

Overland corridors as a substitute for ocean freight in China–Europe trade

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Abstract

Overland corridors offer alternatives to ocean freight, but rising railway traffic does not by itself demonstrate maritime substitution. This study evaluates the scale, direction, and commodity composition of reported modal reallocation in China–European Union trade. An original secondary analysis of Eurostat Comext data reconstructs a fixed 27-country European Union panel for 2015–2025 and applies a symmetric commodity decomposition to 2023–2025 observations. In 2024, railway imports from China increased by 40.6% in value and 59.6% in net mass. Rail’s share of combined rail and sea imports rose from 3.665% to 4.824% by value and from 1.919% to 2.815% by mass. Among 92 matched commodity chapters, within-chapter changes accounted for 1.160 of the 1.163 percentage-point increase in the value share. The value-share increase reversed in 2025, while exports to China displayed falling rail value shares alongside rising mass shares. Diverting 10% of 2024 seaborne import mass would arithmetically require railway throughput 4.45 times its observed level. These findings support a selective and reversible role for rail within a maritime-dominated system. They do not identify causal diversion, corridor-specific performance, or spare capacity. Border-mode measurement, unclassified trade, and incomplete commodity coverage constrain interpretation and motivate shipment-level research.

Keywords: China–Europe trade, rail freight, maritime transport, modal reallocation, trade corridors, Eurostat Comext, commodity decomposition

1. Introduction

The practical question facing China–Europe logistics is how much maritime dependence overland alternatives can reduce, and for which trade flows. Railway services offer a different combination of freight charges, transit time, and reliability from ocean shipping. The economic value of faster delivery is established in research on international transport choice [1]. However, the existence of a time advantage cannot establish the quantity of maritime cargo that actually transfers to rail. That quantity depends on commodity characteristics, demand, access to terminals, service availability, and the alternatives available to the same shipper. A credible assessment must therefore distinguish commercial substitutability from observed traffic growth.

Earlier work identifies potential transfers from sea and air to Eurasian rail and highlights their uneven geography [2,3]. Maritime disruptions have renewed attention to this possibility. The Red Sea crisis changed shipping operations and supply-chain planning, while the pandemic had already demonstrated the vulnerability and

adaptability of container networks [4,5]. These episodes motivate comparison across periods, but they do not turn aggregate trade statistics into a natural experiment. Rail can grow because total trade expands, because the traded product mix changes, or because goods move from other modes. Equally, a declining maritime share can accompany increasing maritime tonnage.

This study develops an empirical diagnostic of substitution using official border-mode records. Its contribution is the joint assessment of long-run modal shares, trade direction, value versus mass, commodity composition, and the arithmetic scale of a potential diversion. The geographical scope is China and the current 27 members of the European Union (EU), held constant throughout 2015–2025. Three expectations guide the analysis: rail remains a minority mode; its import share increases in 2024 relative to 2023; and the interpretation changes when mass replaces value. A further decomposition asks whether changing commodity weights explain the import-share increase. These expectations are evaluated descriptively, without claiming identification of a causal substitution elasticity.

2. Related research and analytical framework

The first strand of research concerns the trade-off between speed and cost. Hummels and Schaur estimate the value of time using exporters' choices between air and ocean transport [1]. Their results justify attention to time-sensitive goods, but are not direct estimates of the China–Europe rail–sea relationship. Dunmore, Preti, and Routaboul examine potential diversion to rail and its implications for European transport infrastructure [2]. Lu and colleagues model the spatial boundary between rail and sea competitiveness, incorporating destination, freight cost, and the value of time [3]. Together these studies suggest heterogeneous opportunities rather than a uniform replacement of maritime transport. They also indicate why a value-based market share may differ from a mass-based share.

A second strand examines the development and operating context of railway services. Benard, Yu, and Pu document the role of policy support, trade patterns, and infrastructure in the evolution of China Railway Express [6]. Their analysis makes clear that observed railway growth reflects a changing institutional environment. Hilmola and Li investigate Finland–China container traffic using regression analysis and identify associations with maritime-market and pandemic variables [7]. That route-specific evidence is informative, but a comparatively small northern market cannot automatically represent the EU as a whole. Aggregation across countries and directions can also obscure divergent commercial conditions. The present study consequently reports imports and exports separately throughout.

Scenario models address questions that historical shares alone cannot answer. Zeng and colleagues compare Arctic shipping, the Suez route, and China–Europe rail under alternative conditions [8]. Wang, Guo, and Wu simulate the potential mitigation offered by China Railway Express during the Red Sea crisis [9]. Baniya, Rocha, and Ruta connect transport-time improvements to potential trade gains using geographical and economic analysis [10]. These contributions concern conditional outcomes, with assumptions governing prices, route choice, or trade responsiveness. Their scenarios should not be treated as observed displacement. Conversely, historical border records cannot establish the welfare effects or network equilibrium that these models investigate. The two approaches are complementary when their different evidential roles remain explicit.

Corridor terminology requires particular care. The World Bank's Middle Corridor assessment describes a multimodal connection whose performance depends on both land transport and maritime interfaces [11]. "Overland" therefore does not necessarily mean a journey without a sea crossing. Moreover, a consignment entering the EU by rail does not reveal which trans-Eurasian corridor it previously used. This study treats rail as an observable border-mode proxy for part of the overland option. Road, air, and other reported modes remain in the wider denominator, but the core comparison concerns rail and sea. No route-specific traffic

totals are inferred from this classification.

The literature review is a targeted narrative synthesis, not a systematic review. Searches combined China–Europe rail, maritime substitution, modal competition, Red Sea disruption, and corridor development, followed by checks of publisher and institutional records. The review prioritizes studies that explain transport choice or demonstrate a distinction between observed flows and modeled alternatives. Its purpose is to derive an interpretable measurement framework rather than claim exhaustive coverage. The empirical contribution is a reproducible combination of indicators applied to a recent official data vintage; neither the decomposition method nor the general proposition that rail can compete with sea is claimed as new.

3. Data and methods

3.1. Source, coverage, and measurement

Data come from Eurostat Comext dataset DS-059334, Extra-EU trade since 2002 by mode of transport, by HS2-4-6 [12]. The extract was downloaded on 7 October 2026, local time, and reports a source update of 15 September 2026. It includes annual and monthly total-product observations for 2015–2025 and annual two-digit Harmonized System (HS) product chapters for 2023–2025. Values in euros and net mass in kilograms are retained. Imports use China as origin and exports use China as destination. Eurostat defines the extra-EU transport mode at the EU frontier and distinguishes import cost-insurance-freight valuation from export free-on-board valuation [13]. These are customs trade measures, not freight rates, vessel movements, or container counts.

The total-product series sums the same 27 national reporters in every period. The changing-membership EU aggregate is not used for the long-run comparison. For the commodity decomposition, the published EU aggregate is used only in 2023–2025, when its total-product values match the sum of the 27 reporters exactly. Retrieval uses the dedicated Comext application programming interface [14]. Raw responses, queries, scripts, and derived tables accompany Supplementary File S1. The reconstructed aggregate has 132 monthly periods and 11 annual periods in each direction.

Missing cells remain missing. No unreported product–mode combination is converted to zero. Aggregate series sum available national observations; their agreement with published EU totals in 2021–2025 supports this reconstruction but does not prove the absence of source error. Monthly sums differ from corresponding annual observations by at most 12 units across the extracted euro and kilogram cells. These small release-level discrepancies are retained and documented. Annual estimates use the annual release; monthly comparisons use the monthly release. The decomposition includes only chapters with observed rail and sea values at both endpoints and positive combined flows. It therefore describes a matched subset, whose coverage is reported explicitly.

3.2. Shares, decomposition, and sensitivity

Let R and S denote reported rail and sea flows for the same direction, period, and unit. The primary indicator is $100R/(R + S)$, while the broader market indicator divides R by the sum of all nine reported transport-mode categories, including unknown mode. Shares are calculated separately for value and mass. Annual changes are expressed in percentage points; growth rates use the preceding year as denominator. Comparing the same calendar month across 2023 and 2024 provides a descriptive check on whether an annual movement is concentrated in a few months. No independence assumption or statistical significance claim is attached to those twelve comparisons.

Commodity decomposition follows the symmetric rate-and-composition logic associated with Kitagawa [15].

For matched chapter i in period t , define $q_{it} = R_{it}/(R_{it} + S_{it})$ and $w_{it} = (R_{it} + S_{it})/\sum_i (R_{it} + S_{it})$. The aggregate share is $\sum_i w_{it} q_{it}$. Its change is decomposed exactly as follows:

$$\Delta q = \sum_i [(w_{i1} + w_{i0})/2](q_{i1} - q_{i0}) + \sum_i [(q_{i1} + q_{i0})/2](w_{i1} - w_{i0}).$$

The first term is the within-chapter component and the second is the composition component. Both are multiplied by 100 for presentation in percentage points. The identity is checked numerically. A within-chapter increase remains compatible with changes among individual products, firms, or prices inside the same broad chapter; it is not a direct observation of a shipment switching modes. Main-text decomposition results concern imports, where matched coverage is high. Export decompositions are supplied separately because their coverage is materially lower, particularly by mass. Exploratory exclusions of machinery chapters 84 and 85 test whether those two sectors alone determine the direction of the findings.

A final accounting exercise considers diversion of a fraction d of observed sea mass onto rail, holding other quantities constant. Required total rail throughput relative to the baseline is $M(d) = 1 + dS/R$. Values of d equal to 0.05, 0.10, and 0.25 illustrate scale; they are not forecasts or engineering capacity estimates. An additional sensitivity envelope allocates all unknown-mode flows U either to sea or to rail, giving bounds $R/(R + S + U)$ and $(R + U)/(R + S + U)$. These intentionally extreme bounds describe classification uncertainty, not confidence intervals. The design uses administrative aggregates, so numerical and coverage checks replace artificial sampling precision. A local analysis protocol preceded computation; it was not independently preregistered.

4. Results

4.1. Long-run scale and the 2024 import rebound

Rail remained small relative to sea throughout the observation window. Its share of combined rail and sea imports rose from 2.091% by value in 2015 to 6.546% in 2021, then fell to 3.665% in 2023. The corresponding mass shares were 1.013%, 3.443%, and 1.919%. Thus, the pre-2024 trajectory already contained a pronounced expansion and contraction. Export shares were also non-monotonic: the value share reached 9.721% in 2021 but was 6.033% in 2023. Figure 1 places the recent changes within this longer history, while Table 1 reports comparable levels and shares.

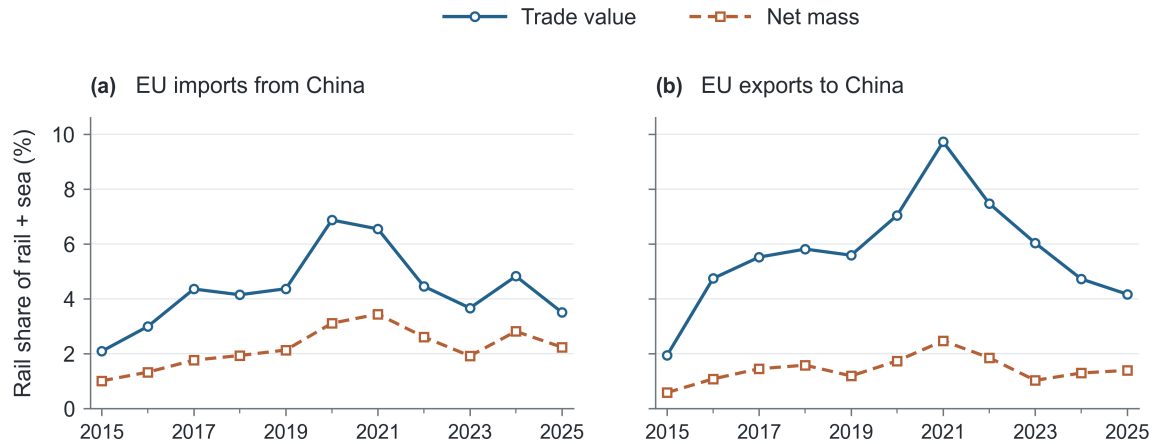


Figure 1. Railway share of combined rail and sea trade, 2015–2025. (a) EU imports from China; (b) EU exports to China. Values and net mass use the same fixed EU-27 geography but different units. Source: calculations from Eurostat [12].

Table 1. Railway trade levels and shares in combined rail and sea flows.

EU flow	Year	€ bn	Mt	Value %	Mass %
Import	2015	3.910	0.460	2.091	1.013
Import	2021	19.960	2.028	6.546	3.443
Import	2023	11.892	1.215	3.665	1.919
Import	2024	16.718	1.939	4.824	2.815
Import	2025	12.918	1.789	3.507	2.237
Export	2015	1.769	0.218	1.941	0.585
Export	2021	12.480	1.250	9.721	2.470
Export	2023	7.245	0.362	6.033	1.030
Export	2024	5.352	0.390	4.724	1.298
Export	2025	4.115	0.370	4.168	1.394

Note: Mt = million tonnes; € bn = billion euros. Imports are from China; exports are to China. Fixed EU-27 membership. Shares use rail plus sea, not all modes. Source: calculations from Eurostat [12].

In 2024, railway import value increased from €11.892 billion to €16.718 billion, a rise of 40.6%. Import mass increased from 1.215 million to 1.939 million tonnes, or 59.6%. Sea imports increased too: value rose by 5.5% and mass by 7.8%. Rail’s combined rail–sea share consequently increased by 1.159 percentage points in value and 0.896 points in mass. Its all-mode shares nevertheless remained only 3.146% and 2.540%, respectively. The result establishes faster growth of reported railway imports, rather than an absolute contraction in maritime imports or a measured volume of cargo transferred from ships.

Calendar-matched monthly comparisons support the breadth of the 2024 import movement. Rail’s value share exceeded its 2023 counterpart in ten of twelve months; the mass share did so in all twelve. Median monthly changes were 1.236 percentage points by value and 0.816 points by mass. Figure 2 also shows the subsequent reversal. In 2025, rail import value fell by 22.7% and mass by 7.7% relative to 2024. The value share declined to 3.507%, below its 2023 level, while the mass share declined to 2.237%, still above 2023. The evidence therefore does not support a sustained, uniform increase across both measures.

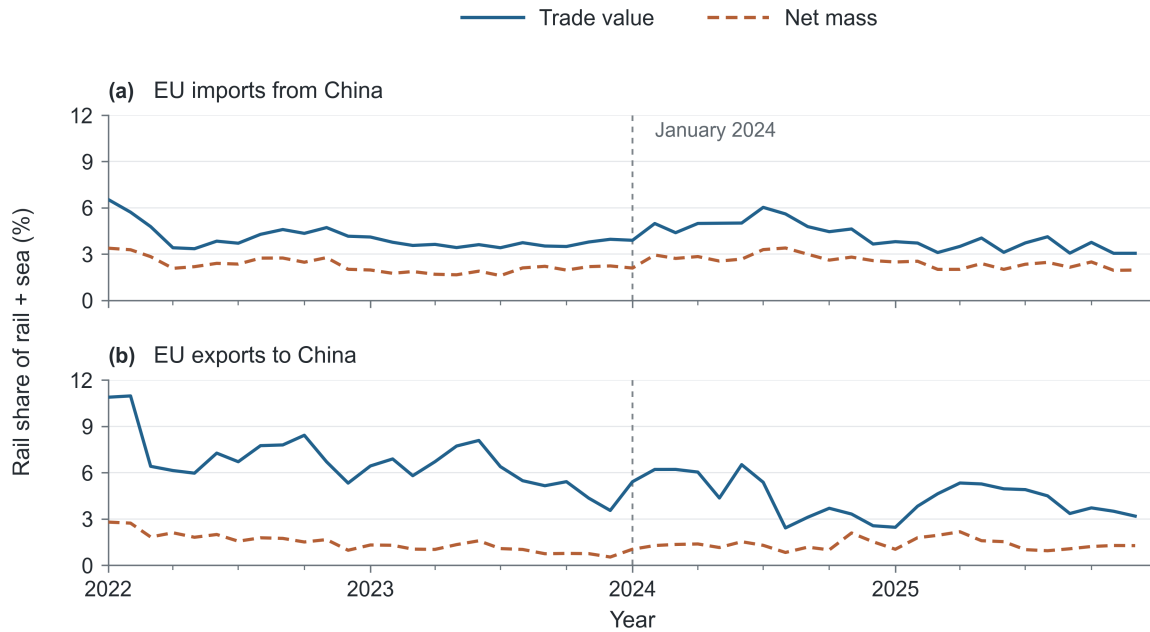


Figure 2. Monthly railway shares of combined rail and sea trade, 2022–2025. The dashed line marks January 2024 for descriptive comparison; it does not identify a causal break. (a) EU imports from China; (b) EU exports to China. Source: calculations from Eurostat [12].

4.2. Commodity composition and directional asymmetry

The 2023–2024 import decomposition contains 92 matched chapters, covering 99.37–99.43% of combined rail–sea value and 98.05–98.17% of mass at the two endpoints. Its value-share increase is 1.163 percentage points, of which 1.160 comes from within-chapter changes and 0.003 from changing chapter weights (Table 2). The mass decomposition likewise attributes most of the increase to within-chapter movements: 0.862 out of 0.916 points. These subset estimates are close to, but deliberately distinguished from, the total-product results. They indicate that broad shifts in commodity composition do not explain the measured import rebound.

Table 2. Commodity decomposition of the change in the railway import share.

Period	Measure	Chapters	Total, pp	Within, pp	Mix, pp
2023–2024	Value	92	1.163	1.160	0.003
2023–2024	Mass	92	0.916	0.862	0.054
2023–2025	Value	91	–0.161	–0.169	0.008
2023–2025	Mass	91	0.345	0.250	0.095

Note: pp = percentage points. Complete rail–sea chapter pairs only; denominators differ slightly from total-product shares. Coverage in 2023–2024 is 99.37–99.43% of value and 98.05–98.17% of mass. In 2023–2025 it is 99.35–99.43% and 97.29–98.17%, respectively. Rounding may affect displayed sums. Source: calculations from Eurostat [12].

Machinery chapter 84 contributes 0.325 percentage points to the within-chapter value component, electrical equipment chapter 85 contributes 0.127, and vehicles chapter 87 contributes 0.112. Other contributions include toys, clothing, plastics, and furniture. Excluding both chapters 84 and 85 leaves an increase of 1.267 percentage points in the matched value share and 1.010 points in the mass share. The positive direction therefore extends beyond the two large machinery categories. For 2023–2025, however, the matched import value share falls by 0.161 points, whereas the mass share rises by 0.345 points. Full contributions and exclusion calculations appear in Supplementary Tables S1–S2 and Supplementary Figure S1.

Exports show a different pattern. Between 2023 and 2024, rail export value declined by 26.1%, from €7.245 billion to €5.352 billion, while mass increased by 7.5%. The combined value share fell from 6.033% to 4.724%, but the mass share rose from 1.030% to 1.298%. By 2025 these shares were 4.168% and 1.394%. A single value-based narrative would therefore miss the increasing relative mass share. The 2023–2024 export decomposition covers approximately 93% of value but only 75–76% of mass, limiting its generalizability. It is retained as a supplementary diagnostic rather than presented as an exhaustive explanation of export change.

4.3. The scale of an alternative to sea

In 2024, reported seaborne imports weighed 66.934 million tonnes, compared with 1.939 million tonnes by rail. A hypothetical transfer of 10% of sea mass would add 6.693 million tonnes to rail, requiring total throughput 4.45 times the observed railway baseline. For exports, the equivalent multiple is 8.60. Table 3 also shows smaller and larger diversion assumptions. These calculations illustrate why a large percentage increase in a small railway flow can coexist with limited replacement of the maritime system. They do not establish whether any corridor could accommodate the additional tonnage or whether those goods would be suitable for rail.

Table 3. Hypothetical diversion of 2024 sea mass to railway transport.

Sea shift	Import Mt	Import ×	Export Mt	Export ×
5%	3.347	2.73×	1.481	4.80×
10%	6.693	4.45×	2.962	8.60×
25%	16.733	9.63×	7.405	20.01×

Note: Mt columns give additional railway mass in million tonnes; × columns give total railway throughput relative to baseline. Other flows are fixed. These are accounting scenarios, not observed transfers, forecasts, or capacity estimates. Source: calculations from Eurostat [12].

5. Discussion

5.1. Selective substitution and reversibility

The findings support a selective role for rail, with an essential qualification: the data reveal changes in reported modal allocation, not the counterfactual mode of any shipment. The 2024 import increase remains visible after controlling arithmetically for broad commodity weights and after excluding large machinery chapters. This is stronger descriptive evidence than a headline count of trains or an aggregate growth rate alone. Yet it does not identify how much additional rail traffic would otherwise have travelled by sea. Demand shifts, competition with air and road, and changes within HS chapters remain possible explanations. The hypotheses of minority scale and a 2024 import-share increase are supported at the descriptive level; persistent displacement is not.

The 2025 reversal is particularly informative. An assessment ending in 2024 could have presented the import rebound as evidence of a durable structural transition. Extending the window changes that interpretation: the value share drops below 2023, while the mass share retains only part of its earlier increase. Reversibility matters for infrastructure planning because a temporary surge and a sustained new traffic base imply different commercial risks. The result also argues for evaluating emergency alternatives across several years rather than treating the first disruption year as representative. Nothing in this comparison determines which event caused the reversal or rules out the continuing value of rail to individual users.

The contrast between value and mass is equally consequential. Customs value reflects the composition and valuation of traded goods, whereas net mass measures their physical weight. A rail service carrying a greater

share of lighter, more valuable products can appear more important in euros than in tonnes. Conversely, the export results show an increasing relative mass share alongside a falling value share. Neither indicator alone captures operational capacity, container utilization, service quality, or profitability. The pattern is consistent with the literature's emphasis on heterogeneous time and cost trade-offs [1–3], while extending that discussion with directly reproducible recent observations. Performance reporting should therefore show direction, units, and denominator together.

5.2. Corridor planning and measurement limits

The throughput exercise translates relative scale into a planning question. If a decision-maker considers shifting a specified share of sea freight, the implied additional tonnage should be compared with a route's actual operating constraints. Relevant constraints include terminal handling, border procedures, available train paths, rolling stock, and interfaces between modes. The present arithmetic supplies the demand-side scale of that question, not an answer about feasible supply. The Middle Corridor report emphasizes the importance of coordination and multimodal connections [11]. Accordingly, these results cannot rank the Middle and Northern corridors, quantify their spare capacity, or justify a particular infrastructure investment. Such decisions require corridor-specific cost, timing, demand, and capacity evidence.

Unknown transport mode creates a substantial measurement limitation. In 2023 and 2024, unknown-mode imports account for 5.813% and 4.858% of all-mode import value. Assigning all such trade to either sea or rail yields overlapping extreme envelopes: approximately 3.35–11.93% in 2023 and 4.49–11.42% in 2024. These are sensitivity bounds, not probabilistic estimates. Their overlap demonstrates that the observed increase is not invariant to arbitrary reclassification of all unclassified trade. The defensible conclusion concerns reported rail and sea flows. Changes in reporting practices could also affect the series even where explicit status flags are absent.

Several further boundaries limit inference. The EU sample excludes the United Kingdom and other European economies throughout; changing their inclusion could alter the apparent trend. Trade value is nominal, and import and export valuation conventions differ. Chapter-level matching excludes absent cells and cannot resolve shifts among individual products. Within-chapter reallocation therefore remains broader than shipper-level mode switching. Aggregate net mass includes commodities that may not be realistically transferable into rail containers. Most importantly, the study contains no matched freight prices, booking records, transit-time distributions, or credible untreated comparison group. No causal effect, substitution elasticity, welfare gain, emissions saving, or statistical significance is claimed on the basis of these aggregates.

A stronger next stage would link shipment or detailed product records to quoted door-to-door prices, delivery commitments, and route identifiers. An explicit identification strategy would need to address simultaneous changes in demand, commodity prices, subsidies, and service availability. It should also distinguish diversion from newly created trade and from transfers out of air or road. The present results help specify such research: imports and exports require separate models; mass and value outcomes should be retained; and the 2025 reversal should be tested rather than omitted. Until those additional data are available, the accounting evidence offers a transparent baseline for evaluating claims about railway substitution without converting correlation into causation.

6. Conclusions

Official China–EU border-mode records show a substantial railway import rebound in 2024, driven mainly by within-chapter changes rather than broad commodity composition. Rail nevertheless remained a small part of reported freight, and its import value-share gain reversed in 2025. Exports followed a different trajectory, with falling value shares and rising mass shares. The arithmetic scale of diverting even one tenth of sea mass is large relative to observed railway throughput. Overland corridors should therefore be assessed as selective alternatives within a system that remains dominated by maritime transport. The original contribution is an auditable empirical diagnosis of that role, with explicit limits on what border-mode data can establish. Corridor-level feasibility and causal displacement remain questions for richer evidence.

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