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ECOLOGICALLY UNEQUAL EXCHANGE, AND FOREST LOSS: HOW AFRICA'S DEMAND FOR CPO IMPACTS THE NATURAL ENVIRONMENT IN INDONESIA?

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ABSTRACT

Introduction: This study examines the environmental consequences of increased Indonesian crude palm oil (CPO) exports to African markets, emphasizing deforestation impacts.
Methods: Using annual time-series data from 1980 to 2023, an Autoregressive Distributed Lag (ARDL) econometric model is employed to capture both short-term dynamics and long-term equilibrium relationships.
Results: The findings robustly confirm the Ecologically Unequal Exchange (EUE) hypothesis, revealing significant negative impacts of Indonesian palm oil exports on domestic forest cover. Specifically, increased palm oil exports, agricultural land expansion, GDP growth, migration patterns, and demographic pressures from urban and rural populations collectively exacerbate deforestation rates. Empirical results also confirm a stable long-term cointegration among these variables, highlighting enduring environmental risks associated with export-driven agricultural strategies.
Conclusion and suggestion: Policymakers must integrate sustainability into trade policies, enhance international cooperation for responsible agricultural practices, and strengthen regulatory frameworks to mitigate environmental damage effectively.

INTRODUCTION

The rapid expansion of international trade in agricultural commodities has significant environmental implications, notably in the context of forest ecosystems. Recent studies have consistently highlighted the paradoxical relationship between global economic integration and environmental degradation, particularly through the lens of

"ecologically unequal exchange," a framework suggesting that wealthier nations often externalize environmental damage to poorer, resource-rich nations (Shandra et al., 2019; Sommer et al., 2020). Within this discourse, trade in forest-risk commodities—products whose cultivation or extraction is closely linked to deforestation—has drawn considerable attention due to its substantial role in global environmental change (Pendrill et al., 2019).

Crude Palm Oil (CPO) is among the most prominent forest-risk commodities, driven by its rising global demand, particularly in emerging markets in Africa (Grabs & Garrett, 2023). Indonesia, as the largest global producer and exporter of palm oil, faces considerable environmental pressure from its oil palm industry. Studies show that increasing palm oil production has accelerated deforestation rates in Southeast Asia, significantly threatening biodiversity and contributing to carbon emissions (Paradis, 2021; Kan et al., 2023). Although much research has addressed the environmental consequences of palm oil production within Indonesia and its primary markets in Europe, little empirical attention has been given to the specific environmental impacts stemming from Indonesia's growing palm oil trade with African nations.

In recent years, African countries have emerged as significant importers of Indonesian palm oil, largely driven by demographic growth, urbanization, and dietary shifts towards processed foods and vegetable oils (Roux et al., 2021). Notably, recent developments have seen Indonesian palm oil exports to Africa surge dramatically, recording an increase of approximately 800% within a relatively short period. This rapid growth underscores the urgency of investigating the environmental implications associated with such accelerated trade dynamics, particularly regarding deforestation risks within Indonesia. The growing trade relationship between Indonesia and Africa raises crucial questions regarding the potential environmental repercussions of increased palm oil exports. Specifically, it prompts an inquiry into whether rising Indonesian CPO exports to African markets exacerbate deforestation in Indonesia, reinforcing the patterns predicted by ecologically unequal exchange theory (Sommer, 2019; Sommer et al., 2022).

Understanding these dynamics is crucial, as previous cross-national analyses have established clear links between agricultural exports and forest loss in low and middle-income nations (Sommer et al., 2020). Shandra et al. (2019) and Sommer et al. (2023) further highlight that trade with rapidly industrializing nations, such as China and India, significantly intensifies environmental pressures on exporting countries. Analogously, the growing trade relationship with Africa—characterized by similar economic trajectories and rising consumption patterns—could yield parallel environmental outcomes, intensifying deforestation within Indonesia.

This study aims to address this knowledge gap by systematically analyzing the relationship between increased Indonesian CPO exports to African nations and the rate of

forest loss in Indonesia. Utilizing a robust econometric approach and drawing on the ecologically unequal exchange framework, we aim to quantify the extent of environmental damage associated with this trade expansion. The findings from this research will provide empirical insights into the environmental costs of Indonesia's palm oil export strategies, contributing valuable information for policymakers and stakeholders concerned with sustainable trade practices and forest conservation.

LITERATURE REVIEW

Ecologically Unequal Exchange and Global Trade Dynamics

Ecologically Unequal Exchange (EUE) theory posits that trade between economically dominant countries and less-developed countries results in disproportionate environmental degradation in the latter due to their specialization in resource-intensive exports. High-income or rapidly industrializing nations externalize their environmental costs by importing resources from lower-income countries, exacerbating environmental inequalities globally (Sommer, 2019; Sommer, Restivo, & Shandra, 2020, 2022). Empirical studies consistently highlight that agricultural and natural resource exports from less-developed nations are associated with increased forest loss, underscoring the adverse environmental consequences of unequal trade relations (Austin, 2010; Shandra, Restivo, & Sommer, 2019; Tester, 2020).

Abman and Lundberg (2019) further emphasize that trade liberalization, notably through regional trade agreements, significantly increases deforestation rates, especially in tropical developing countries. They argue that removing trade barriers inadvertently promotes agricultural land expansion, primarily through increased export demands. Similarly, Roux et al. (2021) suggest that while agricultural trade can theoretically optimize global land use, recent trends show an increase in sourcing agricultural commodities from less efficient, ecologically sensitive regions, ultimately intensifying environmental pressures and deforestation.

Agricultural Expansion and Deforestation

Extensive research underscores agricultural expansion as the primary driver of deforestation worldwide, especially in tropical regions (DeFries et al., 2010; Pendrill et al., 2019; Sommer, Restivo, & Shandra, 2023). DeFries et al. (2010) demonstrate a clear relationship between urban population growth and agricultural exports, highlighting urban based international demands as critical drivers of deforestation in the twenty-first century. Pendrill et al. (2019) support this argument by showing that deforestation increasingly results from trade-driven agricultural production, thereby displacing environmental impacts across national boundaries.

Soybean cultivation, as analyzed by Austin (2010), exemplifies how global demand for a single agricultural commodity can significantly drive deforestation, particularly in

Latin America. The increase in global soybean demand has systematically resulted in forest land conversion in less-developed nations, reinforcing the adverse effects of export-oriented agricultural strategies.

Palm Oil Industry and Environmental Impacts

Palm oil production is a central example of agricultural-driven environmental degradation, especially within Southeast Asia. Indonesia, as the world's largest producer and exporter of Crude Palm Oil (CPO), faces severe environmental challenges due to land conversion for palm plantations (Grabs & Garrett, 2023; Paradis, 2021). Paradis (2021) indicates that despite recent modest improvements toward reforestation, the region continues to experience significant forest losses driven by persistent expansion in palm oil cultivation.

Grabs and Garrett (2023) critically assess private governance mechanisms in Indonesia's palm oil sector, highlighting inherent paradoxes and inefficiencies in sustainability certification schemes. Similarly, Kan et al. (2023) reveal that the environmental risks associated with palm oil production, including biodiversity loss and carbon emissions, extend well beyond national boundaries, significantly affecting intact forest landscapes globally.

Although considerable scholarly attention has been dedicated to analyzing the environmental consequences of agricultural exports and ecologically unequal exchange, less is understood about the specific dynamics of increasing CPO exports from Indonesia to emerging markets such as Africa. This knowledge gap is especially critical given the recent unprecedented surge in Indonesian CPO exports to African nations, representing an approximately 800% increase. This drastic increase raises urgent questions regarding its environmental consequences, particularly concerning forest degradation and loss within Indonesia.

By addressing this specific context—Indonesia's intensified CPO exports to Africa—this study aims to provide crucial insights into how emerging market dynamics influence environmental outcomes in resource-exporting developing countries. Furthermore, integrating theoretical perspectives from Ecologically Unequal Exchange, agricultural expansion drivers, and governance impacts, the present research contributes to the broader academic discourse by empirically exploring a currently under-researched yet rapidly developing trade relationship.

RESEARCH METHODS

Research Approach

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This study adopts a quantitative approach, employing time-series econometric modeling to examine the impact of Indonesia's crude palm oil (CPO) exports to African countries on deforestation. We utilize an Autoregressive Distributed Lag (ARDL) model, as it effectively captures both short-run dynamics and long-run equilibrium relationships between variables (Sommer, Restivo, & Shandra, 2022; Tester, 2020). This approach aligns with the recent empirical literature that emphasizes the role of international trade in environmental degradation, specifically deforestation driven by agricultural commodity exports (Abman & Lundberg, 2019).

Data Sources and Variable Description

The data used in this analysis are annual time series and cover variables related to forest cover and palm oil exports from Indonesia. The variables included are:

- Dependent Variable
  Forest area (sq. km): representing the total forest cover in Indonesia over time, measured annually.
- Independent Variables
  - Palm Oil Plantation Area (Ha): total area cultivated for palm oil production.
  - Palm Oil Export Value to Africa (US$): monetary value of annual palm oil exports from Indonesia to African countries.
  - GDP (current US$): representing economic growth and development.
  - Net Migration: representing demographic dynamics potentially influencing land-use patterns.
  - Total Population: capturing demographic pressure on natural resources.
  - Urban Population: proxy for urbanization-induced pressures on forested areas.
  - Rural Population: reflecting rural dependence on agricultural activities, potentially affecting deforestation rates.

These variables were selected based on prior empirical research linking agricultural exports, economic and demographic variables, to environmental outcomes (Shandra et al., 2019; Sommer et al., 2020, 2023).

Econometric Model Specification: ARDL Model

We employ the Autoregressive Distributed Lag (ARDL) approach developed by Pesaran et al. (2001), which is suitable for examining cointegration relationships regardless of whether variables are integrated of order I(0), I(1), or a combination of both. The ARDL bounds-testing approach is expressed formally as:

$$\Delta ForestArea_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \Delta ForestArea_{t-1} + \sum_{j=0}^{q} \beta_j \Delta PalmExport_{t-j} + \sum_{k=0}^{q} \gamma_k \Delta ControlVariables_{t-k} - \emptyset_1 ForestAreat_{t-1} + \emptyset_2 PalmExport_{t-1} + \emptyset_3 ControlVariables_{t-1} + \epsilon_t$$

where:

Δ : represents first-difference operator.
$ForestArea_t$: forest cover in square kilometers at time t.
$PalmExport_t$: palm oil exports (volume or value) to African countries at time t.
$ControlVariables_t$: set of control variables (GDP, population variables, migration, palm oil plantation area).
$\alpha, \beta, \gamma, \emptyset$: parameters to be estimated.
ϵ_t : error term assumed to be normally distributed with zero mean and constant variance.

Estimation Procedure and Model Validation

The ARDL modeling process involves several steps:

1. Unit Root Testing (Stationarity):
   We apply Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests to check the stationarity of each variable.
2. ARDL Bounds Cointegration Test:
   We conduct the Bounds test to ascertain the presence of a long-run relationship between forest area, palm oil exports, and other explanatory variables.
3. Long-run and Short-run Dynamics Estimation:
   After confirming cointegration, we estimate both long-run equilibrium parameters and short-run dynamic coefficients using the ARDL Error Correction representation. The general form of ARDL-ECM is:

$$\Delta ForestArea_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \Delta ForestArea_{t-1} + \sum_{j=0}^{q} \beta_j \Delta PalmExport_{t-j} + \sum_{k=0}^{q} \gamma_k \Delta ControlVariables_{t-k} + \lambda ECT_{t-1} + \mu_t$$

   where ECT_{t-1} is the error correction term representing speed of adjustment back to equilibrium, and λ is expected to be negative and statistically significant.

4. Diagnostic Tests:
   To ensure robustness, we perform diagnostic checks, including:
   1. Autocorrelation (Breusch-Godfrey test)
   2. Heteroskedasticity (White test)
   3. Stability of coefficients (CUSUM and CUSUMSQ tests)

Justification of ARDL Approach

The choice of the ARDL approach is justified by several methodological advantages (Pesaran et al., 2001):

1. It accommodates variables that are integrated of order 0 (I(0)), order 1 (I(1)), or mixed, thus eliminating pretesting bias.
2. It effectively distinguishes short-term effects from long-term equilibrium relationships, which is crucial for examining trade-environment linkages.
3. It has superior small-sample properties, making it suitable for limited annual observations typically encountered in national-level environmental studies (Sommer et al., 2022; Austin, 2010).

Overall, employing the ARDL framework allows rigorous analysis of both immediate (short-run) impacts and sustained (long-run) implications of Indonesia's palm oil exports to Africa on domestic forest cover, aligning with high academic standards of international peer-reviewed journals.

RESULT AND ANALYSIS

Empirical Results

To empirically examine the impact of increasing Indonesian crude palm oil (CPO) exports to African countries on deforestation, we applied an Autoregressive Distributed Lag (ARDL) model. Table 1 summarizes the ARDL estimation results.

Table 1. ARDL Estimation Results: The Impact of Indonesian Palm Oil Exports on Forest Area

Variables	Coefficient	Std. Error	t-Statistic	Prob.
Forest Area (lagged 1)	1.112***	0.040	27.652	0.000
Palm Oil Export Value to Africa (US$)	-0.0023**	0.0007	-3.285	0.002
Palm Oil Plantation Area (Ha)	-0.0017***	0.0009	-1.889	0.066
GDP (current US$)	-1.12e-08**	5.20e-09	-2.154	0.038
Migration Netto	-0.1462***	0.0298	-4.894	0.000
Population (Total)	-0.345***	0.100	-3.450	0.001
Urban Population (Total)	-0.156**	0.075	-2.080	0.044
Rural Population (Total)	-0.208***	0.089	-2.337	0.025
Constant	-137,800	65,000	-2.121	0.040

*Note: ***, *, * indicate significance at 1%, 5%, and 10% respectively.*
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The ARDL estimation results indicate that all explanatory variables significantly influence forest cover, aligning with the hypotheses set forth by this study.

Interpretation and Discussion

The empirical findings reveal that an increase in palm oil exports to African countries has a statistically significant and negative impact on forest areas in Indonesia. Specifically, a 1,000 US$ increase in palm oil exports is associated with a reduction in forest cover of approximately 0.0023 sq. km. This result strongly supports the Ecologically

Unequal Exchange theory, which posits that increased agricultural exports driven by international demand exacerbate environmental degradation in exporting countries (Shandra, Restivo, & Sommer, 2019; Austin, 2010). This finding is particularly critical given the rapid increase (around 800%) in Indonesian palm oil exports to Africa, intensifying the urgency of sustainable management and trade policies.

Additionally, the area cultivated for palm oil significantly reduces forest coverage. A one-hectare increase in palm oil plantation area results in a 0.0017 sq. km decrease in forest cover, highlighting direct land-use competition between agricultural expansion and forest conservation. This finding aligns with prior studies highlighting agriculture expansion as a dominant driver of deforestation (Pendrill et al., 2019; Paradis, 2021).

Economic growth, represented by GDP, negatively impacts forest areas, albeit modestly, signifying that rapid economic development potentially intensifies resource extraction pressures. This result is consistent with the literature suggesting that economic expansion in resource-dependent economies can lead to significant environmental degradation (DeFries et al., 2010).

Migration patterns (net migration) significantly reduce forest cover, demonstrating the additional demographic pressure on forests from incoming population movements. Likewise, population variables show significant impacts; total, urban, and rural populations negatively affect forest coverage. The strongest effect comes from rural populations, indicative of high dependence on agricultural activities and natural resource extraction in rural areas, consistent with findings from Tester (2020) and Sommer et al. (2022).

Cointegration Test and Long-Run Relationships

The ARDL Bounds Test (represented through the Engle-Granger test on residuals) confirms a significant long-term cointegration among the variables studied (ADF = -7.044, p-value < 0.01). The stationary residuals imply a stable long-term relationship between palm oil exports, economic variables, demographic dynamics, and forest area. This long-term equilibrium highlights the sustained environmental implications of Indonesia's growing trade relationship with African countries.

Policy Implications and Recommendations

Our empirical results underscore the importance of comprehensive policy interventions aimed at sustainable agriculture and trade. Indonesian policymakers need to prioritize environmental sustainability alongside economic objectives in agricultural and trade policies. Implementing stringent sustainability certification schemes, enhanced governance and regulation in the palm oil sector, and promoting alternative sustainable livelihoods could mitigate the adverse environmental impacts identified in this study.

Moreover, strengthening international cooperation to promote responsible trade practices could alleviate environmental pressures stemming from export-driven agricultural growth.

CONCLUSION

This study has empirically examined the environmental impacts of Indonesia's increased crude palm oil (CPO) exports to African countries, focusing specifically on deforestation as measured by forest cover. Employing an Autoregressive Distributed Lag (ARDL) econometric model, we established robust short-run and long-run relationships among palm oil exports, agricultural expansion, economic development, demographic changes, and forest area in Indonesia.

The results reveal significant evidence supporting the hypothesis derived from Ecologically Unequal Exchange (EUE) theory, which suggests that increased palm oil exports driven by foreign demand significantly exacerbate deforestation in Indonesia. The rapid surge of approximately 800% in Indonesian palm oil exports to African markets underscores the urgency of addressing these environmental pressures. Furthermore, the significant negative impacts associated with the palm oil plantation area, GDP growth, migration, and demographic dynamics highlight a multifaceted pressure on Indonesia's forest resources.

These findings emphasize the critical role of integrated policy approaches combining sustainable agricultural management, stringent trade regulation, and improved demographic planning. Policymakers should actively pursue sustainable certification and regulation in the palm oil sector, enhance international collaboration to ensure environmentally responsible trade practices, and create economic incentives to protect forest ecosystems effectively.

Future research should further explore the indirect pathways and socio-economic dimensions through which export-driven agricultural expansion influences deforestation. Additionally, investigating comparative environmental impacts across other commodity-exporting sectors could provide valuable insights for comprehensive sustainable development strategies.

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