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From Enforcement to Compliance–Enforcement Governance: The Role of Institutional Credibility

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JEL classification: Q58, K42, D81, D82, L51

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This is a preprint of the paper forthcoming in a peer-reviewed journal. A link to the published version will be added once it becomes available. We gratefully acknowledge the financial support from the Kajima Foundation for Promotion of Science and the Arts and the Osaka School of International Public Policy research support. We thank Professor Matsushima Noriaki, among other professors at The University of Osaka, for their valuable discussions and comments.

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1. Introduction

Achieving sustainable governance is a challenging endeavor, or even a utopian goal in practice. In the compliance-enforcement and development literature, shared determinants recur — power, costs, probabilities, incentives, and institutional frameworks (Acemoglu & Robinson, 2010; Becker, 1968; Karpoff *et al.*, 2005; Polinsky & Shavell, 2000; Porter & Linde, 1995; Segerson & Tietenberg, 1992; Shimshack & Ward, 2005). Environmental governance relies on two indivisible systems acting in concert: (1) compliance by regulated firms and (2) enforcement by public authorities. They are sides of the same coin, but the analytical literature treats them largely in isolation. Enforcement economics (Becker, 1968; Cohen, 1987; Polinsky & Shavell, 2000; Stigler, 1970) focuses on optimal fine design, inspection intensity, and deterrence, typically taking firm behavior as a passive response. Compliance research examines corporate governance, ESG strategies, and stakeholder pressure (Donaldson & Preston, 1995; Porter & Linde, 1995), but rarely models the enforcement system explicitly.

This separation matters: enforcement credibility shapes compliance incentives, and the compliance landscape, in turn, determines how efficiently enforcement resources are used. An integrated framework that models both simultaneously under a governance-centric perspective as cooperation among relevant agents pursuing better equilibrium outcomes (North, 1990) is thus needed to understand why some enforcement systems achieve compliance, and others do not, even with similar inspection budgets.

Most enforcement systems operate in two sequential stages: initial detection (i.e., whether a violation is found during inspection) and post-detection institutional processing (i.e., whether a detected violation is confirmed and upheld through regulatory procedures). Standard deterrence models merge both stages into a single probability, implicitly assuming that inspection intensity is the primary and sufficient keystone of governance. However, those models neglect a critical distinction: detection probability (p) is primarily a budgetary and operational variable that depends on how many inspectors are deployed and how frequently they inspect, while post-detection confirmation probability (p') is an institutional and legal variable that depends on the quality, consistency, and independence of regulatory procedures, administrative courts, and appeal processes.

When p and p' are treated as equivalent, models predict that investing in more inspections is as effective as strengthening institutional quality. The empirical evidence challenges this prediction: Peru's large-scale fisheries sector experienced 2,246 OEFA inspections over 2018–2026, of which 47% triggered the start of formal sanctioning procedures (Table 1) yet, in 2022, 19.61% of first-instance decisions were subsequently revoked or nullified on appeal (Table 2), indicating that the deterrence value of each inspection was eroded by post-detection credibility gaps. Separating p from p' reveals that these two enforcement dimensions have structurally different effects on compliance and call for distinct policy responses.

This paper addresses this gap and offers new insights into environmental governance by integrating institutional, behavioral, and economic factors that are commonly analyzed in isolation as follows.

First, we formally separate p (detection probability) from p' (post-detection confirmation probability) and prove that $\partial e^*/\partial p' > \partial e^*/\partial p$, that is, institutional credibility exerts a larger marginal effect on optimal compliance effort than inspection intensity. This result substantially changes the governance policy diagnosis by implying that enforcement systems should invest first in strengthening the confirmation stage (i.e., procedural consistency, independence of administrative courts), which is institutionally quality-linked, before expanding inspection capacity. Two channels establish this, with different scopes: Arrow-Pratt risk aversion under a four-state loss lottery, taking certainty equivalence variance distribution (Pratt, 1964) as a condition met in lower-throughput enforcement regimes (illustrated numerically in Appendix A) and an information-theoretic foundation, which holds regardless of risk preferences, that is, conditional variance differences in responses to the shocks regarding institution form (Maskin *et al*., 2000).

Second, where the Arrow-Pratt channel is active, with Decreasing Absolute Risk Aversion (DARA), the $p' > p$ difference (asymmetry) becomes stronger for smaller, less-capitalized firms, generating a testable cross-firm heterogeneity prediction: smaller firms respond more strongly to institutional quality reforms than to equivalent increases in inspection frequency. This behavioral dimension is absent from standard deterrence models.

Third, we incorporate sustainable incentives (I) as a portfolio of financial and non-financial returns from: state (I^O), market (I^M) (e.g., export-driven sustainability (EDS)), reputational (I^R), and productive, as eco-

efficiency (I^P) channels, distinct from the illicit benefit taken for deterrence analysis. This economic integration shows that market profitability and eco-efficiency gains provide governance-relevant compliance incentives alongside formal sanctions.

Finally, we establish a governance multiplier ($\frac{\partial^2 e^*}{\partial I \, \partial p'} > 0$) showing that improving institutional credibility (p') simultaneously amplifies both deterrence and incentive channels. This complementarity implies that the institutional quality reform and positive incentive design should be coordinated rather than treated as substitutes.

Latin America, and Peru in particular, offers a compelling illustration of this framework because (i) its strategic geopolitical and resource conditions and (ii) its fragile stakeholders' cooperation in sustainability (Bastidas *et al*., 2025; Baud *et al*., 2011). Peru underperforms across most governance dimensions (The World Bank, 2024) yet its large-scale fishing sector is among the world's most significant fisheries, contributing 8.7% of GDP and generating substantial export revenues (Cochrane, 2021; Orihuela & Davila-Garcia, 2025; Paredes *et al*., 2024). This combination of rich institutional data, weak governance baselines, and a globally significant industry makes Peru an ideal case for examining how institutional, behavioral, and economic factors interact in shaping environmental compliance.

The framework's core mechanism of sequential enforcement generating a $p' > p$ asymmetry is not unique to Peru; analogous two-stage enforcement architectures exist in the US EPA (Notice of Violation/Consent Decree), EU infringement procedures (The European Green Deal), and multi-stage tax assessment systems.

This study also proposes a new definition of "governance" as joint compliance and enforcement and presents a decision-making model as an expected-utility maximization problem, leading to an extended-version analysis of the well-known "stick and carrot." We use stylized facts regarding large-scale fisheries in Peru as motivating evidence for the framework. The paper proceeds as follows: Section 2 reviews the governance framework underlying our model, Section 3 explains the Peruvian context, Section 4 develops the formal model and testable implications, Section 5 discloses non-intuitive analytical patterns, Section 6

outlines the further empirical research agenda, Section 7 draws conclusions, and Section 8 provides policy implications.

2. Governance Framework

Neither governance nor environmental governance has a single, widely accepted definition (see Appendix C for a survey of governance frameworks). Here, governance is defined as cooperation among relevant agents with different power configurations, pursuing better equilibrium outcomes and social welfare—a multi-actor endeavor extending beyond principal-agent assumptions alone (North, 1990). We acknowledge the push-and-pull between holders' willingness and initiatives and authorities' strategies and capacities, with efforts and trust in the middle.

2.1. Compliance: Corporate governance

Business models typically prioritize profit maximization (Fama & French, 2006) yet long-term sustainability requires strategic effort beyond profitability, including preventing violations through effective cost and resource allocation (Christmann & Klein, 2024).

Contemporary value models such as the corporate social responsibility (CSR) and environmental social governance (ESG) frameworks may align compliance with competitive advantage (Donaldson & Preston, 1995; Porter & Linde, 1995), as evidenced by Barontini & Gioja (2025), Bastidas et al. (2025), and Xie *et al.* (2023), though their performance remains contested by Bond & Levit (2025) and Wanyan & Zhao (2024).

2.2. Enforcement: Authority's power

State agents enforce the behavior of non-state agents primarily through deterrence strategies: varying inspection intensity, sanction type and severity, and internalizing externalities (Becker, 1968; Cohen, 1987; Earnhart, 2000; Gray & Shimshack, 2011; Karpoff *et al*., 2005; Polinsky & Shavell, 2000; Shimshack & Ward, 2008; Stigler, 1970). Scholars often group enforcement into punishments and incentives, or financial and non-financial strategies, regardless of taxonomy; all of them seek social welfare.

Ayres & Braithwaite (1992) organize enforcement along *scope* (persuasion, warning letters, civil and criminal penalties, license suspension, and revocation) and *level (*self-regulation, enforced self-regulation, command regulation with discretionary or nondiscretionary punishment).

2.3. Third-party: Civil Society engagement and user empowerment

Non-state actors play relevant roles in the stakeholder (Donaldson & Preston, 1995), collaborative (Emerson *et al*., 2012), evolutionary (Beunen *et al*., 2022), and ESG (Barontini & Gioja, 2025) governance frameworks.

Civil society can influence detection through third-party complaints, drive non-financial compliance returns, amplify voice accountability, and prompt policymakers and enforcers to act or initiate strategies (Beunen *et al*., 2022). Networks including civil society are crucial to ensuring governance sustainability.

2.4. The joint framework

Compliance and enforcement are indivisibly interrelated, with firms and authorities as leading actors, and civil society playing complementary roles (Figure 1, adapted from Lemos & Agrawal, 2006). Sustainable governance depends on the commitments and capacities of both the holder and authority.

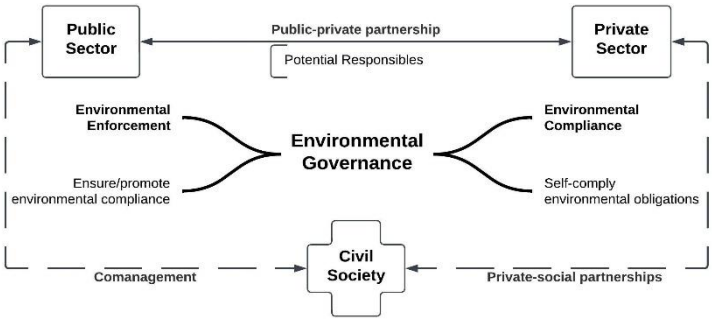

Figure 1: Compliance-enforcement governance. Source: Adapted from Lemos and Agrawal (2006)

Companies that follow regulations without robust public oversight, quality services, or strong institutions may face an unfair competitive disadvantage. Conversely, effective oversight alone is insufficient if firms lack genuine commitment, as it merely shifts non-compliance elsewhere without solving the core issue. A common pattern appears across fields: initially, a clear winner or loser may emerge but, over time, both parties can suffer from uncontrollable factors, dynamics, and consequences. Systems risk collapsing when

numerous non-compliance cases, or peer and neighborhood effects, accumulate, leading to systemic governance failures that even compliant firms will ultimately face.

In ecological terms, the public and private sectors might form distinct symbiotic relationships: when both parties embody mutualism (+/+) or even commensalism (+/0), sustainability is feasible. Conversely, imbalanced associations, such as predation or parasitism, make equilibrium unlikely (Huang & Liu, 2024; Von Jacobi, 2018). In game-theoretic terms, at least two "agents" are needed to address shared issues and spillover "externalities," with outcomes depending on the cooperation degree, number of participants, payoff range, and consequences (Christmann & Klein, 2024).

Non-compliant firms may persist despite oversight, while sustainable ones may struggle against the institutions that impede their compliance efforts by generating externalities and reducing social welfare for all. Therefore, an efficient public-private partnership is built around institutional frameworks under which enforcement credibility and compliance commitment converge to produce better governance equilibria than misaligned ones, especially given their duality.

3. Peruvian Context

3.1. Governance Performance

Based on governance data from the WGI (The World Bank, 2024), from 1996 to 2023, Peru has remained in the second quartile for corruption control, government effectiveness, political stability, and the rule of law; 67-76% of nations performed better than Peru by 2023. Regulation quality and voice accountability remain near the 50th percentile, exhibiting mid-to-low governance performance (See Appendix C, Figure 4).

Socio-cultural factors may amplify governance gaps. Hofstede *et al.* (2010) score Peru's uncertainty-avoidance high, suggesting risk aversion shapes compliance behavior beyond penalty severity alone, consistent with Becker (1968) and the Arrow-Pratt derivation (Section 4). Furthermore, corruption perception may reduce enforcement credibility, weakening deterrence independently of formal sanction levels (Becker & Stigler, 1974; Olken & Pande, 2012; Sundström, 2012; Thompson, 2018).

While Acemoglu and Robinson (2010) emphasize that institutional frameworks are endogenous determinants of nations' development; we claim that governance does. Nations with high income and those with low income follow different paths (The World Bank, 2024). In the first group, state and non-state institutions coordinate their interests effectively, working toward better governance than in the second group; thus, converging enforcement and compliance within robust institutions become central to moving from governance failure toward sustainable equilibrium.

3.2. Peruvian Enforcement System

Most productive activities in Peru operate under specific enforcement systems.[1,2] A crucial system is the National System of Environmental Assessment and Enforcement (SINEFA, e*x post phase*), analogous to the US EPA. It operates through OEFA by performing enforcement to ensure compliance with Auditable Environmental Obligations (AEOs) among large-scale activity holders. The ex-ante phase of the National System of Environmental Impact Assessment (SEIA) – assesses Environmental Management Instruments (IGAs) before activities begin; certified IGAs generate the key AEOs to be supervised by OEFA (see Appendix C, Figure 5 for the SINEFA and SEIA workflow).

The *Project Holder* (firm) carries out an economic activity subject to OEFA's competency. *Auditable Unit* is the physical space to be supervised. IGA is a binding document submitted by the holder, claiming environmental aspects, impacts, and abatement measures; AEOs are obligations from regulations such as IGAs, mandates, and others, to prevent, control, abate, and monitor environmental aspects.

To familiarize readers with Peru's enforcement architecture, a useful analogy maps it to a legal process: AEOs correspond to citizens' legal duties; IGAs to a binding pledge; DSAP (OEFA-supervisor) to a police officer; the DFAI (OEFA-auditor) to a first-instance prosecutor-judge; the TFA (OEFA-court) to an appellate court; and the PAS to an indictment proceeding that may or may not result in a confirmed sanction.

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[1] The Peruvian General Administrative Law System establishes rules between the state and non-state entities, DS N° 4-2019-JUS (TUO LPAG).

[2] The environmental system is the National Management of the Environment System, SNGA, which comprises five systems, including SINEFA & SEIA. SINEFA, environmental enforcement, created in 2009 (Law Nº 29325), and SEIA, environmental assessment, created in 2001 (Law Nº 27446)

Supervisions may or may not become a PAS; a PAS may be due to one or more infractions; holders may appeal DFAI decisions to the TFA, which can revoke, nullify, or confirm the sanction; the holder is not impeded from correcting their actions before, during, and after the supervisions and PAS[3].

3.3. Peruvian Fishing Sector

The fishing sector contributes 8.7% of the GDP (2014–2023), and ranks among the world's top five fishery sectors (Cochrane, 2021; Orihuela & Davila-Garcia, 2025; Paredes *et al*., 2024). This study focuses on large-scale industrial fisheries (EIP) and upper-middle-large-scale aquaculture (AMYGE), under OEFA's competency. Its AEOs [4] include wastewater management, atmospheric emissions abatement, hydrobiological systems, solid waste, and formalities (see the OEFA guideline (2025) and Table 5 in Appendix C).

3.4. Motivating Stylized Facts

The following data are presented not as conclusive tests of model prediction but as stylized facts calibrating framework parameters. From 2018 to March 2026 (Table 1), the sector had 423 auditable units and 328 holders, of whom 296 did not comply at some point. OEFA conducted 2,246 oversights, issued 25 administrative measures, received 229 third-party complaints, initiated 1,064 administrative sanctioning legal procedures (PAS), and confirmed 6,181 tax units (UIT) [5] in fines (OEFA, n.d.-a, n.d.-b). Approximately 47% of supervisions resulted in a PAS (1,064 of 2,246).

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[3] In Peru, and likely in most developing countries, the environmental enforcement strategy design mainly relies on sanctions as fines (pecuniary-based) and on other measures (resource-based to prevent issues, risks, or provide elements to enhance the administrative procedure). In other regions, such as the European Union (EU), an Emissions Trading Scheme (ETS) exists, part of an enforcement strategy relying on a tradable quota of emissions (as part of The European Green Deal). Moreover, the United States of America complements its EPA enforcement actions by implementing Supplemental Environmental Projects (SEPs) and Consent Decrees, which may include a double-dividend approach. Other common scheme in other nations is Pigouvian taxes for pollution, among other measures

[4] A distinctive feature of the fishing industry is that its environmental impacts are generally associated with organic pollution (except for atmospheric pollution and other less common issues), which may be perceived as less hazardous than those from other activities (e.g., mining or hydrocarbon extraction). However, within Peru's fishing sector, the EIPs and AMYGEs could be considered not only the most economically significant but also the most environmentally relevant, particularly the fishmeal and fish oil industries

[5] In 2026, a tax unit (UIT) was equivalent to USD 1500–1600 (DS N° 301-2025-EF)

Table 1. Enforcement records, fishing sector (March 2026)

	Fishing sector	National (*)
Auditable units	**423**	28,602
Auditable holders	**328**	17,658
Holders sanctioned at some point (+)	**296**	–
Audit Units with IGA	**411**	11,399
Third-party complaints	**229**	25,009
Supervisions executed (**)	**2,246**	28,225
Administrative measures (As) (**)	**25**	3,391
PAS initiated (***)	**1,064**	13,619
Confirmed fines (#UIT) (****)	**6,181**	375,663
Infractions sanctioned (+)	**3,360**	24,318
Total fines recorded (#UIT) (+)	**7,634**	431,576

(*) All OEFA-supervised sectors, such as hydrocarbons, Mining, Electricity, and others
(**) Supervision Phase (Direction of Supervision, DSAP)
(***) Auditing Phase, first-instance, starting a PAS or sanctioning process (Direction of Fiscalization, DFAI)
(****) Auditing outcome with or without a second-instance intervention (Environmental Fiscalization Court, TFA)
(+) Holders sanctioned, offenses, and fines recorded in the RUIAS platform from OEFA (until Nov. 2025)
Source: *PIFA platform (OEFA, n.d.-a); RUIAS platform (OEFA, n.d.-b)*

Table 2 restructures the 2022 OEFA quarterly data (OEFA, 2023), to trace the enforcement pipeline from supervisions through final decisions. Of 256 supervisions in the fishing sector, 248 reports were concluded, of which 147 recommended the beginning of a PAS, connected with detection probability (p). OEFA's first instance issued 9.28% and 9.82% of resolutions at the sub-directorial and directorial levels regarding potential infractions in the fishing sector. Notably, across all sectors, OEFA reported that 78% of PAS recommendations led to the beginning of a PAS for which administrative responsibility was present. Subsequently, holders in the fishing sector appealed 21% of the DFAI's PAS decisions (first-instance) as a defense strategy activation (θ). Across all OEFA-supervised sectors, 72.59% of first-instance decisions were confirmed, and 19.61% were revoked or nullified (second-instance) concerning a credibility gap (detection noise: procedural and false positives) (p').

Table 2. Enforcement pipeline outcomes, fishing sector, 2022 (selected)

Supervision phase: OEFA-DSAP (*p* stage)	Inspections conducted	Supervision actions	Reports concluded	Sector archived	Sector PAS recommendation	A(s) issued
	256	265	**248**	101	**147**	1
			average days to make a report	alleged offenses		average days to apply A(s)
				corrected	non-corrected	
			33	30	328	85
Auditable Phase (1st instance) – OEFA-DFAI/SFAI (*p* → *p'* trigger)			Sub-directorial resolutions (%total)	%archived (*)	%PAS beginning (*)	
			128 (9.28%)	22%	**78%**	
			Directorial resolutions (%total)	%archived (*)	% administrative responsibility (*)	%reconsider action(*)
			138 (9.82%)	7%	78%	15%
			UITs–sanction fines imposed	UITs–coercive fines imposed	A(s) - Corrective measure complied (% sector)	
			423.02	**130**	**4** (21%)	
Auditable Phase (2nd instance) – OEFA-TFA (*p'* stage)			DFAI resolutions appealed (% sector)	TFA resolutions (% total)		
			123 (**21**%)	**24** (4.27%)		
	Infractions sanctioned (*)	decision (*)				
		confirm	revoke	null	inadmissible	other
	1142	829 (**72.59**%)	126 (**11.03**%)	98 (**8.58**%)	52 (4.55%)	37 (3.24%)

(*) General across all sectors, not only fishing. Source: *IV trimester 2022 report (OEFA, 2023)*

Tables 1 and 2 are consistent with describing the necessity and implications of separating and tracking *p* and *p'*. From Table 2, we can infer that 19.61% of the revocation-nullification rate may represent false-positive detections and constitutes the empirical basis for the $p' < 1$ assumption in the model; the sector holders appealing to TFA (defense activation, θ) represent 21%.

A qualitative analysis (Jaramillo Abad & Uwasu, 2025) reports that firms attributed most non-compliance records to administrative formalities with limited direct environmental impact, or that activities from small-scale or informal investments showed weaker compliance performance, consistent with the second implication of the model. In Jaramillo Abad and Uwasu (2025), key stakeholders identified flaws in ex-ante and ex-post enforcement procedures, misaligned regulations, inefficient bureaucracy, political interference, and unplanned governance. They also noted implicit market incentives for compliance, labeled as Export-Driven Sustainability (EDS) which aligns with third implication of model on incentives.

This paper does not evaluate environmental impact. However, some findings and stylized facts require distinguishing between substantive environmental obligations, formalities, and processes. While

substantive AEOs are generally linked to environmental impact, this is not always the case, and formalities are usually considered to have no environmental effect. The aim is to develop a compelling model that can enhance governance sustainability, understood as the balance of interests between compliance and enforcement. Some fishing firms have voluntarily pursued sustainability and market condition improvements (Inurritegui B, 2015; SNP, n.d.; TASA, n.d.), while the state has implemented sanctions and incentives (Figure 2). Sanctions range from admonitions to fines, administrative measures, coercive fines, and other strategies for non-compliance or to prevent risks,[6] while honorific recognition or awards of up to a 100 UIT waiver-tradeable due to (over)compliance is also awarded.[7]

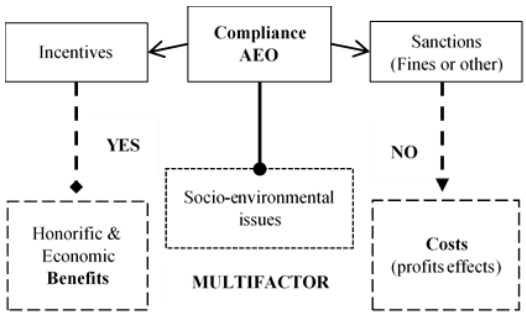

Figure 2. Peruvian environmental enforcement frame

Tables 1 and 2 motivate the joint framework: isolated efforts by key actors have not produced the desired governance outcomes. A 47% PAS initiation rate alongside a 19.61% credibility gap demonstrates that inspection frequency (p) and institutional confirmation quality (p') operate through structurally distinct deterrence channels.

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[6] RCD N°35-2013-OEFA/CD: (Former) Methodology for calculating base fines and aggravating and mitigating factors for graduating sanctions (Modified by RCD N°24-2017-OEFA/CD).
RCD N°45-2013-OEFA/CD: Define infractions and the scale of sanctions related to non-compliance with the Maximum Permissible Limits
RCD N°27-2017-OEFA/CD: Define regulations of the OEFA Administrative Sanctioning Procedure
RCD N°6-2018-OEFA/CD: Define administrative infractions and a scale of sanctions related to Environmental Management Instruments
RCD N°30-2022-OEFA/CD: Define infractions and a scale of sanctions applicable to large-scale fishing activities
RCD N°15-2024-OEFA/CD: Methodology for calculating the coercive fine at OEFA
RCD N°19-2025-OEFA/CD: Regulations for the Supervision, from OEFA
RCD N°23-2025-OEFA/CD: Regulations for granting the benefit of deferral and/or installment payment of fines imposed by OEFA
RCD N°5-2026-OEFA/CD: (New) Methodology for calculating base fines and graduating factors for sanctions

[7] Ministerial Resolution N°167-2014-MINAM: Incentive Regime in the field of Environmental Inspection
RCD N°34-2014-OEFA/CD: Regulations of the register of good environmental practices
RCD N°40-2014-OEFA/CD: Regulations for the incentive system in the area of oversight

4. Model

We start with a single-agent decision model (holder), including considerations of peer-agent (enforcer) influence. The holder's compliance decision is modeled as an expected-utility maximization problem. The variables and parameters are presented in Table 3 and the optimization in Appendix A.

$$\max_{e} \pi_i = \pi - \textbf{Full compliance cost}\,(e) + \textbf{Incentives to comply}\,(e) \qquad \textbf{(M-1)}$$

Holders' and authorities' elements and strategies interact cyclically, not linearly (Beunen *et al*., 2022). Enforcement elicits compliance responses and vice versa, namely the "stick and carrot" framework extended to include sustainable incentives alongside deterrence (Figures 2 and 3).

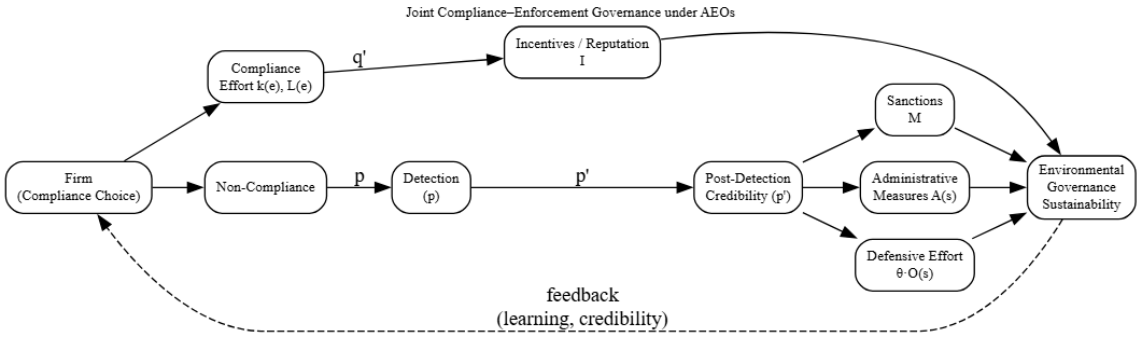

Figure 3. Compliance-Enforcement feedback

4.1. *Model setup*

Player. Firm i (holder); operating auditable units subject to AEOs, aware of OEFA's enforcement parameters (p, p', M, As, I^o) as exogenous institutional features, as given.

Endogenous choices. (a) Compliance effort $e \in \{\text{comply}, 0(\text{non} - \text{comply})\}$; (b) defensive effort $\theta \in [0,1]$, conditionally endogenous, assumed activated post-detection after PAS initiation.

Timing. Four stages: (1) Firm chooses e and production Q^* simultaneously. (2) Nature draws detection: probability p (supervision phase). (3) Conditional on detection, nature draws confirmation as probability p' (auditing phase). (4) Conditional on detection, the firm chooses θ.

Separability. The AEOs in the Peruvian fishing sector are primarily assumed as end-of-pipe abatement requirements (gas scrubbers, atmospheric filters, non-reusable wastewater treatment, monitoring

formalities) imposing additive costs without shifting the marginal cost of production. Therefore, profit-maximizing Q^* is determined by $R'(Q)=C'(Q)$ regardless of e.[8]

Defensive decision rule. At Stage 4, the firm chooses $\theta^* = 1$ (appeal, activating outsourcing cost Os) when the expected saving from a successful second instance of auditing phase reversal exceeds the consulting fee: $Os < (1 - p')(M + As)$. Otherwise, $\theta^* = 0$. This implies that θ^* depends on p', that is, higher institutional confirmation quality reduces the expected benefit of appealing and that large firms with in-house legal counsel face lower effective Os, making $\theta^* = 1$ more frequent for them. Firms that choose $\theta^* = 0$ and also fail to comply with formal sanctions may face coercive fines as an enforcement backstop.[9]

4.2. *Variable classification*

A two-level structure applies to p: OEFA's inspection intensity is exogenous. However, detectability is effort-contingent: $\frac{\partial p}{\partial e} < 0$ captures that a more compliant firm produces fewer violations for inspectors to find.[10] Similarly, OEFA's incentive-assignment rule is exogenous I^O, while the firm's qualifying probability $q'(e)$ is endogenous, increasing and concave in effort[11] (see the optimization and comparative statics in Appendix A).

Sanctions magnitude (M) and administrative measures A(s) are exogenous to the firm, yet holder effort e and institutional credibility p' can affect both. Resource-based sanctions such as administrative measures $A(s)$ may carry a stronger deterrent elasticity than pecuniary fines M alone (Becker, 1968; Earnhart, 2000; Vásquez Cordano & Gallardo Ku, 2006).

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[8] A subset of AEOs,—grease/oil recovery, stickwater evaporation in fishmeal factories—involves process-integrated abatement where compliance generates production input recovery (eco-efficiency exception, Inurritegui, 2015). However, this does not apply to other fishing activities, or if exists is not widely reported, so for simplicity, end-of-pipe separability is the general assumption in this paper.

[9] Coercive fines for non-compliance with administrative measures represent a fifth enforcement state (the firm ignores both M and As) not modeled in the main optimization but noted as an enforcement backstop that increases the effective cost of $\theta = 0$ with non-payment.

[10] The above condition might change in illegal or informal activities or in the absence of enforcer institutional factors or reputation (Earnhart, 2000; Gray & Shimshack, 2011; Shimshack & Ward, 2005, 2008).

[11] This two-level structure is standard in enforcement economics (Becker, 1968; Polinsky & Shavell, 2000) and allows comparative statics to capture both the exogenous environment and the firm's endogenous response.

Table 3. Variables and parameters

Variable	Role	Status	Justification	Remark
$e = ke + Le$	Primary firm choice	Endogenous	Firm allocates capital K and labor L; C(e) compliance effort	Extra rent-capital and wage labor toward AEO compliance (i.e., technologies or supplies to abate) or to do formalities.
θ	Defensive effort	Endogenous (conditional)	Activated post-detection	Strategic choice to appeal ($\theta = 1$) or waive ($\theta = 0$) based on comparison of *Os* vs. expected sanctions saving
Q*	Production quantity	Exogenous to *e*	End-of-pipe separability	
$\pi = R(Q*) - C(Q*)$	Baseline profit	Exogenous to e	Fixed given Q*	
p	Detection probability	Enforcer exogenous (intensity); endogenous (detectability)	Inspection intensity *p*; detectability effort-contingent *p(e)*	$\frac{\partial p}{\partial e} < 0$ in optimization, *p(e)*
p'	Post-detection confirmation	Exogenous authority capacities	Primarily set by state's institutional quality-capacity	Post-detection likelihood "effectiveness-credibility" (i.e., holding decision throughout auditing assessment).
q'(e)	Incentive qualifying probability	Endogenous to *e*, concave	OEFA rule exogenous I^O; yet *q'(e)* qualifying probability endogenous	Firm's likelihood of getting benefits not only from government I^O, but also from other market and non-market incentives portfolio
$S = M + As$	Formal sanction repercussions	Exogenous	Holder repercussions due to sanctions for non-compliance	Monetary fines (M) and administrative measures (As) as formal regulatory consequences amplified by *p'* (section 4.5)
M	Fine level	Exogenous	Determined by M = B + XpT (equation M-6). Pecuniary-based	Penalty (assumed more as a fine, yet not diminishing a potential reputation loss) as tangible and intangible punishment
A(s)	Administrative measures	Exogenous	Different (stronger) deterrence elasticity than *M*. Resource-based	Mandatory effort requested by the authority. Operational restrictions, equipment mandates, remediation orders
$\theta O(s)$	Defensive outsourcing cost	Exogenous (sanction value); endogenous (activation)	OEFA rule exogenous *O(s)*; yet decision of defensive effort θ endogenous	Technical-legal representation costs, incurred post-detection when the firm chooses to contest (θ=1); weighted by detection probability *p* alone, since the fee is at the appeal stage before the second instance of the auditing phase
I	Total sustainable incentive value	Exogenous (value); endogenous (probability)	Portfolio of returns, incentives, see section 4.7.	Incentive due to compliance or overcompliance. Tangible and intangible returns, with state and non-state origins

4.3. *Arrow-Pratt expected-utility extension*

Motivation. Under expected utility with a risk-averse holder, *p* and *p'* enter the variance of the loss distribution through structurally different expressions. The classical risk-neutral baseline treats both as interchangeable multipliers of the expected sanction; the Arrow-Pratt extension breaks this symmetry.

Four-state loss lottery. A non-complying holder faces four scenarios:

- *Not detected* (prob 1-p): profit π.
- *Detected, yet sanction not confirmed* (prob *p(1-p')*): profit $\pi - a$, where $a = \theta Os + \sigma_a$ (outsourcing costs incurred to appeal, which overturns the second instance decision + detection-induced reputational loss, i.e., RUIAS listing risk or third-party complaints).
- *Detected, confirmed, not appealed* (prob *pp'(1-σ)*): profit $\pi - b$, where $b = M + As + \sigma_b$ (full formal sanction + confirmation-induced reputational loss). Note: θ = 0 in this state, so *Os* is not incurred.
- *Detected, confirmed, and appealed to judiciary* (prob. *pp'σ*): profit $\pi - c$, where $c = M + As + Os_J + \sigma_b$(full formal sanctions + judicial defense fee + reputational loss).

Defining the weighted confirmed-state loss as $\bar{b} = (1 - \sigma)b + \sigma c$, we obtain a tractable three-state lottery with losses $\{0, a, \bar{b}\}$ at probabilities $\{1 - p, p(1 - p'), pp'\}$. Empirically, $\bar{b} \gg a$, meaning that confirmed fines could reach hundreds to thousands of UIT, while defense-only costs are modest relative to large firm capitalization. RUIAS (OEFA, n.d.-b) shows that accumulated confirmed fines for the fishing sector average 21.5 UIT (≈USD 32,250 at 1 UIT≈1,500-1,600), which are typically assumed to exceed defense-only costs. Consistent with the defense-only costs remaining well below confirmed-sanction magnitudes, the illustrative examples below (Section 4.3, Appendix A) adopt a = 2UIT as an assumed, not directly estimated, order of magnitude for legal and technical consulting fees at the appeal stage. This assumption may not always apply; for instance, when fines are too low (less than defense-only costs), the costs of appealing may exceed the fine itself, so θ = 0 would be the rational choice. θ = 1 applies to the main model.

Note that, in the four-state lottery, outsourcing cost θOs appears in state 2 (weighted by $p(1 - p')$) and judicial consulting Os_J in state 4 (weighted by *pp'σ*); neither receives the full *pp'* weighting of the formal sanction M + As – being a lottery-level basis separation.

The p and p' differentiation becomes significant under risk-aversion (uncertainty) considerations, expanding the probability of detection in Becker (1968) and subsequent studies. p' includes not only the quality of auditing phases but also the quality of inspection dragged.

Arrow-Pratt certainty equivalent. For a holder with utility $u(\cdot), u' > 0, u" < 0$, the Pratt (1964) local approximation gives:

$$CE_{NC} \approx \pi - E[L] - \frac{1}{2} r_A(\pi) Var(L)$$

where $r_A(\pi) = -\frac{u"(\pi)}{u'(\pi)}$ is the Arrow-Pratt coefficient of absolute risk aversion, $E[L] = p(1-p')a + pp'\bar{b} = p\left[a + p'(\bar{b} - a)\right]$, $E[L^2] = p\left[a^2 + p'(\bar{b}^2 - a^2)\right]$ and $Var(L) = E[L^2] - (E[L])^2$.

The *p* vs. *p'* asymmetry. Because *p'* enters the variance of the loss distribution through a structurally different expression than *p*, risk aversion amplifies compliance responses to *p'* reforms more than to equivalent *p* reforms, but only when the confirmation-driven variance effect exceeds the detection-driven variance effect, a regularity condition we verify directly against Peru's enforcement data in Appendix A:

$$\frac{\partial Var(L)}{\partial p'} = p(\bar{b} - a)\left[(\bar{b} + a) - 2p\left(a + p'(\bar{b} - a)\right)\right]$$

$$\frac{\partial Var(L)}{\partial p} = \left[a^2 + p'(\bar{b}^2 - a^2)\right] - 2p\left[a + p'(\bar{b} - a)\right]^2$$

These expressions are structurally different. For a risk-averse firm with $\bar{b} \gg a$, increasing *p'* concentrates probability mass on the high-loss confirmed-sanction state, $\bar{b}$, raising variance and the risk premium –and making non-compliance strictly worse in certainty-equivalent terms (Rothschild & Stiglitz, 1970).

$$\frac{\partial Var(L)}{\partial p'} > \frac{\partial Var(L)}{\partial p} \textbf{ (M-2)}$$

When the above condition holds, $\frac{\partial e^*}{\partial p'} > \frac{\partial e^*}{\partial p}$ for all risk aversion above a finite threshold $r_A * = 2 \mid \Delta_{mean} \mid \Delta_{var}$. When it fails, no finite r_A establishes the ranking through this channel and the risk-neutral information-theoretic channel below must carry the result. At Peru's current fishing-sector aggregate rates (*p= 0.47*, *p'=0.73*), we verify (Appendix A) that the condition fails for any defense-only cost below the confirmed-sanction average, $\bar{b} = 21.5$ UIT; the Arrow-Pratt channel is thus not currently active for Peru's sector-wide averages, and implication 1 rests on the risk-neutral channel described below.

Appendix A reports a stylized numerical illustration, calibrated to a lower-throughput enforcement regime, in which the regularity condition holds and the Arrow-Pratt threshold is explicit and low ($r_A * \approx 0.098$).

This asymmetry can hold not only under Arrow-Pratt for risk-averse holders (Pratt, 1964) but also under information-theoretic institutional forms (Maskin *et al*., 2000), for any utility function facing shocks.

Risk-neutral information-theoretic foundation. A result valid for any utility function, and the one that carries Implication 1 for Peru's current enforcement pipeline (Appendix A) follows from Maskin *et al*. (2000), in that any incentive scheme conditioned on a lower-quality performance signal can be dominated by a scheme using a higher-quality signal; confirmation reduces the false-positive detection rate from $\alpha_p \approx 19.61\%$ to approximately 0%, satisfying the Blackwell informativeness condition. Under this information-theoretic channel, $\frac{\partial e^*}{\partial p'} > \frac{\partial e^*}{\partial p}$ holds even for risk-neutral holders, and *p + p'* enforcement delivers 25.3% more net deterrence per unit sanction than p-only enforcement ($S \times 0.343\ vs. S \times 0.274$), requiring no assumption about risk aversion (Appendix A).

The two results are complementary: Arrow-Pratt shows risk aversion amplifies the information-theoretic weight advantage of *p'*, while Maskin *et al*. (2000) support that advantage even at a risk-neutral baseline; yet, we do not neglect exogenous factors such as wealth or market diversification as insurance or buffer.

Global Pratt intuition. Pratt (1964) proves globally that if firm A is more risk-averse firm than firm B for all π ($r_{A^A}(\pi) > r_{A^B}(\pi)$), then for any risky lottery, $CE_{NC^A} < CE_{NC^B}$. Risk-averse firms "overcomply" relative to risk-neutral predictions because they value a certain compliance payoff over uncertain sanction lottery; when the regularity condition holds, policy instruments that increase *p'* exploit this tendency more efficiently than fine increases or additional inspections. Risk-averse firms incur higher compliance costs to avoid the disutility of uncertain sanction outcomes, independently of expected-value deterrence. Compliance thus becomes not merely a cost-minimization response to expected fines, but a risk management strategy.

Firm-size heterogeneity. Under DARA, Arrow (1971), smaller, financially constrained holders (low π) are more likely to have risk aversion above $r_A(\pi)$; so, DARA-driven cross-firm heterogeneity prediction

(Implication 2) is sharpest where the regularity condition is satisfied (Section 4.9, Appendix A), consistent with the qualitative observations of size-related compliance differences in Peru (Jaramillo Abad & Uwasu, 2025). Even risk-neutral firms benefit from the *p'* advantage, based on the Maskin *et al*. (2000) information-theoretic channel.

Score function and governance multiplier. $\frac{\partial \mathrm{e}^*}{\partial \mathrm{I}} = \left(\frac{\partial q'}{\partial e}\right) \Big/ |\mathrm{SOC}|$ shows that the compliance effect of sustainable incentives *I* is proportional to the steepness of the qualifying probability function. Maskin *et al*. (2000) predict that this steepness is endogenous to information quality: as *p'* improves, the enforcer can set tighter incentive-assignment rules, producing a steeper $q'_{(e)}$ and a larger $\frac{\partial e^*}{\partial I}$:

$$\frac{\partial^2 \mathrm{e}^*}{\partial \mathrm{I}\, \partial \mathrm{p}'} > 0$$

Therefore, improving post-detection credibility amplifies both deterrence (*pp'S*) and incentive channel (*q'(e).I*).

4.4. *Risk-neutral baseline model*

From the enforcement literature (Becker, 1968; Polinsky & Shavell, 2000), the payoff functions separate the formal sanctions (weighted by *pp'*) from the defensive outsourcing cost (weighted by *p* alone):

$\pi^C = \pi - C_{(e)} + \mathrm{q'}_{(e)}.\mathrm{I}$ **(M-3)** where $C_{(e)} = \left[k_{(e)} + L_{(e)}\right]$ (M-3.1); $\mathrm{q'} = \Pr\left(\frac{\text{reward}}{\text{compliance}}\right)$ (M-3.2)

$\pi^{NC} = \pi - pp'S - p.\theta O_s$ **(M-4)** where $S = [M + As]$ (M-4.1)**;** $p = \Pr\left(\frac{\text{detection}}{\text{inspection}}\right)$ (M-4.2); $p' = \Pr\left(\frac{\text{confirmation}}{\text{detection}}\right)$ (M-4.3); $\theta O(s)$ = defensive cost strategic-efforts (M-4.4), sanction-defensive choice $\theta \in [0,1]$ (M-4.5).

4.5. *Compliance condition*

Firm *i* complies when $\boldsymbol{\pi^C \geq \pi^{NC}}$:

$$pp'.S + p.\theta O(s) + q'(e).I \geq C_e \quad \textbf{(M-5)}$$

Firm i complies when the sum of institutional-credibility-weighted formal sanctions, detection–contingent defensive costs, and sustainable incentives exceeds compliance costs.

This can be expanded:

$$pp'.M + pp'.A(s) + p.\theta O(s) + q'_{(e)}.\mathrm{I} \geq k_{(e)} + L_{(e)} \qquad \text{(M-5.1)}$$

Key inequalities:

$\frac{\partial e^*}{\partial p'} > \frac{\partial e^*}{\partial p}$ (M-5.2) [*p' drives compliance more than p*]

$\frac{\partial e^*}{\partial q'} \geq \frac{\partial e^*}{\partial p}$ (M-5.3) [qualifying probability at least as influential as detection,]

$\frac{\partial^2 \mathrm{e}^*}{\partial \mathrm{I}\,\partial \mathrm{p}'} > 0$ (M-5.4) [governance multiplier: *p'* amplifies compliance effect of *I*]

4.6. Fine formula and Institutional Amplification

Since 2013, OEFA has used a fine calculation methodology and, as of March 2026, it has begun applying a new one: local design assumes that the fine should exceed illicit benefit $\widehat{M} > B$ to deter non-compliance; so other factors are included besides the likelihood of being detected, *p*. Mixing their factors,[12] we obtain:

$$\widehat{M} = B + R \qquad \textbf{(M-6)}$$

where $\mathrm{R} = \mathrm{XpT}$, B = illicit benefit; X = damage/proportion allocation factor or nothing (based on information quality, and/or corrective measures conditions); T = aggravating/mitigating scale (summing factors); $\mathrm{R} = \mathrm{XpT}$ is the regulatory fine residual.

Compliance reduces B (eliminates illicit benefit) and improves T (mitigating factors), grounding the regularity condition from optimization (**A.1.4)** $\frac{\partial \mathrm{S}}{\partial \mathrm{e}} < 0$ – in the institutional framework**.**

Substituting:

$$p'B + p'R + p'A_{(s)} + p\theta O_{(s)} + q'_{(e)}\mathrm{I} \geq k_{(e)} + L_{(e)} \qquad \textbf{(M-7)}$$

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[12] RCD N°35-2013-OEFA/CD: (Former) Methodology for calculating base fines and aggravating and mitigating factors for graduating sanctions (Modified by RCD N°24-2017-OEFA/CD). Three ruling formulas are used to estimate the optimal fine in case of damage due to non-compliance. Rule 1, not enough information to value damage (economic calculation of damage); Rule 2, relevant information exists, and a corrective measure was issued; and Rule 3, relevant information exists, and no corrective measure was issued
RCD N°5-2026-OEFA/CD: (New) Methodology for calculating base fines and graduating factors for sanctions.
The former rules were restructured as Rule 1 on whether the non-compliance is due to formalities or does not generate environmental impact; Rule 2 when the non-compliance generates negative environmental impact; in Rule 3, the impact is significant and there is enough information to make economic valuation
There are other government regulations for estimating the coercive fines due to non-compliance of AM and for assigning enforcer incentives (economic and non-economic); however, we assume in this local scenario that the fine is the main deterrence effect strategy.

Equation (M-7) shows that *p'* multiplicatively amplifies the formal sanction components, namely illicit benefit recovery (*p'B*), residual regulatory fine (*p'R*), administrative measures (*p'A(s)*). By contrast, the defensive outsourcing cost (*p.θO(s)*) is weighted by detection probability *p* alone, correctly reflecting that consulting fees are committed at Stage 4 (post-detection, before TFA confirms) and are thus not amplified by institutional confirmation quality. This separation reinforces the core policy argument: the *p'* reform raises the deterrent value of every formal enforcement action, while the appeal subsystem (*θ, Os*) responds to detection and sanction structure independently.

4.7. Sustainable incentives: Portfolio and scope

Most enforcement models assess agent incentives solely through the "illicit benefit" B conception (i.e., illicit income, cost avoidance, and deferral). We complement this with a new paradigm of positive sustainable incentives *(I)*: returns not for offending (non-compliance), but for abiding (compliance and over-compliance).

Sustainable incentives encompass returns and other integrative business values that drive competitive advantage (Donaldson & Preston, 1995; Porter & Linde, 1995). They come from the government, society, or market, being tangible (e.g., extra income) or intangible (e.g., a gain in value). This may align with creating a new business value model under a 3C framework, such as CRS or ESG.

$$I = I^O + I^M + I^R + I^P \quad \textbf{(M-8)}$$

- I^O = OEFA-administered incentives (tax waivers, honorific recognition, certified-complier status). Currently, in Peru, tax-and-honorific incentive framework have apparently been discontinued, yet regulation remains in effect –for background knowledge see a prior publication (OEFA, 2016) – representing a policy gap.
- I^M = the market incentive, coined as export-driven sustainability (EDS) (Jaramillo Abad & Uwasu, 2025), arises when firms pursuing export-market access simultaneously achieve environmental

compliance as part of quality-seeking behavior, offering greater chances to enhance revenues in terms of price and/or quantity, diversifying their market.[13]

- I^R = reputational incentive (social prestige, trusted-entity classification, insurance benefits, supply-chain integration) – non-financial value returns.
- I^P = production efficiency gains from eco-efficiency, either revenue-driven or cost-minimization-driven (with implications for input-output conversion rates, cost structure, and technology implications)[14]. A compelling example: raw material waste in Peruvian fishmeal and fish oil production decreased from 36% in 1961 to approximately 0.1% today through process-integrated abatement technologies (Inurritegui, 2015), improving conversion rate, making compliance a win-win strategy where environmental performance and production efficiency converge.

Civil society and the incentive portfolio. Civil society actors enter the model through the I^R and I^M channels: reputational returns are partly driven by media, NGOs, and voice-accountability scrutiny, while EDS reflects the ESG-conscious buyer demand.

Compliance payoff. Sustainable incentive I returns are weighted by qualifying probability $q'_{(e)}$, being increasing and concave in effort. Even if I^O (OEFA incentives)[15] continue as discontinued, $I^M + I^P$ can continue operating through the market and civil society channels. Incentive design must avoid moral hazards (Xepapadeas, 1991): non-pecuniary incentives such as I^R through honorific recognition, and market-access sustainable support incentives linked to I^M or certification requirements carry lower moral hazard risk (i.e., perverse incentive) than pure pecuniary waivers because they require demonstrated compliance or multi-audit rather than threshold-meeting.

[13] I^M assumptions apply to both process-integrated abatement and end-of-pipe abatement activities, as this market incentive may be endogenous to market conditions, buyers' expectations, and CSR and ESG paradigms; some countries or regions respond differently to compliance performance of exporters (firms).

[14] As noted by Inurritegui (2015), and Jaramillo Abad and Uwasu (2025), the yield ratio in fishmeal-and -oil production aligns with environmental compliance through new technologies, either requested by authorities or initiated by the proper holder.

[15] OEFA (2016) underscored that Peru was almost a pioneer worldwide or unique in granting a type of incentives I^O (tax waivers and tradable ones). Perhaps the reason for that "uniqueness" was that other nations were aware of potential moral hazards (Xepapadeas, 1991), a fact also noted in the qualitative analysis (Jaramillo Abad & Uwasu, 2025). However, we do not believe that all incentive frameworks are morally hazardous, or at least not those that are aware of and include human socio-cultural factors in policy design.

Assumption (qualifying probability and institutional quality). We assume that q' (e, p') is increasing in both e and p'; formally, $\frac{\partial q'}{\partial p'} > 0$ and $\frac{\partial^2 q'}{\partial e \partial p'} > 0$. This holds when the enforcer can set tighter incentive-assignment criteria as p' improves, more accurately rewarding genuine compliance. The mechanism is that as p' rises, the false-positive awards qualifications rate falls, reducing signal variance; the signal chain under the informative-institutional shape channel (Maskin *et al*., 2000) regarding incentive awards due to shock responses supports a more responsive assignment rule (steepens), same as the conditional-variance logic used in section 4.7.

Grounded portfolio ranking. The moral hazard risk of any incentive scheme (Xepapadeas, 1991) decreases with the conditional variance of the signal on which it is conditioned (Maskin *et al*., 2000). Signals that are harder to game because they are multi-sourced or independently verified or delivered have lower conditional variance and produce both steeper $q'_{(e)}$ functions and less gaming risk.

Ranked from the lowest to the highest *incentive power per unit* of *I*: I^O (OEFA administrative record – highest conditional variance, most gameable) $< I^M$ (EDS: export buyer certification requirements – intermediate) $< I^R$(reputation: multisource, hard to fake) $< I^P$(production eco-efficiency – self-revealing through cost structure).

From M-5.4, as p' (proxied as institutionality or credibility framework) improves, the assignment signal for I^O becomes less gameable (reduction of gaming opportunities), progressively and potentially shifting I^O's effective position in ranking toward I^M.

Incentive productivity-based I^P is an endogenous firm choice, mostly pursued to enhance the yield ratio, subject to technological constraints. It is unaffected by enforcer and civil society scrutiny or expectations.

EDS as yardstick competition. Export-driven sustainability I^M constitutes a form of yardstick competition as per Maskin *et al*. (2000). Export destinations may have different preferences. Competing exporters supplying the same destination markets face common CSR or ESG and quality standard expectations; their relative compliance performance is compared by buyers, certifiers, and civil society actors. This spatial comparison across firms in the same market reduces noise in the compliance

performance signal, as Maskin *et al*. (2000) regional comparison reduces noise in manager performance signals – reinforcing why I^M is both empirically observable and theoretically sound.

This EDS condition is an essential assumption for further robust empirical analysis (see Section 6, Appendix B).

4.8. Model novelty

The model contributes to the literature as follows:

(1) The formal separation[16] of p from p' with Arrow-Pratt derivation shows they enter compliance via structurally different variance pathways, complemented by Maskin *et al*. (2000) risk-neutral foundation when confirmation reduces conditional variance;

(2) Four-state loss lottery incorporating reputational losses σ_a, σ_b and judicial-appeal costs c, thus making the p and p' distinction and interaction tractable from a firm-perspective;

(3) DARA firm-size heterogeneity as a new testable cross-firm prediction;

(4) Sustainable incentives portfolio $I = I^O + I^M + I^R + I^P$ as a positive integral payoff with a moral hazard and conditional variance ranking, grounded in Maskin *et al*. (2000): $I^P > I^R > I^M > I^O$ by incentive power per unit;

(5) Defensive strategy $\theta O_{(s)}$ as a conditionally endogenous post-detection choice; and

(6) The governance multiplier result ($\frac{\partial^2 \mathrm{e}^*}{\partial \mathrm{l}\, \partial \mathrm{p}'} > 0$, M-5.4) showing that improving institutional quality p' simultaneously amplifies both the deterrence channel ($pp'S$) and incentive one ($q'_{(e)}.I$), as a structural result unavailable in single-channel models.

4.9. Testable implications

Three implications constitute the paper's core contribution to the empirical literature, as highlighted in Section 6 and Appendix B.

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[16] Studies, such as Becker (1968) and Vásquez Cordano and Gallardo Ku (2006), noted differences between detection in the supervision and punishment phases (prosecution, judgment, or penalty), but mostly assumed a single probability, or did not go deep into their analyses.

Implication 1. Post-detection credibility *p'* drives compliance more than inspection rate p.

$\frac{\partial e^*}{\partial p'} > \frac{\partial e^*}{\partial p}$ whenever $r_A(\pi) > 0$ and $\bar{b} > a$ –from Section 4.3, whenever the regularity condition holds; this is satisfied in lower-throughput enforcement regimes but not for Peru's current sector-wide averages, where the risk-neutral channel carries the result instead.

Policy: Enforcement reform should prioritize institutional quality (TFA/DFAI) over inspection intensity (DSAP). A 47% non-compliance rate for 2,246 inspections is consistent with moderate *p* but weak *p'*.

Test: Compare compliance rates across firms with high vs low historical TFA/DFAI confirmation ratios, holding DSAP inspection intensity constant. Panel fixed effects absorb time-invariant firm heterogeneity.

Falsification. Part A (Arrow-Pratt mechanism): If firm-level risk proxies (leverage ratio, ownership concentration, financial constraints) show no relationship to the magnitude of the *p'-over-p* differential response (e.g., the differential is uniform across the firms regardless of risk exposure) $r_A(\pi) \approx 0$ (risk-neutral behavior at the relevant margin) or $\bar{b} \approx a$ (collapsing the extended loss lottery). Either finding questions the Arrow-Pratt extension and reverts the analysis to the risk-neutral baseline.

Falsification. Part B (UAI contextual – cross-country future test): If *p'-over-p* asymmetry is no larger in Peru than in low-UAI economies. This raises the question of whether Hofstede's national UAI score (Hofstede *et al*., 2010) translates to firm-level risk aversion in enforcement contexts. Part B is outside the scope of this study but can be used for a future comparative-institutional extension because it requires cross-country panel data not available here.

Implication 2. Risk aversion amplifies the *p'* > *p* asymmetry; Peru's high uncertainty avoidance context and smaller firms magnify this issue (firm size matters).

$\left|\frac{\partial CE_{NC}}{\partial p'}\right| > \left|\frac{\partial CE_{NC}}{\partial p}\right|$, increasing in $r_A(\pi)$ and $(\bar{b} - a)$ is active only where the regularity condition holds (Section 4.3), not at Peru's current sector-wide averages.

Policy: In high-UAI contexts (Hofstede *et al*., 2010) (translated to firm behavior), credibility reforms to *p'* yield larger compliance gains per enforcement investment than fine increases. Enforcement design should

differentiate by firm size, while smaller holders (but formal) respond more strongly to *p'* reforms. For Peru, Vásquez Cordano and Gallardo Ku (2006) suggest that oversight measures could have a large initial impact (e.g., routine inspection intensity for *p*), but lose effectiveness over time as holders adapt. This is consistent with sustained *p'* effectiveness or superiority under the Arrow-Pratt mechanism.

Test: Cross-firm variation in risk proxies (leverage ratio, annual revenues, firm age) should predict differential responsiveness to *p* vs. *p'* shocks. Smaller firms show stronger *p'* > *p* compliance responses.

Falsification. Part A (Arrow-Pratt mechanism): If firm risk proxies show no relationship to the p'/p differential magnitude, it suggests $r_A(\pi) \approx 0$ uniformly across firms (inconsistent with DARA) or $\bar{b} \approx a$. Either finding would question the Arrow-Pratt extension.

Falsification. Part B (Hofstede UAI contextual): If the p' > p asymmetry is not larger in Peru than in low-UAI economies, this would question whether Hofstede's national UAI score translates to firm-level risk aversion, without refuting Part A.

Implication 3. Sustainable incentives *I* complement sanctions *S* in promoting compliance.

$\frac{\partial e^*}{\partial I} > 0$ for all $q' > 0$ (Appendix A, CSI 3)

Policy: Reinstate OEFA's incentive scheme (I^O) with moral-hazard safeguards (Xepapadeas, 1991) or pursue lower moral-hazard alternatives: reputational recognition I^R carries less risk. The government can leverage EDS (I^M) by facilitating export-market certification requirements that simultaneously reward compliance. The interaction term ($I^M \times p'$) should be positive, consistent with the governance multiplier (M-5.4) and Maskin *et al*.'s (2000) steepness results: the compliance effect of sustainable incentives under a higher *p'* (institutional credibility or confirmation rates).

Test: The marginal effect of compliance history on export revenue or market diversification as proxies for I^M firms in high-ESG-requirement markets should show a higher *q'* and I^M and lower violation rates to AEOs.

Falsification. Part A: If $\frac{\partial e^*}{\partial I} \approx 0$, compliance probability is unresponsive to incentive variation, meaning a deterrence-only model is adequate.

Falsification. Part B: If the compliance-incentive association disappears after controlling for firm size and production volume, EDS may reflect a firm-capability rather than a genuine incentive mechanism.

5. Disclosing the Model

Several non-intuitive analytical patterns emerge. **Detection probability *p*** appears in the compliance condition in two distinct ways: as the precondition for post-detection amplification (*pp'S*, equation M-5), and in the fine formula $R = XpT$ (equation M-6). Raising *p* increases both the probability of encountering a confirmed sanction and the sanction magnitude itself. **Increasing *p'* amplifies a sanction** whose magnitude already reflects *p*, through a variance channel rather than a mean channel, which is a structurally different effect that the risk-neutral model cannot distinguish. For a regulator investing in *p* when *p'* is the binding constraint, the enforcement budget may be spent without improving compliance outcomes.

The governance multiplier: As *p'* improves, both the *pp'S* and *q'(e).I* channels become more effective simultaneously (equation M-5.4). The deterrence channel strengthens because *pp'S* is larger. The incentive channel strengthens because OEFA can set tighter assignment rules (lower false-award rates), thus producing steeper *q'(e)* and a larger $\frac{\partial e^*}{\partial I}$ (Appendix A). The two channels are complements under information improvement. A regulator considering only the deterrence argument for *p'* reform understates the return on institutional quality investment by roughly a factor of two.

Tracking the ratio between *p* and *p'* at the individual case-resolution level, from inspection to final TFA decision, could identify critical bottlenecks in enforcement efficiency. Currently, Tables 1 and 2 provide aggregate indicators but not a firm-year-specific *p/p'* ratio; this granularity is among the goals of the companion panel study. The deterrence analysis is incomplete if it relies solely on *p*, but can be enriched by including *p'*, which is particularly important for deterring recidivism of offenses (OEFA, n.d.-b).

Reputational losses $\sigma_a \; and \; \sigma_b$ in the extended lottery have policy implications beyond the formal sanction mechanism: detection alone (e.g., RUIAS listing risk) imposes a deterrence cost through σ_a, independently of whether the PAS results in a confirmed sanction. Improving the informativeness and accessibility of RUIAS data by making reputational consequences more visible and rapid is a low-cost intervention that increases both $\sigma_a \; and \; \sigma_b$ without requiring additional inspections (Karpoff *et al*., 2005).

6. Further empirical research agenda

A future study will test the implications using OEFA disaggregated panel data (2018–2026) linked to firms' export records. Key questions include (i) the differential effects of p' and p on compliance, (ii) how revenues (profits) respond to compliance efforts and sanction repercussions, and (iii) the marginal effect of sustainable incentives I on compliance.

Trade performance might be endogenous to compliance-enforcement performance (Bastidas *et al*., 2025) requiring a panel approach with multivariate methods, control variables, instrumental variables, and fixed effects. See Appendix B for the projected empirical design.

7. Conclusions

Governance is sustainable through the cooperation between compliant firms and effective enforcement authorities. With aligned interests and institutionalism seeking social welfare, the system moves toward a better equilibrium. Conversely, without real commitment and credibility from both sides, issues persist, and the system risks collapse. Civil society channels can serve as important sustainability anchors.

The deterrence effect should not be restricted to the detection probability but also to what happens after detection, such as post-detection credibility, p', which might entail institutional frameworks and others.

The key theoretical result, $\frac{\partial e^*}{\partial p'} > \frac{\partial e^*}{\partial p}$, derived under the Arrow-Pratt global risk aversion and risk-neutral being confirmed, redirects enforcement investment toward institutional quality (p': confirmation credibility) rather than inspection frequency (p: associated with probability of detection).

Risk-averse firms "overcomply" relative to risk-neutral predictions because they value the deterministic compliance payoff over the uncertain non-compliance lottery (sanction tangible and intangible); policy instruments that increase *p'* exploit this tendency more efficiently. Under DARA, smaller firms show the strongest differential response. However, even risk-neutral firms benefit from the *p'* advantage through the information-theoretic channel.

Sustainable incentives *I*, comprising OEFA-administered awards (I^O), export-driven sustainability (I^M) through market channels, reputational returns (I^R), and eco-efficiency gains (I^P), constitute a positive integral compliance payoff complementary to deterrence. Their re-integration into enforcement strategy should proceed with moral-hazard-aware design and the recognition of the EDS mechanism. Beyond typical financial returns, holders may recognize a potential mix of financial and non-financial returns arising from their compliance performance. This is a driver of competitive advantage.

8. Policy implications

Strengthen *p'*, not just *p*. Reforming institutional quality—confirmation-rate consistency, TFA independence, reduction of amendment rates—yields larger compliance gains per enforcement investment than scaling inspections alone. Perhaps, OEFA's PIFA/RUIAS or an integral platform should compute p/p' ratios at the firm-infraction-resolution level to monitor institutional effectiveness.

Differentiate enforcement by firm size. Under DARA, smaller, financially constrained holders respond more strongly to *p'*reforms. Enforcement design should make a difference in *p'* investment in contexts with high proportions of small-scale operators. However, this might not apply equally to informal investments.

Reinstate and redesign the sustainable incentive framework. OEFA's discontinued incentive scheme should be reconsidered with emphasis on non-pecuniary incentives I^R (honorific recognition, certified-complier status) and market-access linkages I^M via export certification facilitation. The portfolio ranking—$I^P > I^R > I^M > I^O$—should guide design priorities, yet always holding moral hazard safeguards.

Invest in RUIAS or other informativeness platforms. Faster, more accessible public listing of confirmed violators increases reputational deterrence costs σ_b and strengthens deterrence without large additional

inspection resources. However, platforms recognizing compliant and over-compliant performers amplify non-pecuniary incentives I^R, yet with potentially different elasticity than financial incentives.

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Appendix

Appendix A. Optimality Demonstration

Maximization problem

The permit holder chooses compliance effort e to maximize the expected net payoff:

$$\max_{e} \pi_i(e) = \pi - C(e) + q'(e)I(e) - p(e)p'S(e) - p(e)\theta O_s \qquad \text{(A.1)}$$

where

- $C(e)$ denotes the cost of compliance effort,
- $q'(e)$ is the probability of obtaining sustainable incentives,
- $I(e)$ is the value of sustainable incentives,
- $p(e)$ is the effort-contingent probability that non-compliance is detected ($p_e < 0$),
- p' is the institutional confirmation probability,
- $S(e)$ is the expected sanction,
- O denotes the opportunity cost to face regulatory intervention, and
- $\theta \in [0, 1]$ scales the opportunity-cost burden.

The first three terms in (A.1) capture the private benefits of compliance, whereas the last two represent expected regulatory losses.

We make the following assumptions to guarantee an interior solution:

- **Compliance cost:** $C_e > 0,\ C_{ee} > 0$ (A.1.1)
- **Sustainable incentive probability:** $q'_e > 0,\ q'_{ee} < 0$ (A.1.2)
- **Effort-contingent detectability:** $p_e < 0,\ p_{ee} > 0$ (A.1.3)
- **Sanction repercussions:** $S_e < 0.$ (A.1.4).

Now, we derive the first-order necessary conditions. Differentiating (A.1) with respect to effort yields:

$$\frac{\partial \pi_i}{\partial e} = -C_e + q'_e I + q' I_e - p'[p_e S + pS_e] - \theta O_s . p_e = 0 \qquad \text{(A.2)}$$

Rearranging this yields:

$$C_e = \underbrace{q'_e I + q' I_e}_{\text{Marginal reward benefit}} - \underbrace{p'[p_e S + pS_e]}_{\text{Marginal sanction-reduction benefit}} + \underbrace{(-\theta O_s . p_e)}_{\text{Marginal defense-cost reduction}} \qquad \text{(A.2.1)}$$

(For compliance) (Sustainable incentives) (Sanction schemes scenarios) (Appealing strategy)

Equation (A.2.1) states that optimal compliance effort is achieved when marginal compliance costs equal the combined marginal benefits from sustainable incentives and reduced expected sanctions.

Then, the second-order condition is:

$$\frac{\partial^2 \pi_i}{\partial e^2} = -C_{ee} + q'_{ee} I + 2q'_e I_e + q' I_{ee} - p'[p_{ee} S + 2p_e S_e + pS_{ee}] - \theta O_s . p_{ee} < 0. \qquad \text{(A.2.2)}$$

Under assumptions (A.1.1)–(A.1.4), the objective function is strictly concave, thus ensuring a unique interior optimum e^*. Now, we define:

$$F(e, \alpha) = -C_e + q'_e I + q' I_e - p'[p_e S + pS_e] - \theta O_s . p_e,$$

where α is any exogenous parameter. The optimal effort satisfies $F(e^*, \alpha) = 0$. Therefore, applying the implicit function theorem yields:

$$\frac{\partial e^*}{\partial \alpha} = -\frac{F_\alpha}{F_e}. \qquad \text{(A. 2.3)}$$

As $F_e < 0$ by the second-order condition, the sign is determined solely by F_α.

Comparative Statics Implications (CSI) via the implicit function theorem

Here, we present comparative statics to see how the changes in exogenous parameters affect the optimal value of the optimal effort level, e.

CSI 1: An increase in institutional confirmation probability raises optimal compliance effort:

$$\frac{\partial e^*}{\partial p'} = -\frac{F_{p'}}{F_e}, \qquad \text{(A.4)}$$

where $F_{p'} = -[p_e S + pS_e]$. As $p_e < 0$, and $S_e < 0$, both components are positive after the leading minus sign, implying $F_{p'} > 0$. Because $F_e < 0$, it follows that:

$$\frac{\partial e^*}{\partial p'} > 0.$$

The result implies that strengthening institutional credibility increases the equilibrium compliance effort.

CSI 2: Suppose sanctions depend on monetary fines M, so that $S = S(M)$. Then,

$$\frac{\partial e^*}{\partial M} = -\frac{F_M}{F_e}, \qquad \text{(A.5)}$$

where $F_M = -p' p_e S_M$. As $S_M > 0$, and $p_e < 0$, we obtain $F_M > 0$, and thus:

$$\frac{\partial e^*}{\partial M} > 0.$$

Higher sanctions increase the optimal compliance effort analogously for administrative measures, yet with different elasticity.

CSI 3: Differentiating with respect to incentive value,

$$\frac{\partial e^*}{\partial I} = -\frac{F_I}{F_e}, \qquad \text{(A.6)}$$

where $F_I = q'_e > 0$. Hence,

$$\frac{\partial e^*}{\partial I} > 0.$$

Larger sustainable incentive payments increase the equilibrium compliance effort.

CSI 4 (Conditional): Defensive outsourcing costs raise compliance effort for appealing firms,

$$\frac{\partial e^*}{\partial Os} = -\frac{F_{Os}}{F_e}, \qquad \text{(A.7)}$$

where $F_{Os} = -\theta . \frac{\partial p}{\partial e}$

As $\frac{\partial p}{\partial e} < 0$ $(A.1.3)$, $F_{Os} = -\theta . \frac{\partial p}{\partial e} \geq 0$, with $F_{Os} > 0$ exactly when $\theta^* = 1$ (Stage-4 appeal is activated) and $F_{Os} = 0$ when $\theta^* = 0$.

Because $F_e < 0$ (second-order condition), it follows that:

$$\frac{\partial e^*}{\partial Os} \geq 0.$$

With the strict inequality holding exactly in the appeal-active regime:

$$\frac{\partial e^*}{\partial Os} > 0.$$

Raising the cost of mounting a legal defense makes appeal less attractive relative to compliance; firms for which $\theta^* = 1$ respond by increasing the compliance effort. This result is conditional on the Stage-4 decision rule ($Os < (1 - p')(M + As)$, Section 4.1): as *p'* increases, that threshold falls, narrowing the population of firms for which this *Os* channel is active; as such, *p'* raises effort directly (CSI 1) and, at the margin, shrinks the set of firms for which CSI 4 applies.

Arrow-Pratt note: We show how a permit holder's risk aversion, measured by the Arrow-Pratt coefficient of absolute risk aversion, affects their compliance response to different types of regulatory reforms.

Let the representative permit holder exhibit constant absolute risk aversion,

$$r_A(\pi) = -\frac{U''(\pi)}{U'(\pi)} > 0.$$

Higher institutional confirmation probability (p') reduces the uncertainty regarding enforcement outcomes, while increases in fines (M), administrative sanctions (A_s), or inspection intensity (p) primarily change the magnitude of the penalties conditional on detection. As a result,

$$\left|\frac{\partial CE_{NC}}{\partial p'}\right| > \left|\frac{\partial CE_{NC}}{\partial p}\right|,$$

with the difference increasing in the Arrow–Pratt coefficient of absolute risk aversion,

$$\frac{\partial}{\partial r_A}\left(\left|\frac{\partial CE_{NC}}{\partial p'}\right| - \left|\frac{\partial CE_{NC}}{\partial p}\right|\right) > 0. \qquad \text{(A.7)}$$

That is, more risk-averse permit holders respond more strongly to reforms that enhance institutional credibility than to equivalent increases in fines, administrative sanctions, or inspection intensity because credibility reduces both expected losses and uncertainty surrounding enforcement outcomes.

Under risk aversion $\left|\frac{\partial CE_{NC}}{\partial p'}\right| > \left|\frac{\partial CE_{NC}}{\partial p}\right|$, increasing in $r_A(\pi)$. Risk aversion reinforces the compliance response to p' reforms relative to *M*, *As,* or *p* reforms.

Net deterrence gain (p + p' vs. p-only). Define net deterrence as D = S × (detection-weighted probability minus false-positive rate). Under p-only enforcement, D(p-only) = S(p - α_p); under p + p' enforcement,

D(p + p') = S(pp'- $\alpha_{pp'}$), where $\alpha_{pp'} \approx 0$ once confirmation eliminates false positives (Section 4.3). D(p + p') > D(p-only) whenever p'>1 - $\alpha_{p/p}$. At Peru's rates (p = 0.47, α_p = 19.61%; Table 2): 1 - 0.196/0.47 = 0.583 < 0.73, so the condition holds. Numerically: D(p-only) = S(0.47 - 0.196) = 0.274S and D(p + p') = S(0.343 - 0) = 0.343S, namely the 25.3% gain cited in Section 4.3. This holds for any risk preference and requires no assumption about risk aversion.

Peru verification. At the sector-wide aggregate rates (p = 0.47, p' = 0.73; Tables 1 and 2) with a = 2 UIT and $\bar{b} = 21.5$ UIT: $\frac{\partial \mathrm{Var(L)}}{\partial \mathrm{p}'} = 75.51$ and $\frac{\partial \mathrm{Var(L)}}{\partial \mathrm{p}} = 90.76$, so the regularity condition fails; the confirmation-driven variance effect is smaller than the detection-driven one. The Arrow-Pratt channel is thus not active for Peru's current sector-wide averages, and Implication 1 for Peru rests on the risk-neutral channel (Section 4.3). For comparison, in a stylized lower-throughput regime (p = 0.20, p' = 0.15, same a and $\bar{b}$), the condition holds ($\frac{\partial \mathrm{Var(L)}}{\partial \mathrm{p}'} = 83.97 > \frac{\partial \mathrm{Var(L)}}{\partial \mathrm{p}} = 63.04$) with a low activation threshold $r_A * \approx 0.098$ – illustrating that the Arrow-Pratt channel is most relevant in earlier-stage or lower-throughput enforcement pipelines.

Appendix B. Empirical Design for Further Robust Empirical Analysis (section M-7**)**

Structural Form (Derived from Equations M-3, M-4, and M-5)

The theoretical model predicts that a firm complies with its AEO enforced by OEFA when the expected benefit from compliance exceeds the expected cost of non-compliance. Accordingly, the compliance decision is represented as:

$$\Pr(\mathrm{Com}_i = 1) = \Pr(q'(e_i)I_i \geq C(e_i) + p(e_i)p'S_i), \qquad \text{(B-1)}$$

where $q'(e_i)I_i$ denotes the expected gain from sustainable incentive portfolio payoff through compliance, including but not limited to the market access represented in I^M; $C(e_i)$ is the cost of compliance effort, and $p(e_i)p'S_i$represents the expected environmental sanction from non-compliance with AEOs, weighted by its probabilities of detection and post-detection outcome.

Conditional on non-compliance, the realized monetary sanction or penalty is determined by:

$$\log(\mathrm{Fine}_i) = f(p_i, p_i', M_i, A_{s,i}, \theta O_{s,i}) \text{ for non-complying firms,} \qquad \text{(B-2)}$$

where M_i captures the fine level determined by OEFA (financial-based) as an institutional variable, $A_{s,i}$ denotes the sanction as an administrative measure type and its repercussions (resource-based), while $\theta O_{s,i}$ represents the organizational or reputational cost associated with enforcement and firm outsourcing efforts needed to reduce or avoid the sanction.

Reduced-form panel specifications: (firm i, year t)

To examine the theoretical predictions empirically, the following panel regressions are estimated.

Compliance equation

$$\text{Com}_{it} = \alpha_0 + \alpha_1 \text{Export}_{it} + \alpha_2 p_{it} + \alpha_3 p'_{it} + \gamma X_{it} + f_i + \tau_t + \varepsilon_{it}, \qquad \text{(B-3)}$$

where $\text{Com}_{it}$is a binary indicator equal to 1 if firm $i$complies with its AEOs (i.e., has no active PAS from OEFA in year t). Equation (B-3) may be estimated using either a linear probability model with fixed effects or a conditional fixed-effects logit specification.

Sanction equation

$$\log(\text{Fine}_{it}) = \beta_0 + \beta_1 \text{Export}_{it} + \beta_2 p_{it} + \beta_3 p'_{it} + \delta X_{it} + f_i + \tau_t + \varepsilon_{it}, \qquad \text{(B-4)}$$

where the dependent variable is the logarithm of the monetary fine imposed on non-complying firms.

Variable Definitions

- Export_{it}: export revenue, serving as a proxy for the market-access benefit (I_{it}^M) and firm profitability.
- p_{it}: probability of infraction detection, capturing the intensity of OEFA supervision (DSAP).
- p'_{it}: probability of post-detection sanction confirmation through OEFA's first/second-instance review (DFAI/TFA).
- X_{it}: vector of control variables, including firm size, revenues, volume exported, share exported, investment, firm age, geographic location, labor productivity, AEO type, certification status and type, customs office of origin, number and type of inspections, sanction type, frequency, and monetary amount, infraction type and frequency.
- f_i: firm fixed effects controlling for time-invariant unobserved heterogeneity.
- τ_t: year fixed effects capturing macroeconomic conditions and regulatory changes.
- ε_{it}: idiosyncratic error term.

Note. (i) Potential instrumental variable: the destination country regulatory changes (Bartik shift-share) to tackle export endogeneity. (ii) Including an interaction term $I_{it}^M \times p_{it}^*$ to test the governance multiplier (equation M-5.4), the Implication 1 test: $H_0: \alpha_3 \leq \alpha_2 vs. \alpha_3 > \alpha_2$.

Appendix C. Complementary Context Information

Table 4. Governance frameworks: Brief survey

Framework	Representative literature*	Assumptions
Agency	Jensen and Meckling (1976); Fama (1980)	Agents act in self-interest; principals must monitor.
Stewardship	Donaldson and Davis (1991); Chrisman (2019)	Managers act motivated by trust, duty, and collective goals.
Stakeholder	Freeman *et al*. (1984, 2010); Donaldson and Preston (1995)	Firms accountable to multiple stakeholders, not just shareholders.
Resource Dependence	Pfeffer and Salancik (1978, 2006); Hillman *et al*. (2009)	External resources influence; governance manages these dependencies.
Institutional	DiMaggio and Powell (1983); Zucker (1987); North (1990)	Norms, rules, and cultural and cognitive pressures shape governance.
Network / Collaborative	Rhodes (1996); Newman *et al*. (2004); Ansell and Gash (2008)	Inter-organizational networks, non-hierarchical coordination
Good Governance	Graham *et al*. (2003); Kulshreshtha (2008); Gisselquist (2012)	Transparency, accountability, participation, rule of law.
Evolutionary	Van Assche *et al*. (2014); Beunen *et al*. (2015, 2022)	Coevolution of actors, institutions, and discourses toward sustainable goals.
Adaptive	Folke *et al*. (2005); Brunner (2010); Chaffin *et al*. (2014)	Systems learn and respond under uncertainty.
Polycentric	Ostrom (1999, 2010); Berardo and Lubell (2016)	Multiple autonomous decision centers govern jointly.

***** *Authors listed for contextual reference, not all these sources appear in the reference list. Full citations available from the authors upon request.*

Table 5. Typical AEOs: Large-scale fisheries

Environmental aspects	AEOs
Industrial wastewater	Solid traps, grease traps, air injectors, and gluewater evaporator plant.
Domestic wastewater	Discharge into public drainage or domestic wastewater treatment plants.
Atmospheric emissions (process)	Gas scrubbers, bag houses, and particulate matter filters.
Combustion emissions	Soot traps, equipment maintenance, and energy matrix change.
Refrigerant gas leaks	Transition to eco-friendly refrigerants.
Industrial solid waste	Outsourcing specialized waste management services.
Hydrobiological waste	Residual meal or reuse plant, and ichthyocompost.
Sediments	Rotation of aquaculture crops, and solid management.
Formalities and assessment	Reports, monitoring, and other requirements (likely main source of formal infractions).

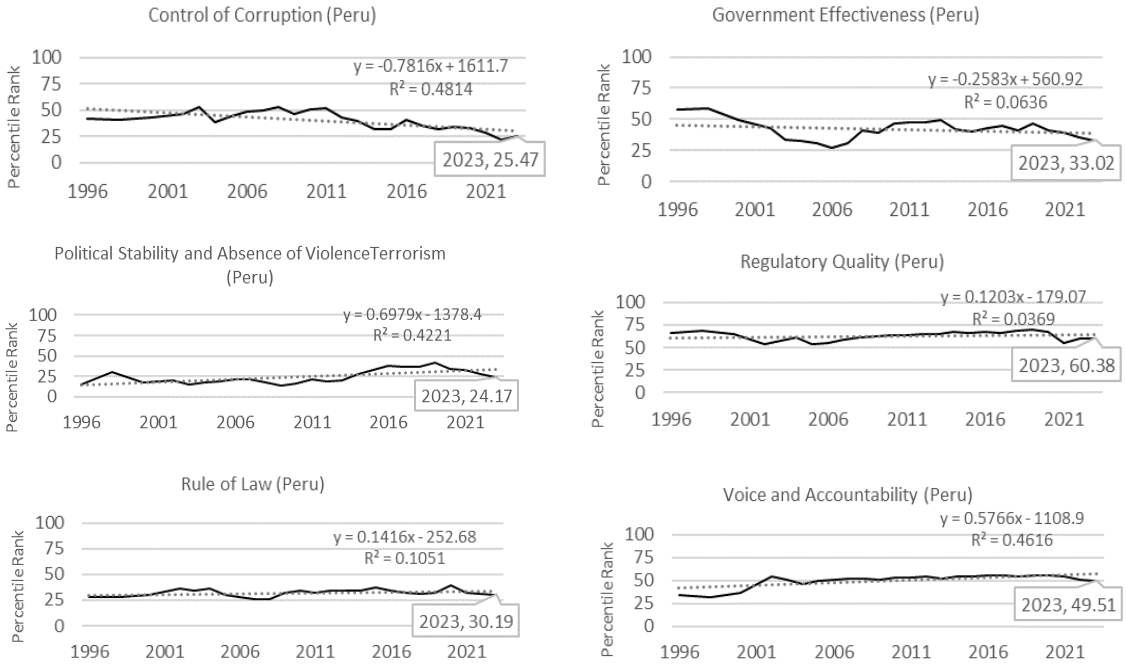

Figure 4: Worldwide Governance Index for Peru

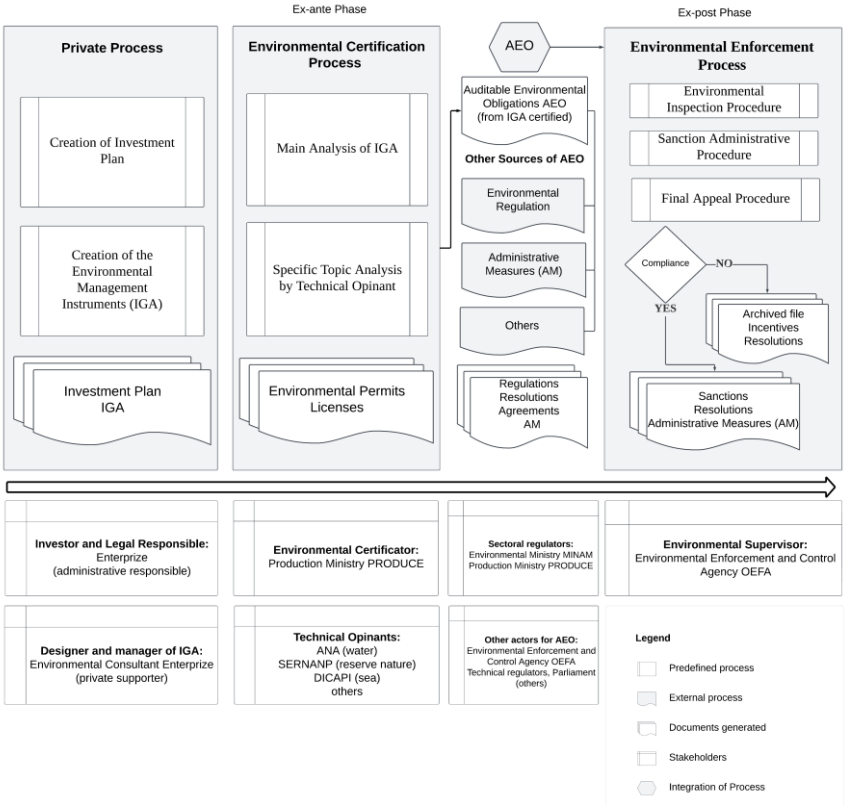

Figure 5. SEIA** and SINEFA systems (large-scale fisheries)

***The SEIA environmental certification competency on the Fisheries and Aquaculture subsector was recently transferred from the Ministry of Production (PRODUCE) to the National Service for Environmental Certification for Sustainable Investments (SENACE) on July 13, 2026.*