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Phosphate price fluctuations and economic growth in Morocco: An ARDL-bounds approach

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ABSTRACT

This research examined the relationship between international phosphate price volatility and economic growth in Morocco for the 1994-2020 period, using the Autoregressive Distributed Lag (ARDL) bounds testing approach to capture the short-run and long-run dynamics. The data used is annual in frequency and includes yearly time series of several key macroeconomic indicators, including nominal GDP, phosphate prices, CO_2 emissions, fertilizer consumption, gross fixed capital formation, and unemployment. The study identified that phosphate price changes significantly affect Morocco's short-run economic growth but have no statistically significant long-run impact on GDP. The increase of phosphate prices in the short run results in higher export revenues, but long-lasting price volatility limits economic diversification and environmentally sustainable options. Several structural inefficiencies were also found in Morocco's economy, including the limited effect of capital allocation and high levels of unemployment that restrict sustainable growth. The study identified several key aspects that should be considered by Morocco as it looks to reduce its dependency on the phosphate sector, including economic diversification with a commitment to sustainable resource management across the economy, such as the use of human capital investments, green technologies, infrastructure investments, and appropriate changes to governance and policy. The study highlights the literature contributions of Morocco as an exceptional specific case, being the number one country for phosphate with a highly developed phosphate sector, and emphasizes that sustainable resource expenditure and volatility, drawn from effective policy responses to resource price volatility, are needed to support sustained human development.

Contribution/ Originality: This study contributes to the existing literature in several ways. It employs the ARDL bounds testing approach to estimate the relationships involved. Additionally, this research is among the few that have examined phosphate price fluctuations, rather than oil or gas, and their impact on economic growth in Morocco.

1. INTRODUCTION

The connection between natural resources and economic growth has long been a topic of academic and policy discourse. For resource-rich developing countries, natural resources such as oil, gas, and minerals have provided key drivers of economic performance, including significant revenues, and have promoted the use of resources to develop

their economies (Aslan & Altinoz, 2021). However, this dependence also raises substantial challenges: exposure to international markets, depletion of natural resources, and the effects of resource allocation on the environment (Majeed, Wang, Zhang, & Kirikkaleli, 2021).

Morocco represents an interesting case study of this issue as it is a key supplier of phosphates. Phosphates are non-renewable and are essential to the chemical and agricultural industries. Phosphate production accounts for around 5% of Morocco's GDP and is also a significant export (OCP Group, 2024). There are many challenges associated with phosphate production, relating to issues of overdependence on this resource, market events that drive price variations, and the need for economic diversification (Al Rawashdeh & Maxwell, 2011; Geissler, Hermann, Mew, & Steiner, 2018).

Historically and in modern economic theories, different views have been presented about the importance of natural resources for economic growth. Earlier economic models considered resources to be significant drivers of prosperity, drawing value from resources in the wealth creation and development processes (Davis, 1995; Weinthal & Luong, 2006). In recent years, however, the role of natural resources and natural resource dependence has been characterized as complex, contradictory, and, in some cases, paradoxical, exemplifying the "resource curse." Many countries with natural resource wealth have not been able to convert this wealth into growth in economic development and have consequently become overly reliant on resources for economic success, experiencing institutional inadequacies, economic volatility, and limited growth potential (Amini, 2018; Gylfason, 2001).

Studies also confirm that if resource wealth is efficiently managed, it can enhance public investment and infrastructure, and contribute to socio-economic development through development assistance and risk reduction associated with the impacts of poverty (Anggraeni, 2020; Shah, Zaman, Khan, & Rashid, 2022). In contrast, when market mechanisms promote overdependence on resources that export revenue, volatility increases, institutions weaken (e.g., unable to impose rules on dodgy license holders), diversification is not prioritized, and this counteracts long-term growth potential (Havranek, Horvath, & Zeynalov, 2016; Muhamad, Heshmati, & Khayyat, 2021).

Phosphate is an essential ingredient used in fertilisers for growing crops. In Morocco, phosphate production has contributed to the economy in terms of GDP and exports and represents one of the significant challenges facing the economy. While phosphate production accounts for economic contributions in GDP and export sectors, the Moroccan economy is exposed to international price volatility, which increases vulnerability and risks for planning. In addition to the economic risks, phosphate production entails a range of environmental and social costs. These costs include the intensive use of water in a region with desert-like conditions where water is scarce; the production of hazardous waste that pollutes water sources and degrades soils; and the increasing potential risks to public health (Herring & Fantel, 1993; Mehahad & Bounar, 2020).

Despite a considerable amount of research on the different relationships between natural resources and economic growth, there is limited contextual focus on Morocco as a leading exporter of phosphates: most studies focus on oil- or gas-exporting nations and do not reflect on how the fluctuation of phosphate prices impacts the economic development of a resource-dependent economy like Morocco.

This study aims to address the identified gap in knowledge by exploring the impact of international phosphate price fluctuations on Morocco's economic growth. The study seeks to answer the question: Is Morocco economically vulnerable to price changes in the global phosphate market as a leading exporter of phosphates? By examining this relationship, the study aims to provide insights into effective resource management and the broader implications for sustainable economic growth.

To achieve these objectives, the study is structured as follows. The first section introduces the research topic and outlines its significance. The second section comprehensively reviews the literature on the relationship between natural resources and economic growth. The third section describes the methodology employed in the study. The fourth section presents the empirical findings and discusses policy implications. The fifth section concludes with key insights and recommendations for future research.

2. LITERATURE REVIEW

The relevant literature on price volatility surrounding phosphorus and the relationship with a specific country's rate of economic growth (=GDP) is limited, as far as the author is aware. In this context, our study aims to make a worthwhile contribution by analyzing the effects of phosphorus price volatility on GDP growth in Morocco.

Researchers have attempted to consider the linkages between natural resource prices and economic performance for years using different lenses. However, there is little research directly aimed at phosphorus as a natural resource, especially with respect to economic growth and price volatility. Our study is going to lean on some of the studies related to other natural resources, like oil and gold, for ideas around formatting these themes.

Over time, many researchers have analyzed the relationships between different natural resource prices and economic performance in various contexts. However, there is limited research on the relationship between phosphorus as a natural resource and economic growth, and particularly, price volatility. To engage in this conversation, we draw on studies concentrating on a variety of natural resources, including petroleum and gold, to paint a better picture of this relationship.

There has been a significant amount of academic literature examining the relationship between economic growth and natural resources, particularly in developing economies. Natural resources can be either a blessing or a curse for economies, which leads to different opinions on the relationship between natural resources and economic performance (Khan, Ponce, Yu, & Ponce, 2022). This is a multi-dimensional topic that has evolved over time, especially with recent studies focusing on the volatility of natural resource prices and economic growth, particularly in discussions surrounding petroleum and gold.

During the early 2000s, within academia, the discussion shifted as researchers began to examine how changes in commodity prices affected economic stability. For example, Gylfason (2001) expressed how countries that rely heavily on commodities often neglect their financial institutions for other areas, which ultimately affects economic growth. Gylfason (2001) perspective was further supported by Van Der Ploeg and Poelhekke (2009) who wrote that price volatility creates economic instability in countries dependent on natural resources, which further complicates economic growth.

As concerns surrounding price volatility grew, especially with respect to oil markets, economists began to study the impact of volatility on economic growth more thoroughly. The 2008 financial crisis and subsequent commodity price volatility events prompted further academic inquiry into this relationship (Baumeister & Peersman, 2013; Park & Ratti, 2008). Similarly, Ebrahim, Inderwildi, and King (2014) wrote that oil price uncertainty hampers and disrupts economic growth, creating challenges for sustainable development in oil-dependent economies.

Recent studies have examined both petrol and gold price volatility and their effects on economic growth in resource-rich countries (Guan, Zhao, Wang, & Zhang, 2021). Using econometric models, the studies concluded that long-run price volatility of natural resources impedes GDP growth, while in the short run, the fluctuations in prices for gold have a positive impact on development, possibly because gold is viewed as a haven in times of uncertainty. Also, understanding the price volatility around resource or non-renewable prices requires a theoretical basis. Hotelling (1931) argued that the cost of a non-renewable resource should ultimately increase over time at the interest rate for a competitive market, and he was implying an optimal rate of extraction price that provides short-run profit and long-run monotonic societal gain.

This perspective established the foundation for understanding how market structures, such as monopolies or competitive situations, impact exhaustible resource extraction rates and prices (Fischer & Laxminarayan, 2004). Nevertheless, empirical evidence of oil and mineral resources reveals variation from this predicted price trend, which is evidence that factors such as technological change, studied by Lin and Li (2008) can help balance resource depletion costs and stabilize prices, even if only temporarily, and not if they become scarce. While technological change will not alleviate long-run depletion pressures, it can highlight the importance of efficient management and sustainable extraction practices (Acemoglu, Johnson, & Robinson, 2005; Schilirò, 2019).

Institutional quality reappears in the literature and mediates the channels between natural resource prices and economic growth. El-Anshasy, Mohaddes, and Nugent (2017) argued that oil revenue volatility may subsequently lead to the "resource curse" if oil price monitoring is not well managed with proper fiscal policy and state institutions. Mohammed, Omar, and Nor (2020) endorsed this argument, claiming that the extent to which resource-poor countries' governments directly allocate state resources and economic growth initiatives. The point of mention has led us to include activity and trade openness rates in our analysis.

Building on the concept of institutional quality, Rahim (2021) investigated the relationship between natural resource abundance, human capital development, and economic growth in the Next Eleven (N-11) countries during 1990-2019, using the resource curse hypothesis. Rahim also demonstrated several econometric methods to show that while natural resource rents act as a disincentive for economic growth, human capital development, financial growth, industrialization, technological innovation, and international trade serve as positive influences on economic performance. More importantly, human capital development appears to be an instrumental means to mitigate the adverse effects associated with resource abundance. Therefore, one could assume that if all N-11 countries can benefit from natural resource wealth, investing in education or skills development resources that might otherwise contribute to a resource curse could instead lead to significant growth increments or become transferable assets.

The use of natural resource revenues further demonstrates the importance of institutional frameworks. Where countries have transparent and accountable governance structures, there is a growing use of resource wealth to facilitate sustainable economic growth; however, stagnation is common among developing countries with substantial resource wealth, failing to gain traction (Tavares & Wacziarg, 2001; Zallé, 2019). Governance is critical in deciding how far the social contract and natural resource wealth can act as a positive influence on development outcomes (Mejía, 2013).

Stepping back to the global economy, increased complexity, such as the implications of COVID-19, has further complicated the ties between natural resources and economic growth outputs (McNeely, 2021). COVID-19 created unparalleled volatility in commodity markets, as oil prices were driven by market conditions and turned negative in 2020. Gold reflected increased value as investors searched for safety amid uncertainty (Guan et al., 2021). Such volatility multiplied the challenges for countries' factions, which were able to increase natural resource growth through volatility with policies. Zhang, Chen, and Zhao (2024) suggested that engaging tasks in environmental management schemes integrated into a pricing regime might build resilience against price fluctuations. It is essential to once again stress that, as the world faces immediate climate issues along with sustainability issues, environmental policies and resource management must engage higher objectivity.

Methodologically, the ways of studying the relationship between economic growth and natural resource prices have changed considerably. The Autoregressive Distributed Lag (ARDL) model has become routine in recent work, permitting an understanding of the impact of price volatility on economic growth in the short and long term, as Guan et al. (2021) show with the PMG estimator when applying the ARDL, which demonstrates its ability to handle complex dynamic relationships between fluctuations in oil and gold prices and their effects on GDP growth.

In broadening the theoretical issue of resource economics, writers like Schubert (2006) systematically examined the choice of discount rates in long-term environmental decisions; the ethics of intergenerational resource use were emphasized in Schubert's arguments for a variable and/or declining discount rate used in ecological cost-benefit analysis. Schubert's approach for assessing impacts on resources over an extended timeline is a useful one, and this demonstrates how one could mitigate the ethical implications of discounting to foster environmental policies and regulations that address the needs of future generations.

Likewise, the study of Mrabet and Alsamara (2017) underlines the overall importance of a stable framework for the economy and exhibits that there is a negative long-term relationship between parallel market exchange rate volatility, which has a negative impact on real GDP. The use of the ARDL in application shows how this exchange

rate volatility has affected the macroeconomic sustainability of the economy, highlighting that the economy and the environment are closely interconnected with the sustainability of future generations.

In conclusion, the literature discussed above highlights the complicated links of the volatility of natural resources prices that are interlinked with economic growth and the importance of institutional quality, governance, and human capacity. Throughout, much of the existing literature has concentrated more broadly on a set of resources—oil or gold, etc. This study intends to use existing models and explore a gap in the literature for phosphorus price volatility and the resulting impacts on Morocco's GDP growth. It hopes to provide a promising understanding of sustainable policies for resource-rich economies in pursuit of its objectives through the existing economic theoretical framework and employing models from modern econometrics.

3. METHODOLOGY

3.1. Data Sources, Hypothesis, and Model Specification.

3.1.1. Data Sources

The present study examines the impact of fluctuations in international phosphate prices on Morocco's economic growth. The dataset employed for this analysis encompasses various relevant indicators, as presented in Table 1:

Table 1. Data summary.

Variables		Symbols	Expected impact on GDP		Period	Source
			Short-run	Long-run		
Dependent variable	Nominal GDP	LNGDP	-	-	From 1994 to 2020	WDI*
Independent variables	Phosphate price	LPhprice	Negative	Negative		IM**
Control variables	Fixed capital formation as a percentage of GDP	LGFCF	Positive	Positive		WDI
	Emission of CO2 in KT	LCO2	Positive	Negative		WDI
	Fertilizer consumption as a percentage	LFC	Positive	Positive		WDI
	Unemployment rate	LUnem	Negative	Negative		WDI

Note: *Index Mundi.
** World development indicators.

3.1.2. Hypotheses

***Hypothesis 1 (H_1): Short-Run Impact of Phosphate Price Volatility**.*

Short-term fluctuations in international phosphate prices negatively impact Morocco's economy and NGDP.

In the short term, volatility in phosphate prices directly affects Morocco's export revenues, a key component of its GDP. Fluctuating prices create economic uncertainty, discouraging domestic and foreign capital formation investments. This reduction in investment can hinder immediate economic growth and negatively impact GDP per capita.

***Hypothesis 2 (H_2): Long-Run Impact of Phosphate Price Volatility**.*

In the long term, ongoing fluctuations in international phosphate prices negatively influence Morocco's NGDP.

Over the long term, sustained price volatility in the phosphate market can limit Morocco's ability to diversify its economy, maintaining an overreliance on phosphate exports. This lack of diversification increases vulnerability to external shocks and undermines sustainable growth. Additionally, prolonged dependence on phosphate extraction can lead to significant environmental degradation, imposing further economic costs and reducing overall productivity.

3.1.3. Model Specification

The study is based on the annual data for 1994-2020, and the sample period was chosen based on two primary considerations: the availability of data and an improved economic structure concerning the Moroccan economy. The

sample period includes a post-liberalization phase during which Morocco integrated its economy into the global market and implemented structural reforms in sectors such as extractives and exports, particularly focusing on phosphate. The period also encompasses multiple international commodity price shock events, including those affecting phosphate.

The selection of variables for the model is based on both theoretical rationales and empirical studies concerning resource economics and economic growth literature. The dependent variable, nominal GDP (LNGDP), is used to represent overall economic performance. The principal independent variable, international phosphate price (LPhprice), reflects Morocco's financial exposure to fluctuations in its main export commodity. Gross fixed capital formation (LGFCF) is included to represent investment intensity in the economy for control purposes. CO_2 emissions (LCO_2) serve as a proxy for environmental pressure levels and industrial activity. Fertilizer consumption (LFC) indicates agricultural sector productivity, while the unemployment rate (LUNEM) accounts for labor market pressures. Reduced reliance on phosphate extraction may also lead to environmental improvements, but the inclusion of other macroeconomic drivers remains necessary.

The Autoregressive Distributed Lag (ARDL) approach is used to consider the impact of the fluctuations of the international phosphate price and subsequently its role in the economic growth of Morocco. The ARDL captures the short-term time effects of price volatility and economic price evolution over time. The additional variables considered include CO_2 emissions and the unemployment rate, captured with respect to economic growth. The model specification allows better renderings of the factors affecting Morocco's economic development.

The ARDL modeling approach is relevant for this analysis, and it provides deeper insights into the short-run and long-run interactions of the respective time series. The alternative to testing the models separately could have added some convenience in methodological simplicity; however, the ARDL approach allows the integration of additional variables that can be stationary and non-stationary. Ultimately, through the ARDL methodology, this study aims to provide a significant assessment of the interactions of natural resource prices, manipulated by their price volatility, and the natural environmental dynamics affecting the economy's performance in Morocco.

To investigate the relationship between the impact of phosphate price volatility and the economic growth of Morocco through the use of the econometric model ARDL BOUNDS, the output results will be analyzed to observe the short-run dynamics and long-run relationships described by the different prices, using relevant performance variables when necessary.

The model is structured in the classical format, where volatility influences real GDP growth in phosphate prices and controlled variables such as CO2 emissions, fixed capital formation, and the unemployment rate. This multifaceted approach provides a comprehensive understanding of how phosphate price fluctuations impact economic growth while accounting for other influential factors.

The ARDL method is particularly appropriate for this analysis as it accommodates variables that may be integrated into different orders, ensuring robust results despite potential variations in data stationarity. This methodology aims to provide insights into the sustainability of Morocco's economic growth in the context of fluctuating natural resource prices.

$$ngdp = f\ (PHprice, Gfcf, Co2, FC, UNEM) \quad (1)$$

In addition, following the specification described above, we implement another version of our model in which all variables are recorded in their natural form. Our multivariate regression model is specified as follows, utilizing a log-log model in our study. We will use the data in natural logarithms to derive elasticities, as follows:

$$Lngdp = f\ (lPhprice, lGfcf, lco2, lFC, lUnem)$$

$$lngdp_t = \beta_0 + \beta_1\, lphprice + \beta_2\, lGfcf + \beta_3\, lCo2 + \beta_4 lFC + \beta_5 lUnem + \varepsilon t \quad (2)$$

t: Represents the period (i.e., year).

ε: This is the error term.

βi: Represents the constant term (where i = 1, 2, 3) and represents the coefficients of the examined explanatory variables.

An error correction representation of the ARDL model of Equation (2) can be written as:

$$\Delta \text{lngdp}_t = \alpha_0 + \delta_1 \text{lngdp}_{t-1} + \delta_2 \text{lnhprice}_{t-1} + \delta_3 \text{lgfcf}_{t-1} + \delta_4 \text{lco2}_{t-1} + \delta_5 \text{lFC}_{t-1} + \delta_6 \text{lUnem}_{t-1} + \sum_{i=1}^{\rho} \emptyset_i \Delta \text{lngdp}_{t-i} + \sum_{i=1}^{\rho} \varphi_i \Delta \text{lnhprice}_{t-i} + \sum_{i=1}^{\rho} \omega_i \Delta \text{lgfcf}_{t-i} + \sum_{i=1}^{\rho} \theta_i \Delta \text{lco2}_{t-i} + \sum_{i=1}^{\rho} \beta_i \Delta \text{lFC}_{t-i} + \sum_{i=1}^{\rho} \eta_i \Delta \text{lUnem}_{t-i} + \nu_t \quad (3)$$

Where:

- Δ: Represents the first difference operator.
- $\delta_1, \delta_2, \delta_3, \delta_4, \delta_5, \delta_6$ are the long run parameters.
- And ρ it is the optimal lag minus 1.

Utilizing the ARDL approach allows for estimating both short-term and long-term dynamic relationships. Consequently, equation 3 can be reformulated as the error correction version of the ARDL model in the following manner:

$$\Delta(lngdp)_t = \alpha_0 + \sum_{I=1}^{P} \emptyset \Delta \text{lngdp}_{t-i} + + \sum_{i=1}^{\rho} \varphi_i \Delta \text{lphprice}_{t-i} + \sum_{i=1}^{\rho} \omega_i \Delta \text{lgfcf}_{t-i} + \sum_{i=1}^{\rho} \theta_i \Delta \text{lco2}_{t-i} + \sum_{i=1}^{\rho} \beta_i \Delta \text{lFC}_{t-i} + \sum_{i=1}^{\rho} \eta_i \Delta \text{lUnem}_{t-i} + \upsilon ecm_{t-1} + \varepsilon t \quad (4)$$

Where,

ecm_{t-1}: Is the error correction model.

The error correction model includes a term for the adjustment rate toward long-term equilibrium after a short-term shock. Therefore, the coefficient of this term should be negative and statistically significant.

4. FINDINGS AND DISCUSSION

4.1. Descriptive Statistics

Based on the data presented in the Table 2, the standard deviation (Std. Dev) reveals that LPhprice is the most volatile variable, whereas LFC exhibits the least volatility. Regarding the skewness coefficient, LPhprice and LUnem demonstrate positive skewness (Skewness > 0), indicating a right-skewed asymmetry, while the remaining variables display negative skewness (Skewness < 0), reflecting a left-skewed asymmetry. The kurtosis values suggest that the distributions of all variables are flatter than the normal distribution, with coefficients falling within the acceptable range (-3 to +3). Furthermore, the Jarque-Bera test results confirm the normality of all variables, as the probabilities exceed the 5% threshold.

Table 2. Descriptive statistics.

	LNGDP	LPHPRICE	LCO2	LFC	LGFCF	LUNEM
Mean	25.080	4.233	10.710	3.024	3.257	2.378
Median	25.107	3.951	10.743	3.145	3.266	2.272
Maximum	25.540	5.491	11.170	3.680	3.442	2.645
Minimum	24.538	3.481	10.229	1.805	3.081	2.187
Std. Dev.	0.322	0.641	0.300	0.530	0.103	0.173
Skewness	-0.162	**0.455**	-0.195	**-0.958**	-0.086	0.432
Kurtosis	1.645	1.931	1.666	**2.972**	1.810	1.541
Jarque-bera	2.182	2.217	2.171	4.137	1.624	3.235
Probability	**0.335**	**0.330**	**0.337**	**0.126**	**0.443**	**0.198**
Sum	677.176	114.316	289.187	81.673	87.948	64.216
Sum sq. dev.	2.701	10.691	2.345	7.308	0.278	0.778
Observations	27	27	27	27	27	27

4.2. Unit Root Test Findings

Performing unit root tests such as the ADF (Augmented Dickey-Fuller) and PP (Phillips-Perron) tests is essential to verify whether a series is stationary, as these tests help determine if the series is stationary or not. Table

3 presents the results of the Augmented Dickey-Fuller test, showing that while the variables are non-stationary at the level, they become stationary after first differencing, confirming an integration order of I(1). Similarly, Table 4 reports the outcomes of the Phillips-Perron test, which further validates the ADF findings by confirming that all variables attain stationarity only after first differencing.

Thus, each variable in our model has an integration order of I(1); however, none is I(2) or higher, further confirmed by the PP test. Therefore, the integration condition is satisfied, and based on these findings, we can utilize the ARDL bounds approach.

Table 3. Unit root table (Augmented Dickey-Fuller).

Variables		T-Statistic-Test for unit root at level	ADF Critical values			T-statistic (Test for unit root in first difference	Order of integration
Dependent variable	LNGDP	4.422	1%	5%	10%	-3.354***	I(1)
			-2.65	-1.95	-1.60		
Independent variables	LPhprice	0.192	-2.66	-1.95	-1.60	-4.984***	I(1)
Control variables	LCO2	4.627	-2.66	-1.95	-1.60	-3.276***	I(1)
	LFC	-1.095	-2.66	-1.95	-1.60	-5.865***	I(1)
	LUNEM	-0.800	-2.66	-1.95	-1.60	-4.368***	I(1)
	LGFCF	0.346	-2.66	-1.95	-1.60	-5.112***	I(1)

Note: *** significance at the 1%.

Table 4. Unit root table (Phillips-Perron).

Variables	Symbols	T-Statistic-Test for unit root at level	PP Critical values			T-statistic (Test for unit root in first difference	Order of integration
Dependent variable	LNGDP	5.303	1%	5%	10%	-3.687***	I(1)
			-2.65	-1.95	-1.60		
Independent variables	LPhprice	0.652	-2.66	-1.95	-1.60	-5.335***	I(1)
Control variables	LCO2	6.358	-2.66	-1.95	-1.60	-3.199***	I(1)
	LFC	-1.202	-2.66	-1.95	-1.60	-5.865***	I(1)
	LUNEM	-0.813	-2.66	-1.95	-1.60	-4.587***	I(1)
	LGFCF	0.376	-2.66	-1.95	-1.60	-5.111***	I(1)

Note: *** significance at the 1%.

5. BOUNDS TEST LONG RUN, AND SHORT RUN ESTIMATION

5.1. Bounds Test of Cointegration

To interpret the results of the Bounds Test, there are three hypotheses:

H_1: Fisher value > upper bound, presence of cointegration.

H_2: Fisher value < lower bound, no cointegration.

H_3: Fisher value between the two bounds, no conclusion.

The Bounds Test is a crucial step for examining the presence of a long-run relationship. When conducting the bounds cointegration test, the results confirm the presence of a cointegrating relationship, and the alternative hypothesis H1 is accepted.

The results in Table 5 indicate that the F-statistic value of 8.4039 is greater than the upper bound of the critical values, regardless of the chosen critical threshold (10%, 5%, 2.5%, 1%).

Table 5. Bounds-test.

Test statistic	Value	Signification	Lower bound I(O)	Upper bound I(1)
F-statistic	8.4039*	10%	2.08	3
		5%	2.39	3.38
		2.5%	2.7	3.73
		1%	3.06	4.15

Note: * Reject the null hypothesis at 1% significance.

5.2. ARDL Long-Run Estimation

In this section, Table 6 presents the results of the ARDL long-run estimation. Overall, the ARDL long-run estimation provides valuable analysis of the structural relationships among the primary macroeconomic variables and the phosphate sector. The results indicate that phosphate price (LPhprice) has a positive, though not statistically significant, relationship with GDP in the long run, where a 1% increase in LPhprice is expected to result in a marginal increase in GDP of 0.067%. This implies that the price of phosphate is an important component in economic performance, but other structural or external influences likely moderate the relationship in the long run.

On the other side, carbon emissions (LCO2) show a positive and statistically significant relationship to GDP, where a 1% increase in LCO2 indicates a 0.70% increase in GDP. This result reflects the environmental aspect of economic activities in the phosphate sector and uncovers how the industry is reliant upon processes that consume resources and exhibit carbon emissions. Therefore, reconciling sustainable environmental practices across all sectors requires immediate attention, as the strongly correlated emissions suggest that potential economic growth is subject to ecological limits, including carbon emissions.

Table 6. ARDL Long-run estimation.

Levels equation				
Case 2: Restricted constant and no trend				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
LPHPRICE	0.067	0.059	1.132	0.283
LCO2	0.705**	0.309	2.274	**0.046**
LFC	-0.051	0.040	-1.272	0.231
LGFCF	-0.777	0.627	-1.240	0.243
LUNEM	-0.694	0.624	-1.111	0.292
C	21.709	6.427	3.377	0.007

Note: **, shows 5% significance levels.

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The other variables show negative and mostly insignificant impacts on long-run GDP, reflecting unresolved structural challenges in the economy more broadly. For example, fertilizer consumption (LFC) and gross fixed capital

formation (LGFCF) would merely suggest that there are negative long-term economic influences resulting in a statistically insignificant relationship. On the whole, current investment and financial approaches have yet to be sufficiently coordinated to achieve the efficiency desired to stem new investments and assist long-term economic growth. Interestingly, unemployment (LUNEM) showed a negative, yet not statistically significant, economic influence on unemployment, which suggests that long-term structural inefficiencies are still considerable for labor at this time.

In summary, the findings prompt comprehensive structural reform and evidence-based policy intervention, focusing greater attention toward shifting the macroeconomic variables with an aim to foster long-term economic growth, rather than simply demonstrating some economic performance in the short run. Increased attention should focus on investing in human capital, embedding sustainable environmental approaches and practices, and aiming for a more equal, inclusive, and sustainable framework for developing the potential of an economy over the long term.

5.3. ARDL Short-Run Estimation

The outcomes displayed in Table 7 the results of the ARDL short-run estimation, illustrating the dynamic relationships between key variables and economic performance, specifically within the phosphate sector. The price of phosphate (LPhprice) exhibits a positive and significant relationship at lag 0 but a negative and significantly adverse effect at lag -1. The presence of these two contrasting effects from LPhprice indicates a high sensitivity of the phosphate sector to fluctuations in global prices; short-term increases in prices tend to stimulate economic activity, whereas lagged price increases can produce adverse effects through shocks, reflecting either volatility or sectoral adjustment over time.

Carbon emissions (LCO2), on the other hand, are insignificant with an adverse effect at lag (0) but significant with an adverse impact at lag (-1).

This suggests that although immediate changes in emissions related to carbon do not directly affect economic performance, the lagged changes of this variable still indicate inefficiencies in the economic structure related to underlying variations formed through factors associated with carbon emissions and environmental pressures, all contributing to the detriment of sustainable development.

The labor market effects shown are also crucial in the short run, with the significant and negative impact of unemployment (LUNEM) on economic performance. This highlights the adverse implications that high rates of unemployment carry for sectoral performance related to economic growth, emphasizing the need for interventions directed towards job creation and further reform in the market.

Gross fixed capital formation also shows a relatively complex reaction over the years and suggests a combination of lagged values. The first lag of LGFCF to t has a negative and significant effect on economic performance, implying an initial reduction in capital investment.

However, this effect becomes positive and significant at lag [-1]. This indicates that economic growth is driven by both sustained and strategic levels of expenditure on capital for long-term growth. Overall, the trajectory of changes in GFC also demonstrates shifts toward more productive and efficient fixed capital investment in the sector. Fertilizer consumption (LFC) was omitted from the short-run analysis due to its automatic lag selection procedure under the OECD script's selection criteria, as it was too slow to act within the short-run timeframe, which measures actions over an extended period.

The error correction term (CointEq (-1)) is significant and furthermore notes an adjustment of approximately -0.339, suggesting that approximately 33.9% of deviations from the long-run equilibrium are corrected in the period of an observation. This also signifies that the phosphate sector is resilient to shocks imposed by short-run fluctuations and that the phosphate sector can return to long-run equilibrium over time.

Table 7. ARDL short-run estimation.

ECM regression Case 2: Restricted constant and no trend				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
D(LPHPRICE)	0.033***	0.007	4.358	**0.001**
D(LPHPRICE(-1))	-0.034***	0.006	-4.926	**0.000**
D(LCO2)	-0.060	0.071	-0.844	**0.418**
D(LCO2(-1))	-0.304***	0.083	-3.654	**0.004**
D(LGFCF)	-0.348***	0.054	-6.415	**0.000**
D(LGFCF(-1))	0.249***	0.053	4.655	**0.000**
D(LUNEM)	-0.431***	0.045	-9.548	**0.000**
D(LUNEM(-1))	-0.131*	0.060	-2.179	**0.054**
CointEq(-1)*	-0.339	0.035	-9.701	**0.000**
R-squared: 0.93 Adjusted R-squared: 0.89				

Note: ***, * shows 1%, and 10% of significance levels.

5.4. Diagnostics Tests

5.4.1. Residual Test

Table 8 summarizes the diagnostic tests conducted to assess the robustness and reliability of the estimated ARDL model. The Breusch-Godfrey test for autocorrelation yields a Fisher probability of 0.047, slightly below the 5% threshold. Consequently, the null hypothesis of no autocorrelation in the residuals is rejected, suggesting that the error terms are correlated.

The heteroscedasticity test reports a probability of 0.561, leading to the acceptance of the null hypothesis. This result indicates that the variance of the residuals is constant (homoscedasticity), and there is no evidence of heteroscedasticity. Furthermore, the normality of the residuals is confirmed by the Jarque-Bera test, which produces a probability of 0.7614, supporting the acceptance of the null hypothesis and confirming that the residuals are normally distributed.

Table 8. Residual diagnostic test.

Diagnostic tests	**Test statistic**	**Probability**
Normality	2.61 (Kurtosis) 0.54 (Jarque-Bera)	0.7614
Heteroscedasticity (Breusch-Pagan-Godfrey)	F-statistic: 0.9295 Obs*R-squared: 14.13 Scaled explained SS: 1.82	0.561 0.439 1.000
Breusch-Godfrey Serial correlation LM test (2 lags)	F-statistic: 4.59 Obs R-squared: 13.59	0.047 0.001
Ramsey RESET Test	F-statistic: 2.07	0.184
CUSUM	Stable	
CUSUM SQ	Stable	

5.4.2. Stability Diagnostics Tests

The results of the diagnostic tests confirm that the estimates are robust, showing no signs of autocorrelation, heteroscedasticity, or non-normal distribution of residuals. Additionally, the Ramsey RESET test supports the model's correct specification. The estimated coefficients' stability is confirmed by the CUSUM and CUSUM of squares tests, as they fall within the critical bounds at the 5% significance level. Figure 1 shows that the blue line consistently remains below the 5% significance threshold, further supporting the estimated model's stability. Similarly, Figure 2 illustrates that the CUSUM of squares stability test indicates the model is globally stable, as the blue line slightly exceeds the 5% significance level.

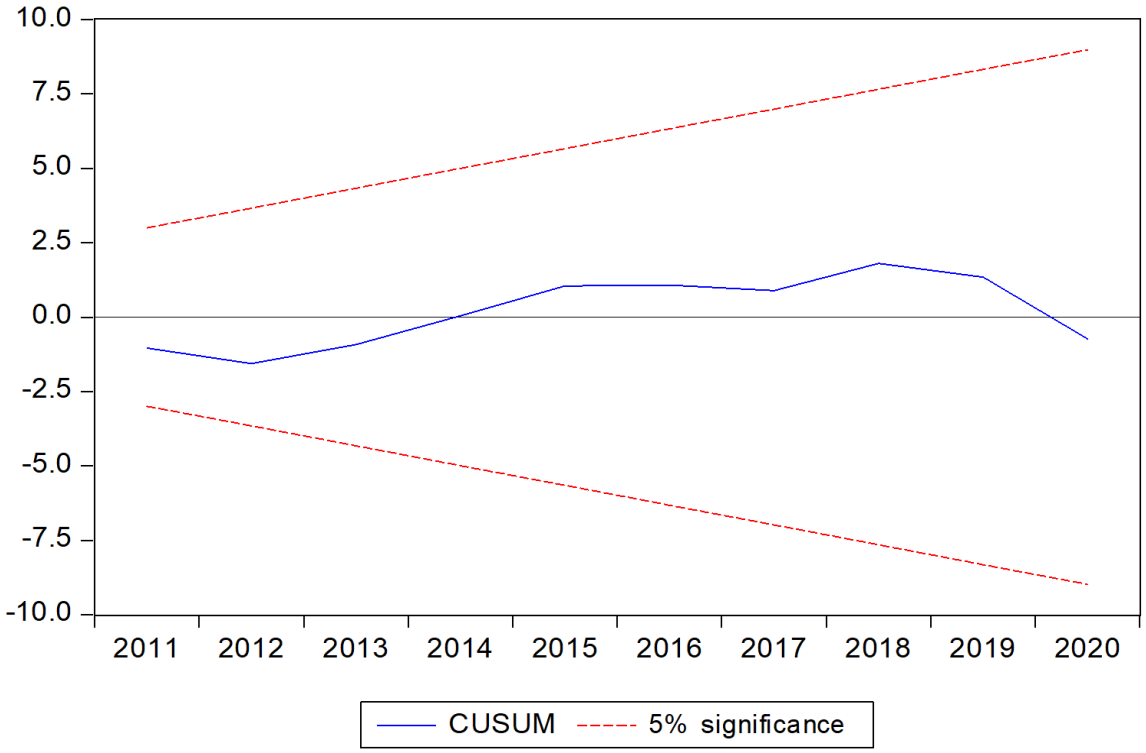

Figure 1. CUSUM test.

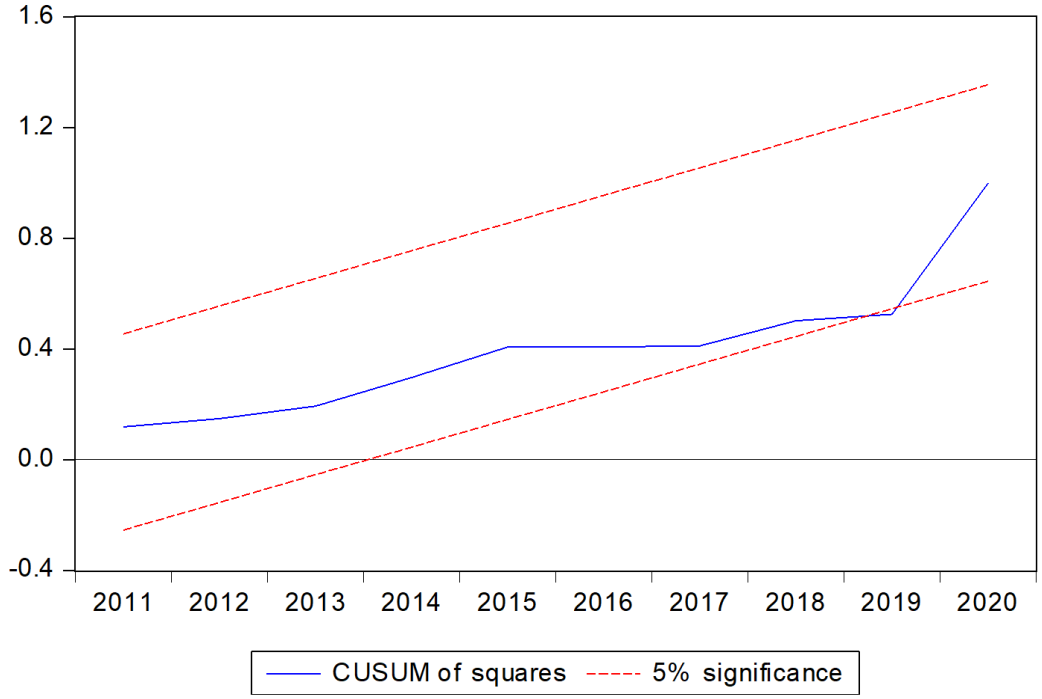

Figure 2. CUSUM of squares test.

6. DISCUSSION

The findings of this study illustrate the multifaceted relationship between the volatility of phosphate prices and the economic growth of Morocco, confirming that while phosphate prices and Morocco's nominal GDP (NGDP) simultaneously grow negatively in the short run, the direct relationship is affected by international market forces. This correlation also indicates that Morocco structurally depends on the phosphate sector as a significant engine of economic activity.

Furthermore, the negative and significant influences from gross fixed capital formation (LGFCF) provide structural constraints on immediate economic growth, which also has a negative and significant effect (LUNEM - unemployment), highlighting the importance of the labour market dynamics of economic outcomes. To rigorously test the proposed hypotheses, this study implemented an ARDL bounds testing procedure, which is an established and robust econometric technique, allowing for the short- and long-run dynamics of time series data.

The empirical outcomes of this study support hypothesis H_1, which indicates that, in the short run, phosphate price volatility has a negative impact on economic growth in Morocco (-1, 1-quarter lag). However, the long-run analysis rejects hypothesis H_1, indicating that phosphate price volatility positively impacts economic growth, which is problematic for meeting the original theoretical expectations that volatility is an impediment for economies that are successfully diversifying and thus lessening environmental degradation problems. Instead, we suggest the evidence demonstrates Morocco's economic structure is resilient to resource price volatility in the longer run. The variations present in the short- and long-run effects serve to highlight the complicated nature of resource-dependent economies, where price volatility enables short-term economic activity while long-term obstacles remain with our continued reliance on resources as structural constraints for these economies. The robustness of the ARDL model and the confirmation of cointegration support these conclusions, which demand a radical rethink of the theory and its potential assumptions and policy implications with the benefit of validated empirical evidence. There is existing literature that evidences that natural resource price volatility has economic growth effects; it is correct that the impact/remedies will remain context-specific.

The outcomes of this study corroborate the literature on natural resource price volatility and growth involving works such as Daly et al. (2024); Guan et al. (2021); Ebrahim et al. (2014) and Lin and Zhu (2019) in which higher prices, can lead to positive economic growth in the short run because of resource revenues from exports and fiscal capacity in government revenue. This is sustained against diverse literature which acknowledges the long-term consequences of continuation/volatility in Oyinlola, Adeniyi, and Kumeka (2023); Gylfason (2001) and Mehahad and Bounar (2020) which points to dependence on natural resources in the economy. We see that phosphate price volatility positively affects Morocco's economic growth in the long run because the diversification paths that have not been developed will ultimately be able to provide actions taken in response to environmental problems.

Overall, we contribute to the global scholarly dialogue by confirming that the short- and long-term economic effects of resource price volatility (i.e., phosphate) are context-specific with regard to particular aspects of the national economy, the exact variables included, and the capacity of institutions to understand and react to price volatility.

7. CONCLUSION

This research examined the relationship between phosphate price volatility and economic growth in Morocco. We used the ARDL bounds testing to assess the period of short- and long-term effects. We found statistically significant short-term economic returns from phosphate exports, while we were unable to document the long-term returns on growth as valid due to issues of economic diversification and prioritizing risk aversion rather than environmental sustainability. The research asserted that there are structural inefficiencies in capital effects that limit the potential of capital to create sustainable economic growth. We would recommend that Morocco reduce its dependence on the phosphate source and focus on more economic diversification and sustainable resource management approaches. Investing in education, infrastructure, new green technologies, and governance will be a gradual process in Morocco's future move towards a robust, equitable, and sustainable economy.

Future research could utilize a more disaggregated analysis of phosphate revenues across all economic sectors in the Moroccan economy. An additional aspect for future assessments would be to examine phosphate dependency in relation to institutional quality and environmental sustainability. This approach would aid in developing more robust (or regressive) policy adjustments aimed at achieving sustainable economic growth over a longer temporal horizon. Future research considerations and limitations include leveraging interactive models for the phosphate-growth

relationship to evaluate the effects of institutional quality (and policies), green innovation, and environmental regulation within the two systems. It would also be valuable to determine the economic growth threshold at which phosphate dependency becomes detrimental.

7.1. Future Research Suggestions and Limitations

The primary limitation of the research is that the focus solely on the national level (of GDP) would not permit our exploration of phosphate revenues and their effects at the country sectoral level. In this regard, we firmly believe that it would be beneficial for disaggregated data on phosphate prices and revenues, access, and cash flows to be available in order to assess the blended combinations of phosphate price volatility on the less economically limited impacts on those economic sectors most challenged or benefited by phosphate revenues. In conclusion, this evidence highlights the importance of helpful adjustments to policies relating to economic diversification opportunities, green infrastructure, and collaborative labor relations. Morocco will have to and must find methods to coordinate these strategies, as overdependence on phosphate exports can become more than detrimental to sources of sustainability governance, economic, environmental, and challenges associated with sectoral/micro-level responses and adaptations to structural and ecological inequalities.

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Data Availability Statement: Upon a reasonable request, the supporting data of this study can be provided by the corresponding author.
Competing Interests: The authors declare that they have no competing interests.
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Appendix:

ARDL Model:

The empirical results of the estimated ARDL model are essential for discussion. The following Table A1 presents the ARDL model. We will use the AKAIKE INFORMATION CRITERION (AIC) to select the optimal ARDL model. We selected the ARDL model, which corresponds to the optimal number of lags and minimizes the Akaike criterion.

Table AI. ARDL model.

Selected model: ARDL (1, 2, 2, 0, 2, 2)				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
LNGDP(-1)	0.660	0.206	3.195	0.009
LPHPRICE	0.033	0.014	2.270	0.046
LPHPRICE(-1)	-0.044	0.014	-3.034	0.012
LPHPRICE(-2)	0.034	0.012	2.783	0.019
LCO2	-0.060	0.142	-0.422	0.681
LCO2(-1)	-0.004	0.125	-0.036	0.971
LCO2(-2)	0.304	0.152	1.997	0.073
LFC	-0.017	0.011	-1.491	0.166
LGFCF	-0.348	0.110	-3.158	0.010
LGFCF(-1)	0.334	0.116	2.863	0.016
LGFCF(-2)	-0.249	0.092	-2.689	0.022
LUNEM	-0.431	0.076	-5.661	0.000
LUNEM(-1)	0.064	0.118	0.546	0.596
LUNEM(-2)	0.131	0.102	1.280	0.229
C	7.372	3.011	2.448	0.034
R-squared	0.999	Mean dependent var		25.121
Adjusted R-squared	0.997	S.D. dependent var		0.297
S.E. of regression	0.013	Akaike info criterion		-5.431
Sum squared resid.	0.001	Schwarz criterion		-4.700
Log likelihood	82.893	Hannan-Quinn criterion.		-5.228
F-statistic	787.322	Durbin-Watson stat		2.263
Prob(F-statistic)	0.000			

The following Figure A1 shows the Akaike information criterion values for the twenty best models. Our selected ARDL model (1, 2, 2, 0, 2, 2) is the most optimal among the other models presented, as it offers the lowest AIC value.

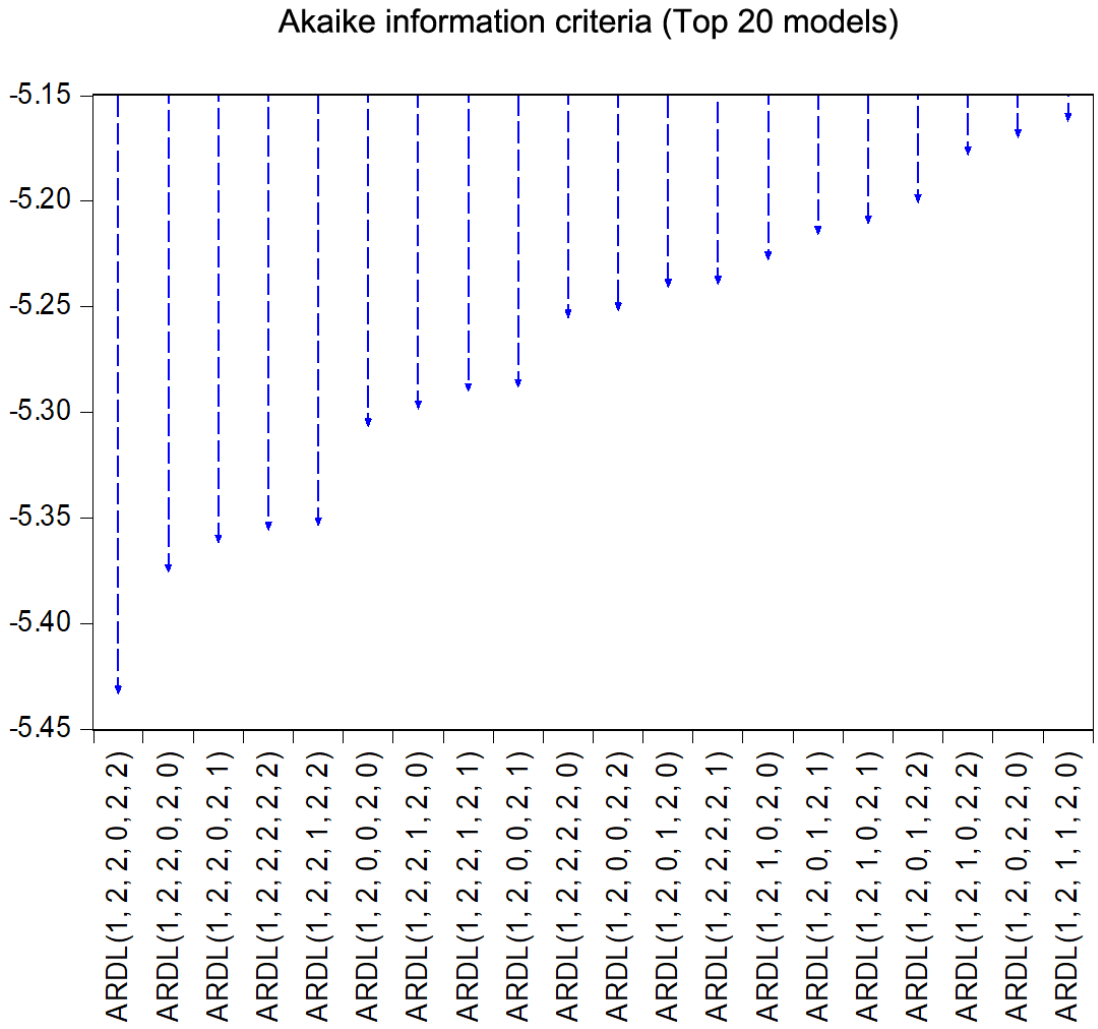

Figure A1. Criteria graph.