Beyond Certification: Spatial Spillovers and Compliance Design in Indonesia's Palm Oil Sector

1 Research Problem

Palm oil serves as a vital global commodity and its production has been growing exponentially in the past 20 years, exceeding 80 million tonnes in 2021. However, this economic boom in producing countries like Indonesia has driven severe negative externalities, most notably vast deforestation resulting in loss of biodiversity and global warming through carbon emissions. To combat these issues, eco-certification schemes, such as the prominent Roundtable on Sustainable Palm Oil (RSPO), were established to ensure sustainable and ethical production.

The core research problem addressed in this paper is the system-wide effectiveness of such eco-certification schemes. While the RSPO strictly monitors environmental compliance and limits deforestation on land owned by certified members, it imposes no restrictions on neighboring, uncertified areas. This creates a high risk of regulatory arbitrage and spatial leakage, wherein the conservation gains achieved on certified land might be completely offset by displaced deforestation into economically connected regions. We investigate this phenomenon utilizing a panel dataset spanning Indonesian Sumatra and Kalimantan over the years 2001 to 2021 to determine if the RSPO's certification policy inadvertently serves as a displacement engine for environmental damage. The observed outcome of interest is the future primary forest cover loss of a focal cluster i which we regress on treatments defined as the certification of focal clusters ($T_{i,t}^{\text{local}}$) as well as certification of neighbors ($T_{i,t}^{\text{spillover}}$).

2 Key Methodology

To capture the spatial complexities of the palm oil supply chain and overcome the identification challenges inherent in continuous spatial designs – such as Stable Unit Treatment Value Assumption (SUTVA) violations – we constructed a spatial panel of the study area with a 2×2km resolution, aggregated into 1,388 mutually exclusive supply-shed clusters. The methodology can be described in three stages:

Reduced-Form Empirical Analysis: We utilize a staggered Synthetic Difference-in-Differences (SDiD) approach with continuous treatment to isolate local economic market spillovers. This helps us effectively replicate local pre-trends and eliminate bias through unobserved regional differences and macro-shocks.

Structural Land-Use Model: Because reduced-form estimates inherently suffer from endogeneity through local cross-border shocks and cannot simulate counterfactual policies, we developed a structural model of sequential land expansion. The model assumes a myopic profit-maximization framework where each cluster balances the net marginal benefit of agricultural expansion against convex land conversion costs.

Heckman Selection and GMM Estimation: To correct for sample selection bias (since industrial expansion is only observed in clusters that have overcome initial capital costs), we employ a two-stage Heckman correction. A Probit model evaluates the probability of industrial footprint establishment based on historical forest endowments, followed by a Generalized Method

of Moments (GMM) estimation to recover the latent behavioral parameters driving sequential expansion.

3 Main Results

The empirical and structural models yield compelling evidence that RSPO certification generates profound, unintended externalities, as seen in Tables 3.1a and 3.1b. The SDiD models confirm a statistically significant spillover effect, indicating that certification pushes non-compliant demand into neighboring areas. While the reduced-form SDiD approach captures local economic spillovers, it suffers from endogeneity regarding unobserved local cross-border shocks, which biases the local treatment effect.

This bias is successfully resolved by our structural GMM approach, which explicitly models regional leakage using baseline forest cover as exogenous instruments. The structural estimates reveal the true behavioral mechanisms at play: local certification acts as a severe compliance friction, drastically reducing the marginal benefit of clearing land ($\beta_{T_{\text{local}}} = -8.7746$). However, this beneficial local conservation effect is entirely overwhelmed by massive regional leakage ($\beta_{T_{\text{spillover}}} = 11.0641$), as uncertified neighboring areas aggressively absorb the displaced demand.

Table 3.1: Results of reduced-form and structural models

(a) Synthetic Difference-in-Differences Approach Estimating the Treatment Effect on Forest Loss

Dependent Variable:	$Future2YearForestCoverLoss_{i,t,z}$	
Model:	(1)	(2)
$T_{i,t}^{\text{local}}$	0.0938**	
	(0.0408)	
$T_{i,t}^{\text{spillover}}$		0.3995***
		(0.0793)
$Fertility_{i,t,z}$	0.0683	-0.0561
	(0.0702)	(0.0693)
$logAge_{i,t,z}$	-0.2960***	-0.3145***
	(0.0340)	(0.0375)
$PlantationArea_{i,t,z}$	0.0044	0.0471
	(0.0723)	(0.0876)
$PlantationArea_{i,t,z}^2$	-0.1755***	-0.2693***
	(0.0494)	(0.0611)
$RemainingForest_{i,t,z}$	3.548***	3.779***
	(0.2203)	(0.2052)
$RemainingForest_{i,t,z}^2$	-2.233***	-2.389***
	(0.2623)	(0.2244)
Fixed-effects		
i-sub_experiment	Yes	Yes
t-sub_experiment	Yes	Yes
Fit statistics		
Observations	183,464	126,806
R^2	0.57715	0.57079
Adjusted R^2	0.25609	0.54606

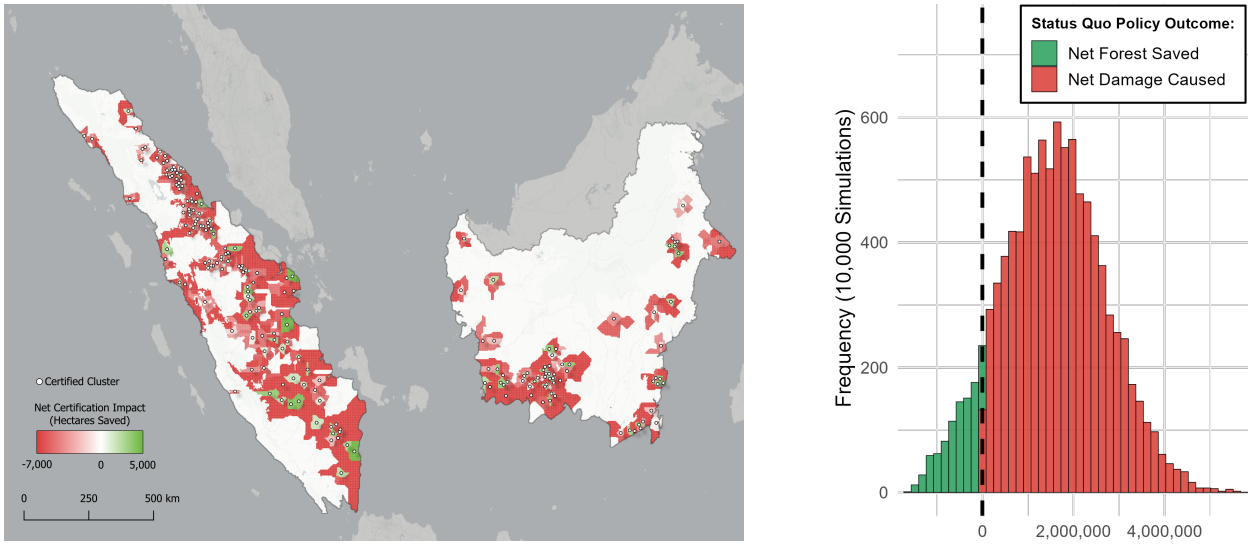
Standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

(b) Structural Model Approach Estimating the Treatment Effect on Land Expansion

Structural Parameter	Main Specification
Constant	1.8884
	(1.9444)
$T_{i,t}^{\text{local}}$	-8.7746
	(6.3321)
$T_{i,t}^{\text{spillover}}$	11.0641
	(7.1833)
$Fertility_{i,t,z}$	-0.0163
	(0.0410)
$RemainingForest_{i,t,z}$	-0.4590***
	(0.1025)
$HeckmanCorrection_{i,t,z}$	0.1581**
	(0.0650)
$PanelYearNo_t$	-0.0643***
	(0.0173)
$MarketDistance_{i,t,z}$	0.2219***
	(0.0679)
Model Diagnostics	
Observations	23,094
Hansen J-statistic	0.2379
J-test p-value	0.6257

Standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

To evaluate the net environmental impact of the current RSPO policy, we drew 10,000 parameter sets from the multivariate normal distribution of our GMM variance-covariance matrix and simulated counterfactual landscapes. Figure 3.1a visually highlights this spatial asymmetry: while certification shields highly localized pre-developed cores, it triggers a "ring of fire" of deforestation in surrounding areas. Comparing the status quo to a counterfactual reality in which certification never occurred, we find a severely asymmetric risk profile. In over 90% of the simulation runs, the partial RSPO regime actively increased total primary forest loss compared to a baseline of doing nothing (Figure 3.1b).



(a) Net Effect of Certification

(b) Status Quo vs. No-Certification

Figure 3.1: Results of counterfactual study evaluating the effectiveness of the status quo certification policies pursued by RSPO

4 Implications

The findings present critical managerial and policy implications for supply chain governance and environmental standards: First, implementing rigorous standards in highly interconnected markets fails if compliance is not universal. The net environmental value of a certification scheme is dictated by the absorption capacity of non-members, not just the compliance of its members. Further, uncertified producers currently absorb displaced demand because they can easily sell non-compliant products globally. To dismantle this expansion pressure, policymakers must transition from intransparent tracking to strict supply chain segregation. Moreover, individual producer certifications merely displace deforestation. Certification authorities should pivot to landscape-level or jurisdictional certification (e.g., certifying larger areas simultaneously) to functionally eliminate uncertified neighboring sinks and force an aggregate reduction in deforestation. Ultimately, this research demonstrates that partial eco-certification regimes can perversely accelerate environmental degradation, underscoring the urgent need for comprehensive, systemic supply chain reforms.