From Barriers to Gateways: An Economic Impact Analysis of Kazakhstan's E-Customs Reforms (1995–2030)

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ABSTRACT

What generates welfare gains from digital customs reform: the elimination of time wasted at borders, or the reduction of administrative fees extracted from traders? This paper addresses that identification problem for Kazakhstan, a landlocked transition economy advancing toward a "Digital by Default" customs ecosystem by 2030. Using a GTAP v11 Computable General Equilibrium framework calibrated with primary survey data from 165 stakeholders, we separately model import-augmenting efficiency (*ams*), transit efficiency (*atm*), and administrative rent reduction (*tms*) shocks across three scenarios. Aggregate results confirm that technical efficiency improvements generate $292.99 million in welfare gains (99.4% of the $294.68 million total under combined reform), establishing that border time reduction functions as productivity enhancement. Sector-level decomposition reveals meaningful heterogeneity: three of five sectors (Agriculture and Food, Textiles, Logistics and Services) are rent-dominated, while Light Manufacturing drives aggregate efficiency dominance through the highest *ams* shock (1.24%) and the only substantial *atm* gain (0.50%). Combined reform yields a 0.18% real GDP increase and $71.67 million in regional spillovers. These results reframe the policy prescription from a uniform digital-platform mandate to a sector-calibrated strategy: time-minimizing investment for manufacturing supply chains, complemented by targeted cost reduction where administrative fee structures remain the binding constraint.

Keywords: Digital customs; GTAP CGE model; Kazakhstan; Welfare analysis; Border efficiency; Landlocked economies

JEL Codes: F13, F14, F17, O24, C68

1. INTRODUCTION

What generates the welfare gains from digital customs reform: the elimination of time wasted at borders, or the reduction of administrative fees extracted from traders? The distinction carries direct policy consequences, yet trade facilitation research has largely failed to identify which mechanism dominates. Gravity models typically employ aggregate clearance-time proxies (Djankov et al., 2010). The World Bank Logistics Performance Index bundles speed and cost into composite indicators. CGE analyses have generally applied efficiency-augmenting shocks or tariff-equivalent cost reductions, but rarely both in a framework permitting direct welfare comparison (Zaki, 2010; OECD, 2017). Consequently, policymakers cannot determine whether to prioritize process speed through digital platforms and automated risk assessment, or fee reduction through administrative simplification, because the relative welfare contributions remain unquantified.

Iceberg cost theory establishes that border delays constitute real resource waste rather than transfers (Samuelson, 1954; Hummels, 2001), implying that time compression functions as a productivity-enhancing shift in production frontiers. Institutional economics literature on transition economies emphasizes instead the rent-extraction dimension of administrative procedures (Zaki's "phantom taxes"), where discretionary fees transfer surplus from traders to intermediaries without generating productive output. For landlocked economies where structural time penalties and inherited administrative rent-seeking coexist, theory cannot adjudicate which channel dominates welfare outcomes from customs modernization.

Kazakhstan provides a compelling empirical setting. The country has progressed through three phases of customs digitalization, from foundational automation (1995–2017) through the ASTANA-1 system (2018–2023) to the AI-integrated Keden platform (2024–present), with a target for completing a "Digital by Default" ecosystem by 2030. Its landlocked geography amplifies the stakes of mechanism identification: if time-based inefficiency dominates, transit corridor digitalization along the Trans-Caspian Middle Corridor is the strategic priority; if rent extraction dominates, institutional reform targeting fee structures takes precedence. Drawing on stratified survey data from 165 logistics companies, customs brokers, and traders who independently reported time burdens and cost burdens, we achieve respondent-level channel separation unavailable from aggregate administrative sources.

Three research hypotheses organize the analysis. Hypothesis 1 (Efficiency Dominance): efficiency-channel shocks (Scenario 2: ams + atm) generate substantially larger welfare gains than rent-reduction shocks (Scenario 1: tms only). Hypothesis 2 (Landlocked Transit Channel): atm improvements produce positive but sector-differentiated effects, concentrated in transit-intensive manufacturing. Hypothesis 3 (Sectoral Reallocation): combined reform induces significant restructuring consistent with Heckscher-Ohlin logic as effective trade costs decline. Principal results confirm Hypothesis 1 strongly, provide partial support for Hypothesis 2, and confirm Hypothesis 3 with sector-channel heterogeneity that enriches the aggregate finding.

2. THEORETICAL BACKGROUND AND LITERATURE

The conceptual foundation for this study integrates three strands of trade facilitation research. Samuelson's (1954) iceberg cost formulation, operationalized in CGE frameworks by Hertel (1997) through import-augmenting technical change variables (ams), characterizes border inefficiencies as real resource waste reducible by digitalization. Zaki (2010, 2014) represents the principal effort to implement dual-channel separation within a CGE framework, distinguishing efficiency waste from rent extraction for Egypt and demonstrating that rent effects contributed substantially to welfare gains in a coastal economy where administrative extraction is the binding margin. Whether this finding extends to landlocked transition economies, where structural transit penalties compound administrative costs, remained an open question prior to this study.

Hummels (2001) established the benchmark translating time savings into ad valorem cost equivalents at 0.5%–0.8% per day for manufactured goods, decomposed by Hummels and Schaur (2013) into inventory holding, depreciation, and demand volatility components, each representing real resource consumption. Djankov et al. (2010) corroborated these estimates across income levels using cross-country clearance data.

For the rent channel, Ecorys (2009) and Francois et al. (2013) estimated that approximately 40% of non-tariff barrier effects represent pure extraction while 60% constitute resource waste, supporting the parallel tms and ams/atm specification.

The landlocked penalty literature motivates separate modeling of transit efficiency (atm). Pomfret (2013) documented that Central Asian landlocked penalties increase container costs by up to 70% relative to coastal peers through third-party crossings, infrastructure gaps, and regulatory heterogeneity. Cheong and Turakulov (2021) confirmed that Central Asian trade facilitation interventions generate larger welfare returns than equivalent tariff liberalization, providing precedent for efficiency-dominance over rent-reduction. ADB (2022) analysis of Middle Corridor dynamics suggests coordinated digital customs integration could reduce effective transport distances by 15–25%, with asymmetric benefits for landlocked intermediary nodes. This literature collectively motivates atm as a structurally distinct variable from ams: conflating them would obscure mechanisms specific to Kazakhstan's geographic position as a transit intermediary.

International implementation precedents provide calibration benchmarks. Singapore's TradeNet (1989) reduced declaration processing from days to minutes and generated estimated annual GDP gains exceeding 1% alongside 20–35% paperwork cost reductions (Teo et al., 1997; Engman, 2009). ASEAN integration evidence confirms that systematic digital customs integration generates larger welfare gains through indirect productivity effects than direct cost reduction (Intal, 2015; Artuso and Nguyen, 2016), consistent with efficiency-dominance predictions. Prior CGE analysis of Kazakhstan established positive welfare effects from trade policy reform alongside modest terms-of-trade deterioration (Turakulov, 2020), setting baseline expectations for how productivity-enhancing reforms transmit through the economy.

3. INSTITUTIONAL CONTEXT

Kazakhstan's digital customs evolution spans three decades. During Phase 1 (1995–2017), foundational automation began with Government Resolution establishing the Unified Automated Information System in 1995, followed by Government Decree No. 294a (1997) creating the Republican Customs Service Data Exchange Network. The Customs Automated Information System launched in 2009–2010. WTO accession in 2015 and the Single Window system in 2017 completed this foundational phase.

Phase 2 (2018–2023) represented a paradigm shift anchored by the Code on Customs Regulation (2017), which provided the legal framework for electronic declaration and paperless trade. The ASTANA-1 platform, developed with UNCTAD support on the ASYCUDA World architecture, went live April 2018 encompassing all customs procedures. The Green Corridor mechanism enabled automatic release for low-risk declarations. The Tez Customs pilot (December 2023) reduced rail transit clearance from three hours to 30 minutes along China–Central Asia–Europe corridors.

Phase 3 (2024–present) transitions toward the Keden National Integrated Platform, which consolidates legacy databases into unified architecture and deploys AI and machine learning for risk management, goods classification, and inspection analysis. By late 2025, 16 of 20 modules were operational, reducing transit declaration processing from 30 minutes to 10 minutes. The strategic 2030 target is a "Single Digital Platform

for Foreign Economic Activity" operating within the EAEU Trusted Digital Space, establishing cross-border recognition of digital signatures and enabling seamless electronic document exchange among member states.

4. THE GTAP COMPUTABLE GENERAL EQUILIBRIUM FRAMEWORK

The GTAP v11 database encompasses 160 regions, 65 sectors, and 8 factors. The framework models four optimizing agents under perfect competition with constant returns to scale: producers, a regional household, government, and rest of world. Primary factors are mobile across sectors within regions but internationally immobile under standard closure.

Trade facilitation reforms enter through three distinct shock variables. Import-augmenting technical change (ams) captures efficiency improvements that expand effective import availability for given expenditure: $M\_eff = (1 + ams) \times M$. This iceberg formulation converts clearance time savings into effective resource expansion without generating revenue transfers. Transit efficiency (atm) reduces the international transport margin bridging FOB and CIF prices, a channel particularly salient for landlocked Kazakhstan where third-country transit costs constitute independent trade barriers. Trade cost equivalent (tms) models administrative rent reduction as an ad valorem import cost generating no revenue; unlike tariffs, it redistributes surplus from rent-extractors to importers without expanding productive capacity.

These three channels generate structurally distinct general equilibrium effects. The ams and atm shocks shift production possibility frontiers outward, producing first-order efficiency gains. The tms shock redistributes existing surplus without directly expanding resources, explaining its comparatively modest welfare contribution. Welfare is measured through Equivalent Variation, ensuring all income, substitution, and productivity effects are captured. The six-region aggregation (Kazakhstan, EAEU, China, EU, Central Asia, Rest of World) and five-sector aggregation (Agri_Food, Heavy_Mfg, Light_Mfg, Textiles, Log_Services) are designed to capture bilateral Middle Corridor dynamics.

5. SURVEY METHODOLOGY AND SHOCK CALIBRATION

Forward-looking shocks were derived from a structured questionnaire administered to 165 respondent companies (customs brokers, logistics providers, and international traders) in late 2025. The questionnaire was bifurcated by design: time components elicited current and projected clearance and transit durations under baseline and 2030 Digital by Default scenarios, informing ams and atm calibration; financial components captured current administrative cost shares as a percentage of total shipment value and expected reduction rates, informing tms calibration. This respondent-level separation provides empirical grounding for the channel distinction that composite trade facilitation indicators cannot supply.

Time savings are converted to efficiency shocks using the Hummels (2001) benchmark: $ams\_i = \Delta Days\_i \times 0.5\%$. For Heavy Manufacturing, median clearance times decline from 1.5 days to 0.03 days under full Keden implementation ($\Delta Days = 1.47$, ams = 0.74%). Light Manufacturing exhibits the largest improvement ($\Delta Days = 2.48$, ams = 1.24%). Agriculture and Food records minimal gains (ams = 0.03%), reflecting already-expedited perishable processing. The tms shock is scaled by baseline cost shares: $tms\_i = -$(Expected

Cost Reduction % × Current Cost Share %), ensuring shocks isolate administrative red tape rather than factory-gate price effects. Three scenarios isolate transmission mechanisms: Scenario 1 (tms only), Scenario 2 (ams + atm only), Scenario 3 (all shocks combined).

Table 1: Sector-Level Shock Calibration and Dominant Transmission Channel

Sector	ams (%)	atm (%)	tms (%)	Dominant Channel	Economic Interpretation
Agriculture & Food	0.00	0.01	−1.25	Rent/Cost	Near-zero time savings; primary friction is administrative fees on expedited perishable processing
Heavy Manufacturing	0.74	0.02	−2.25	Mixed (both operative)	Largest tms and substantial ams; time and cost channels both active for capital-intensive GVC clearance
Light Manufacturing	1.24	0.50	−0.60	Efficiency (strongest)	Highest ams and only substantial atm in sample; documentation-intensive high-volume shipments where time savings are structural
Textiles & Apparel	0.01	0.00	−1.13	Rent/Cost	Minimal time gains; high inspection frequency limits clearance duration compression
Logistics & Services	0.03	0.01	−0.69	Rent/Cost (mild)	Intermediary sector where fee structures are the primary cost lever; time savings marginal

Notes: ams = import-augmenting technical change; atm = transit-augmenting technical change; tms = trade cost equivalent. All shocks derived from primary survey data (n = 165) using Hummels (2001) 0.5%/day benchmark for efficiency channels and baseline cost-share scaling for the rent channel.

6. SIMULATION RESULTS

6.1 Macroeconomic Welfare and Hypothesis 1

Table 2 presents aggregate outcomes across three scenarios. The Combined Reform scenario (Scenario 3) generates $294.68 million in Equivalent Variation. Scenario 2, isolating the *ams* and *atm* channels, accounts for $292.99 million (99.4% of the total), while Scenario 1 (*tms* only) contributes $1.69 million (0.6%). Hypothesis 1 is strongly confirmed: technical efficiency improvements overwhelmingly dominate administrative rent reduction.

Table 2: Kazakhstan Macroeconomic Impact Comparison

Macroeconomic Indicator	Scenario 1 (Cost-Only)	Scenario 2 (Efficiency-Only)	Scenario 3 (Combined)
Real GDP (qgdp), % change	0.00	0.18	0.18
Social welfare (EV), USD million	1.69	292.99	294.68
Terms of trade (tot), % change	0.00	−0.04	−0.04

The regional decomposition (Appendix Table A.1) reveals that Scenario 1 generates negative welfare effects for most trading partners (ROW: −$1.07m; EAEU: −$1.08m; China: −$0.29m), while Scenario 2 produces positive spillovers across all regions. Rent reduction redistributes existing surplus with Kazakhstan gaining partly at trading partners' expense; efficiency gains expand the global welfare frontier. Real GDP increases

0.18% in Scenarios 2 and 3, with zero measurable effect in Scenario 1, reinforcing that productivity enhancement drives macroeconomic expansion while rent redistribution leaves real output unaffected.

An efficiency paradox is evident: Scenario 3 yields +0.18% real GDP and $294.68 million in welfare alongside a −0.04% terms-of-trade decline. The *ams* and *atm* shocks lower effective export costs, strengthening competitiveness and moderating relative export prices, while expanding effective resource endowments through fewer goods "melting away" in transit. This productivity interpretation is consistent with prior CGE findings for Kazakhstan (Turakulov, 2020) and underscores that terms-of-trade indicators alone would lead policymakers to underestimate reform welfare returns.

The 99.4% aggregate efficiency share should not be interpreted as a uniform economy-wide signal. As Table 1 documents, three of five sectors exhibit near-zero efficiency shocks, making the rent channel their operative mechanism. Aggregate efficiency dominance is driven by the economic weight of Manufacturing sectors, where baseline clearance times are long and documentation-intensive procedures create substantial scope for time-saving productivity gains. This heterogeneity conditions the policy interpretation examined in Section 7.

6.2 Sectoral Restructuring and Hypothesis 3

Table 3 disaggregates Scenario 3 impacts, revealing substantial reallocation consistent with Hypothesis 3.

Table 3: Sectoral Shifts in Output and Trade in Kazakhstan (Scenario 3)

Sectoral Cluster	% change in sectoral output (qo)	% change in aggregate exports (qxw)
Agri_Food	0.06	0.01
Heavy_Mfg	−0.15	0.36
Textiles	−0.03	0.18
Light_Mfg	−1.14	0.49
Log_Services	0.07	−0.03

Light Manufacturing exhibits the most pronounced restructuring: domestic output declines 1.14% while aggregate exports rise 0.49%. This divergence reflects general equilibrium factor reallocation as the large ams shock (1.24%) and substantial atm gain (0.50%) reduce effective trade costs, inducing a shift from domestic to export-oriented production while enhanced import efficiency enables domestic demand substitution toward more competitive foreign alternatives. The pattern is consistent with Heckscher-Ohlin specialization logic: cost reductions intensify comparative advantage specialization.

Heavy Manufacturing records analogous but moderated dynamics (output −0.15%, exports +0.36%), reflecting ams-enhanced intermediate input access enabling export competitiveness gains alongside comparative disadvantage in domestic production in the post-reform equilibrium. Agriculture and Food expands modestly (+0.06%), consistent with already-expedited perishable processing and lower baseline trade costs. Logistics and Services expands output (+0.07%) reflecting increased demand for digitally-coordinated

transit management, while the marginal export decline (−0.03%) reflects compositional transformation away from traditional intermediary functions as direct trader-customs interaction becomes digitally feasible.

The alignment between channel heterogeneity in Table 1 and reallocation patterns in Table 3 is interpretively important. Efficiency-dominated sectors undergo the most pronounced restructuring: Light Manufacturing records both the largest output decline and the largest export expansion. Rent-dominated sectors exhibit qualitatively different and more modest adjustment, with Agriculture and Food registering near-zero structural change consistent with near-zero efficiency shocks. This sector-channel mapping supports the argument that the aggregate welfare decomposition reflects Manufacturing sector economic weight rather than a uniform mechanism operating identically across the economy.

6.3 Regional Spillovers and Hypothesis 2

Table 4 documents welfare spillovers confirming Hypothesis 2 and demonstrating that digital customs reform generates positive-sum regional gains.

Table 4: Regional Welfare Spillovers (Scenario 3, USD Million)

Region	EV (USD Million)
Kazakhstan	294.68
Rest of World	28.74
EU	22.35
China	13.15
EAEU	6.50
Central Asia	0.92
Total	**366.35**

Total welfare gains reach $366.35 million, of which Kazakhstan captures $294.68 million (80.4%) and trading partners receive $71.67 million (19.6%). The EU emerges as the largest external beneficiary ($22.35 million), consistent with its role as the primary destination for Trans-Caspian transit cargo: atm improvements and Smart Customs infrastructure reduce effective transport costs for EU exporters and importers utilizing the Middle Corridor. China captures $13.15 million, reflecting its position as a major origin for rail cargo transiting Kazakhstan toward European markets, with the Tez Customs pilot directly reducing rail transit processing times. The EAEU collectively gains $6.50 million through enhanced customs integration under the Trusted Digital Space framework.

The Hypothesis 2 result receives partial support. Transit efficiency improvements through atm contribute measurably to aggregate welfare, with effects concentrated in transit-intensive manufacturing sectors as predicted. The simulation design does not permit complete separation of ams and atm contributions within Scenario 2, representing a limitation for future research. What the results establish unambiguously is that explicit atm modeling is analytically essential: conflating transit efficiency with standard import processing efficiency would obscure structurally distinct mechanisms and underestimate Kazakhstan’s strategic value as

a transit intermediary. The positive regional spillovers justify coordinated investment in digital customs infrastructure through mechanisms such as the EAEU Trusted Digital Space.

7. CONCLUSION AND POLICY IMPLICATIONS

This study provides quantitative general equilibrium evidence on the transmission mechanisms driving welfare gains from digital customs reform, employing simultaneous channel modeling in a framework permitting direct welfare comparison between efficiency enhancement and rent reduction. Three principal findings emerge.

Hypothesis 1 (Efficiency Dominance) is strongly confirmed. The Combined Reform scenario yields $294.68 million in Equivalent Variation, with 99.4% ($292.99 million) attributable to ams and atm efficiency improvements and 0.6% ($1.69 million) to tms rent reduction. For Kazakhstan, border time reduction operates primarily as productivity enhancement, shifting production frontiers outward rather than redistributing existing surplus. The coexisting 0.18% real GDP gain and −0.04% terms-of-trade decline constitute an efficiency paradox: export competitiveness improvements lower relative export prices while expanding real output through effective resource expansion, yielding net welfare gains that terms-of-trade metrics alone would misclassify as harmful.

Hypothesis 2 (Landlocked Transit Channel) receives partial support. Transit efficiency improvements contribute to aggregate gains with effects concentrated in transit-intensive Light Manufacturing, which records the largest combined efficiency shock and greatest export expansion (+0.49%). The EU's emergence as the largest external beneficiary ($22.35 million) confirms that Kazakhstan's transit facilitation generates disproportionate corridor-endpoint gains. Separate atm modeling is analytically necessary: conflation with ams would obscure structurally distinct transmission pathways and underestimate the strategic value of Kazakhstan's geographic position.

Hypothesis 3 (Sectoral Reallocation) is confirmed, enriched by the sector-channel heterogeneity in Table 1. Efficiency-dominated sectors undergo the most pronounced adjustment: Light Manufacturing records output decline (−1.14%) alongside export expansion (+0.49%) consistent with comparative advantage specialization as effective trade costs fall. Rent-dominated sectors (Agriculture and Food, Textiles and Apparel, Logistics and Services) exhibit more modest and qualitatively different adjustment, consistent with their near-zero efficiency shocks. This heterogeneity demonstrates that digital customs reform constitutes structural economic transformation operating through differentiated mechanisms rather than a uniform administrative upgrade.

Three sector-calibrated policy recommendations follow directly. First, investment promotion instruments, export credit guarantees, and special economic zone incentives should be concentrated in Heavy and Light Manufacturing, where the largest efficiency shocks and export expansion responses create the strongest platform for converting static efficiency dividends into dynamic capital accumulation. Second, domestic producers in these sectors face intensified import competition as ams shocks simultaneously raise import efficiency (Heavy Manufacturing imports +0.59%, Light Manufacturing imports +0.13%); sequenced

competitiveness-enhancing measures, including targeted workforce upskilling and technology adoption subsidies, are warranted ahead of the 2027–2028 Smart Borders phase. Third, for Agriculture and Food, Textiles, and Logistics and Services, where the rent channel is operative, reform priorities should emphasize administrative simplification and fee transparency rather than platform investment, recognizing that time-minimizing infrastructure generates minimal welfare returns where baseline clearance is already expedited.

The 2030 Digital by Default roadmap receives empirical validation. Immediate-phase priorities (process automation, biometric access controls) address ams-channel inefficiencies responsible for the overwhelming majority of welfare gains. Medium-term Smart Borders and IoT integration target atm improvements critical for landlocked transit efficiency. Long-term Single Digital Platform completion institutionalizes paperless trade within the EAEU Trusted Digital Space. These policy phases should be accompanied by the sector-calibrated industrial measures outlined above to ensure that border efficiency gains translate into sustainable productive capacity expansion within the domestic economy.

Extensions warranting future research include dynamic CGE analysis incorporating capital accumulation and technology diffusion, distributional analysis across income deciles and subnational regions, explicit modeling of uncertainty reduction and investment risk premia, and game-theoretic analysis of coordinated regional digital customs investment given the documented positive spillovers.

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APPENDIX: SUPPLEMENTARY TABLES

Full regional and sectoral decomposition tables (A.1 through A.6) are available in the supplementary materials. Table A.1 presents regional EV decomposition by scenario; Table A.2 reports real GDP and terms-of-trade effects; Tables A.3, A.4, and A.5 provide sectoral output, export, and import volume changes by region and scenario; Table A.6 documents nominal GDP changes.