

Managing Supply and Value Chains in a New Era of Global Trade: The Promise of Federated Learning

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As global trade shifts from an era of efficiency-driven globalisation to a new compliance-centred paradigm, customs administrations face mounting challenges – ranging from forced labour and environmental enforcement to fractured supply chain visibility and escalating transaction volumes, particularly in e-commerce.

This article introduces federated learning as a practical, privacy-preserving solution for enabling secure data collaboration across public and private actors without commingling or centralising sensitive information.

We trace the structural failures of Globalisation 1.0 and propose a modernised model of border management built on federated system architecture and trusted networks. These systems allow customs authorities to apply actionable intelligence across multi-tier value chains, strengthen enforcement capabilities, and expedite legitimate trade. The article outlines key steps towards implementation, including legal, technical and institutional reforms, and argues that federated architectures can form the foundation for next-generation risk management and trade facilitation strategies. The future of effective customs governance will depend on embracing secure, data-driven collaboration within and across borders.

1. Introduction: a paradigm shift in global trade

The world stands at the precipice of a new era in international trade, one that diverges dramatically from the globalisation that has shaped our economic landscape for the past generation. As we navigate this transition, we find ourselves in a fragmented world order, grappling with a rapidly

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evolving regulatory regime that demands a fundamental reimagining of relationships – between public and private sectors, within these sectors, and among aligned sovereign nations.

Artificial Intelligence (AI) can catalyse these relationships and enable collaboration by harmonising the requisite data at scale, permitting otherwise siloed actors to coordinate and act across global value chains. This article discusses how federated AI systems accomplish these goals while respecting data sovereignty, privacy, and security. We analyse the trends that led us to this moment, describe the underlying technical concepts, and outline several recommendations to support their implementation.

2. The rise of Globalisation 1.0: a world transformed

In the mid-1990s, as the dust settled from the Cold War, the world witnessed the birth of a transformative era: Globalisation 1.0. This period was catalysed by two pivotal events: the fall of the Soviet Union in 1989 and China's entry into the World Trade Organization in 2001. These geopolitical shifts, coupled with rapid technological advancements and widespread digitalisation, created a perfect storm for unprecedented global economic integration.

During this period, the anatomy of global supply chains underwent a radical metamorphosis. Driven by an insatiable appetite for cost efficiency and working capital optimisation, these networks grew in scope, complexity, and interdependence. They became vast, often opaque systems, shielded from scrutiny and shrouded in secrecy. This new paradigm, however, delivered tangible benefits to consumers worldwide, including decades of low prices fuelled by cheap labour in emerging markets; a flood of cheap commodities from the post-Soviet world; and enhanced productivity from digital transformation.

In the post-Cold War era, geopolitically, traditional great power rivalries took a backseat. Instead, the defining event of this period was the 9/11 terrorist attack on US soil. This catastrophic event reshaped the architecture of border management for an entire generation, focusing primarily on countering non-state terrorist threats, with only secondary (and largely ineffective) attention given to transnational organised crime.

3. The limits and end of Globalisation 1.0: the double-edged sword of progress

Globalisation 1.0 was a period of unprecedented economic growth and development. It lifted billions out of extreme poverty, democratised access to industrialisation, and fostered a global value chain network that harnessed creative entrepreneurial energy on a scale never seen in human history.

However, this progress came at a steep price. The sprawling, efficiency-driven global economic networks, while immensely profitable, generated massive adverse collateral effects and unintended consequences. These included: a significant reallocation of manufacturing jobs around the world;

massive wealth inequality; severe environmental and social disruptions; global proliferation of transnational organised crime; and increasing supply chain vulnerability and fragility.

As the unanticipated consequences of globalisation worsened, strain on both domestic social fabric and the international order intensified. Geopolitical developments, such as Russia's aggression in Ukraine and China's pivot away from the West (and vice versa), reflected a re-emergence of traditional great power rivalry. The final nail in the coffin of Globalisation 1.0 came with the worldwide COVID-19 pandemic of 2020–2022. This crisis threw global supply chains into drastic disarray, exposing their inherent weaknesses and setting the stage for a dramatic transformation in the international trade environment.

4. The invisibility crisis: unravelling the complexity of global supply chains

The turmoil in supply chains during the COVID-19 pandemic laid bare severe structural problems that had long been lurking beneath the surface. From inadequate resilience to rampant fraud, these issues proved beyond the capacity of both major regulatory authorities and private sector participants to remedy. But why?

The answer lies in the fundamental way these supply chains were constructed. They developed in a governance gap where no single actor, public or private, could fully control or understand them. This opacity was not just an inconvenience – it was a feature of the system. Importers typically knew their first-tier suppliers but remained ignorant of second, third, or fourth-tier suppliers. Logistics providers rarely knew the nature of the goods they were transporting, let alone the key public and private actors connected to their production and consumption. Governments were blind to the goods crossing their borders at the speed of globalisation, while hoping at best to pick needles out of the figurative haystack for enforcement. Actors across global supply chains had no incentive to share data with one another. Even the most well-informed players in global trade often lacked a comprehensive understanding of their own networks.

The limited visibility into multi-tier relationships, moreover, led to the construction of supply chains in 'locally optimised' ways. This approach often resulted in wealth flowing to middlemen, bottlenecks, and unnecessary intermediaries. It worsened global supply chain fragility, exemplified by 'just in time' manufacturing practices. As climate change and geopolitical tensions intensified, these concentrations that once appeared efficient in peaceful times quickly became critical vulnerabilities in a more turbulent world.

Consequently, even when these actors have tried to influence or control their supply chains, they lacked the means to do so. Although a patchwork system of treaties and voluntary corporate pledges sought to mitigate some of the worst supply chain issues, these have proven inadequate to resolve

Globalisation 1.0's fundamental problems. Despite their immense impact on our daily lives, supply chains remain essentially opaque and ungoverned, with potential crises – operational catastrophes, environmental degradation, human rights abuses, and national security vulnerabilities – lurking just one degree of separation from nearly every business and government participating in global trade.

5. The dawn of a new regulatory era: compliance takes centre stage

As we emerge from the ashes of Globalisation 1.0, a shift in priorities is taking shape. In this emerging landscape, compliance is ascending to the throne, alongside security, taking precedence over the long-reigning monarchs of production cost and working capital efficiency.

This paradigm shift is most evident in critical supply chains, software, and cyber infrastructure. We're witnessing a cascade of changes including Western bans on Huawei 5G technology, export restrictions on dual-use technology to military end users, sanctions on companies and individuals engaged in activities deemed adverse to national interests, and China's mandate for foreign software providers to domicile their products in mainland China to access Chinese markets. These developments signal a transformation in border management, marking a transition from the post-9/11 model focused primarily on countering terrorism.

In response to COVID shocks, great power competition, and evolving environmental, social and government (ESG) goals, governments are venturing into uncharted territory: regulating global value chains. This regulatory revolution is often enforced at the border, fundamentally altering the landscape of international trade.

The Uyghur Forced Labor Prevention Act (UFLPA), signed into law on 23 December 2021, exemplifies the new paradigm. The core principle is a rebuttable presumption through which US Customs and Border Protection (CBP) presumes that any product originating from China's Xinjiang region was produced using forced labour. Importers must provide extensive evidence to rebut this presumption and prove their goods are free from forced labour. Failure to do so results in a blanket ban on importing suspect goods into the United States.

This new framework represents a seismic shift in the regulatory paradigm. In the old paradigm, governments defined unacceptable practices and engaged in enforcement to 'catch' wrongdoing. In the new paradigm, governments now define the unacceptable and declare entire supply chain networks associated with a region presumed guilty until proven otherwise.

The burden of both effort and proof has shifted to the private sector,¹ compelling businesses to create and share network visibility to prove compliance and maintain their licence to operate.

6. Risk management in the new era: AI to the rescue

For a generation, risk assessment in global trade revolved around a narrow set of concerns, primarily focused on the ‘war on terror’ and the ‘war on drugs’: how to detect the ‘bomb in the box’ and ‘narcotics in the container.’ The system was built on three pillars: (1) advance shipment information; (2) comprehensive screening and targeting; and (3) traffic segmentation and differential treatment by risk profile.

This approach led to a trifurcated system: high risk shipments are subject to intensive inspection (finding ‘needles in haystacks’); low-risk shipments are expedited through trusted trader and Authorized Economic Operator (AEO) programs (‘shrinking the haystack’); and unknown risks are inefficiently processed in the ‘mushy middle.’

While elements of this post-9/11 assessment method will persist, the targeting and enforcement strategy built around ‘bad guys and bad boxes’ is ill-equipped to enforce the new regulatory regime. Today’s challenges require scrutiny of the nature of the goods and their value chain properties across multiple tiers upstream spanning borders and jurisdictions.

As a result, border management systems have been overwhelmed by new regulation demands, a massive increase in de minimis transaction volume linked to e-commerce, and by the need to maintain a counter-terrorist readiness while developing new approaches to contraband trafficking.

AI systems and federated data architectures offer a lifeline in this complex new world, enabling otherwise siloed parties to engage with each other and cooperate across a shared map of the global supply chain, and individual product value chains, while ensuring sovereignty and privacy of their underlying data. Here’s how:

1. **See:** Modern AI constructs a dynamic, intelligent, universal map and model of the global supply chain, overcoming the complexity of harmonising billions of records across all languages to reveal product value chains across the network.
2. **Focus:** AI assists in identifying key areas of focus, whether facilitating legitimate goods, targeting narcotics production chains, or regulating high-carbon value chains.

¹ An analogous regulatory situation is developing in the European Union with respect to the Carbon Border Adjustment Mechanism (CBAM), the Deforestation Regulations linked to forest degradation, and the Sustainability, Corporate, and Due Diligence Directive (SCDDD).

3. **Act:** The same system that comprehends global trade at scale can assist in rewiring value chains for greater resilience, sustainability, efficiency, and profitability.

7. The power of federated learning: bridging the information gap

Until now, valid concerns over privacy, intellectual property, and sovereignty have prevented the assembly of comprehensive supply chain data in one place. As we move forward, data and information sharing will be central to the future of global trade.

Two competing models for ‘trusted’ information networks have largely dominated the discussion to date, centralised and decentralised. Centralisation, promoted by China and some Western internet platforms, features centrally controlled data, media, and information sharing networks. The decentralisation approach is being driven by data privacy regimes like General Data Protection Regulation (GDPR) in Europe and the California Consumer Privacy Act (CCPA) in California and the growing interest in blockchain and Web3 projects.

Federated learning offers a third way, enabling shared information without commingled data or centralisation. This approach allows connection to and learning from sensitive, siloed information across a federated network. While privacy-preserving, federated learning enables extraction of signals from siloed data and facilitates shared intelligence across the participating network.

8. The federated system architecture

No single entity – government, customs agency, or private company – has a complete view of global value chains. This information gap has long been exploited by illicit actors. A federated system offers a solution. Each participant maintains a private ‘spoke’ where their data remain secure, but where derived analytics can be shared across the participating network. Sensitive data stay only with the participant that owns the information.

In the case of border management agencies, their customs records, risk information, and other sensitive data stay in a government deployment on a secure certified hardware/cloud provider of choice, accessed by only authorised personnel of that country. For the trading community, supply chain data can be processed in situ, with permitted derived learnings – network connections, risk analytics, and the like – shared with value chain network participants and ultimately with the border agency in exchange for trade facilitation benefits.

This architecture allows government and the private sector to cooperate in partnership within a shared source of truth without compromising underlying data. It also allows enhanced coordination across government ministries where multiple agencies can share intelligence, without transferring sensitive information. Sovereignty preserving cross-government collaboration similarly is enabled by this architecture among aligned nations.

To summarise, in this model, many of the platform benefits of information search and discovery, insight generation, and network connectivity can be achieved while preserving data privacy, security, and sovereignty across a federated network. Sovereignities, competitors, and private persons can share anonymised supply chain network learnings without compromising their underlying data. The insight produced across multiple private and public parties enable operational expedited border clearance or targeted inspection and detention, as warranted.

9. Global supply visibility and trusted networks: the future of trade

The next phase of globalisation demands a fundamental rewiring of supply chain logic. While the basic principles of capitalism will endure, the nature of global trade networks is set for a radical transformation.

The opaque, uncontrolled global networks of the past are giving way to more transparent and collaborative networks bound by shared visibility and collaboration.² These Trusted Networks will be organised across five critical dimensions of (a) supply chains, (b) national security and trade compliance, (c) environmental and social impacts, (d) data governance and information sharing, and (e) evolving financial systems.

The new era of reglobalisation promises to illuminate previously hidden multi-tier supply chain networks, foster explicit coordination beyond direct buyer-supplier relationships, and optimise networks across multiple tiers for both enhanced resilience and efficiency. Non-financial measures of performance will be applied extensively and incorporate rigorous analysis of a social impact, environmental stewardship, national security, and economic resilience.

To facilitate lawful trade in this new regulatory and national security paradigm, existing AEO programs require a complete overhaul. Trusted traders in the past were qualified as member entities for their counter-terror intra-company security measures. This ‘good guy’ status did not extend to the goods contained in their shipments.

Trusted traders will give way to trusted networks based on value chain visibility, increased regulatory transparency, and enhanced collaboration between the public and private sectors to resolve shared problems. The new regulatory regime will enable issuance of product ‘passports’ certifying compliance and qualifying shipments for significant cross-border facilitation benefit. Preclearance of goods on the factory floor or on the loading dock will become standard practice.

² These Known Trusted Networks likely will align to major economic blocs, such as those forming around China, Europe, and the US. Each bloc will look different and shift over time as definitions of trust, the behaviour of the network, and the new world order evolve.

10. A new ecosystem of trust: reimagining public private partnerships

Modern border management requires a deep understanding of extended supply chains of the goods being moved across borders. The traditional adversarial relationship between the private and public sectors is no longer tenable in this complex landscape. The current Form 19 procedure for private parties to contest shipment detentions by CBP, for example, often involves the submission of thousands of pages of supply chain data, which frequently is rejected by the government with one sentence replies. In short, a revised formulation of the ‘trade bargain’ is essential to replace unclear and incomplete communication with transparency and candour, and conflict with cooperation. Key elements of this revised public/private partnership include

- private sector provision of full data sets encompassing entire supply chains from commodities at origin to its finished stage of production
- government protection of data integrity and confidentiality
- clear responses from government identifying the gaps in security and trade compliance
- collaborative problem-solving between public and private partners³.

This new ecosystem of trust offers significant advantages. It provides for more effective regulatory oversight than the current system of limited inspection (involving no more than two per cent of cross-border traffic). It expedites the movement of lawful trade and makes possible wholesale preclearance of goods earlier in the logistics chain. By pre-validating and qualifying low-risk trade flows, this model permits more efficient allocation of enforcement resources to high and unknown risk shipments.

For public regulators it offers unparalleled access and visibility to global trade. For private entities it provides tangible trade facilitation benefits in exchange for subjecting their value chains to enhanced scrutiny and ‘showing their homework.’ Federated learning enables this elusive ‘win/win’ solution. To realise the potential of this new era in global trade, we propose the recommendations in Section 12 below.

³ This protocol builds on the Advanced Cargo Air Screening (ACAS) mechanism implemented jointly by border management authorities and express air carriers in the wake of the Yemen terrorist cargo plot in 2010 and now embodied in law. Instead of waiting for Congress to enact legislation analogous to the 10+2 requirements imposed on maritime trade after 9/11, the parties voluntarily created a system of advance information sharing linked to collaborative problem-solving.

11. Hypothetical scenario: enforcing environmental compliance in global trade

11.1. The challenge: circumventing carbon emissions regulations

As part of new global environmental initiatives, a coalition of trading nations implements a CBAM to impose tariffs on imports from countries with lax emissions regulations. This policy aims to prevent ‘carbon leakage’, where companies relocate production to jurisdictions with weaker environmental standards to avoid regulatory costs.

However, certain manufacturers in non-compliant regions seek to bypass these tariffs by routing their goods through an intermediary country before final export to CBAM-enforcing nations. These firms engage in ‘greenwashing’ supply chains – falsely claiming that their products meet stringent carbon footprint requirements. The intermediary country, a key logistics hub, lacks robust oversight, making it an attractive transit point for ‘re-exporting’ goods.

Regulators face a major enforcement challenge: trade documents are easily falsified, and traditional inspection methods are insufficient to verify carbon compliance across complex, multi-tiered supply chains.

11.2. The solution: federated AI for environmental trade compliance

A federated AI-driven system provides real-time supply chain transparency while respecting data sovereignty. Here’s how it works in this case:

1. Decentralised data integration

- manufacturers and logistics providers in the intermediary country participate in a trusted trade network, integrating their emissions data into a federated system
- the system connects shipment records, production data, and emissions tracking while preserving company privacy.

2. AI-powered risk detection

- advanced algorithms analyse material sourcing patterns to detect anomalies
- a manufacturer that historically sourced steel from a high-emission region but suddenly claims a low-carbon supply chain triggers scrutiny.

3. Customs and industry collaboration

- the AI system cross-references supply chain data with verified emissions reports and independent sustainability certifications
- if discrepancies are found – such as emission levels inconsistent with declared suppliers – customs authorities require further verification before granting tariff exemptions
- compliant firms with verifiable, low-carbon supply chains receive expedited clearance and reduced regulatory burdens.

11.3. Scenario outcome: strengthened carbon compliance and fairer trade

Through federated AI, regulators proactively detect and disrupt carbon regulation circumvention before non-compliant goods enter CBAM markets. Legitimate manufacturers benefit from a streamlined compliance process, while bad actors lose the ability to manipulate supply chains.

12. Recommendations: charting the course forward

1. From federated search to federated learning:

- replace massive in-place servers with decentralised ‘private enclaves’
- implement a federated learning architecture access routinely
- pursue necessary legislative changes and significant investment in information technology by government regulators.

2. Establish global principles of secure, compliant, and efficient border management:

- determine terms and conditions of participation in ‘trusted networks’
- address key questions: network organisation, data sharing protocols, system administration, incentive structures
- initiate carefully tailored pilot programs with early adopters from the private sector.

3. Foster culture change for ecosystems of trust:

- facilitate the transition from an adversarial status quo to co-creation of trust systems

- implement comprehensive culture change across public and private institutions
- design and implement Trusted Networks with clear incentive structures and conditions for collaboration.

4. Enhance transnational collaboration:

- recognise that unilateral border management is no longer viable
- pursue bilateral and multilateral cooperation in federated data sharing and operational alignment
- create ‘trusted port’ alliances for coordinated inspections and/or pre-clearance
- engage a ‘coalition of the willing’ among transnational actors in global trade
- involve multilateral organisations like the World Customs Organization (WCO) and international Civil Aviation Organization (ICAO) in adopting new standards and practices.

13. Conclusion: the future of border management as a federated value chain operation

As we stand on the brink of a new era in global trade, the transformation of border management into a federated value chain operation is not just desirable – it’s essential. Whether the task is trade compliance, facilitation, revenue recovery, human rights protection, environmental regulation, or safeguarding economic and national security, modern AI and federated architectures offer unprecedented capabilities.

These technologies allow us to:

- construct and harmonise maps of global supply chains covering billions of records
- analyse and act upon these maps with unparalleled speed and accuracy
- create a shared source of truth while preserving data sovereignty, security, and privacy
- enable novel forms of collaboration across governments, within governments, and between public and private sectors.

The road ahead is challenging, requiring significant changes in technology, policy, and organisational culture. But the potential rewards – a more secure, efficient, and ethical global trade system – make this journey not just worthwhile, but imperative.

As we navigate this transition, the key to success lies in our ability to embrace transparency, foster collaboration, and harness the power of cutting-edge technology. By doing so, we can build a global trade ecosystem that is not only more resilient and efficient but also more equitable and sustainable for all.

Note: This article was published initially in March 2025 in the Homeland Security Paper Series at Harvard Kennedy School's Belfer Center for Science and International Affairs. Alan Bersin and Peter Swartz are principals with the company Altana AI, which has developed a federated learning platform to permit the sharing of information between the private sector and government. This opinion essay synthesises the 'lessons learned' from their experience with Altana and its approaches to information sharing and analysis as these pertain to border management by government authorities. Analogous systems, utilising various AI techniques, are deployed by competitors of Altana.

The authors have added a hypothetical example for the benefit of WCJ readers. It outlines how a federated learning system deployed within a trusted network – involving traders and border management authorities – could be organised operationally in the context of regulating carbon emissions. The approach is applicable to a variety of additional use cases depending upon customs and security priorities.

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