) examined the effects of climate on the distribution of agricultural yields. Using data on wheat and corn yields from seven Italian provinces during the period 1900-2014, they estimated a quantile regression model to analyze the dynamic evolution of yield distributions. Their findings showed that the effects of climate are asymmetric, with much greater impacts on the lower tail of the yield distribution than on the upper tail. They also demonstrated that adverse climate has significant and persistent effects on agricultural productivity.

Bobrikova (2022) in her article examines weather risk management through the application of weather derivatives in agriculture and evaluates the efficiency of coverage. She states that agriculture is a sector highly sensitive to meteorological elements that affect the yield of many crops. The underlying weather indices are analyzed based on temperature, precipitation, and wind speed. Pricing follows the index modeling method using Burn analysis to calculate the fair premium. The study investigates and analyzes proposed hedging strategies against excess rainfall during the growing cycle using weather options for the Košice region in eastern Slovakia. The results show that the application of weather derivatives in weather risk management reduced yield volatility in agriculture.

In their study on the impact of temperature shocks, Addoum et al. (2023) concluded that extreme temperatures significantly affect the profits of more than 40% of industries, presenting bidirectional effects: some industries are harmed, while others benefit. Analysts and investors do not immediately react to observable intratrimestral temperature shocks, although earnings forecasts already account for temperature effects toward the end of each quarter in many industries.

Blanc and Schlenker (2017), on the use of panel models in evaluating the impacts of climate change on agriculture, state that there is an increasing reliance on panel models to examine the relationship between agricultural outcomes and climate fluctuations. Additionally, the large number of observations provided by a panel dataset allows for

the identification of a non-linear response function, which is an important step in modeling the effects of climate change, as the response can be highly non-linear.
Antle and Stockle (2017) in their conclusions stated that economic assessments of climate impacts and adaptation could be improved through the development of methods, data, and software that enable researchers to use biophysical models of agricultural, livestock, and cropping systems in conjunction with economic models.
Mahanama et al. (2022), in their study of natural disasters such as tornadoes, floods, and wildfires, highlight risks to life and property that require intervention from insurance companies. One of the most visible consequences of climate change is the increase in the intensity and frequency of extreme weather events.

Hess (2022), in the face of global warming events and ongoing climate change, states that weather derivatives are playing an increasingly important role for many companies and financial investors, as they serve as useful hedging instruments against unfavorable weather conditions.

Olivares and Zingaretti (2017), in a study conducted on the effects of climate change on agriculture in Venezuela from 1980 to 2014, used statistical methodology based on multivariate analysis, which allowed for the identification of groups of years that showed similar patterns of meteorological drought index according to the time series. The study serves as the backbone for spatial planning and strengthening strategies for food security in those regions.

For Gutiérrez y Sueiros (2015):

> *The first transzonal issue refers to the anthropogenic pollution of the Humboldt Current Large Marine Ecosystem (GEMCH), which results from the settlement of the largest proportion of human and industrial activity in coastal areas, with economic and environmental consequences. The second refers to the suboptimal use of fishery resources, meaning that, in some cases, there is a*

> *decline in the abundance or catch of certain species that are key to food security. However, this problem also refers to the low quality of fishery production or deficiencies in its sanitary condition, which leads to economic, social, and environmental impacts. The third, a common issue, concerns the high levels of illegal fishing or bycatch and discards, which have been recognized as occurring in both countries, Peru and Chile. (p. 9).*

Bush and Paquin (2012) state that the increasingly intense impacts of climate change and the resulting pressures on the three environments mean that companies that do not address these pressures through appropriate mitigation and adaptation strategies jeopardize their competitiveness, profitability, and potentially even their survival.

Martelo (1998) explains to us the phenomenon of El Niño as follows:

> *El Niño is one of several irregular climatic cycles that occur due to the interaction between the ocean and the atmosphere. It is a phenomenon of climate variability (not climate change), which manifests through changes in the normal patterns of behavior of: • ocean currents, • wind flows, and • the distribution of precipitation and temperature. El Niño is not a new phenomenon; there is evidence that it has existed for thousands of years. However, it was not until the last decade that we were able to understand satisfactorily how it forms and persists.*
>
> *In recent years, we have learned that the warming of the sea in December off the coasts of Peru and Ecuador is only part of a much broader phenomenon that involves the entire tropical Pacific Ocean and also has atmospheric manifestations, which are observed as changes in the normal distribution of precipitation. The changes in the atmospheric system are referred to as the "Southern Oscillation," which is why scientists coined the acronym ENSO (El Niño-Southern Oscillation) to refer to the combined phenomenon of oceanic and atmospheric changes (p. 48-55).*

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How does it impact nature? Here is a summary of the impacts:

• Droughts in eastern Australia and Indonesia, extending to the Philippines.

• Increased rainfall on the Pacific coast of the Americas, especially in Peru and Ecuador.

• An increase in tropical storms and hurricanes in the Pacific.

• A tendency for warmer-than-normal astronomical winters in the Northern Hemisphere (December) on the Pacific coast of the United States and Alaska.

And what about its consequences in other parts of the world?:

• Droughts in the Sahel (the area south of the Sahara Desert).

• Droughts in Northeast Brazil (rainy season from February to May).

• Reduced rainfall caused by summer monsoon winds (July-September) over India.

• Reduced tropical storms and hurricanes in the Atlantic.

• Increased rainfall in the Gulf of Mexico area, southern Brazil, Uruguay, Paraguay, and northern and central Argentina.

• Decreased rainfall in southeastern Venezuela.

The scientific community is alarmed because the occurrence of these phenomena in the Northern Hemisphere used to happen in May. Now, they are unpredictable and occur at any time of the year. The issue is important because Peru's image as an exporter of fishmeal is at stake, along with the 150,000 jobs dependent on this activity.

This issue is of interest because an industrial sector without raw materials to process affects the economy of companies, reduces tax revenue for the state, and leaves workers without jobs, decreasing the standard of living in the sector and increasing poverty. This is not a new issue, but it has gained notoriety due to its multiplier effect, impacting thousands of people both domestically and internationally.

Aguirre and Méndez (2015), from Trujillo, northern Peru, explain:

> *For this economic research, a time series design will be applied, which will allow determining the model that explains the relationship between the fishing GDP and national GDP. The design includes the Least Squares Method to obtain the model that explains the behavior of the variables and series, facilitating the corresponding objectives. (p. 29).*

They conclude:

> *(1). In this research, it has been determined that during the period 1970-2014, the fishing sector is a variable that has a small impact on real GDP. This is confirmed by the empirical evidence from the econometric model, which shows that when the fishing sector increases by 1%, the economy (real GDP) grows by 0.04%. This is also corroborated by the weight or share of the fishing sector, which is less than 1% of real GDP. (p. 68-69).*

Caparrós (2006) defines the concept of climate risk as the risk of incurring unexpected losses due to adverse movements in temperature caused by the presence of rain, droughts, or frosts. It is no longer possible to avoid climate change, but it is possible to protect economies and societies to some extent against its impacts. In the early 1990s, the first climate derivatives OTC were created, and by the end of that decade, standardized climate derivatives began to be traded on the Chicago Exchange, allowing hedge operations for companies in sectors affected by climate risk. In this regard, Srivastava and Bhatt (2025) assert that communities, groups, and households need to develop adaptation solutions and implement actions to respond to the current and future impacts of climate change. Mitigation actions depend on the particular context of a community, business, organization, country, or region.

Castro (2009) states that climate derivatives are a tool to reduce the financial risk faced by companies whose profits are correlated with weather conditions. Derivatives provide coverage against highly probable events such as rain, droughts, and high temperature variability. A climate derivative is based on an underlying asset that is not traded in the financial asset market. In the case of a climate option applied to fishing and agriculture, the goal is to cover uncertainty about the volumes produced. The first OTC (over-the-counter) transaction involving climate derivatives took place in 1996 when Koch Industries and ENRON completed a swap for the winter of 1997 in Milwaukee, Wisconsin.

The first applications of derivatives were made in the United States in 1997, under OTC contracts, which are agreements between two private companies outside of the organized market. The first contract recorded in the literature took place between Enron Capital and Trade Resources in the energy sector. This contract was designed by Koch Industries and conceived as a temperature swap for the winter of 1997 in the city of Milwaukee, United States. The contract in reference had as a precedent the contract between Aquila Energy and Consolidated Edison Co. in July 1996 for the purchase and sale of electricity (Hull, 2021, p.477).

The OTC contract type is used to refer to all transactions negotiated outside of an organized market. These markets have characteristics that make them very attractive to investors, and some of these are: the contracts are tailor-made for various underlying assets, there are no payments to intermediaries, they are settled on their expiration date, the risk of default is assumed by the contracting parties before a competent judge, as stipulated in the contract, and they are not subject to regulation (Soriano, 2012, p.4).

Benito (2012) states that OTC contracts are found in options contracts. The advantage of such contracts is that a financial institution can tailor them to meet the specific needs of a corporate treasurer or fund manager. The factors that influence the value of a stock option are as follows:

- The current price of the underlying asset
- The strike price (insured amount).
- The expiration date of the contract.
- The volatility of the underlying asset.

- The risk-free interest rate (p.16).

Table 1

Impact of the El Niño Phenomenon in Peru

Affected activity or sector	Effects of the El Niño Phenomenon (FEN)
Fishing	- Main economic activity affected - Migration of marine species to cooler areas. - Impact on industrial fishing due to the scarcity of anchovies. - Decline in fishmeal production.
Agriculture	- Affected by the increase in temperature and humidity, as well as by floods. - Reduction in the harvests of tubers and fruits.
Exports	- Reduction in fishery and agricultural exports.
Energy	- Damage to hydroelectric plants.
Transport	- Destruction of roads and bridges.

Note. Adapted from MINAM Peru, 2016.

Table 1 clearly shows the effects of the ENSO phenomenon (FEN) on various sectors of the Peruvian economy as of 2016. Muhammad et al. (2021) stated that the presence of climate change is a factor severely damaging the agricultural system in many food-producing regions around the world.

Objective:

The objective of the research is to analyze and explain the impact of the climatic phenomenon "El Niño" on the financial profitability of Peruvian fishing and agro-industrial companies, as well as the mitigation of climate risks through the adoption of financial options, given that there is no organized derivatives market in the Peruvian market.

Hypothesis:

There is evidence of the impact of temperature changes and the El Niño phenomenon on the profitability of fishing and agricultural companies listed on the Peruvian stock market, as well as on climate risk coverage under the options theory.

METHODOLOGY

This is a quantitative, explanatory, and longitudinal research study. By convention, two fishing companies and two agro-industrial companies listed on the Lima Stock Exchange from 2000 to 2022 are selected. Financial statement data published in the Lima Stock Exchange database, temperature changes, and the presence of the El Niño phenomenon are collected through the database managed by SENAMHI Peru.

Time series data for the companies' ROE and temperature are organized. The temperature variation over time and the variation in the companies' ROE are then obtained. The data are processed using panel data analysis to obtain a causal model that describes and shows the effects of temperature changes on the profitability of Peruvian fishing and agricultural companies. The risk coverage model with long position PUT options is then used, aiming to model the insurance of the companies' profitability.

To study the effects of the El Niño phenomenon (FEN) on fishing and agricultural activities in Peru, two fishing companies and two agricultural companies listed on the

Lima Stock Exchange from 2010 to 2022 are selected by convention. The effects are reflected in the companies' results, specifically in the financial profitability. The ROE model, explained by temperature, the presence or absence of the FEN in a given year, and economic performance, is formulated, and its mathematical expression is as follows:

$ROE = f(Temperature, El_{Niño}, PBI)$ and the panel data expression is as follows:

$ROE_{it} = \beta_0 + \beta_{it}(T) + \beta_{it}(FEN) + \beta_{it}(PBI) + \varepsilon$, from where

ROE : Return on equity (ROE) of the company.
T : Temperature
FEN : Dichotomous variable that takes the values 1: presence of FEN, 0: no FEN.
PBI : The behavior of the regional Peruvian economy where each of the studied companies is located.

Once the impact of FEN on agricultural and fishing activities is identified, the aim is to model the protection of climate risks with financial options, using the long position of PUT as an insurance instrument to preserve the value of the profitability of the affected companies. For this, the financial options pricing models of Black & Scholes (Hull, 2021, p.273) are invoked, applicable to options that are exercised on their expiration date.

$$c = X * N(d1) - E * (e^{-R_f * T}) * N(d_2)$$
$$p = X * [N(d_1) - 1] - E * (e^{-R_f * T}) * [N(d_2) - 1]$$

Where:

c : Value of the CALL option

p : Value of the PUT option

$d_1 = \frac{\ln\left(\frac{X}{E}\right) + R_f * T + \frac{1}{2}(\sigma^2) * T}{\sigma\sqrt{T}}$

$d_2 = d_1 - \sigma\sqrt{T}$

$$N(d_1) = distr.norm.estand(d_1)$$

$$N(d_2) = distr.norm.estand(d_2)$$

N(d) : It is the probability distribution function for a standardized normal variable.

E : It is the strike price of the option, in this case, the insurance rate.

Rf : Risk-free rate

T : Contract maturity time

e : 2.718281, constant value

X : Value of the underlying asset, which in our case is. $ROE = \frac{Net\ income}{Equity}$

Once the insurance value is obtained, it is necessary to evaluate the sensitivity that describes the underlying asset, for which the delta function of the put option is used, and its mathematical expression is presented as follows:

$\frac{dp}{dX} = N[(d_1)\text{-}1)]$, It indicates the variation of the put option that depends on the changes occurring with the ROE.

RESULTS

Through the financial statements, it is confirmed that in the analyzed period, fishing companies have been the most affected, showing negative economic results, with a substantial decrease in sales of up to -25% annually and incurring higher financial costs. Agro-industrial companies have been less affected, with an average of about -12% annually during the periods when the El Niño phenomenon was present.

The need for risk mitigation instruments is evident, in order to maintain the planned profitability, a situation addressed in the study through the long position of PUT options under the OTC contract type.

As shown in Table 2 and Figure 1, in 2016, the fishing company Exalmar obtained a return of -11%, while Agroindustrial Paramonga had 2%. During the periods of El Niño presence in 2015, 2016, and 2017, the companies showed a decreased return on equity as a result of the El Niño effect. On the other hand, in years when El Niño was not present, the companies showed acceptable profits. This was the case with Exalmar and Austral Group in 2011, with quite acceptable profits of over 7% annually. During periods of El Niño presence, temperatures were observed to be above 30°C, whereas under normal conditions, they were around 20°C in these regions.

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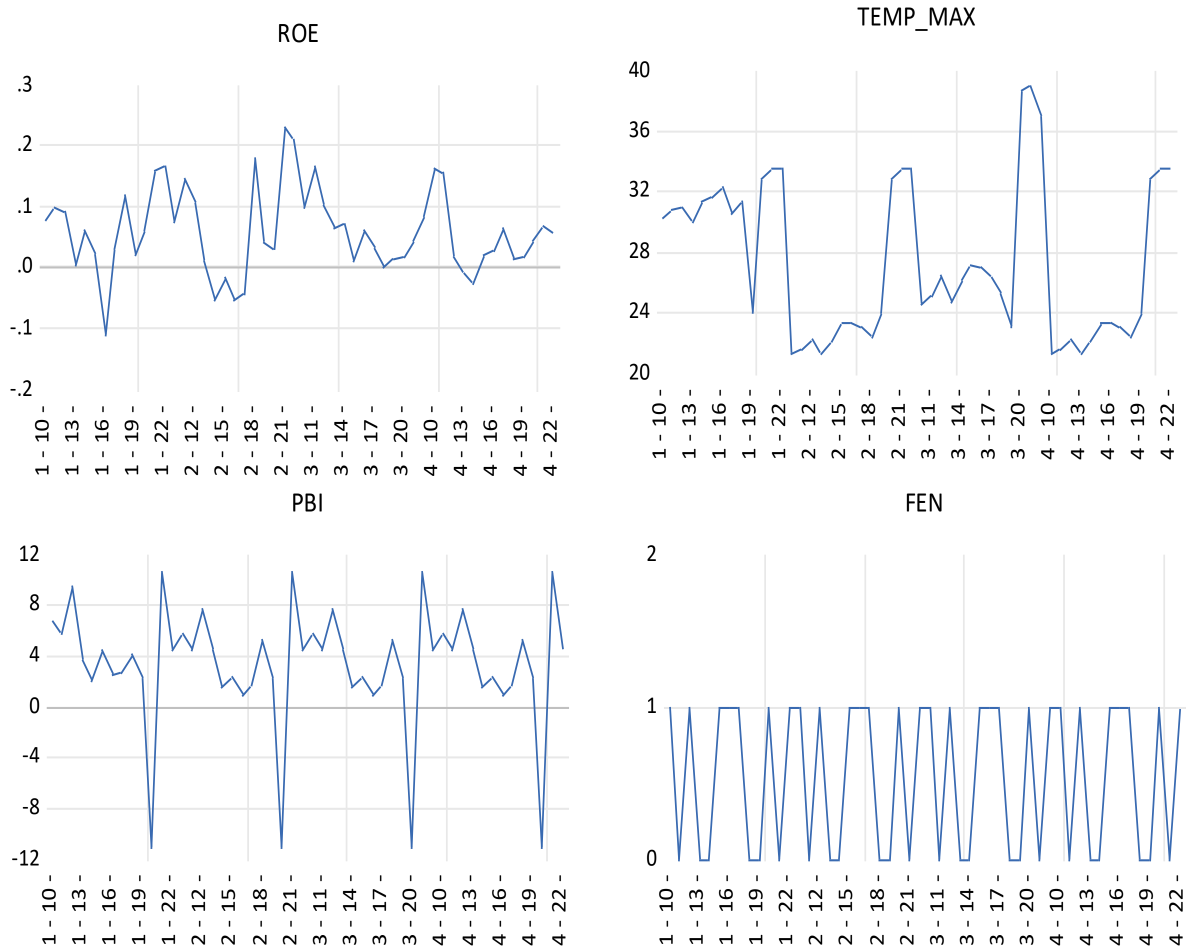
Figure 1

Descriptive illustration of the model variables



Note. Prepared by the author with the sample data.

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Table 2

Factores Incidentes en el ROE

YEAR	COMPANY	ROE	MAX. TEMP.	FEN	C.PBI
2010	PESQUERA EXALMAR SAA	7.89%	30.3	1	6.8
2011	PESQUERA EXALMAR SAA	9.92%	30.8	0	5.8
2012	PESQUERA EXALMAR SAA	9.18%	31.0	1	9.5
2013	PESQUERA EXALMAR SAA	0.31%	30.0	0	3.6
2014	PESQUERA EXALMAR SAA	6.05%	31.3	0	2.1
2015	PESQUERA EXALMAR SAA	2.20%	31.7	1	4.4
2016	PESQUERA EXALMAR SAA	-11.00%	32.3	1	2.5
2017	PESQUERA EXALMAR SAA	3.00%	30.6	1	2.6
2018	PESQUERA EXALMAR SAA	12.00%	31.3	0	4.1
2019	PESQUERA EXALMAR SAA	2.27%	24.0	0	2.2
2020	PESQUERA EXALMAR SAA	6.21%	32.8	1	-11.1
2021	PESQUERA EXALMAR SAA	16.02%	33.5	0	10.7
2022	PESQUERA EXALMAR SAA	16.68%	33.5	1	4.5
2010	AUSTRAL GROUP SAA	7.67%	21.3	1	5.8
2011	AUSTRAL GROUP SAA	14.79%	21.6	0	4.5
2012	AUSTRAL GROUP SAA	10.74%	22.3	1	7.7
2013	AUSTRAL GROUP SAA	1.05%	21.3	0	4.4
2014	AUSTRAL GROUP SAA	-5.23%	22.1	0	1.5
2015	AUSTRAL GROUP SAA	-1.51%	23.4	1	2.3
2016	AUSTRAL GROUP SAA	-5.14%	23.3	1	0.9
2017	AUSTRAL GROUP SAA	-4.41%	23.1	1	1.7
2018	AUSTRAL GROUP SAA	17.88%	22.4	0	5.3
2019	AUSTRAL GROUP SAA	4.10%	24.0	0	2.2
2020	AUSTRAL GROUP SAA	3.00%	32.8	1	-11.1
2021	AUSTRAL GROUP SAA	23.00%	33.5	0	10.7
2022	AUSTRAL GROUP SAA	21.00%	33.5	1	4.5
2010	AGROINDUSTRIAL LAREDO SAA	9.81%	24.5	1	5.8
2011	AGROINDUSTRIAL LAREDO SAA	16.59%	25.1	0	4.5
2012	AGROINDUSTRIAL LAREDO SAA	10.15%	26.5	1	7.7
2013	AGROINDUSTRIAL LAREDO SAA	6.53%	24.7	0	4.4
2014	AGROINDUSTRIAL LAREDO SAA	7.28%	26.2	0	1.5
2015	AGROINDUSTRIAL LAREDO SAA	1.01%	27.1	1	2.3
2016	AGROINDUSTRIAL LAREDO SAA	6.22%	27.0	1	0.9
2017	AGROINDUSTRIAL LAREDO SAA	3.20%	26.3	1	1.7
2018	AGROINDUSTRIAL LAREDO SAA	0.22%	25.3	0	5.3
2019	AGROINDUSTRIAL LAREDO SAA	1.39%	23.0	0	2.2

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2020	AGROINDUSTRIAL LAREDO SAA	1.93%	38.7	1	-11.1
2021	AGROINDUSTRIAL LAREDO SAA	4.37%	39.0	0	10.7
2022	AGROINDUSTRIAL LAREDO SAA	8.49%	36.9	1	4.5
2010	AGROINDUSTRIAL PARAMONGA SAA	16.47%	21.3	1	5.8
2011	AGROINDUSTRIAL PARAMONGA SAA	15.59%	21.6	0	4.5
2012	AGROINDUSTRIAL PARAMONGA SAA	1.78%	22.3	1	7.7
2013	AGROINDUSTRIAL PARAMONGA SAA	-0.79%	21.3	0	4.4
2014	AGROINDUSTRIAL PARAMONGA SAA	-2.47%	22.1	0	1.5
2015	AGROINDUSTRIAL PARAMONGA SAA	2.10%	23.4	1	2.3
2016	AGROINDUSTRIAL PARAMONGA SAA	2.70%	23.3	1	0.9
2017	AGROINDUSTRIAL PARAMONGA SAA	6.51%	23.1	1	1.7
2018	AGROINDUSTRIAL PARAMONGA SAA	1.45%	22.4	0	5.3
2019	AGROINDUSTRIAL PARAMONGA SAA	1.94%	24.0	0	2.2
2020	AGROINDUSTRIAL PARAMONGA SAA	4.45%	32.8	1	-11.1
2021	AGROINDUSTRIAL PARAMONGA SAA	6.84%	33.5	0	10.7
2022	AGROINDUSTRIAL PARAMONGA SAA	5.74%	33.5	1	4.5

Note. Created by the author using financial statement data and data from SENAMHI.

The results presented in Table 3 confirm the negative impact of the FEN and temperature variable on the equity profitability of the fishing and agricultural companies during the period 2010 to 2022. The variable with the greatest impact is the presence of the FEN, followed by the temperature variable. On the other hand, the behavior of the regional economy where the companies are located positively affects the companies' results.

Table 3

Panel data model of the companies ROE

Dependent Variable: ROE
Method: Panel Least Squares
Date: 02/09/25 Time: 18:50
Sample: 2010 2022
Periods included: 13
Cross-sections included: 4

Total panel (balanced) observations: 52

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.0659	0.0610	-1.0814	0.2853
TEMP_MAX	0.0041	0.0022	1.8814	0.0664
FEN	-0.0074	0.0198	-0.3753	0.7092
PBI	0.0052	0.0020	2.6152	0.0121
Effects Specification				
Cross-section fixed (dummy variables)				
R-squared	0.1895	Mean dependent var		0.059071
Adjusted R-squared	0.0814	S.D. dependent var		0.070157
S.E. of regression	0.0672	Akaike info criterion		-2.436445
Sum squared resid	0.2035	Schwarz criterion		-2.173777
Log likelihood	70.3476	Hannan-Quinn criter.		-2.335744
F-statistic	1.7535	Durbin-Watson stat		1.230699
Prob(F-statistic)	0.1306			

Note. Results with panel data processing.

In the model stated below, the impact of the variables on the companies' equity profitability is clearly visible.

Model (1):

$$ROE = -0.0659 + 0.0052 * PBI_{REGION} + 0.0041 * TEMPERATURE - 0.0074 * FEN + E$$

Once the harmful impact of the FEN on the companies' ROE is observed, the objective is to model the type of insurance contract against the loss of value in the companies' ROE. To do so, the long position of the PUT contract is proposed, determining the premium value for an exercise price of 12%, assuming that the underlying is the

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profitability of the companies affected by the FEN, with a risk-free rate (Rf) of 8% and a European-style contract duration of 90 days.

Table 4
The price and sensitivity of the contract

ROE	VOLATILITY	Rf	TIME	d1	d2	N(d1)	N(d2)	Delta Put	Put
0%	40%	8%	0.25	0.00	0.00	0.00	0.00	0.00	0.0000
2%	40%	8%	0.25	-8.76	-8.96	0.00	0.00	-1.00	0.0976
4%	40%	8%	0.25	-5.29	-5.49	0.00	0.00	-1.00	0.0776
6%	40%	8%	0.25	-3.27	-3.47	0.00	0.00	-1.00	0.0576
8%	40%	8%	0.25	-1.83	-2.03	0.03	0.02	-0.97	0.0378
10%	40%	8%	0.25	-0.71	-0.91	0.24	0.18	-0.76	0.0202
12%	40%	8%	0.25	0.20	0.00	0.58	0.50	-0.42	0.0083
14%	40%	8%	0.25	0.97	0.77	0.83	0.78	-0.17	0.0027
16%	40%	8%	0.25	1.64	1.44	0.95	0.92	-0.05	0.0007
18%	40%	8%	0.25	2.23	2.03	0.99	0.98	-0.01	0.0002
20%	40%	8%	0.25	2.75	2.55	1.00	0.99	0.00	0.0000
22%	40%	8%	0.25	3.23	3.03	1.00	1.00	0.00	0.0000
24%	40%	8%	0.25	3.67	3.47	1.00	1.00	0.00	0.0000
26%	40%	8%	0.25	4.07	3.87	1.00	1.00	0.00	0.0000
28%	40%	8%	0.25	4.44	4.24	1.00	1.00	0.00	0.0000
30%	40%	8%	0.25	4.78	4.58	1.00	1.00	0.00	0.0000
32%	40%	8%	0.25	5.10	4.90	1.00	1.00	0.00	0.0000
34%	40%	8%	0.25	5.41	5.21	1.00	1.00	0.00	0.0000
36%	40%	8%	0.25	5.69	5.49	1.00	1.00	0.00	0.0000
38%	40%	8%	0.25	5.96	5.76	1.00	1.00	0.00	0.0000
40%	40%	8%	0.25	6.22	6.02	1.00	1.00	0.00	0.0000

Note. Prepared by the author with the sample data.

The values observed in the PUT column are displayed in terms of both the contract premium price, which varies as the ROE value changes, while other factors remain constant, applied in the Black & Scholes PUT model. The contract premium (PUT)

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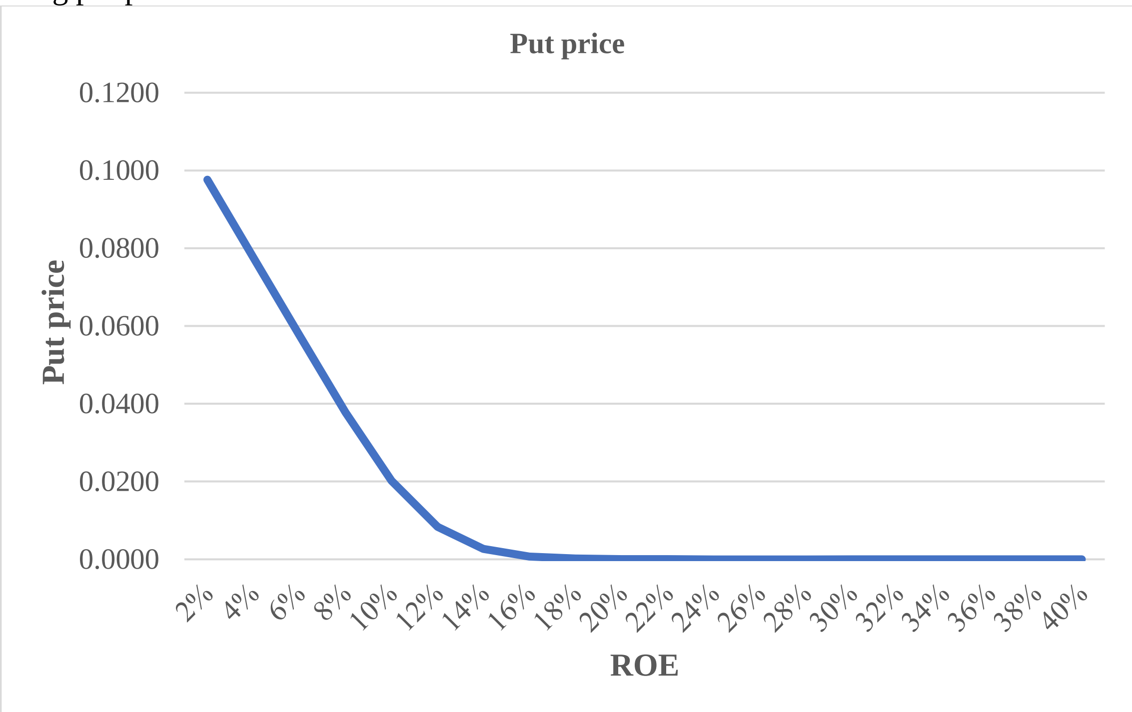
increases as the companies' equity profitability decreases. Figure 2 clearly illustrates the level of protection the companies would have as they lose value in equity profitability due to the effect of the FEN, with the protection strengthening as the underlying value falls below 14%. Figure 3 illustrates the sensitivity of the contract price to changes in the underlying variable, contrasting the protection power of the contract. It shows that the contract premium increases as the companies' equity profitability decreases.

Figure 2
Long put price



Note. Created by the author using sample data.

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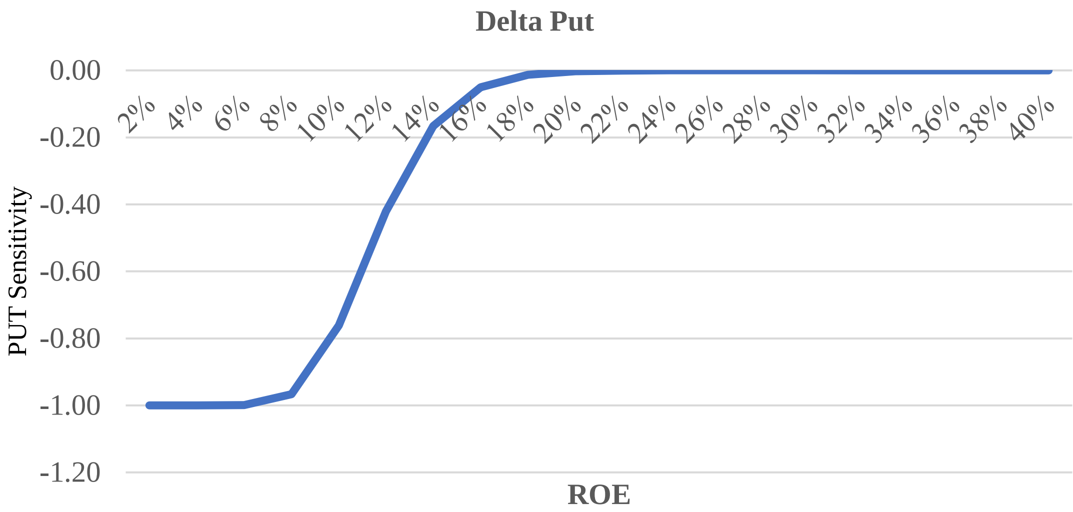
Figure 3

Sensitivity of the PUT contract price in a long position.



Note: Prepared by the author using the sample data.

DISCUSSION

In model (1), the negative effects of the El Niño phenomenon (FEN) and temperature fluctuations on the financial profitability of Peruvian fishing and agricultural companies are reflected. These results align with the findings of the study by Galarza and Kamiche (2012), which demonstrate the negative effects of FEN on the economic activities of fishing and agriculture in northern Peru. Additionally, the conclusions of this study coincide with those of Martelo (1998), who also observed the adverse effects of temperature variability on fishing and agricultural activities.

On the other hand, Blanc and Schlenker (2017) studied the impact of climate fluctuations on agricultural businesses using a quantitative panel data model, as was done in this study. Likewise, Muhammad et al. (2021) and Addoum et al. (2023) highlighted how climate change affects the agricultural system and the profits of businesses, which is consistent with the results presented in this study.

Castro (2009), Hess (2022), Viet et al. (2024), and Bobrikova (2022) investigated climate risk coverage through derivative instruments. To apply climate derivatives, it is necessary to have standardized temperature and precipitation indices, indicators that currently do not exist in Peru. For this reason, the use of a financial derivatives model for climate risk coverage is proposed. In this regard, Bems and Aydin (2021) assert that, since climate derivatives share similar parameters and rules with traditional financial derivatives, it is possible to apply similar pricing approaches for both types of derivatives.

Regarding risk coverage through derivatives, studies by Castro (2009) and Hull (2002) conclude that the use of derivative financial instruments, traded outside the organized market, offers significant protection opportunities for fishing and agricultural activities against risk events associated with FEN. These findings are consistent with the results obtained in model (1) and presented in Table 3, which suggest the use of long-position PUT options to preserve the financial profitability of the companies.

In line with what Benito (2012) mentions, the factors influencing the option price in this research include the current price of the underlying asset, financial profitability, exercise price, the insured sum of expected financial profitability, the contract term, underlying volatility, and the risk-free rate.

CONCLUSIONS

Based on the results presented in Table 3 and model (1), it can be concluded that there are factors influencing the financial profitability of Peruvian fishing and agricultural companies due to the presence of the El Niño phenomenon (FEN) and the effects of the regional and sectoral economy. The decrease in ROE (Return on Equity) as a consequence of FEN could be insured through the subscription of OTC contracts for long-position PUT options, as observed in the values presented in Table 4 and the illustrations in Figures 2 and 3. It is important to highlight that the price of these contracts will increase when events occur that reduce the ROE due to a strong impact from FEN, especially if the price of the underlying asset is below the exercise price.

REFERENCES:

Addoum, J., Ng, D. & Ortiz-Bobea, A. (2023).Temperature shocks and industry earnings news. *Journal of Financial Economics*.Volume 150, Issue 1, Pages 1 - 45. Doi: https://doi.org/10.1016/j.jfineco.2023.07.002

Aguirre, S. & Méndez, K. (2015). *Incidencia del sector pesquero en el crecimiento económico en el Perú durante el periodo: 1970-2014*. Universidad Privada Antenor Orrego, Trujillo, Perú. https://hdl.handle.net/20.500.12759/1498

Antle, J. & Stockle, C. (2017). Climate Impacts on Agriculture: Insights from Agronomic-Economic Analysis. *Review of Environmental Economics and PolicyVolume 11, Number 2*. https://doi.org/10.1093/reep/rex012

Benito, J. (2012*). El Modelo de Black & Scholes de Valoración de Opciones Financieras*. Universidad de Barcelona, Barcelona, España. https://diposit.ub.edu/dspace/bitstream/2445/32883/1/Benito_el_modelo_de_ Black_Sholes.pdf

Bems, J. & Aydin, C. (2021). Introduction to weather derivatives. *Wires Energy and Environment.* Doi: https://doi.org/10.1002/vene.426

Black, F. & Scholes, M. (1973). The Pricing of Options and Corporate Liabilities. *The Journal of Political Economy*, Vol. 81, No. 3 (May - Jun., 1973), pp. 637-654, The University of Chicago. Press Stable URL: http://www.jstor.org/stable/1831029

Blanc, E. & Schlenker, W. (2017). The use of panel models in assessments of climate impacts on agricultura. *Review of Environmental Economics and Policy*. Volume 11, Issue 2, Pages 258 - 2791. Doi: https://doi.org/10.1093/reep/rex016

Bobrikova, M. (2022).Weather Risk Management in Agriculture Using Weather Derivatives. *Italian Review of Agricultural Economics*. Vol. 77 No. 2 (2022). https://doi.org/10.36253/rea-13416

Brocket, P., Yang, Ch. & Wang, M. (2005). *Weather derivatives and weather risk management*. Risk Management and Insurance Review, Vol. 8, No. 1, 127-140. https://ideas.repec.org/a/bla/rmgtin/v8y2005i1p127-140.html

Bush, T. & Paquin, R. (2012). Managing for climate risk. *Sage Publications*. DOI: http://dx.doi.org/10.4135/9781452218601.n56

Caparrós, A. (2006). *El informe Stern sobre la Economía del Cambio Climático*. Asociación española de ecología terrestre, Madrid, España. http://hdl.handle.net/10261/10276

Castro, M. (2009). *Managing Weather Risk with Rain Fall Option*. Universidad Torcuato di Tella, Buenos Aires, Argentina. Doi: http://dx.doi.org/10.33326/27086062.2020.1.904

Chavas, J., Di Falco, S., Adinolfi, F. & Capitanio, F. (2019). Weather effects and their long-term impact on the distribution of agricultural yields: evidence from Italy, *European Review of Agricultural Economics*, Volume 46, Issue 1, February 2019, Pages 29–51. https://doi.org/10.1093/erae/jby019

Cruz, J. & Llinas, A. (2010). *Modelo analítico de derivados de clima para eventos específicos de riesgo en la agricultura en Colombia*. Bogotá, Colombia. Doi: https://doi.org/10.11144/Javeriana.cdr7-64.madc

Galarza, E. P., & Kámiche, J. N. (2012). *Impactos del Fenómeno El Niño (FEN) en la economía regional de Piura, Lambayeque y La Libertad*. Informe Técnico No. 1. Universidad del Pacífico / GIZ. https://faculty.up.edu.pe/es/publications/impactos-del-fen%C3%B3meno-el-ni%C3%B1o-fen-en-la-econom%C3%ADa-regional-de-piura

Gutiérrez, M.& Sueiros, J. (2015). *Análisis sobre la transparencia en el Sector Pesquero Peruano*, Programa de las Naciones Unidas.

Hess, M. (2022). Pricing and Hedging of Temperature Derivatives in a Model with Memory. *International Journal of Theoretical and Applied Finance (IJTAF), Vol. 27, No. 1, 2350031, February 2024.* SSRN: https://ssrn.com/abstract=4308980

Hilpisch, Y. (2015). *Derivatives Analytics with Python Data Analysis*, Models, Simulation, Calibration and Hedging (Wiley Finance Series). Wiley. ISBN: 978-1-119-03799-6.

Hull, C. (2021). *Options, Futures, and Other Derivatives, Global.* 11th edition published by Pearson Education, Inc., Publishing as prentice hall, INC.ISBN-10 : 1292410655

Juarez-Torres, M., & Sanchez-Aragon, L. (2012). *Effectiveness of Weather Derivatives as a Cross-Hedging Instrument against Climate Change: The Cases of Reservoir Water Allocation Management in Guanajuato, Mexico and Lambayeque, Peru*. https://doi.org/10.18235/0011402

Mahanama, T., Shirvani, A. & Rachev, S. (2022). "*A Natural Disasters Index," Environmental Economics and Policy Studies, Springer;Society for Environmental Economics and Policy Studies - SEEPS*, vol. 24(2), pages 263-284, DOI: https://doi.org/10.1007/s10018-021-00321-x

Martelo, M. (1998). *El Fenómeno del Niño. Ministerio del Ambiente y Recursos Naturales Renovables*. Venezuela COMUNIICA, año 3, número 9, p. 48-55.

Muhammad, F., Xia, Ch., Azhar, A., Muhammad, R. Shoaib, A., Muhammad A. & Abdelrahman, A. (2021). Do risk perceptions and constraints influence the adoption of climate change practices among small livestock herders in Punjab, Pakistan?. *Environmental Science and Pollution Research*. 28(12). https://org.doi/10.1007/s11356-021-13771-3

Olivares, B. & Zingaretti, J. (2017). *Análisis de la Sequía Meteorología en cuatro localidades agrícolas de Venezuela mediante la combinación de métodos multivariados.* Universidad Nacional de Villa María, Córdoba, Argentina.

Rubio, A. & Roig, S. (2017). *Impactos, vulnerabilidad y adaptación al cambio climático en los sistemas extensivos de producción ganadera en España*. Ministerio de Agricultura y Pesca, Alimentación y Medio ambiente. https://www.miteco.gob.es/content/dam/miteco/es/cambioclimatico/temas/impactos-vulnerabilidad-y-adaptacion/informe_ganaderia_extensiva_tcm30-435573.pdf

Serrano, J. & Rico, J.(2013). *Derivados Climáticos*. Universidad Autónoma de Bucaramanga, Colombia.

Soriano, Y. (2012). *Análisis Comparativo de Métodos de Valuación de Opciones Asiáticas y con Barrera*. México D.F.

Srivastava, S. Bhatt, M. (2025). Climate Extremes: Pathways for Prepararedness and Anticipatory Action. https://aidmi.org/wp-content/uploads/2025/01/215-Climate-Extremes_Pathway-for-Preparedness-and-Anticipatory-Action.pdf

Stern, N. (2014). The Economics of Climate Change. Cambridge University Press. https://doi.org/10.1017/CBO9780511817434

Velásquez-Hidalgo, O., Yabar-Torres, G., Tavera-Huarache, H., Gómez-Avalos, J., & Villena-Mavila, M. (2024). Impacto del fenómeno El Niño 2017 en la región Piura. *Scientia*, 26(26). https://doi.org/10.31381/scientia.v26i26.6937

Viet, D., Thu, N. & Tram, V. (2024).Risk management and private debt contracts: The role of weather derivatives. .*Journal of Business Finance and Accounting*. *Open Access*Volume 51, Issue 9-10, Pages 2848 – 2883. Doi: https://doi.org/10.1111/jbfa.12800

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