

UDC 339.5:006.032:629.3(4:73)

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DOI: <https://doi.org/10.25313/2520-2057-2026-7-12093>

REGULATORY HARMONIZATION ANALYSIS AND STRATEGIC RECOMMENDATIONS: A CASE STUDY ON THE IMPORT OF EUROPEAN HEAVY-DUTY TRUCK COMPONENTS AND THEIR IMPACT ON THE U.S. MARKET

***Summary.** This article investigates the jurisprudential and technical divergence between the US self-certification regime (ex-post enforcement) and the EU type approval paradigm (ex-ante verification), identifying this discrepancy as the primary driver of market fragmentation. Employing a hybrid methodology that integrates comparative jurisprudence, systems engineering and economic impact assessment, the study exposes critical compliance gaps in photometric standards, chemical composition disclosure (REACH vs. TSCA) and certification markings. The analysis quantifies the compliance premium - excessive costs attributed to redundant validation and logistical friction, demonstrating how current protocols foster oligopolistic market structures and disrupt just-in-time supply chains. To resolve these inefficiencies, the article proposes a novel proposed framework. This model advocates for a paradigm shift from geometric prescription to functional equivalence, predicated on three*

pillars: harmonized cross-validation of testing facilities, blockchain-based digital product passports and conditional mutual recognition. Implementation of this mechanism is projected to reduce the landed cost of European components by 15-20%, eliminate bureaucratic latency and accelerate the adoption of safety-critical innovations within the US domestic market ecosystem.

Key words: *harmonization, transatlantic, automotive market, supply chain, certification, divergence.*

Introduction. In the contemporary architecture of global trade, the automotive industry occupies a unique position, acting simultaneously as a driver of technological innovation and a hostage to archaic regulatory barriers [1]. Despite its substantial capacity and technological proximity, the transatlantic automotive component market remains fragmented due to profound regulatory contradictions. While engineers strive for platform unification, the legal systems of the United States and the European Union continue to function within isolated realities. Divergences in safety standards (FMVSS vs UNECE), environmental testing protocols (EPA vs WLTP), and labeling requirements create a paradoxical scenario wherein a technically superior and safe European component may be rendered legally illicit on the American market absent costly modification [2].

The jurisprudential bifurcation between conformity assessment regimes in the United States and the European Union represents one of the most persistent challenges to the harmonization of international technical regulation [3]. The significance of this study is anchored in the necessity to surmount the compliance premium - excessive economic costs stemming from procedural duplication and the absence of mutual recognition [4]. Consequently, this article undertakes a comprehensive analysis of regulatory divergence to identify critical non-conformance zones and assess their economic impact on pricing and logistics. Also it conducts a comparative analysis of the normative frameworks of both

jurisdictions to detect specific vulnerabilities inherent in the importation of European components.

In response to these identified challenges, this article proposes a conceptual model designated as the Transatlantic Compliance Protocol (TCP). This framework is engineered to supersede obsolete geometric prescriptions with a modern system based on the principle of functional equivalence and the implementation of digital verification tools.

Materials and methods. This study employs a comprehensive qualitative research methodology, integrating comparative jurisprudence, systems engineering analysis and economic impact assessment to examine the transatlantic automotive regulatory landscape. The primary evidentiary basis for this research comprises the legislative and technical regulations governing vehicle homologation procedures within the United States and the European Union. The analysis focuses on the National traffic and motor vehicle safety act, the Code of federal regulations (specifically Title 49, Part 571 FMVSS), enforcement protocols of the National highway traffic safety administration (NHTSA), as well as environmental mandates from the EPA (Title 40 CFR) and California’s Proposition 65 [5; 6; 7; 8]. Also the study examines the framework of the UNECE 1958 Agreement, specific UN Regulations (R112 for lighting systems, R43 for glazing), the EU Type Approval framework regulation (EU) 2018/858 and chemical safety standards under REACH [9; 10; 11].

A comparative review of SAE (Society of automotive engineers) standards and ISO (International organization for standardization) norms was conducted to identify specific engineering divergences. A dialectical comparison was applied to contrast the philosophy of ex-ante verification in the EU with the ex-post enforcement regime in the US [12]. This phase utilized legal hermeneutics to interpret how procedural differences transmute into non-tariff trade barriers. Supply chain management principles were applied to evaluate the impact of regulatory friction on just-in-time logistics. Qualitative economic analysis was

utilized to decompose the landed cost structure, isolating specific cost multipliers associated with redundant certification and risk mitigation. Specific automotive components, namely lighting systems, glazing and hydraulic assemblies, were utilized as case studies to empirically ground the theoretical analysis.

In the final phase, the Transatlantic Compliance Protocol was designed using a systems engineering approach. This model was synthesized by integrating existing best practices in digital credentialing (blockchain technology) with the legal principle of functional equivalence, aiming to propose a theoretically viable mechanism for regulatory harmonization.

Juxtaposition of US regulatory frameworks and EU standardization protocols. Notwithstanding the pervasive globalization of the automotive industry, regulatory divergence persists as a formidable barrier between the United States and the European Union. While the overarching teleological objectives in both jurisdictions remain congruent, namely the assurance of road safety and the minimization of environmental impact, the jurisprudential pathways employed to achieve them exhibit a fundamental bifurcation [13]. The foundational distinction between the American and European systems lies less in technical granularity than in the legal philosophy of conformity assessment.

Pursuant to the National traffic and motor vehicle safety act, the United States operates under a self-certification regime. Under this framework, the manufacturer bears the sole burden of attesting that its components comply with the Federal motor vehicle safety standards (FMVSS), as codified in the Code of federal regulations (CFR). Conversely, federal regulatory bodies, such as the National highway traffic safety administration (NHTSA) and the Department of transportation (DOT), generally refrain from conducting pre-market testing. Instead, oversight is exercised through an ex-post enforcement mechanism, characterized by sporadic compliance audits following market entry and a rigorous liability framework encompassing mandatory recall campaigns and litigation risks [14].

In stark contrast, the European model affords significantly less autonomy to the manufacturer, relying on a stricter control paradigm. The European approach is predicated on ex-ante verification, technically termed as type approval (or homologation). Prior to market launch, components must undergo mandatory testing by accredited technical services and subsequently obtain certification from a competent authority - the KBA in Germany or the RDW in the Netherlands [15].

These systemic disparities constitute a primary impediment to the seamless transposition of European logistical algorithms onto American soil. The integration of supply chains is impossible without a nuanced understanding of these legal idiosyncrasies and systemic bottlenecks. Specifically, the possession of a full suite of European certifications (the E-mark) holds no statutory validity within the US jurisdiction, thereby necessitating a redundant cycle of internal validation by the importer to mitigate legal liability [16]. Technical standardization reveals a deep schism. The American framework frequently codifies SAE (Society of Automotive Engineers) standards directly into federal law (49 CFR). Modifications to these standards entail a labyrinthine rulemaking process, often resulting in regulatory inertia [17].

Conversely, the European system is harmonized with UNECE Regulations and ISO standards, facilitating a more agile adaptation to technological innovations. Critical discrepancies are evident in requirements regarding lighting systems, glazing, rearview mirrors and braking assemblies. For instance, European aspherical mirrors or matrix lighting technologies may fail to meet the rigid geometric prescriptions of FMVSS, notwithstanding their empirical efficacy, thus precluding direct importation and complicating supply chain dynamics [18].

The most acute contradictions, however, arise within the domain of environmental regulation concerning powertrains and exhaust systems. Given the global imperative for carbon neutrality and green performance metrics, environmental mandates have become integral to transatlantic logistical

mechanisms. While both the Environmental Protection Agency (EPA) and the California Air Resources Board (CARB) enforce stringent thresholds for nitrogen oxides (NO_x) and particulate matter, the core conflict resides in the test cycles. American protocols (FTP-75) simulate specific driving conditions that diverge significantly from European WLTP or RDE (Real Driving Emissions) cycles [19].

Consequently, an emission control component optimized for European load profiles may exhibit deviations when subjected to EPA methodology, rendering it effectively illegal without profound technical modification, even if its actual ecological footprint is minimal.

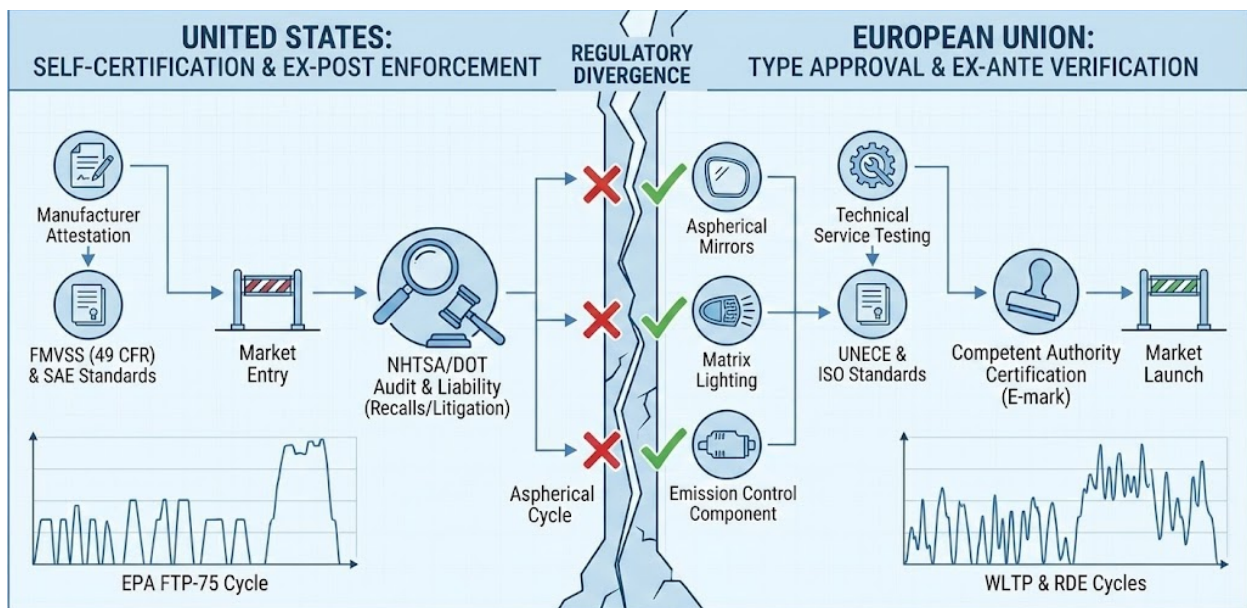


Fig. 1. Conceptual diagram of systemic regulatory divergence between the US and the EU

Source: generative artificial intelligence and prompt were used to create the image

Detecting critical compliance gaps in the US certification process for EU origin components. The transition from a theoretical juxtaposition of regulatory frameworks to the operational reality of importation exposes a series of critical compliance gaps, manifesting as specific technical or chemical parameters where the direct application of commercial off-the-shelf European components is rendered impossible without substantial modification.

One of the most insidious, yet frequently underestimated, risk zones concerns the regulation of chemical composition. While the European Union operates under the REACH regulation, which primarily focuses on the direct prohibition or restriction of hazardous substances, the United States framework relies heavily on the Toxic substances control act (TSCA) and, more critically for importers, California’s Proposition 65 [20]. Unlike the European “prohibition” model, the American model often mandates “disclosure” and consumer warning. Hence, a European plastic component may be fully compliant within the EU. However, if it contains micro-traces of a substance listed under Proposition 65 without the requisite warning label, the entity is exposed to significant litigation risks. This enforcement is frequently driven by private enforcement litigants, colloquially known as bounty hunters, creating a regulatory paradox wherein a technically safe component becomes statutorily toxic solely due to the absence of a warning sticker [21].

Additionally, photometric incompatibility constitutes a formidable engineering barrier due to fundamental divergences in beam pattern geometry. SAE J standards in the US and ECE R regulations in Europe stipulate distinct requirements for light distribution: the European low-beam standard mandates a sharp cut-off gradient to prevent glare, whereas US standards specifically require a certain degree of upward light leakage to illuminate overhead gantry signs [22]. As a result, a European headlamp with focus characteristics that are considered ideal under ECE protocols may be deemed non-compliant under FMVSS 108 due to insufficient illumination of the upper sector, rendering the direct import of optical units impossible without a comprehensive re-engineering of the reflector or lens optics.

Beyond functional performance, the third tier of vulnerability pertains to safety-critical components where the lack of mutual recognition regarding certification markings creates absolute barriers to market entry. The European E-mark on automotive glass holds no validity in the US. Instead, glazing must bear

the DOT certification and an AS (American standard) code, attesting to successful penetration and light transmissibility tests which differ methodologically from European norms [23]. Similarly, hydraulic assemblies such as brake hoses must feature an indelible DOT marking and a manufacturer identification code registered directly with NHTSA. The absence of this specific code, regardless of the component’s intrinsic quality or performance, serves as grounds for the immediate confiscation of the shipment, thereby confirming that technical excellence is insufficient without precise adherence to US statutory labeling requirements.

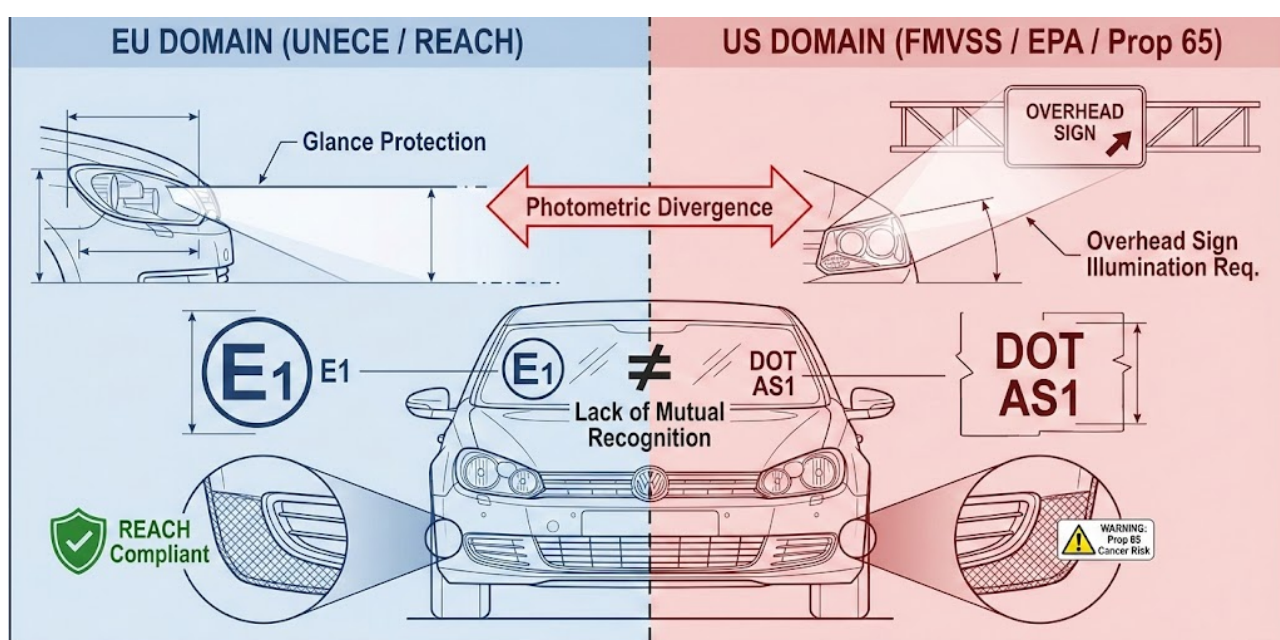


Fig. 2. Schematogram illustrating systemic compliance gaps between EU type approval and US self-certification requirements across photometric, material and marking domains

Source: generative artificial intelligence and prompt were used to create the image

The economic and logistical implications of regulatory divergence on import dynamics, pricing strategies and lead time. The technical incompatibility of standards delineated in the preceding sections inevitably transmutes into quantifiable economic inefficiencies, fundamentally distorting the structure of transatlantic automotive trade. Regulatory divergence operates as a

pervasive non-tariff barrier, creating a cost multiplier effect at every node of the supply chain [24].

The primary economic impact strikes the structure of the landed cost. The importer is compelled to factor in also the amortization of re-certification overhead, which serves as an absolute prerequisite for market access. The process of conducting redundant trials in US laboratories to corroborate compliance with FMVSS standards - even when identical European protocols exist, necessitates significant capital investment and temporal resources. These fixed costs are particularly deleterious for small and medium-sized consignments, effectively foreclosing the American market to niche European manufacturers unable to leverage economies of scale to dilute these expenses. Therefore, an oligopolistic market structure emerges, dominated exclusively by large multinational corporations capable of financing dual production standards. Meanwhile, small, medium or nascent enterprises remain marginalized in the shadows, although their quality and potential fully warrant entry into the transatlantic logistics and sales ecosystem.

The logistical dimension of this issue manifests in the destabilization of supply chains and the elongation of lead times. The absence of harmonized digital documentation precipitates substantial customs friction. Any discrepancy in labeling or manufacturer identification codes detected by NHTSA inspectors at the port of entry initiates cargo detention protocols that may persist for weeks. Under the contemporary just-in-time paradigm, such unpredictability compels American distributors to abandon efficient logistics in favor of accumulating excessive safety stock [25]. This defensive strategy immobilizes working capital in inventory and escalates warehousing costs, standing in direct contradiction to the principles of lean manufacturing.

Table 1

Structural decomposition of regulatory cost multipliers in transatlantic trade

Economic variable	Mechanism of inefficiency	Impact on supply chain + pricing
Certification overhead	Mandatory reiteration of identical technical tests (FMVSS vs. ECE) for market entry	Increases CAPEX requirements. Creates prohibitive entry barriers for SME, fostering an oligopolistic market structure
Inventory management	Disruption of just-in-time flows due to unpredictable customs detention risks (NHTSA holds)	Forces accumulation of excessive safety stock, immobilizing working capital and increasing warehousing OPEX
Liability mitigation	Necessity to insure against strict US liability laws and bounty hunter litigation (Prop 65)	Adds a significant risk premium to the wholesale price. Necessitates expensive legal counsel retention
Time-to-market	Delays caused by bureaucratic rulemaking and non-harmonized digital documentation	Erodes competitive advantage of new technologies and also increases the likelihood of obsolescence before retail sale

Ultimately, this regulatory burden is transferred to the consumer via the pricing mechanism. The retail price of a European component in the US incorporates a “compliance premium” - a surcharge covering legal liabilities and localization costs. Moreover, the uncertainty regarding delivery timelines forces suppliers to embed additional risk margins, eroding the price competitiveness of high-quality European parts vis-a-vis cheaper, lower-quality alternatives from jurisdictions with more flexible or less monitored standards. Thus, the regulatory gap not only decelerates trade turnover, but also artificially drives inflation within the automotive component sector, diminishing overall market efficiency.

Development of a novel framework for regulatory harmonization.

To surmount the established barriers and mitigate the consequent economic hemorrhage, a paradigm shift away from archaic, siloed regulatory methodologies is critically required. This section posits a proposed framework designated as the Transatlantic Compliance Protocol. The proposed architecture does not necessitate total legislative unification, a politically unfeasible objective, but

rather establishes a mechanism of functional equivalence. The model is predicated on three integrated components: harmonized technical pre-attestation, digital ledger credentialing and conditional mutual recognition.

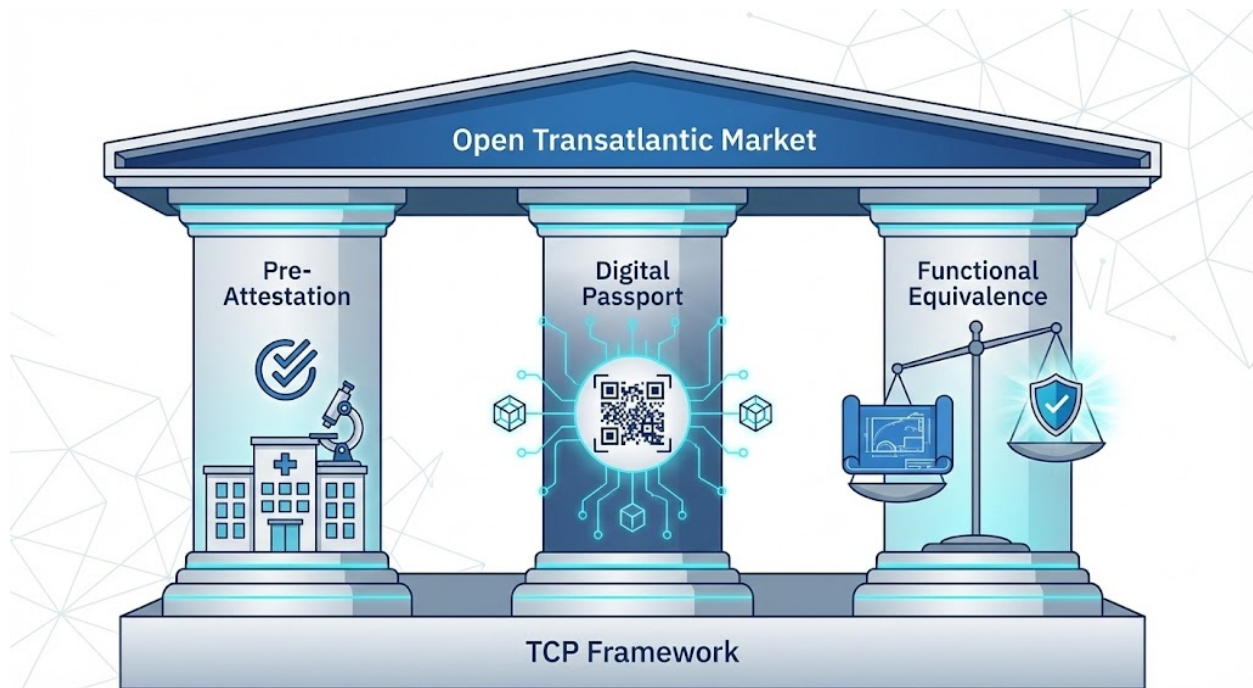


Fig. 3. Schematic representation of the proposed structure of the Transatlantic compliance protocol (TCP)

Source: generative artificial intelligence and prompt were used to create the image

The first stratum involves the implementation of a harmonized pre-attestation mechanism through the cross-validation of testing facilities. Laboratories already accredited within the EU to conduct testing under UNECE standards should be granted “Trusted technical service” status by the NHTSA. This designation would facilitate the in-situ execution of US-mandated protocols (FMVSS 108 for optical systems) directly within European territories, obviating the need for the physical export of test samples to the United States. As a consequence, test results ratified by an accredited EU laboratory would be recognized by US regulators as legally binding substantiation for self-certification, thereby eliminating the redundancy of duplicative validation by the importer.

Concomitantly, the second tier addresses logistical friction through digital ledger certification. To resolve supply chain bottlenecks, the framework advocates for the abandonment of physical etching and paper-based documentation in favor of a digital product passport. Under this regime, every component batch is tagged with a unique QR code or RFID identifier linked to a secure, immutable blockchain ledger. Upon scanning, a customs officer or DOT inspector gains immediate access to verified test protocols, material declarations (spanning REACH and Proposition 65), and chain-of-custody data. This digitalization ensures absolute supply chain transparency and drastically reduces customs clearance latency from weeks to mere minutes, effectively eradicating the human factor risk, associated with manual label verification.

The third component is the agreement on mutual recognition of functional equivalence. This represents a fundamental transition from geometric prescriptive compliance to functional performance recognition. Rather than demanding identical design specifications, regulators must acknowledge the equivalence of safety outcomes. Specifically, if a European matrix headlight demonstrates road illumination and glare prevention capabilities that exceed the minimum safety thresholds of FMVSS, it must be deemed admissible to the US market via the MRA mechanism, even if it formally deviates from the obsolete geometric prescriptions of the 1970s.

This holistic architecture is engineered to resolve the multipolar crisis - encompassing economic, ecological, logistical and jurisprudential dimensions, ultimately unlocking the market for innovation and reducing the landed cost of technology for the end consumer.

Projected impact on the US domestic market ecosystem. The implementation of the proposed protocol framework precipitates a profound structural reconfiguration of the US automotive component market, extending far beyond the mere simplification of import procedures. The primary and most tangible effect is the exertion of deflationary pressure on retail pricing. The

elimination of redundant certification expenditures and the mitigation of logistical risks are projected to reduce the landed cost of European products by approximately 15-20%.

The projected 15-20% cost reduction represents a cumulative estimate derived from three distinct economic vectors. The primary component involves the elimination of redundant certification overhead (3-5%), which encompasses the substantial expenses related to the transatlantic shipment of test samples, US-based laboratory fees and destructive testing protocols - fixed costs that disproportionately erode profit margins for small and medium-sized consignments. Additionally, logistical optimization contributes an additional 5-7% saving. Currently, the unpredictability of customs clearance compels distributors to maintain a safety stock covering two to three months of demand and halving this requirement through regulatory predictability significantly reduces carrying costs, which typically average 20-25% annually relative to the goods' value. Finally, the alleviation of the risk premium offers a potential reduction of 5-8%, as the implementation of the TCP mitigates the need for importers to hedge against recalls and liability litigation, allowing competitive pressure to erode this surcharge and yielding an aggregate conservative lower bound estimate of 15%.

This reduction will effectively dismantle the artificial compliance premium, rendering high-quality European original equipment manufacturer components price-competitive against budget-tier alternatives from the Asian region. The second vector of impact pertains to the democratization of technology and the erosion of oligopolistic barriers. Lowering the market entry threshold will grant access to European small and medium-sized enterprises specializing in niche, high-technology solutions - entities previously precluded from the market by the prohibitive capital requirements of FMVSS certification. This will result in a substantial diversification of supply: the American consumer will gain direct

access to advanced active safety systems and environmentally sustainable technologies that were historically obstructed by regulatory gateways.

Finally, harmonization will engender enhanced supply chain resilience. The transition to digital credentialing and mutual recognition will eliminate the variable of delivery unpredictability, enabling American distributors and service centers to revert to efficient inventory management models. In the long term, the integration of standards will serve as a catalyst for the renewal of the national vehicle fleet, accelerating the transition toward carbon neutrality and elevating overall road safety standards through the adoption of proven global innovations without bureaucratic latency.

Conclusion. The comprehensive analysis undertaken herein underscores that the regulatory divergence between the US and EU automotive sectors constitutes an archaic constraint impeding technological advancement and economic efficiency, rooted in the dichotomy of ex-ante verification versus ex-post enforcement. As demonstrated, this bifurcation engenders barriers manifesting as chemical, photometric and administrative compliance gaps, which artificially inflate the landed cost of European components and stifle supply chain agility. The research has quantified the substantial compliance premium driven by the absence of mutual recognition, revealing how current certification protocols function as unintentional drivers of inflation and mechanisms of market exclusion for innovative SME.

The proposed Transatlantic Compliance Protocol demonstrates that contemporary technological instruments, specifically digital product passports and cross-validated pre-attestation are capable of resolving this systemic inefficiency. Consequently, the harmonization of standards is identified herein as a fundamental catalyst for restoring market equilibrium, reducing consumer expenditures and ensuring the unimpeded flow of vital automotive innovations across the Atlantic. By leveraging distributed ledger technologies to ensure transparency and shifting the regulatory paradigm toward functional equivalence,

it becomes feasible to harmonize standards without compromising safety or environmental objectives. The implementation of such a framework constitutes a strategic imperative for fostering a sustainable, innovative and cost-effective transatlantic market. Ultimately, the trajectory of the transatlantic aftermarket depends on the willingness of regulators to embrace the principle of functional equivalence. This measure will also accelerate the adoption of critical safety systems and environmentally sustainable technologies, thereby accruing benefit to the ultimate stakeholder - the consumer.

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