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The Impact of El Nino and La Nina on the Price of Vietnam's Coffee Export

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Abstract— *The study focuses on analyzing the impact of the extreme climate phenomenon El Nino and La Nina (ENSO) on Vietnam's coffee export price in the period 2014–2023. We used the Newey-West regression method to overcome the autocorrelation phenomenon, to clarify the relationship between factors such as export output, world coffee price, rainfall, GDP growth rates of importing countries and the two El Nino and La Nina phenomenons with coffee export price. The results show that El Nino often reduces coffee price while La Nina can push price up but at the same time make harvesting difficult. From there, the study proposes response solutions such as developing drought-tolerant varieties, improving the climate forecasting system and diversifying export markets to improve the competitiveness and sustainable development of Vietnam's coffee industry in the context of climate change.*

Keywords— *El Nino, La Nina, export coffee price, Vietnam.*

I. Introduction

Climate change is becoming one of the most serious challenges to the global economy, especially in the agricultural sector. Extreme weather events such as El Nino and La Nina cause abnormal climate fluctuations, changing temperature, rainfall and humidity, directly affecting the yield and quality of crops, including coffee. According to the Food and Agriculture Organization of the United Nations (FAO) and the World Bank (WB), in the next 30 years, global coffee production could decline by up to 25%, seriously threatening supply chains and market price.

Coffee is one of Vietnam's key agricultural exports, accounting for 15% of the total export turnover of agricultural products and more than 10% of the GDP of the agricultural sector. Vietnam is the world's second-largest coffee exporter and a leader in Robusta, creating jobs for more than 600,000 farming households, playing an important role in rural economic development. However, Vietnam's coffee industry is vulnerable to climate changes. El Nino causes drought, lack of irrigation water, reduces yields; and La Nina leads to heavy rains, flooding, an increase in pests and diseases, affecting the quality of coffee beans. These changes cause supply instability and export price fluctuations, affecting people's income and Vietnam's competitive position in the world market.

Therefore, it is very urgent to study the impact of El Nino and La Nina on Vietnam's coffee export price. The research results will help the coffee industry better understand climate risks, proactively respond to and propose solutions to stabilize production, develop sustainably and improve international competitiveness.

II. Theoretical basis and literature review

2.1. Theoretical basis

Concept of the ENSO phenomenon

ENSO is a combined ocean-atmosphere phenomenon, characterized by periodic fluctuations in sea surface temperature and atmospheric pressure in the tropical Pacific region. According to Wang & Picaut (2004), Wang et al. (2017), the ENSO phenomenon has 3 main states: El Nino (hot phase), LaNina (cold phase), and neutral state.

El Nino is an abnormally warming phenomenon of surface sea water in the central equatorial region and the Eastern Pacific Ocean, occurring every 2-7 years, on average every 4 years. El Nino makes the sea water 3-6 degrees hotter, causing hot weather and heavy rain, flooding in the Eastern Pacific, drought in the Western Pacific.

La Nina is a cold weather phenomenon, usually after El Nino, from March to June, strongest from December to February of the following year. The characteristic of La Nina is that the Pacific Ocean sea water is unusually cold, causing a decrease in air temperature, causing severe cold and adversely affecting the affected area.

A neutral state is a period when sea surface temperatures in the Pacific Ocean are near long-term averages, with no major fluctuations in temperature, rain or wind, creating stability in the climate and oceans.

Criteria for determining the ENSO phenomenon

The US Climate Prediction Agency (CPC) – NOAA has set criteria for announcing the time of El Nino and La Nina:

El Nino occurs when the ONI ≥ +0.5°C and persists for at least 3 consecutive months.

La Nina occurs when the ONI ≤ -0.5°C and persists for at least 3 consecutive months.

When the ONI fluctuates between -0.5°C and +0.5°C, the climate is considered neutral.

ENSO's Impact on Global Climate and Vietnam

The ENSO phenomenon, especially El Nino and La Nina, has a profound impact on the global climate and the region of Vietnam. El Nino causes drought in many areas, while causing

flooding in other areas, increasing the frequency of storms in the Pacific region, heat waves and wildfires in some localities. In Vietnam, El Nino reduces the number of storms, causing temperatures to rise and end the cold air phenomenon earlier than usual. In addition, El Nino also causes a shortage of rainfall, especially in the North Central Region, leading to drought and increasing the fluctuation of rainfall in the region. Meanwhile, in La Nina conditions, there are an average of 0.80 storms per month, about 38% more than the annual average, tropical cyclones are usually more common in the second half of the hurricane season (September-November). The average temperature in the months is lower than normal, in the North it is more affected than in the South.

2.2. Literature review

The relationship between the ENSO phenomenon and agricultural output has been examined through studies. In a study by CGIAR (2016), weather fluctuations caused by ENSO have a significant impact on agricultural output in the Central Highlands, along with 18 provinces and cities in the Southeast and the Mekong Delta. Not only Vietnam's agriculture but also agricultural products of countries in the ASEAN region are also vulnerable due to the El Nino phenomenon. The HSBC report (2023), which analyzes the impact of the El Nino phenomenon on ASEAN agriculture and trade, has identified the three main ASEAN products most vulnerable to El Nino: rice (Thailand and Vietnam), palm oil (Malaysia and Indonesia), and coffee (Vietnam and Indonesia). The ENSO phenomenon also directly affects agricultural production in Africa, according to research by Sazib et al. (2020) through the exploitation of the link between ENSO, plant conditions and soil moisture; and the analysis of differences in soil moisture and plant conditions in two extreme ENSO stages, El Nino and La Nina; The authors suggest that ENSO affects crop yield depending on crop location, crop type and ENSO stage.

The relationship between the ENSO phenomenon and the price of agricultural products has also been considered in a number of studies. Fajri et al. (2019) studied food price fluctuations in Indonesia due to the influence of the two extremes El Nino and La Nina. Using static array data analysis, the study indicates that El Nino increases rice and soybean price but decreases corn price due to the effects of drought, while La Nina has a more significant impact on rice price. Another study by Fitriana et al. (2022) on the price of cabbage and chives in Indonesia in the period 2010-2020 also affirmed that ENSO significantly affects the price of agricultural products, especially La Nina has a stronger impact.

The relationship between climate change and coffee exports has also been looked at in previous studies. The results of the study by Kath et al. (2021) shows that weather conditions including variations in precipitation and temperature have far-reaching impacts on coffee bean size and disability. From the effects on bean quality, the ENSO phenomenon affects coffee price. Research by Bastianin et al. (2016) in Colombia indicates that El Nino can reduce coffee price due to favorable weather conditions for production, while La Nina reduces production and increases coffee price. Richardson et al. (2023) also confirmed that ENSO affects coffee price, from which export coffee price are also inevitable. In Vietnam, research on this topic is very limited. According to a study by Yen Pham (2021), one of the regions most affected by the correlation between climate change and coffee exports is the Central Highlands.

III. RESEARCH DATA AND PROPOSED MODEL

Research Data

The study used time series data collected quarterly during the period from 2014 to 2024. Observed variables include: Economic variables such as Vietnam's export Robusta coffee price (Pxk) and world price (Pw), output (Q), GDP growth rate of major importing countries (GGDP); Climate variables such as weather phenomena (ElNino, LaNina), total rainfall (Pre).

The data are compiled from reliable sources, where economic indicators are collected from official reports, and climate factors are compiled from meteorological organizations with specific sources listed in the table below.

TABLE 1. Variables used in the research model

Data	Ampersand	Unit	Frequency	Source
Export Robusta coffee price	Pxk	USD/Ton	Precious	VietnamBiz
World Robusta coffee price	Pw	USD/Ton	Precious	Trading Economics
Export Robusta Coffee Output	Q	Ton	Precious	Vietnam Biz
Average GDP growth rate of major importing countries	GGDP	%	Taking Quarter 1/2014 as a basis	Trading Economics
ElNino; LaNina Dummy variables	ElNino; LaNina	1: a phenomenon that occurs; 0: The phenomenon does not occur	Precious	NOAA
Total rainfall nationwide at monitoring stations by quarter	Pre	Mm	Precious	General Statistics Office

Source: Author group

Proposed model

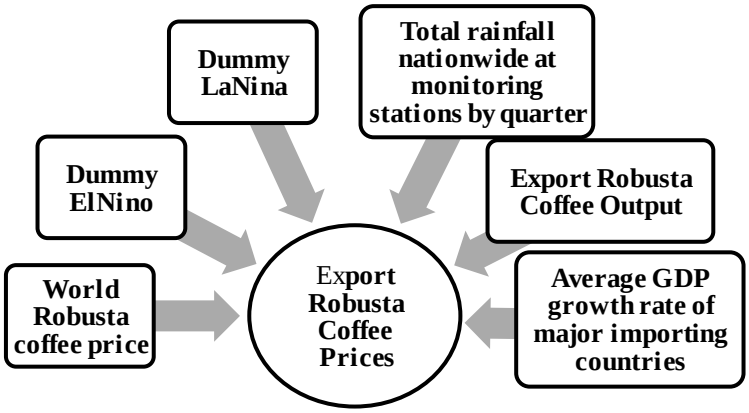

Figure 1. Proposed model
Source: Construction author group

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Estimation Process

- Correlation analysis between variables.
- Using the OLS method to estimate the model with the lag variables of independent variables to more accurately describe the relationship between these factors and the export price of Vietnamese coffee, a model regression model is built in the form of.

$$\widehat{Pxk}_t = \hat{\alpha} + \widehat{\beta}_1 ElNino_{t-3} + \widehat{\beta}_2 LaNina_{t-6} + \widehat{\beta}_3 Pre_{t-2} + \widehat{\beta}_4 Pw_t + \widehat{\beta}_5 Q_{t-3} + \widehat{\beta}_6 GGDP_{t-1}$$

- Checking for Multicollinearity with Variance Inflation Factor – VIF.
- Detection of autocorrelation by Breusch-Godfrey assay.
- Checking for heteroscedasticity with White test.
- Correct autocorrelation using Newey-West method, to adjust the standard errors of the OLS.

IV. Results of research and discussion

Before conducting regression analysis, the study performed descriptive statistics to evaluate the overview of the variables in the model. The descriptive statistical results show the mean, standard deviation, and largest and smallest values of each variable, thereby helping to identify the characteristics of data distribution. This analysis helps to identify fluctuations in variables over time, and at the same time detect abnormal values that can affect the regression model. The statistical results describing the variables shown in Table 1 show that the variables in the model are not abnormal.

Next, the study examined the correlation between the variables. The correlation coefficient matrix in Table 2 will provide information about the linear relationship between independent and dependent variables, and help determine the risk of multilinearity in the model.

TABLE 1. Statistics describing variables

	Pxk	ElNino	LaNina	Pre	GGDP	Pw	Q
Average	2237.620	0.350000	0.500000	7734.388	1.531050	3148.599	396075.0
Median	2069.331	0.000000	0.500000	7789.450	1.639667	2736.633	385500.0
Largest	3686.467	1.000000	1.000000	14263.30	13.86667	5320.000	600000.0
Smallest	1703.719	0.000000	0.000000	928.9000	-11.96867	2068.667	246000.0
Sum	89504.79	14.00000	20.00000	309375.5	61.24200	125948.0	15843000
N	40	40	40	40	40	40	40

Source: Authors' calculation.

TABLE 2. Correlation coefficient matrix between variables

	Pxk	El Nino	La Nina	Pre	GGDP	Pw	Q
Pxk	1.000000						
El Nino	0.037943	1.000000					
La Nina	0.065817	-0.568399	1.000000				
Pre	0.317564	-0.190173	0.197545	1.000000			
GGDP	0.168415	-0.090865	0.254566	0.044278	1.00000		
Pw	0.712940	-0.209853	0.384762	0.207389	0.322964	1.000000	
Q	-0.161380	-0.225120	0.070201	0.669554	-0.01159	0.075268	1.000000

Source: Authors' calculation.

TABLE 3. Model estimation results by OLS method

Variable	Estimation coefficient
C	1048.785*** (340.3824)
ElNino(-3)	-251.1832* (129.3670)
LaNina(-6)	226.6305* (116.5677)
Pre(-2)	-0.028868** (0.013399)
Pw	0.307897*** (0.063402)
Q(-3)	0.001253* (0.000622)
GGDP(-1)	-22.69456 (15.72183)
Other Indicators	
R-squared	0.705701
Prob(F-statistic)	0.000004

Notes: *, ** and *** indicate statistical significance at p-value levels 0.1, 0.05 and 0.01 respectively; standard errors in parentheses.
Source: Authors' calculation.

The correlation coefficient table shows the remarkable relationship between several pairs of variables. The El Nino and La Nina have an inverse relationship (-0.5684), which is consistent with the opposing nature of these two phenomena. Rainfall (Pre) and yield (Q) have a negative correlation (-0.6696), suggesting that heavy rainfall may negatively affect agricultural production. Commodity price (Pw) and exports (Pxk) have a close relationship (0.7129), indicating that price may affect exports. The relationships between other pairs of variables are insignificant.

Use the OLS method to estimate the model. Table 3 shows the regression results, which illustrate how the independent variables in the study affect the dependent variable.

In addition to the GGDP(-1) variable, the other explanatory variables in the model are statistically significant, so it makes sense to include them in the analysis.

Performing tests to see if the model is subject to autocorrelation, multilinearity or heteroscedasticity, we get the results in Table 4.

From the above results, it can be seen that the model has no other defects except for the autocorrelation. To overcome this, the study used the Newey–West regression method to adjust the standard errors. In the results of the new model, the regression coefficients did not change, the standard error of the coefficients decreased, but the LaNina(-6) variable was not statistically significant.

The model estimation results show that the impact of the El Nino phenomenon on Vietnam's coffee export price is statistically significant at 10%. Specifically, the regression

coefficient of the ElNino(-3) variable with a value of (-251.1832) shows that after 3 quarters since this phenomenon appeared, coffee export price decreased by an average of 251.18 USD/ton, if other factors remain unchanged. It can be explained that the El Nino phenomenon often causes prolonged droughts, which reduce coffee production, and can negatively affect the quality of coffee beans due to dry conditions during growth and development. The decline in both output and quality can lead to lower export price. This result is consistent with previous studies on the negative impact of El Nino on agricultural production in general and the coffee industry in particular.

TABLE 4. Results of inspections

Test	Statistics	Value	P-value	Conclude
Autocorrelation Test (BG Test)	F-statistic	24.08804	0.0000	autocorrelation
	Obs*R-squared	16.35108	0.0000	
Variance Inflation Factor (VIF)	ElNino(-3)	1.4408	-	No serious multicollinearity
	LaNina(-6)	1.2623	-	
	Pre(-2)	1.1975	-	
	GGDP(-1)	1.2558	-	
	Pw	1.5392	-	
	Q(-3)	1.0867	-	
Heteroscedasticity Testing (WHITE)	F-statistic	2.05589	0.0924	No serious heteroscedasticity
	Obs*R-squared	10.66219	0.0994	
	Scaled explained SS	11.36862	0.0776	

Source: Authors' calculation.

In contrast, the La Nina phenomenon has a positive impact on coffee export price. The regression coefficient of the LaNina(-6) variable has a value of 226.6305 and is statistically significant at 5%, showing that after 6 quarters since the appearance of La Nina, coffee export price have increased by an average of 226.60 USD/ton with the condition that other factors have not changed. Explained by La Nina is often accompanied by abundant rainfall and more favorable weather conditions, which help coffee plants grow well, improve the yield and quality of coffee beans. At the same time, La Nina can have a negative impact on coffee production in Brazil – the world's largest coffee exporter and Vietnam's main competitor. When Brazil's coffee production declines due to La Nina, this can reduce supply in the international market, thereby boosting Vietnam's coffee export price. Even though La Nina has a beneficial effect, El Nino's detrimental effects are nonetheless larger than La Nina's beneficial effects in terms of the amplitude of its influence, highlighting the significance of climate change adaptation measures in the coffee business.

Comparing the results with previous studies, including the HSBC report and the study in Indonesia, it has also been shown that ENSO has a significant effect on agricultural production and price. The overall results from many studies show that La Nina often increases the price of agricultural products, while El Nino tends to decrease the price, due to their impact on climatic conditions and crop production.

The research model also confirms these trends when it shows that Vietnam's coffee export price increased during the La Nina period and decreased during the El Nino period. This agrees with the findings of Fajri et al. (2019) or Fitriana et al. (2022) regarding the effect of ENSO on the agricultural industry in Southeast Asia.

In addition, the regression results also indicate that rainfall has a small effect on coffee export price. The regression coefficient of the variable Pre(-2) has a value of (-0.028868) which is statistically significant at 5%, with a negative but very small value, indicating that rainfall has a very limited effect. One reason may be that rainfall mainly impacts coffee harvesting and processing but does not cause significant changes in export price. This may also stem from the fact that coffee production and quality are affected by many factors, not just rainfall in a short period of time.

One of the most statistically significant variables in the model is the world coffee price. The regression coefficient of the Pw variable has a value of 0.307897 which is statistically significant at 1%, showing that when the world coffee price increases by 1 USD/kg, the export price of Vietnamese coffee increases by an average of 0.3788 USD/ton. This result reflects the close relationship between the Vietnamese coffee market and the global coffee market, showing that domestic export price are greatly influenced by international price. This emphasizes that coffee exporters need to closely monitor global market price movements to make timely adjustments in business strategies and sign export contracts.

In addition, the coffee production variable Q(-3) has a small positive coefficient and is statistically significant at 10%, showing that when coffee production increases, export price also tend to increase slightly. However, the very small impact shows that output is not a major determinant of export price. One reason may be due to the characteristics of the coffee market: although production increases, export price are usually decided in advance through long-term contracts, so the effect of output on price may not be significant in the short term.

Finally, the coefficient of the variable of the average GDP growth rate of major importing countries is not statistically significant. This can be explained by two main reasons. Firstly, Vietnam's coffee price are mainly dominated by world price and factors that directly affect major competitors such as Brazil, including climate change and the output of these countries. Secondly, the GDP growth rate of importing countries does not fluctuate identically with the fluctuation of coffee price, leading to this variable not having statistical significance in the model.

Besides, the model's key indicators, including R-squared = 0.705701 and Prob(F-statistic) = 0.000004, indicate that the model has a relatively high fit. Specifically, about 70.57% of the fluctuation of coffee export price is explained by independent variables in the model. This shows that ENSO (El Nino, LaNina), rainfall, world coffee price, coffee production

and GDP growth rates of importing countries have an important impact on Vietnam's coffee export price.

V. Conclusion

Research shows that the ENSO phenomenon has a significant impact on Vietnam's coffee export price, with El Nino reducing price and La Nina tending to increase price. In addition, world coffee price are identified as the strongest dominating factor for export price, while domestic factors such as production or rainfall have only a limited impact. The research results are consistent with the trends recorded in international studies, and also confirm the importance of climate factors in Vietnam's coffee value chain.

From these findings, it is necessary to prioritize the development of accurate and timely climate forecasting systems, expand agricultural insurance based on climate indicators, and promote investment in production technologies that adapt to climate change. Export enterprises need to shift to increasing product value and diversifying markets, effectively taking advantage of free trade agreements. On the farmer side, the application of water-saving farming techniques, the use of drought-tolerant varieties and participation in cooperatives are practical solutions to increase resistance.

However, the study still has some limitations due to the scope of the data and does not fully consider non-climatic factors as well as regional differences. Further studies should scale up the analysis and delve deeper into local fluctuations in order to propose more detailed and effective adaptation solutions.

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