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Export Performance Under Environmental and Political Frictions: Evidence From Indonesia

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Abstract

This study examines how environmental quality and political stability shape Indonesia's export performance, focusing on interactions among macroeconomic, environmental, and institutional factors. Using annual data from 1996 to 2023, the research applies multiple regression models to assess direct, nonlinear, and interactive effects of key variables, including GDP, carbon emissions, political stability, and exchange rate fluctuations. The empirical findings highlight three key points. First, economic growth consistently emerges as a strong and significant driver of export performance, underscoring the role of domestic productive capacity. Second, the relationship between environmental pressure and exports is nonlinear; initial industrial expansion tends to boost exports, but excessive carbon emissions can undermine long-term competitiveness. Third, environmental concerns appear to diminish the effectiveness of exchange rate depreciation, indicating a conditional limit on macroeconomic policy. Fourth, political stability does not directly affect exports but significantly shapes how exchange rate changes influence them, underscoring the importance of institutional quality as an enabling factor. Overall, the findings indicate that export performance results from a complex interplay of macroeconomic fundamentals, environmental conditions, and institutional factors. Policy-wise, the results suggest that export promotion should go beyond traditional methods focused on growth and exchange rate policies and should also include environmental improvements and institutional capacity-building. This research adds to the literature by presenting an integrated empirical framework that accounts for nonlinearities and interaction effects, providing a more thorough understanding of export behavior in developing countries.

INTRODUCTION

Export activity remains essential for economic growth and structural change, especially in emerging economies such as Indonesia (Andriansyah et al., 2023; Goh & Potter, 2022; Juliansyah et al., 2022; Lestari et al., 2024; Nopiana et al., 2022). As a major source of foreign exchange, industrial growth, and jobs, exports are vital for connecting local economies with global markets. In recent decades, Indonesia's export structure has evolved from primarily relying on raw commodities to a broader mix that includes manufacturing and resource-based sectors. However, export performance remains highly influenced by internal and external factors, underscoring the intricate interplay among macroeconomic fundamentals, environmental issues, and institutional factors.

Traditionally, researchers have examined the factors influencing export activity using macroeconomic variables such as output growth and exchange rate changes. Economic theory posits that increased domestic production boosts export supply, while currency depreciation

enhances international price competitiveness. However, recent empirical findings indicate that these traditional factors alone cannot fully account for export behaviors in today's interconnected global economy. The expansion of global value chains, the significance of sustainability standards, and the heightened vulnerability to global shocks add new complexities that influence export performance in more intricate and nonlinear ways.

Environmental pressure is an increasingly critical factor in international trade. While higher industrial activity, often linked to increased carbon emissions, can boost export growth by expanding production capacity, it also risks long-term competitiveness. Environmental degradation may lead to stricter regulations, higher compliance costs, and limited access to eco-sensitive markets, ultimately constraining exports. Additionally, global sustainability efforts, such as carbon pricing and environmental trade measures, have deepened the link between environmental performance and export success. Consequently, the relationship between environmental factors and exports is likely nonlinear, balancing short-term production benefits against long-term sustainability challenges.

Institutional factors, especially political stability, are crucial in influencing export performance. A stable political climate reduces uncertainty, boosts investor confidence, and enhances the efficiency of economic transactions, thereby supporting firms' engagement with international markets. Conversely, political instability can heighten risks, disrupt production and trade networks, and undermine the effectiveness of economic policies. Yet, recent findings indicate that the influence of political stability on exports is often indirect. Instead, institutional quality typically affects how macroeconomic variables, such as exchange rates and growth, affect export outcomes. This suggests that the success of traditional policy measures may rely heavily on the broader institutional environment in which they are applied.

Another important factor affecting export activity is the exchange rate, which influences both price competitiveness and production costs. Although traditional theory suggests that currency depreciation encourages exports, real-world data shows a more nuanced relationship. In economies heavily dependent on imported intermediate inputs, depreciation can raise production costs, offsetting the benefits of improved competitiveness. Additionally, exchange rate volatility creates uncertainty, which can deter long-term trade agreements and reduce export consistency. These dynamics indicate that the impact of exchange rates is increasingly shaped by structural factors such as production networks, firm differences, and susceptibility to global shocks.

The significance of these factors becomes even more pronounced during major global disruptions. Incidents such as the Asian Financial Crisis, the Global Financial Crisis, and the COVID-19 pandemic have shown that export performance is highly susceptible to external shocks that affect both supply and demand. These shocks frequently affect the economy through various channels, such as output declines, currency fluctuations, and rising uncertainty, underscoring the importance of accounting for their effects in empirical studies of export behavior.

Increasing research has examined how macroeconomic conditions, environmental factors, and institutional quality jointly influence export performance. However, most studies tend to analyze these factors separately rather than within an integrated framework. In the environmental sphere, research such as Tang et al. (2025) finds that stricter environmental regulations can limit export participation due to higher compliance costs, while Tao et al.

(2025) and Ma and Song (2025) suggest that green policies may boost export competitiveness by promoting innovation and upgrading. Internationally, Wang et al. (2026) highlight external environmental constraints, like carbon border measures, that restrict exports from carbon-intensive economies. The macroeconomic literature continues to emphasize exchange rate dynamics, though results are mixed. Tarakçı et al. (2022), Sugiharti, Esquivias, and Setyorani (2020), and Handoyo et al. (2023) report negative long-term impacts of exchange rate volatility on exports, while Thorbecke and Sengonul (2023) and Liu, Kawasaki, and Sato (2025) find that depreciation does not always enhance export performance due to rising input costs and pricing strategies.

Institutional research underscores the importance of political stability for trade. Mamba, Wonyra, and Evlo (2025) and Li and Huang (2023) show that stable institutions support exports by reducing uncertainty, whereas Yang and Peng (2025) point to the negative impact of policy uncertainty. At the firm level, Zhang, Liu, and Wang (2020) and Sharma, Cheng, and Leung (2020) demonstrate that political connections and institutional settings influence export decisions in complex and often contrasting ways. Nonetheless, few studies explicitly combine environmental, macroeconomic, and institutional factors within a single empirical framework, especially for developing economies. The existing evidence is mixed—some highlight direct effects, while others focus on nonlinearities and conditional relationships. This gap underscores the need for a comprehensive approach that captures direct, nonlinear, and interaction effects to better explain export dynamics.

This study aims to thoroughly examine the factors influencing Indonesia's export performance by integrating macroeconomic, environmental, and institutional perspectives into a unified empirical model. Unlike typical studies that examine only a few determinants, this paper explicitly investigates the nonlinear effects of environmental pressure and the conditional impact of political stability through interaction effects. This methodology is designed to capture the complex and interconnected nature of export dynamics in a rapidly evolving global environment. The research employs a time-series econometric approach using annual data from 1996 to 2023. Multiple model specifications are estimated to ensure robustness and to distinguish between direct effects, environmental nonlinearities, and interaction-driven conditional effects. This approach facilitates a more detailed and multi-dimensional understanding of how various factors collectively influence export performance.

This study makes three key contributions. First, it broadens the export literature by introducing environmental pressure as a nonlinear factor, highlighting potential thresholds where environmental degradation could harm export competitiveness. Second, it offers new insights into how political stability influences outcomes conditionally, illustrating that institutional quality modifies the effects of macroeconomic variables rather than acting as a direct cause. Third, it conducts a thorough comparative analysis of various model specifications, enriching the methodological literature by showing how different model choices can influence empirical findings and policy recommendations.

The remainder of the paper is structured as follows. Section 2 reviews the relevant literature on environmental, institutional, and macroeconomic determinants of export activity. Section 3 outlines the data and methodology. Section 4 presents the empirical results and discussion, including a comparative analysis across model specifications. The final section concludes with key findings and policy implications.

RESEARCH METHOD

This study used a quantitative time-series method to analyze how environmental factors, political stability, and export performance are related in Indonesia. It uses annual data from 1996 to 2023 and applies multiple regression models to evaluate both direct and conditional effects among these variables.

Data and Variables

The empirical analysis uses secondary data from reputable, authoritative sources to ensure consistency and reliability. Export data are sourced from UN Comtrade, while GDP and carbon emissions data are sourced from the World Bank. Political stability is measured through the Worldwide Governance Indicators (WGI) from the World Bank, and exchange rate information is collected from Bank Indonesia. Due to data limitations, especially for political stability, the effective sample size is reduced to 25 observations in models that include this variable.

The dependent variable is export performance, measured as the natural logarithm of total exports (log_export). Key explanatory variables include the natural logarithm of GDP (log_gdp), representing macroeconomic scale, the natural logarithm of carbon emissions (log_carbon) as an environmental pressure indicator, and its squared term (log_carbon^2) to assess nonlinear effects. Political stability is considered an institutional variable, while the exchange rate reflects external competitiveness. In addition, the model incorporates a dummy variable to account for major crisis episodes that may affect export performance. This variable takes the value of one during the Asian Financial Crisis (1998), the Global Financial Crisis (2008), and the COVID-19 pandemic period (2020–2022), and zero otherwise. Including this variable allows the analysis to control for exogenous disruptions that are not fully captured by standard macroeconomic indicators.

All key economic variables are expressed in natural logarithmic form. This transformation helps stabilize variance and allows the estimated coefficients to be interpreted as elasticities, capturing proportional relationships between variables.

Model Specification

To examine the robustness of the empirical relationships, this study specifies four alternative regression models of increasing complexity. All models are estimated in level form to preserve long-run relationships, as supported by the cointegration results.

Model 1 (Baseline Specification) captures the direct effects of macroeconomic, environmental, institutional, and crisis variables on export performance:

$$ln\,E\,xport_t = \beta_0 + \beta_1\,ln\,G\,DP_t + \beta_2\,ln\,C\,arbon_t + \beta_3(ln\,C\,arbon_t)^2 + \beta_4 ExchangeRate_t + \beta_5 PoliticalStability_t + \beta_6 Shock_t + \varepsilon_t$$

Model 2 (Nonlinear Environmental Model) retains the same structure as Model 1 but is interpreted as the primary specification for identifying the nonlinear (quadratic) environmental effect, particularly the potential inverted-U relationship between carbon emissions and exports:

$$\ln E\,xport_t = \beta_0 + \beta_1 \ln G\,DP_t + \beta_2 \ln C\,arbon_t + \beta_3(\ln C\,arbon_t)^2 + \beta_4 ExchangeRate_t + \beta_5 PoliticalStability_t + +\beta_6(\ln G\,DP_t \times \ln C\,arbon_t) + \beta_7(ExchangeRate_t \times \ln C\,arbon_t) + \beta_8 Shock_t + \varepsilon_t$$

Model 3 (Institutional Interaction Model) introduces interaction terms between political stability and key macroeconomic variables to capture conditional institutional effects:

$$\ln Export_t = \beta_0 + \beta_1 \ln GDP_t + \beta_2 \ln Carbon_t + \beta_3 (\ln Carbon_t)^2 + \beta_4 ExchangeRate_t + \beta_5 PoliticalStability_t + \beta_6 (\ln GDP_t \times PoliticalStability_t) + \beta_7 (ExchangeRate_t \times PoliticalStability_t) + \beta_8 Shock_t + \varepsilon_t$$

Model 4 (Fully Interacted Model) extends the specification by incorporating a broader set of interaction terms to capture more complex joint dynamics among environmental, macroeconomic, and institutional variables:

$$\ln Export_t = \beta_0 + \beta_1 \ln GDP_t + \beta_2 \ln Carbon_t + \beta_3 (\ln Carbon_t)^2 + \beta_4 ExchangeRate_t + \beta_5 PoliticalStability_t + \beta_6 (\ln GDP_t \times PoliticalStability_t) + \beta_7 (ExchangeRate_t \times PoliticalStability_t) + \beta_8 (\ln GDP_t \times \ln Carbon_t) + \beta_9 (ExchangeRate_t \times \ln Carbon_t) + \beta_{10} (PoliticalStability_t \times \ln Carbon_t) + \beta_{11} Shock_t + \varepsilon_t$$

Across all specifications, εt denotes the error term assumed to satisfy classical linear regression assumptions. These four models collectively allow the analysis to distinguish between direct effects, nonlinear environmental effects, and conditional relationships involving institutional and macroeconomic variables.

Estimation Strategy

The models are estimated using Ordinary Least Squares (OLS). Before estimation, a series of preliminary tests checks the time-series properties of the data. Unit root tests, such as the Augmented Dickey–Fuller (ADF) test, indicate that the variables are integrated of order 1 (I(1). To prevent spurious regression, cointegration tests are conducted to confirm a long-run equilibrium relationship among the variables. The evidence of cointegration supports estimating the models in level form, since differencing the data would eliminate important long-term information.

Diagnostic Tests

To assess the reliability of the estimated models, standard tests for classical assumptions are conducted. The Breusch–Pagan test indicates that residuals are homoscedastic (i.e., have constant variance), while the Breusch–Godfrey test confirms the absence of serial correlation (i.e., autocorrelation over time). Moreover, skewness and kurtosis assessments verify that residuals are approximately normally distributed. These diagnostic results confirm that the models satisfy the classical linear regression assumptions, ensuring unbiased, consistent, and efficient coefficient estimates and valid statistical inferences.

Empirical Strategy

This study estimates various model specifications to evaluate the robustness of the relationships and to differentiate between direct, nonlinear, and interaction effects. By combining baseline and extended models, it provides a comprehensive understanding of how environmental pressure, institutional quality, and macroeconomic conditions jointly affect Indonesia's export performance.

RESULTS AND DISCUSSION

Descriptive statistics

The empirical analysis uses annual time-series data for Indonesia from 1996 to 2023. The dataset is compiled from various reputable international sources to ensure its accuracy and consistency. Export data (log_export) come from UN Comtrade, while GDP (log_gdp) and carbon emissions (log_carbon) are retrieved from the World Bank. Political stability indicators are sourced from the World Bank's Worldwide Governance Indicators (WGI), and exchange rate data are from Bank Indonesia. Due to limitations in data availability, especially for the political stability variable, the sample size is reduced to 25 observations in models that include it. Descriptive statistics are shown in Table 1.

Table 1: Descriptive Statistics

Variable	N	M	SD	Min	Max
$\ln Export_t$	28	23.57	1.00	21.74	25.02
$\ln GDP_t$	28	26.93	0.81	25.28	27.95
$\ln Carbon_t$	28	4.53	0.37	4.00	5.00
$PoliticalStability_t$	25	-0.96	0.56	-2.10	-0.38
$ExchangeRate_t$	28	10,490.66	3,224.12	2,342.30	15,236.88

All key economic variables, such as exports, GDP, and carbon emissions, are expressed in natural logarithmic form. The use of logarithms serves two primary purposes: first, to stabilize variance and reduce heteroskedasticity in time-series data; second, to facilitate interpretation, as coefficients of logged variables can be understood as elasticities. This means the coefficients roughly indicate percentage changes, so shifts in these variables can be viewed as growth rates. Although the log transformation doesn't directly measure growth, differences in logs approximate growth rates, enabling the analysis to focus on proportional changes rather than absolute levels. Besides these core variables, the model includes a shock variable and a dummy variable indicating major systemic crises that may affect export performance. This variable is set to one during the Asian Financial Crisis (1998), the Global Financial Crisis (2008), and the COVID-19 pandemic (2020–2022), and zero otherwise. Incorporating this variable helps control for significant external shocks that might bias the estimated relationships.

The descriptive statistics highlight several key aspects of the data. Export performance, measured in logarithmic units, has a mean of 23.57 and a standard deviation of about 1.00, indicating moderate variation and a steady upward trend over time. Since the data is log-transformed, these variations suggest proportional changes in export performance rather than absolute differences. GDP shows a higher average of 26.93, with less dispersion (standard deviation of 0.81), indicating consistent macroeconomic growth throughout the period. Environmental pressure, proxied by log carbon emissions, has a mean of 4.53 with limited variability, reflecting gradual structural changes in Indonesia's production and energy consumption rather than sudden environmental shifts. Conversely, political stability displays considerable volatility, ranging from −2.10 to −0.38, reflecting Indonesia's transitions through institutional reforms and governance adjustments. The exchange rate varies greatly, with a mean of 10,490.66 and a large standard deviation of 3,224.12, indicating significant

fluctuations in Indonesia's external competitiveness, especially during crises such as the Asian Financial Crisis and other global shocks, as captured by the shock dummy variable.

Overall, these descriptive patterns suggest that Indonesia's export performance is influenced by a combination of macroeconomic fundamentals, environmental dynamics, institutional conditions, and discrete crisis events.

Economic modeling

This study analyzes the robustness of the links between environmental factors, political stability, and export performance by estimating four different model specifications. Model 1 acts as the baseline, including macroeconomic, environmental, institutional, and crisis variables. Model 2 simplifies the structure by adding interaction terms to emphasize direct effects. Model 3 introduces interaction terms involving political stability to examine how institutional influences depend on it. Model 4 provides a fully interactive framework for investigating complex joint effects among variables. The estimation results are shown in Table 2.

Before estimation, several preliminary diagnostic tests were performed. Unit root tests, such as the Augmented Dickey–Fuller (ADF) test, show that the variables are non-stationary in levels but become stationary after first differencing, indicating they are I(1). Cointegration tests confirm a long-term equilibrium relationship among the variables across all model specifications. These supports using the variables in their level form, as differencing would eliminate the long-run information crucial for analysis.

Additionally, all models meet the assumptions of classical linear regression. The Breusch–Pagan test indicates no heteroskedasticity, indicating that the errors have constant variance. The Breusch–Godfrey test confirms no serial correlation in the residuals, ensuring unbiased coefficient estimates. Normality tests for skewness and kurtosis indicate that residuals are approximately normally distributed. Overall, these diagnostic results demonstrate that the models are econometrically valid, and the regression inferences are reliable.

Table 2: Model Estimations

Variables	Model 1	Model 2	Model 3	Model 4
$\ln GDP_t$	1.122**	-6.789	3.441**	-6.080
$\ln Carbon_t$	*29.961*	-50.475	-5.495	-103.475
$(\ln Carbon_t)^2$	*-3.316*	-0.150	0.376	5.708
$ExchangeRate_t$	7.84e-06	0.00209**	-0.000436**	0.00406
$PoliticalStability_t$	-0.109	-0.097	-24.683	11.563
$\ln GDP_t \times PoliticalStability_t$	–	–	1.107	0.812
$ExchangeRate_t \times PoliticalStability_t$	–	–	-0.000540***	-0.000312
$\ln GDP_t \times \ln Carbon_t$	–	2.012	–	-1.204
$ExchangeRate_t \times \ln Carbon_t$	–	-0.000461**	–	-0.000215
$PoliticalStability_t \times \ln Carbon_t$	–	–	–	2.441
$Shock_t$	0.315	0.117	0.092	0.210
$Constant$	-74.097**	–	–	–
Observations	25	25	25	25

Variables	Model 1	Model 2	Model 3	Model 4
R-squared	0.7879	0.8565	0.8666	0.8775
Adj. R-squared	0.7172	0.7847	0.7999	0.7739
Prob > F	0.0000	0.0000	0.0000	0.0003

** p < 0.10, ** p < 0.05, *** p < 0.01*

Model 1: Baseline model

Model 1 assesses Indonesia's export determinants using a baseline model that includes macroeconomic, environmental, institutional, and crisis-related variables. The model is statistically significant (F (1, 1) = 11.14, p = 0.0000) and shows strong explanatory power, with an R-squared of 0.7879 and an adjusted R-squared of 0.7172. This indicates that the variables explain a large portion of the variation in export performance over the sample period, despite the limited number of observations.

Results highlight that economic growth is a major factor influencing export performance. The positive coefficient for log GDP (1.1216) is significant at the 5 percent level, indicating that a 1 percent increase in GDP is associated with roughly a 1.12 percent increase in exports, holding other factors constant. This aligns with theoretical and empirical trade literature, which links higher output to greater productive capacity and export potential. It underscores that Indonesia's export success is strongly connected to its macroeconomic growth.

A key feature is the nonlinear link between environmental pressure and exports. The coefficient for log carbon emissions is positive (29.961) and marginally significant at the 10 percent level, while the squared term is negative (-3.316), also marginally significant. This suggests an inverted-U relationship where initial increases in emissions may boost exports, possibly through industrial growth and energy-intensive processes. However, beyond a certain point, further emissions detract from export performance. The estimated turning point is around 4.52, close to the sample's mean log carbon emissions. This implies that Indonesia might already be near the peak of this curve, where additional environmental degradation could start to impair export competitiveness.

In contrast, political stability, used as a proxy for institutional quality, does not have a statistically significant direct impact on export performance. Although the coefficient is negative, it is highly insignificant, indicating that changes in political stability do not independently influence export movements within this model. Similarly, the exchange rate, despite its positive sign, is low in magnitude and statistically insignificant, suggesting that currency fluctuations do not strongly affect exports when other macroeconomic factors are taken into account. This may be because exchange rate effects are either absorbed by broader economic conditions or operate through complex channels not captured here. The shock variable, representing major crises like the Asian Financial Crisis (1998), the Global Financial Crisis (2008), and the COVID-19 pandemic (2020–2022), also shows no significant impact. This suggests that, after accounting for macroeconomic and environmental factors, these crises do not independently affect export performance. A possible explanation is that their effects are already reflected in variables such as GDP and exchange rates, rather than acting through a separate mechanism.

Overall, Model 1 shows that Indonesia's export success is primarily driven by economic

fundamentals, especially output growth. Environmental factors have a nonlinear effect on exports. The absence of significant impacts from political stability and exchange rates suggests they may influence exports indirectly, or through their interactions with other variables. Importantly, the inverted-U relationship between carbon emissions and exports highlights a structural limitation: while carbon-intensive growth can initially boost exports, it may eventually undermine competitiveness as environmental concerns rise. This underscores the importance of integrating environmental sustainability into long-term export strategies.

Model 2: Empirical Results and Interpretation

Model 2 extends the specification to include both direct effects and selected interaction terms, enabling a richer examination of how macroeconomic and environmental factors jointly influence export performance. The model is statistically significant overall (Prob > F = 0.0000) and demonstrates strong explanatory power, as indicated by an R-squared of 0.8565 and an adjusted R-squared of 0.7847. These values suggest that the model explains a substantial proportion of the variation in Indonesia's exports, indicating a good empirical fit despite the relatively small sample size.

The coefficient on log GDP is negative (-6.789) and statistically insignificant (p = 0.298), indicating that economic growth does not exert a direct, measurable impact on exports in this specification. This finding contrasts with the positive, significant effect observed in Models 1 and 3, suggesting that the role of GDP is sensitive to model structure, particularly when interaction terms are included. The lack of significance implies that the effect of economic growth on exports may not be linear or independent, but instead operates through indirect channels captured by interaction terms.

The environmental variables, including log carbon emissions and its squared term, both have negative coefficients (-50.475 and -0.150) and are statistically insignificant (p = 0.150 and p = 0.967). This suggests there is no evidence of a direct or nonlinear (quadratic) link between carbon emissions and export performance in this model. Unlike Model 1, which showed an inverted-U relationship, these results imply that the environmental impact is not consistent across different model specifications and might operate through interaction effects rather than direct influences.

By contrast, the exchange rate is a statistically significant factor impacting exports. The coefficient is positive (0.00209) and significant at the 5% level (p = 0.019), indicating that a rise in the exchange rate correlates with improved export performance. Since the exchange rate is defined as domestic currency per unit of foreign currency, this suggests that currency depreciation boosts export competitiveness, aligning with standard international trade theories. The coefficient for political stability is negative (-0.097) but statistically insignificant (p = 0.830), implying that institutional quality does not directly affect exports. This pattern remains consistent across all models and hints that political stability's influence on exports might be indirect, possibly through interactions with other variables rather than as an independent factor.

Model 2's significant contribution is its interaction terms. The positive interaction between GDP and carbon emissions (2.012) is not statistically significant (p = 0.193), suggesting limited evidence that environmental conditions influence the effect of economic growth on exports. Conversely, the negative and statistically significant interaction between the exchange rate and carbon emissions (-0.000461; p = 0.019) is noteworthy. It indicates that

as carbon emissions increase, the positive impact of exchange rate depreciation on exports weakens. In other words, environmental degradation reduces the effectiveness of exchange rate policy in boosting export competitiveness. This reveals a conditional environmental constraint on the efficacy of macroeconomic policy. The shock variable, representing events like the Asian Financial Crisis (1998), the Global Financial Crisis (2008), and the COVID-19 pandemic (2020–2022), has a positive value (0.117) but is not statistically significant (p = 0.697). This suggests that, after accounting for macroeconomic and environmental factors, these crises do not independently impact export performance, with their effects likely reflected indirectly through GDP and exchange rate changes.

Overall, Model 2 shows that Indonesia's export performance is mainly determined by exchange rate movements. Environmental and institutional factors have a limited direct impact. However, the notable interaction between exchange rates and carbon emissions highlights that environmental conditions significantly moderate this relationship, diminishing the positive effect of exchange rate depreciation on exports. This suggests that macroeconomic strategies to enhance export competitiveness should also address environmental concerns, since rising environmental pressures could weaken the gains from conventional policies.

Model 3: Empirical Results and Interpretation

Model 3 extends the basic framework by incorporating interaction terms with political stability, allowing institutional conditions to influence export performance indirectly through macroeconomic pathways. The model is highly significant (p = 0.0000) and shows strong explanatory power, with an R-squared of 0.8666 and an adjusted R-squared of 0.7999. Compared to previous models, Model 3 achieves a good balance between complexity and fit, suggesting that adding conditional institutional effects improves its ability to explain export behavior.

The coefficient for log GDP remains positive (3.441) and is statistically significant at the 5 percent level (p = 0.022), demonstrating a strong and consistent link between economic growth and export performance. In terms of elasticity, this indicates that a 1 percent rise in GDP correlates with more than a 3 percent increase in exports, assuming other factors are constant. The size of this coefficient is significantly larger than in Model 2, implying that the impact of economic growth on exports is magnified when institutional conditions interact with macroeconomic variables. This finding underscores the importance of domestic productive capacity and suggests that its effectiveness may depend on the broader institutional context.

In contrast, environmental variables do not show statistically significant direct effects in this model. The coefficient for log carbon emissions is negative, but its squared term is positive; however, both are highly insignificant. This suggests that once institutional interaction channels are included, the nonlinear environmental effect observed in Model 2 becomes less robust. In other words, environmental factors do not have a direct, independent impact on exports in Model 3, implying their influence is likely mediated through other variables rather than acting alone.

The exchange rate coefficient is negative and significant (p = 0.013), indicating that higher exchange rates are associated with lower export performance. Initially, this seems to oppose standard trade theory, which suggests currency depreciation should enhance exports. However, because of the interaction terms, this coefficient reflects only a partial effect when political stability is fixed at zero, a value that is not meaningful, since all political stability

values in the sample are negative. Thus, the exchange rate effect should be considered together with its interaction term. The direct impact of political stability is large but not statistically significant, indicating that institutional quality does not directly influence exports. Nonetheless, this does not mean it is irrelevant; rather, political stability likely affects exports indirectly through other factors captured by interaction terms. For example, the interaction between GDP and political stability is positive but not statistically significant, implying that better institutional conditions might enhance the growth–export relationship, but the evidence isn't conclusive.

More importantly, the interaction between the exchange rate and political stability is negative and statistically significant ($p = 0.007$). This is the key finding of Model 3, indicating that the influence of exchange rate fluctuations on exports depends on the level of political stability. Specifically, the negative interaction implies that the positive effects of exchange rate changes on exports diminish as political stability shifts. Since the political stability index can have negative values, this suggests that fragile institutional conditions may weaken or distort the effectiveness of exchange rate policies in boosting exports. From an economic standpoint, this result emphasizes that exchange rate competitiveness alone cannot ensure strong export performance without a stable and credible institutional framework. Political instability tends to increase uncertainty, transaction costs, and diminish investor confidence, thereby counteracting potential benefits from favorable exchange rate movements. The shock variable remains statistically insignificant, indicating that major crisis episodes do not independently affect exports after accounting for macroeconomic factors and institutional dynamics.

Overall, Model 3 offers valuable insights into how institutions influence outcomes. While political stability does not directly affect exports, it plays a crucial role in moderating the impact of macroeconomic factors, especially the exchange rate, on export performance. This indicates that institutional quality functions as a facilitator or barrier rather than a core cause. The results imply that Indonesia's export success depends not only on macroeconomic fundamentals but also heavily on the institutional environment. The findings emphasize the importance of policy coordination: initiatives like exchange rate management and growth strategies may be less effective without stable, credible institutions. Consequently, improving institutional quality could enhance the effectiveness of macroeconomic policies in boosting export performance.

Model 4: Empirical Results and Interpretation

Model 4 offers the most detailed specification by including all interaction terms among macroeconomic, environmental, and institutional variables. It is designed to better capture complex and nonlinear relationships. The model is statistically significant ($Prob > F < 0.01$) and has the best fit among all versions, with an R-squared of 0.8775. However, the adjusted R-squared drops to 0.7739, indicating that the increased complexity improves fit but may lead to overfitting, especially given the small sample size. Notably, none of the individual coefficients in Model 4 are statistically significant at conventional levels. Key variable coefficients—such as log GDP, log carbon emissions, the squared carbon term, exchange rate, and political stability—show large standard errors and high p-values. Similarly, interaction terms involving carbon emissions, political stability, and exchange rate are also statistically insignificant. This contrasts with earlier models, such as Models 2 and 3, in which several variables had meaningful and statistically significant effects.

The absence of statistical significance in Model 4 does not necessarily indicate a lack of

economic relationships; rather, it reflects estimation challenges associated with model saturation. The inclusion of multiple interaction terms, especially in a dataset with only 25 effective observations, substantially increases the model's dimensionality and introduces high multicollinearity. This inflates the standard errors of the estimated coefficients, making it difficult to precisely identify individual effects. In such cases, the model may still have high explanatory power at the aggregate level but lacks the precision required for reliable inference at the parameter level.

From an economic perspective, Model 4 indicates that attempting to include all possible interaction channels simultaneously can obscure rather than clarify the underlying relationships. The unstable coefficients across different variables suggest that the data lack enough variation to support such a complex, highly parameterized model. Notably, the nonlinear environmental effects identified in Model 2 and the institutional interaction effects from Model 3 are no longer observable when all interaction terms are combined. This suggests these effects are sensitive to model specification and should be interpreted within simpler, more parsimonious frameworks. Importantly, Model 4's findings offer a key methodological insight: increasing model complexity does not automatically lead to better empirical identification. Although the approach is theoretically attractive, the limited sample size hampers the precise estimation of such a detailed structure. Consequently, Model 4 should mainly serve as a robustness check rather than a preferred model.

Overall, Model 4 emphasizes the need to balance theoretical completeness with empirical simplicity. The results indicate that the most reliable insights into Indonesia's export performance come from simpler models that focus on key channels, such as the nonlinear environmental effect (Model 2) and the conditional institutional effect (Model 3), rather than attempting to estimate all interactions at once.

Comparative Discussion Across Model Specifications

Across the four model specifications, the results reveal that Indonesia's export performance is determined by macroeconomic fundamentals, environmental factors, and institutional contexts, with the strength of these relationships varying across specifications. A consistent observation across the models is that GDP is a key predictor of export performance. In Models 1 and 3, GDP positively and significantly influences exports, suggesting that higher domestic output boosts export capacity by increasing production and supply. This aligns with the broader trade literature, which asserts that macroeconomic growth improves export performance by expanding productive capacity and competitiveness. It also supports the idea from the literature review that export activity depends not only on external demand but also on the domestic economy's ability to efficiently generate output.

The influence of environmental factors is more complex and appears to be highly dependent on specific conditions. In Model 1, the data on carbon emissions and their squared term reveal an inverted-U shape, suggesting that environmental pressure may initially increase with industrial growth and exports, but beyond a certain point, it may start to hinder export performance. This aligns with earlier environmental research. For example, Tang et al. (2025) suggest that environmental regulation can eventually diminish export competitiveness due to higher compliance and production costs. Conversely, Tao et al. (2025) and Ma and Song (2025) propose that environmental constraints may eventually encourage firms to adopt upgrades and greener approaches. Nevertheless, this nonlinear environmental effect is absent in Models 2, 3,

and 4, suggesting that the carbon-export link is not solely a direct effect. Instead, environmental pressure seems to act more as a contextual factor, interacting with other macroeconomic variables, rather than as a standalone determinant.

This interpretation becomes clearer in Model 2, where direct environmental terms are insignificant, but the interaction between exchange rate and carbon emissions is negative and statistically significant. This suggests that exchange rate depreciation is less effective in boosting exports when environmental pressures are high. In other words, macroeconomic benefits from currency movements can be partly offset by environmental inefficiencies, carbon-heavy production structures, or trade constraints related to sustainability. This finding aligns well with existing literature, which emphasizes that export success in modern trade increasingly depends on environmental compliance and sustainability. It particularly reflects Wang et al. (2026), who show that external environmental policies, such as carbon border adjustment mechanisms, can reduce exports from carbon-intensive economies, and Ayla and Cihan (2025), who argue that export competitiveness increasingly hinges on structural shifts toward low-carbon approaches. Consequently, Model 2 makes an important contribution by illustrating that, in Indonesia, environmental factors may not directly decrease exports but can weaken the impact of traditional exchange-rate-based export promotion.

The impact of the exchange rate varies across different specifications, reflecting the ambiguity highlighted in existing literature. In Model 2, a positive and significant coefficient indicates that depreciation enhances exports by improving price competitiveness, consistent with standard trade theory and the notion that a weaker domestic currency lowers export prices abroad. Conversely, Model 3 reveals a negative and significant direct coefficient when accounting for the interaction with political stability. This shift suggests that the exchange rate effect depends on the institutional context, consistent with the literature, which indicates that exchange rate effects are nonlinear, asymmetric, and influenced by structural factors. Studies such as Tarakçı et al. (2022), Handoyo et al. (2023), and Ibrahim et al. (2024) highlight that exchange rate changes are not isolated, especially amid uncertainty and vulnerabilities. Consequently, Indonesian results demonstrate that managing exchange rates alone is insufficient for boosting exports when environmental and institutional issues persist.

The findings regarding political stability are also insightful. In all four models, political stability does not exhibit a statistically significant direct influence on exports. At first glance, this seems weaker than the literature, which typically recognizes political stability as a factor that supports trade by lowering uncertainty and transaction costs, as evidenced by Mamba, Wonyra, and Evlo (2025) and Li and Huang (2023). However, Model 3 shows that political stability has an indirect effect by influencing how exchange rates impact export performance. The notable interaction between exchange rate and political stability suggests that institutional quality determines how macroeconomic variables affect export outcomes. This aligns with more advanced political economy research, which posits that institutions often operate through enabling or constraining mechanisms rather than direct effects. Thus, the Indonesian data is more consistent with Yang and Peng (2025), who find that policy uncertainty influences firm performance via risk pathways, and with studies that highlight that political conditions interact with firm capabilities and market behavior rather than uniformly impacting exports. Consequently, the results do not undermine the importance of political stability; instead, they indicate that its influence is conditional and indirect.

Another important finding is that the shock variable remains insignificant in all models. Although the dummy accounts for major disruptions such as the Asian Financial Crisis, the Global Financial Crisis, and the COVID-19 pandemic, it has no independent effect once GDP, exchange rates, and interaction terms are included. This indicates that major crises mainly impact exports through macroeconomic transmission channels rather than via a separate effect. This aligns with Ibrahim et al. (2024) and Liu et al. (2026), who argue that shocks influence exports by disrupting production, raising uncertainty, and affecting exchange rate movements, rather than through a standalone mechanism. In Indonesia, this suggests that declines in exports during crises are already reflected in slower GDP growth, greater exchange rate volatility, and changing institutional conditions.

From a comparative standpoint, the four models offer valuable methodological insights. Model 1 clearly demonstrates a direct, nonlinear relationship between the macroeconomy and the environment. Model 2 suggests that environmental factors are better understood as moderators of exchange rate effectiveness. Model 3 emphasizes that institutional quality is more relevant as a conditioning factor rather than a direct predictor. Although Model 4 has the highest R-squared, it lacks statistically significant coefficients, likely because of over-parameterization and multicollinearity due to the small sample size. This indicates that simpler models tend to yield more meaningful insights than more complex ones. Substantively, the results imply that Indonesia’s export activity is best explained through a layered framework: GDP affects export capacity, environmental pressures reduce the effectiveness of competitiveness policies, and political stability influences the institutional context in which macroeconomic variables operate.

Overall, the results are consistent with existing research and lead to three main conclusions. First, they confirm that export performance heavily relies on domestic productive capacity, consistent with traditional macro-trade theories. Second, they suggest that environmental factors influence exports mainly as nonlinear and moderating effects rather than direct causes, aligning with emerging sustainability-trade studies. Third, they show that political stability alone does not automatically increase exports but influences how effectively macroeconomic policies translate into export growth, underscoring the importance of conditional effects highlighted by institutional research. In summary, this comparative evidence indicates that Indonesia's export strategies should go beyond growth or exchange rate policies to include environmental improvements and institutional reforms, ensuring that macroeconomic gains translate into sustainable export competitiveness.

CONCLUSION

This study aimed to examine the factors affecting Indonesia's export performance by integrating macroeconomic, environmental, and institutional factors into a unified empirical framework. Utilizing annual data from 1996 to 2023 and various model configurations, the analysis provides valuable insights into the drivers of export activity and the mechanisms through which these factors operate. The findings indicate that macroeconomic conditions, particularly economic growth, are key drivers of Indonesia's exports. In more detailed models, GDP consistently demonstrates a positive and significant influence, highlighting the role of domestic productive capacity in supporting export expansion. However, the results also suggest that macroeconomic variables alone do not fully account for export trends. Environmental

pressures and institutional quality also play roles, though their effects are sometimes indirect. Notably, the baseline model reveals a nonlinear relationship between carbon emissions and exports, implying that while initial industrialization may enhance exports, excessive environmental degradation can ultimately undermine competitiveness. Additionally, environmental factors act as moderators, diminishing the impact of exchange rate depreciation on exports. The impact of political stability is mainly indirect but economically meaningful. While it does not have a statistically significant direct effect on exports, it is vital in buffering the influence of exchange rate changes on export performance. This indicates that the quality of institutions fosters a favorable environment that shapes how macroeconomic policies influence export outcomes. Moreover, the data reveal that external shocks, such as crisis periods, do not directly affect export performance once macroeconomic factors are controlled for, suggesting their effects operate through broader economic channels, such as output and exchange rate shifts. In sum, these findings suggest Indonesia's export success results from complex interactions among macroeconomic fundamentals, environmental influences, and institutional quality. These elements do not act independently; instead, they interact to either reinforce or oppose each other, making policy effectiveness dependent on their combined configuration.

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