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MAXIMIZING TAX COLLECTION EFFICIENCY THROUGH STRATEGIC CUSTOMS TECHNOLOGY ADOPTION: A REVIEW OF GLOBAL TRENDS AND APPLICATIONS

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Abstract:

Governments are accelerating customs digitalization to safeguard revenue while enabling faster, risk-based clearance. This paper refines and synthesizes recent evidence on how strategic customs technologies translate into measurable gains in tax collection efficiency (TCE). We conduct a structured narrative review of 2020–2025 peer-reviewed studies and flagship policy reports (Scopus/WoS; WCO/OECD/World Bank/IMF), integrating insights through the Technology Acceptance Model (TAM) and Institutional Theory. The synthesis indicates that integrated e-customs/Single Window, API-based interoperability, and AI-enabled risk engines are consistently associated with shorter clearance times, higher audit hit-rates, improved valuation accuracy, and greater post-clearance recovery—conditional on user-centred design, training/ICT support, robust data governance, and enabling legal frameworks. For middle-income administrations, benefits are maximized by phased use-case pilots, data-quality programs, and human-in-the-loop analytics with transparent KPIs (e.g., Time Release Study (TRS), audit yield, recovery per audit, cost-to-collect). Originality stems from integrating behavioural (TAM) and institutional lenses to convert global evidence into an actionable 12–24-month roadmap tailored to administrations such as the Royal Malaysian Customs Department (RMCD).

Keywords:

Customs Digitalization; National Single Window; Risk Management; Interoperability (API); Data Governance; AI-Enabled Compliance; Tax Collection Efficiency

Introduction

Collecting taxes fairly and efficiently is a core responsibility of customs agencies. Over the last five years, many of these agencies have moved from traditional paperwork to digital systems. These digital systems are designed to reduce revenue loss, improve compliance, and support legal trade. However, while many new technologies are being adopted, there is still limited clear evidence on how specific tools actually improve tax collection outcomes across different countries and systems (Ahmad, 2010; Cantens, Ireland, & Raballand, 2012; OECD, 2025).

This paper helps fill that gap. It reviews recent global trends in how customs agencies have used technology since 2020. It explains how tools like automated risk engines, electronic single windows, and shared data systems affect staff performance and revenue outcomes. The paper also proposes a practical 12–24 month strategy that could help middle-income countries—like Malaysia—get the most from digital customs systems (World Bank, 2020; Royal Malaysian Customs Department, 2022).

Our analysis uses two key ideas. The first is the Technology Acceptance Model, which helps explain how officers decide to use technology based on how useful and easy it seems (Davis, 1989; Venkatesh & Davis, 2000). The second is Institutional Theory, which looks at how laws, regulations, peer examples, and public values affect how new systems are adopted (DiMaggio & Powell, 1983; Scott, 2008).

This review makes three contributions:

1. It organizes recent findings by key technology areas, such as single window platforms, data-sharing APIs, risk analysis systems, and data quality programs (Chandini & PushpaH, 2014).
2. It links these technologies with clear tax performance outcomes like shorter clearance times, more effective audits, better revenue recovery, and lower costs per tax dollar collected (Ndonga, 2013).
3. It offers a simple, results-focused roadmap to help agencies like Malaysia's Royal Customs Department adopt these tools in a step-by-step way (Kanyinji et al., 2021); (Abd et al., 2024); (Zhou & Li, 2020).

Background and Related Literature

Definitions and Scope

National Single Window (NSW)

A National Single Window (NSW) is a digital platform led by the government that lets importers and exporters submit all required documents through a single portal. It connects customs with other agencies like ports and regulators to speed up clearance and reduce manual work. By avoiding duplicate data entry and making processing status visible, mature NSW systems help both traders and authorities work more efficiently. In some countries, NSW systems are linked regionally to support cross-border trade and data sharing (Kanyinji et al., 2021; Rogmann & Zelenska, 2017).

Risk Engine

A risk engine in customs is a system that uses rules and data models to decide which shipments to inspect. Basic versions use expert-defined rules, while advanced versions apply machine learning to detect fraud like misclassification or under-invoicing. These systems analyze data

before goods arrive, at the border, and after clearance. They combine structured data like trader profiles and invoice values with unstructured inputs like scanned documents. Well-managed risk engines also include oversight features, such as logs and performance tracking, to ensure transparency and accountability (Harrison & McDonald, 2021; Ndonga, 2013).

API-Based Interoperability

Application Programming Interfaces (APIs) allow different systems—such as customs, port operators, and other regulators—to share information in real time. APIs help validate licenses and send updates, reducing delays and manual errors. Successful API systems require common data formats, security controls, and monitoring tools to track usage and errors. While the technology enables faster decisions, success often depends just as much on how different agencies agree to work together (Zhou & Li, 2020; Künnapas & Maslionkina, 2025).

Data Governance

Data governance means managing the accuracy, security, and sharing of customs data. This includes deciding who oversees specific data sets (like trader profiles or HS codes), setting rules for how accurate or up-to-date data must be, and defining how digital records can be shared legally across agencies or borders. Good governance also requires tools for tracking changes, reviewing who accessed what, and ensuring that evidence from digital systems is legally valid (Grainger, 2014; Thomas, 2018; Agamagomedova, 2023).

Theoretical Framework

This review is guided by two well-known frameworks that help explain why customs officers and institutions adopt new technologies: the Technology Acceptance Model (TAM) and Institutional Theory.

Technology Acceptance Model (TAM)

TAM helps explain why people decide to use a new system. It focuses on two things: how useful the technology seems and how easy it is to use. If officers believe a new system will help them do their job better—and it's not too complicated—they are more likely to accept and use it. For example, digital audit systems that automatically flag risky shipments save time and effort, making them more attractive to frontline officers (Davis, 1989; Venkatesh & Davis, 2000; Iramaidha & Hidayat, 2025).

TAM has been widely used in public finance research to study the success of e-filing systems, online payment platforms, and customs declaration tools. It helps explain not just the adoption of technology, but also long-term use, skill development, and feedback behavior among officers (Restianto et al., 2018).

Institutional Theory

Institutional Theory looks at how laws, public expectations, and peer influence shape the choices of organizations. In customs, this means looking at how regulations, international guidelines, and the actions of other countries push agencies to modernize. Some customs authorities digitize their processes not only to improve results, but also because it is the expected norm in trade agreements or regional cooperation frameworks (DiMaggio & Powell, 1983; Scott, 2008).

Institutional pressures can come from global organizations like the World Customs Organization or from donors and trading partners. These outside forces often shape internal

reforms, whether by encouraging legal updates, offering funding, or providing model systems to follow (Ndonga, 2013; UNCTAD, 2020).

An Integrated View

TAM and Institutional Theory are complementary. TAM clarifies the micro-mechanisms linking features and support to usage and individual performance. Institutional Theory sets the meso/macro context that conditions these links—by determining what data can be shared, which analytics are permissible, and how accountability is assigned for automated triage. In practice, institutional enablers (clear mandates, data-sharing MOUs, budgetary stability) amplify the effect of PU/PEOU on sustained use, while institutional frictions (legal ambiguity, fragmented ownership, shifting priorities) dampen it. This review therefore, treats institutional arrangements as moderators or organisational mediators in the pathway from technology to TCE.

Measuring Tax Collection Efficiency: Core KPIs

To measure the success of digital customs reforms, agencies need to use clear, data-based Key Performance Indicators (KPIs). These indicators help track how technology changes affect revenue collection and enforcement outcomes. Based on global studies and institutional best practices, we focus on six core KPIs.

Time Release Study (TRS)

TRS measures the time taken from goods arriving at the border until they are released. Faster release times suggest better processing efficiency and fewer informal practices. Digital systems like NSWs and pre-arrival processing tools have been shown to reduce clearance times significantly (Widdowson, 2005; World Bank, 2020).

Audit Hit-Rate

This refers to how often audits actually detect fraud or underpayment. A higher hit rate means better targeting by risk engines and fewer unnecessary audits. Automated risk tools tend to increase hit rates by focusing on high-risk shipments (Cantens et al., 2012).

Audit Recovery Per Case

This KPI tracks how much additional revenue is recovered per audit conducted. It reflects both the quality of audit planning and the effectiveness of digital tools in spotting hidden discrepancies (Abd et al., 2024).

Cost-To-Collect (CTC)

CTC measures how much the customs agency spends to collect each unit of revenue. Lower CTC values signal greater efficiency. Agencies with strong digital ecosystems, like automated declarations, risk scoring, and digital payments, tend to have lower CTC values (IMF, 2021).

E-Submission Penetration

This measures the percentage of customs declarations submitted electronically. It reflects how well digital platforms are being adopted by traders. High e-submission rates indicate that the system is user-friendly and trusted by the trading community (Iramaidha & Hidayat, 2025).

Discrepancies Tare between Declared and Accessed Duties

This KPI compares what traders declare versus what customs later finds through inspection or audit. A high rate could signal widespread misdeclaration or weak verification controls. AI tools and cross-checks using third-party data can help reduce this gap (Zhou & Li, 2020).

Together, these KPIs give a balanced picture of efficiency, accuracy, and fairness in tax collection efforts. They also help agencies measure the real impact of their technology investments over time.

Methodology: Structured Narrative Review

Review Type

We used a structured narrative review approach. This method allows us to cover a wide range of sources while still producing findings that can be applied in practice. Unlike systematic reviews that strictly follow PRISMA guidelines, our approach is more flexible. This is important because studies on customs and tax efficiency vary widely in their design and findings, making a rigid framework less practical (Grant & Booth, 2009).

Sources and Time Frame

Our main focus was on peer-reviewed journal articles indexed in Scopus and Web of Science, published between 2020 and 2025. We also included key reports from global institutions such as the World Customs Organization, the OECD, the World Bank, and the IMF. In some cases, we referred to grey literature—like working papers or government reports—when peer-reviewed sources did not provide enough detail on specific technologies (World Bank, 2020; IMF, 2021; OECD, 2025).

Search Strategy

We designed search strings that combined technology terms with fiscal outcomes. For example, we searched phrases such as:

- “customs digitalization” AND “risk management” AND “audit yield” OR “recovery per audit”
- “National Single Window” AND “interoperability” AND “time release study”

These targeted searches ensured that our sources captured both the technological elements and their direct connection to revenue outcomes (Cantens et al., 2012; Kanyinji et al., 2021).

Eligibility Criteria

We included studies that linked customs digital technologies with either operational outcomes (like clearance time and compliance) or fiscal outcomes (such as audit results, revenue recovery, or cost-to-collect). We excluded studies that focused only on trade facilitation without financial indicators or those lacking empirical data. This filter helped ensure that our findings stayed focused on tax collection efficiency (TCE) (Ndonga, 2013).

Data Extraction and Synthesis

For each study, we extracted details on the type of technology, country context, research method, key performance outcomes, and any reported challenges or enablers. We then grouped findings by technology domain (e.g., Single Window, APIs, risk engines, data governance) and compared patterns across countries. The synthesis highlighted not only positive outcomes but

also limitations, risks, and conditions that influenced results (Zhou & Li, 2020; Abd et al., 2024).

Results and Synthesis

Global Technology Trends (2020–2025)

Between 2020 and 2025, three major technology trends in customs modernization stand out:

- National Single Window (NSW) with API integration — Many countries have invested in NSW systems that link customs with port operators and licensing agencies through APIs. These platforms reduce paperwork and make clearance faster (Chandini & PushpaH, 2014; Kanyinji et al., 2021).
- Analytics-driven risk management — Risk systems have moved from simple rules to advanced analytics and machine learning that detect misclassification, under-valuation, and fraud. These tools allow customs to focus resources where they are most needed (Ndonga, 2013; Harrison & McDonald, 2021).
- Data governance frameworks — Increasingly, customs agencies are adopting structured data governance, which covers trader records, HS code accuracy, and policies for sharing data and using digital evidence. This is critical for both domestic audits and cross-border cooperation (Thomas, 2018; Agamagomedova, 2023).

Technology → Impact on Tax Collection Efficiency

The evidence shows that digital tools directly improve tax outcomes:

- Risk-based controls raise audit hit-rates and recovery amounts by targeting high-risk shipments more accurately (Cantens et al., 2012; Abd et al., 2024).
- Valuation and classification accuracy improve with integrated systems, which helps reduce revenue leakages (Zhou & Li, 2020).
- Process efficiency improves through shorter clearance times (measured in TRS) and less duplication of data entry (World Bank, 2020).
- Post-clearance audits supported by analytics lead to more revenue recovery per audit while minimizing disruption for compliant businesses (Ndonga, 2013).

These gains are most effective when officers receive proper training, when ICT support is reliable, and when systems are designed with the user in mind (Iramaidha & Hidayat, 2025).

Barriers and Enablers

Despite successes, countries face recurring challenges:

- Barriers include fragmented legacy systems, poor data quality, limited analytical expertise, and legal gaps around the use of electronic evidence (Kostin, 2021).
- Enablers include strong political support, a clear data governance plan, stable operational funding, and active involvement of frontline officers in design. Human-in-the-loop analytics that provide explainable results also help build officer trust (Künnapas & Maslionkina, 2025).

Comparative Snapshots: Ghana – Indonesia – Malaysia

- Indonesia has upgraded its NSW and risk management systems over time, showing the value of step-by-step reforms supported by updated laws (Restianto et al., 2018).

Together, these forces create an environment that either strengthens or weakens the link between technology adoption and actual results. Countries that combine strong legal frameworks, clear governance, and peer learning tend to achieve more consistent improvements in tax collection efficiency (DiMaggio & Powell, 1983; Scott, 2008; UNCTAD, 2020).

Figure 1 positions institutional enablers as organizational-level conditions that strengthen the TAM pathway from usage to performance and ultimately to TCE.

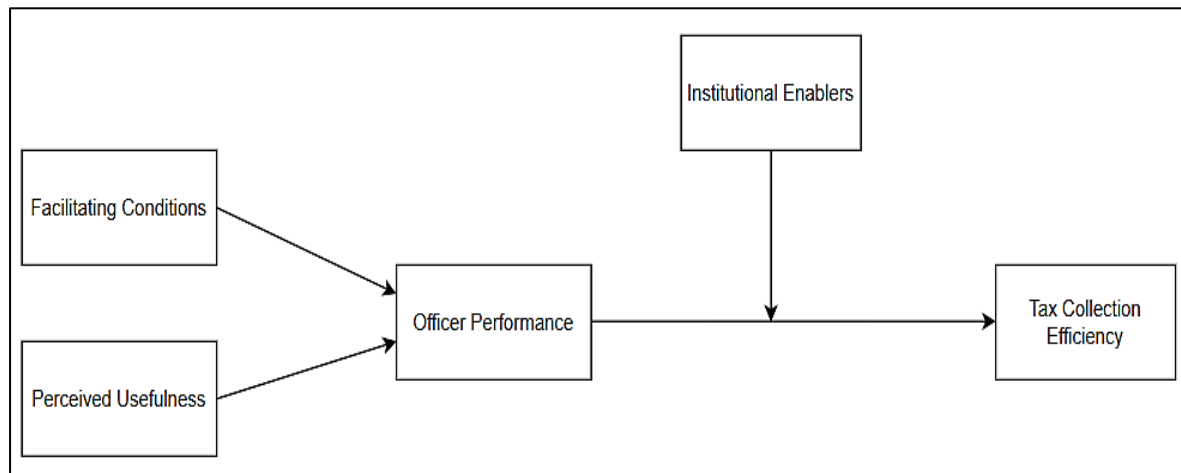


Figure 1: Integrated Conceptual Model Framework

Implications for RMCD: A 12–24-Month KPI-Oriented Roadmap

In the short term, the Royal Malaysian Customs Department (RMCD) can pursue several initiatives that offer quick and visible improvements in efficiency and revenue assurance. Within the first twelve months, pilot programs using AI to detect tariff misclassification and under-valuation in three high-risk commodity groups can deliver measurable results. Parallel to this, a data-quality program should be launched to improve trader master records and HS code mapping, while an API gateway can be deployed to connect the National Single Window with ports and community systems. During this phase, RMCD should also roll out an internal KPI dashboard to monitor critical indicators such as median clearance times (TRS), audit hit-rate and yield, recovery per audit, cost-to-collect, and e-submission penetration. These steps align with best practices emphasized in global literature, where integrated data flows and monitoring tools are linked to reduced clearance times and improved compliance (World Bank, 2020; OECD, 2025).

Over a 12–24 months horizon, RMCD should move beyond pilot projects and begin systematically scaling reforms. Expanding the coverage of risk engines to a broader range of commodities will ensure greater enforcement reach, while legal modernization is necessary to formally recognize electronic evidence and allow secure cross-border data sharing. Institutionalizing human-in-the-loop analytics, paired with officer training, will help build trust in AI-based decisions while ensuring explainability and fairness. At the same time, establishing an inter-agency data governance council with stewardship roles and standard operating procedures can provide a sustainable foundation for integrated data use (Agamagomedova, 2023). These reforms can be tracked against measurable targets such as a 20% reduction in TRS, an 8–12 percentage point increase in audit hit-rate, a 15–25% increase in recovery per

audit, over 95% e-submission penetration, and more than an 80% reduction in duplicate data entry in priority lanes (Cantens et al., 2012).

Table 2: KPIs and Definitions

KPI	Definition	Measurement Notes
Time Release Study (TRS)	Median time from arrival to release	Segment by channel (green/yellow/red); track median & Interquartile range (IQR)
Audit hit-rate	Share of targeted audits with findings	Disaggregate by risk rule/model; monthly trend
Audit yield / Recovery per audit	Value recovered per completed audit	Include post-clearance audits; control for case mix
Cost-to-collect	Operational cost per 1 unit of additional revenue	Standardize allocation rules; annualized
% e-submission	Share of declarations fully digital	Track by trader segment and port/airport

With reference to Table 2, TRS measures the median time from arrival to release, so track it by risk channel (green, yellow, red) and look at the spread using the IQR to avoid being misled by outliers. Audit hit rate is the share of targeted audits with findings, so break it down by rule or model and monitor monthly trends. Audit yield or recovery per audit shows the value recovered per completed audit; calculate on cash actually collected, include post-clearance audits, and control for differences in case mix. Cost-to-collect captures the operational cost required to secure each additional unit of revenue; standardize cost allocation and separate capex from opex. The percent of e-submission indicates the extent of digitization; higher values usually enable smoother straight-through processing, so track it by trader segment and by port or airport. In short, a healthy performance pattern is TRS going down, hit rate and yield or recovery going up, cost-to-collect staying stable or going down, and e-submission going up.

Malaysia's strategic location and trade volumes provide both opportunities and pressures for RMCD to modernize. The agency has already embarked on reforms, including AI-driven risk assessment and enhanced e-declaration systems, within a supportive policy environment (Royal Malaysian Customs Department, 2022). Moving forward, modular AI-based risk engines should be deployed to address misclassification and under-invoicing, combining machine intelligence with human expertise to strengthen accuracy while safeguarding fairness. Strengthening single window integration is equally important, as seamless connectivity between RMCD, port authorities, and trade regulators reduces duplication and accelerates revenue collection. Enhancing data governance by establishing national standards for trader and HS code data, underpinned by API-driven system design, will ensure higher quality and scalability (Zhou & Li, 2020).

Legal modernization also plays a crucial role. Updating evidentiary rules to recognize digital documents and clarifying inter-agency data sharing arrangements will help align operational efficiency with privacy safeguards. Capacity building remains essential, requiring training in digital literacy, AI interpretability, and change management to empower officers to adapt effectively. Piloting blockchain for specific use cases, such as certificates of origin, can also provide lessons on scalability and performance before wider implementation. Yet, RMCD will likely face challenges including resource constraints, inter-agency coordination gaps, and

resistance among staff or traders. These can be mitigated through phased pilots, multi-year funding commitments, inter-agency governance mechanisms, and stakeholder engagement campaigns that demonstrate benefits such as reduced clearance times and predictable compliance processes (Ndonga, 2013).

Evaluation mechanisms are central to sustaining momentum. In addition to tracking revenue outcomes, compliance rates, clearance times, and cost-effectiveness, RMCD should monitor qualitative indicators such as stakeholder engagement, training effectiveness, issue resolution speed, and user retention. Employing advanced analytical methods, such as control-group comparisons, randomized pilots, or difference-in-differences studies, can provide robust evidence on the contribution of specific technologies relative to broader reforms (Abd et al., 2024).

At a broader policy level, the findings underline the importance of embedding digital modernization within statutory planning, budgeting cycles, and organizational mandates. This ensures that digital initiatives become part of the agency's operating culture rather than temporary projects. Aligning officer performance metrics to reward the quality of enforcement and revenue protection, rather than throughput alone, is equally important. Legal modernization must continue to adapt frameworks to AI-assisted decision-making and digital evidence, while investment in shared infrastructure and regional data platforms can reduce costs and enhance interoperability (DiMaggio & Powell, 1983; UNCTAD, 2020).

Finally, this review identifies several areas for further research. Longitudinal and causal studies are needed to quantify the fiscal impacts of digital technologies across different jurisdictions. Exploring officer behavior through the lens of TAM can provide insights into how training, support, and organizational culture affect adoption. Comparative studies on cross-border data governance are also necessary to understand how legal frameworks influence transnational revenue collection. Moreover, research into AI fairness and explainability can shed light on how explainable AI methods influence trust among officers and traders. Cost-benefit analyses, especially in low- and middle-income settings, would provide vital evidence for scalability and cost-effectiveness of digital reforms. Together, these steps will ensure RMCD positions itself as a forward-looking institution equipped to safeguard revenue and facilitate trade in a digital era.

Limitations and Future Research

This review highlights several limitations in the existing body of evidence on customs digitalization and its effects on tax collection efficiency. First, the studies available display considerable heterogeneity in design, outcome measures, and reporting standards, which makes direct comparison or meta-analysis difficult. Future research should prioritize the standardization of key outcome definitions, such as Time Release Study (TRS) metrics and audit yield indicators, to enable more consistent cross-country benchmarking (Widdowson, 2005). A second limitation concerns attribution: very few studies employ quasi-experimental methods that can clearly separate the impact of digital technologies from other policy or structural reforms occurring simultaneously. More rigorous designs, such as difference-in-differences or synthetic control methods, are therefore needed, particularly when evaluating pilot projects at specific ports or commodity groups (Abd et al., 2024).

A further weakness relates to data quality and governance. Many digital implementations under-invest in the curation of master data—such as trader records and HS code mapping—and often neglect data lineage and stewardship. Future research should explore the return on investment of systematic data-quality programs and assess different governance models for effective inter-agency data sharing (Agamagomedova, 2023). Another critical concern is fairness and explainability in AI-driven targeting. Automated systems can embed biases, leading to unintended inequities in enforcement. Addressing this requires stronger validation protocols, transparent model documentation, and officer training in explainable AI. Future research should test and benchmark explainable AI methods (XAI) specifically within customs contexts to assess their impact on both trust and effectiveness (Iramaidha & Hidayat, 2025).

Finally, questions of scalability and sustainability remain underexplored. While pilot projects often show promising results, there is limited documentation on long-term financing for operations and maintenance, as well as the risks of vendor lock-in. Comparative case studies that investigate procurement models, the role of open standards, and strategies for technology transfer and capacity building would provide valuable insights for ensuring sustainability in low- and middle-income settings (Ndonga, 2013). By addressing these gaps, future research can offer policymakers and practitioners stronger evidence to guide investment decisions and maximize the fiscal and operational benefits of digital customs systems.

Conclusion

This review shows that strategic customs digitalization built on interoperable data flows, risk-based controls, and strong governance can significantly improve tax collection efficiency. By applying the Technology Acceptance Model (TAM) and Institutional Theory, we clarify how new technologies influence officer performance and how organizational environments shape outcomes. For administrations such as the Royal Malaysian Customs Department (RMCD), a practical roadmap centered on targeted analytics, data quality improvements, and training for explainable AI can deliver short-term gains while building a foundation for long-term reforms. Future research using quasi-experimental methods and standardized outcome metrics, such as TRS, audit hit-rate, and recovery per audit, will further strengthen the evidence base and provide clearer guidance for policymakers (Cantens et al., 2012; Abd et al., 2024).

For agencies like RMCD, success depends on more than adopting new tools; it requires a phased and institutionalized approach that integrates technology into statutory planning, budgeting, and officer performance frameworks. Prioritizing data governance, ensuring interoperability across agencies, building staff capacity, and modernizing legal rules are all essential steps. Future studies should focus on rigorous impact evaluations, cross-border data governance arrangements, and strategies to ensure AI adoption remains fair, explainable, and trusted by both officers and traders (UNCTAD, 2020). Ultimately, digital transformation in customs is as much about fostering supportive institutions as it is about deploying new systems. When pursued holistically, it can strengthen transparency, efficiency, and compliance while facilitating legitimate trade and delivering better economic outcomes.

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