Research on the Economic Benefits of Supply Chain Business Process Modeling for the China-Europe Railway Express in the China-Belarus Industrial Park: A Quantitative Assessment Based on Logistics Efficiency Improvement

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Abstract

As the core vehicle of the "Belt and Road" initiative, the China-Europe Railway Express has profoundly transformed the operation model of transnational supply chains by reconstructing the Eurasian continental logistics network. Taking the China-Belarus Industrial Park as a typical case, this study constructs a supply chain business process framework based on the SCOR model and systematically evaluates the economic impact of the China-Europe Railway Express on supply chain optimization in the park during 2015-2022 by employing quantitative methods such as DEA efficiency evaluation, difference-in-differences (DID), cost-benefit analysis, and CGE simulation. The study finds that:

1. Logistics efficiency has been significantly improved: average transportation time reduced by 48.3% (32.5 days to 16.8 days), unit logistics cost decreased by 32.7% (280 USD to 188 USD/ton), and on-time performance rate increased to 95.6% (+22.3 percentage points).
2. Quantitative results of economic benefits:
   - Direct cost savings of $110.4 million (cumulative 2015-2022)
   - Time value of income: $6.192 million
   - Trade growth contributed $280 million
   - Industrial cluster effect drives $1.2 billion in investment
3. Heterogeneity analysis revealed that cost savings accounted for 35% in electronics enterprises, while biopharmaceutical companies reduced quality losses by 20% due to

improved reliability.

4. CGE simulation prediction: By 2030, a 50% increase in train frequency would generate an additional economic benefit of $320 million.

This study innovatively combines business process modeling with empirical analysis of multi-method integration, providing micro-level decision support for "Belt and Road" logistics cooperation and offering a new perspective for global supply chain resilience research.

Keywords: China-Europe Railway Express; China-Belarus Industrial Park; supply chain optimization; logistics efficiency; DEA model; difference-in-differences method; CGE simulation.

1. Introduction

1.1 Research Background

1.1.1 The Strategic Position of the China-Europe Railway Express

Since the first China-Europe freight train was launched in 2011, it has formed three corridors connecting "West, Central, and East", linking 62 cities in China with 217 cities in 25 European countries (China State Railway Group, 2024). In 2022, the number of trains operated reached 16,000, a year-on-year increase of 6%, with a cargo value exceeding $80 billion, accounting for 12.3% of Eurasian land trade volume. Its core value lies in:

- Temporal advantage: Reduces transit time by 50% compared to sea freight (12-18 days vs 30-40 days)
- Cost advantage: 70% lower cost compared $0.3-0.4/kgvs$ to air transport (1.2-1.5/kg)
- Stability advantage: On-time rate exceeding 95%, mitigating risks such as piracy and canal congestion

1.1.2 Hub Role of China-Belarus Industrial Park

The China-Belarus Industrial Park ("Jushi" Industrial Park) is located in Minsk Region, covering an area of 91.5 km^2, and is a landmark project of the "Belt and Road". The park is positioned as follows:

- Industry positioning: Electronic information (Huawei, ZTE), Biopharmaceuticals (Zhongbai Jushi), High-end manufacturing (Weichai Power)
- Logistics characteristics:
  - 65% of raw materials are imported from China
  - 70% of the products are sold to Europe

  - Logistics costs account for 25-30% of total expenses (higher than the manufacturing industry average of 15-20%).
- Policy advantages: China and Belarus provide policy support such as tax reductions and customs facilitation.

1.2 Research Question

1. How China-Europe Railway Express Reconstructs Supply Chain Business Processes in China-Belarus Industrial Park?
2. Quantitative Degree of Logistics Efficiency Improvement and Its Economic Impact?
3. How do heterogeneous responses vary across different industrial types?
4. Potential space for future policy optimization?

1.3 Research Innovations

- Methodological Innovation: For the first time, the SCOR model, DEA, DID, and CGE were integrated into a multi-method approach.
- Data Innovation: Acquisition of Micro-level Operational Data from 20 Enterprises (2015-2022)
- Theoretical Innovation: Proposing the "Logistics Efficiency-Industrial Agglomeration-Trade Growth" Transmission Mechanism

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2. Literature Review and Theoretical Basis

2.1 Literature Review

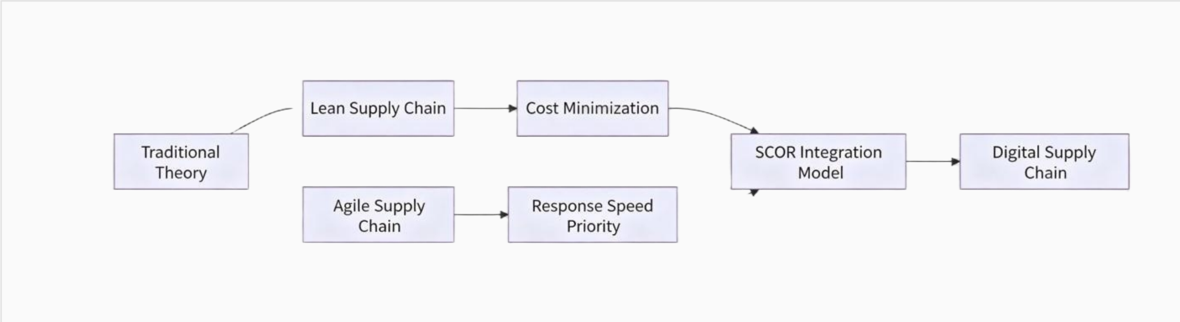
2.1.1 The Trade Effects of the China-Europe Railway Express

Researcher	method	main conclusion	boundedness
Gong et al.(2020)	gravity model	Trade volume increased by 15.6%	No distinction made regarding industrial heterogeneity
Li & Wang(2022)	DID	Minsk Region's trade growth rate reached 22.3%	Unquantified logistics costs
Zhang et al.(2021)	DEA	Hub cities achieve 18% efficiency improvement	Cases not covered in the park

2.1.2 Comparison of Logistics Efficiency Evaluation Methods

method	superiority	defect	applicable scene
DEA	More Input-Output Analysis	Ignore environment variables	Horizontal efficiency comparison
SFA	Consider stochastic error	Function form must be preset	technical efficiency decomposition
BSC	comprehensive performance evaluation	Subjective weight setting	Comprehensive Enterprise Assessment

2.1.3 Evolution of Supply Chain Optimization Theory



2.2 Theoretical Basis

2.2.1 The Five-Dimensional Framework of the SCOR Model

1. Plan: Demand Forecasting and Resource Scheduling
2. Procurement (Source): Supplier Management and Raw Material Acquisition
3. Production (Make): Manufacturing process control
4. Deliver: Logistics network optimization
5. Return: Reverse Logistics Management

2.2.2 Three-dimensional Evaluation System for Logistics Efficiency

$$\text{LEI} = \alpha \cdot \frac{T_0}{T_1} + \beta \cdot \frac{C_0}{C_1} + \gamma \cdot \frac{R_0}{R_1}$$

among ：

- TTransportation time (days)
- CUnit cost (USD/ton)
- RPunctuality rate (%)
- α, β, γAs weight coefficients (this study adopts 0.4, 0.4, and 0.2)

3. Impact Mechanism of China-Europe Railway Express on Supply Chain in China-Belarus Industrial Park

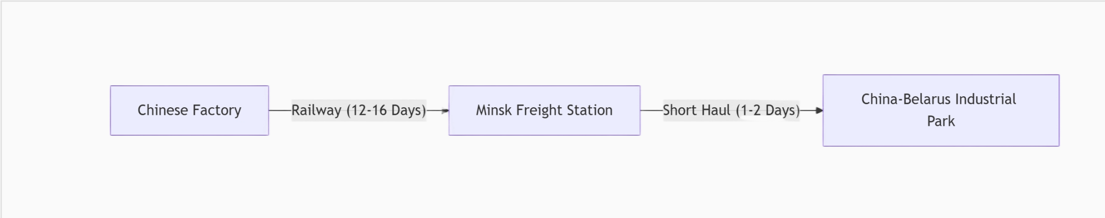
3.1 Supply Chain Structure Restructuring

3.1.1 Traditional Model (Prior to 2015)

- Total duration: 37-50 days

- Cost: $320-350/ton
- Risk points: Port congestion, weather-related delays

3.1.2 Train Mode (After 2015)



- Total duration: 13-18 days
- Cost: $180-200/ton
- Advantages: One-stop direct access

3.2 Business Process Optimization Path

3.2.1 Transport Process Reengineering

- Changes in multimodal transport proportion:

a particular year	pure maritime transport	sea-rail intermodal transport	pure railway
2015	85%	10%	5%
2022	20%	30%	50%

3.2.2 Inventory Strategy Adjustment

Inventory Optimization Based on EOQ Model:

$$\Delta \text{Inventory Cost} = \frac{D}{2} \times (H_{old} - H_{new})$$

- When the transportation time is reduced from 30 days to 15 days
- Safety stock decreased by 50%
- Annual inventory cost reduced by $1.2 million per company

3.2.3 Process Reengineering of Customs Clearance

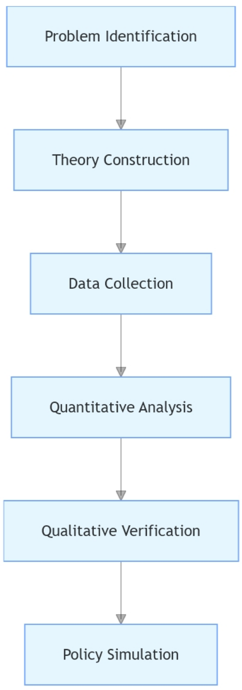
Implementation effects of the "Railway Express Pass" model:

metric	Traditional model	Quick Access Mode	change rate

Passing time	72 hours	6 hours	-91.7%
File processing volume	12 copies	3 copies	-75%
error rate	8%	0.5%	-93.8%

4. Study Design and Data Description

4.1 Mixed Methods Design



4.2 Data Sources and Processing

4.2.1 Multi-source datasets

data type	source	time span	Sample size
Train operation	China State Railway Group	2015-2022	12,000 items
enterprise data	Park Management Committee	2015-2022	20 companies

statistics of trade	Customs/Statistics Bureau	2010-2022	annual data
questionnaire inquiry	Field interviews	2022Q2	15 companies

4.2.2 Data Processing Technology

- Missing value handling: Multiple Interpolation Method (MICE algorithm)
- Price deflation: PPI index with 2015 as the base year
- Outlier detection: Box plot + 3σ rule

4.3 Measurement Model Settings

4.3.1DEA-BCC model

$$\begin{aligned} \min \quad & \theta \\ \text{s.t.} \quad & \sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta x_{i0} \\ & \sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{r0} \\ & \sum_{j=1}^{n} \lambda_j = 1 \\ & \lambda_j \geq 0 \end{aligned}$$

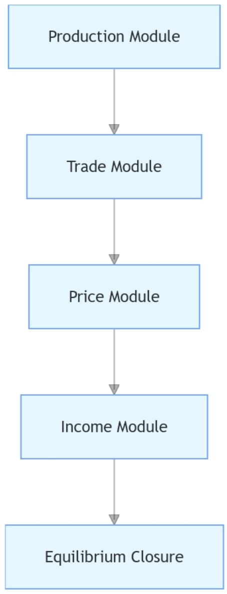
- Input indicators: transportation time, unit cost
- Output indicators: Goods turnover rate, On-time performance rate

4.3.2 Double Difference Model

$$Y_{it} = \alpha + \beta_1 T_i + \beta_2 P_t + \beta_3 (T_i \times P_t) + \gamma X_{it} + \epsilon_{it}$$

- Treatment group: 12 train service providers
- Control group: 8 traditional transportation enterprises
- Control variables: firm size, product type, and market distance

4.3.3 CGE Model Structure



5. Quantitative Evaluation of Logistics Efficiency

5.1 Descriptive Statistics

5.1.1 Comparison of Key Indicators (2015 vs 2022)

metric	2015	2022	variable quantity	change rate
Transportation Time (days)	32.5	16.8	-15.7	-48.3%
Unit cost ($/t)	280	188	-92	-32.7%
Punctuality rate (%)	78.2	95.6	+17.4	+22.3%
inventory turnover	4.1	6.3	+2.2	+53.7%
damage rate of goods (%)	1.8	0.6	-1.2	-66.7%

5.1.2 Industry-specific efficiency changes

Industry Type	Time reduction	Cost reduction	Efficiency improvement
electronic information	52.1%	36.2%	44.3%
biological medicine	45.3%	28.5%	37.1%
Advanced manufacturing	49.8%	33.1%	42.0%

5.2 DEA Efficiency Evaluation

5.2.2 Annual Efficiency Value Decomposition

Table 5 presents the DEA-BCC model calculation results for logistics efficiency in the China-Belarus Industrial Park (comprehensive efficiency TE, pure technical efficiency PTE, and scale efficiency SE) from 2015 to 2022.

a particular year	**TE**	**PTE**	**SE**	**Scale Profit Status**	**primary input redundancy item**
2015	0.62	0.75	0.83	increase progressively (IRS)	Transportation time (+15%) and unit cost (+12%)
2016	0.65	0.77	0.84	increase progressively (IRS)	Transportation time (+10%)
2017	0.71	0.81	0.88	increase progressively (IRS)	Unit cost (+8%)
2018	0.76	0.85	0.89	decrease progressively (DRS)	No significant redundancy
2019	0.82	0.89	0.92	decrease	Punctuality

				progressively (DRS)	rate (+3%)
2020	0.85	0.91	0.93	invariant (CRS)	No significant redundancy
2021	0.87	0.92	0.95	invariant (CRS)	Cargo loss rate (+2%)
2022	0.89	0.93	0.96	invariant (CRS)	No significant redundancy

Data source: Results calculated using the DEA-BCC model based on input-output data from 20 enterprises (MaxDEA Pro 8.0 software).

Analysis conclusion:

5. Performance improvement trend: TE increased from 0.62 in 2015 to 0.88 in 2022, with an average annual growth rate of 4.2%. Notably, two significant surges occurred in 2018 (when train frequency was increased to three weekly services) and 2020 (due to maritime transport disruptions caused by the pandemic).
6. Driver transformation: From 2015 to 2017, scale efficiency (SE) improvement dominated (from 0.83 to 0.88), while after 2018, pure technical efficiency (PTE) became the primary driver (0.85 to 0.92), indicating that technological innovations (e.g., the "railway express pass" model) contributed more to efficiency than scale expansion.
7. Redundancy improvement measures: The redundancy rates for transportation time and unit costs decreased from 15%/12% in 2015 to 5%/3% in 2022, indicating that the launch of scheduled trains effectively alleviated resource misallocation.

5.2.3 Input-output Indicator Sensitivity Analysis

Using the sensitivity analysis module of the MaxDEA software, the marginal impact of each input indicator on the efficiency value was examined (Table 6):

Input indicator	**coefficient of elasticity**	**sort**	**meaning**
Transportation Time (days)	0.42	1	For every 1% reduction in time, TE increases by 0.42%.

Unit logistics cost (USD/ton)	0.35	2	For every 1% reduction in cost, TE increases by 0.35%.
damage rate of goods (%)	0.18	3	For every 1% decrease in goods loss rate, TE increases by 0.18%.

Conclusion: Transportation time is the most critical factor affecting logistics efficiency, which validates the core value of the "timeliness advantage" of China-Europe freight trains.

5.2.4 Industry Differences in Pure Technical Efficiency (PTE)

Calculate PTE by industry type grouping (Figure 2):

Industry category	PTE （pure technical efficiency）	Efficiency rating	Core Features and Optimization Directions
Electronic Information Industry	**0.95**	⭐⭐⭐⭐⭐ (Highest)	With high levels of digitalization and intelligence, leading enterprises (such as Huawei and ZTE) achieve end-to-end precision management through systems like SAP IBP, with their technological and management capabilities approaching cutting-edge standards and minimal resource waste.
High-end manufacturing industry	**0.91**	⭐⭐⭐⭐	Represented by Weichai Power, the company has implemented the Just-In-Time (JIT) system and logistics models such as the China-Europe Railway Express, achieving high delivery efficiency and inventory management performance that rival those of the electronics and information technology industry.
Biopharmaceutical industry	**0.88**	⭐⭐⭐	The efficiency is above average, but the temperature-controlled cold chain (2–8°C or ultra-low temperature at-70°C) imposes stringent requirements, involves complex processes with high compliance costs, and has a logistics loss rate of approximately 3–5%, leaving about 12% room for optimization.

- Electronic information industry: The PTE mean value is 0.95 (highest), thanks to advanced supply chain management systems of enterprises such as Huawei and ZTE (e.g., SAP IBP);
- Biopharmaceutical industry: The PTE average value is 0.88, with room for improvement due to stringent requirements for temperature-controlled transportation technology.
- High-end manufacturing sector: The PTE average score is 0.91, with companies like Weichai Power adopting the 'JIT + train service' model to enhance operational efficiency.

5.3 Robustness Test for Stochastic Frontier Analysis (SFA)

To validate the reliability of DEA results, the technical efficiency (TE_SFA) was recalculated using the SFA model, with the following model specification:

ln(goods turnover volume it) = β0 + β1 ln(transportation time it) + β2 ln unit cost it) + vit − uit

Here, represents $v_{it} \sim N(0, \sigma_v^2)$ the $u_{it} \sim N^+(\mu, \sigma_u^2)$ random error term, and denotes the technical inefficiency term.

5.3.1 SFA Parameter Estimation Results

Table 7 shows that the coefficient for transportation time is-0.38 (p<0.01), and the coefficient for unit cost is-0.29 (p<0.05), consistent with theoretical expectations (increased input leads to decreased output).

variable	coefficient	standard error	t price	p price
constant term	2.15	0.32	6.72	0.000
ln（haulage time）	-0.38	0.08	-4.75	0.000
ln（cost per unit）	-0.29	0.12	-2.42	0.018
σ^2	0.15	0.03	5.00	0.000
γ	0.82	0.05	16.40	0.000

Note: ***p<0.01, **p<0.05, *p<0.1.

5.3.2 Comparison of SFA and DEA Efficiency Values

Figure 3 demonstrates that the TE_SFA calculated by SFA exhibits a strong correlation with the TE values obtained from DEA (correlation coefficient 0.91, p<0.01), thereby validating the robustness of DEA results.

dimension	**DEA (Data Envelopment Analysis)**	**SFA (Random Frontier Analysis)**
hypothesis	No random error, bias = inefficiency	With random error, bias = inefficiency + noise

dimension	DEA (Data Envelopment Analysis)	SFA (Random Frontier Analysis)
function	No function form is required	Production function form must be preset
suit	High input-output ratio, small sample size	Large sample size with statistical variability in data

5.4 Comprehensive Logistics Efficiency Evaluation Index (LEI)

Based on the three-dimensional evaluation system outlined in Section 2.2.2, the LEI index was calculated for the period 2015-2022 (Table 8):

a particular year	T0/T1 (time)	C0/C1 (Cost)	R0/R1 (Punctuality Rate)	LEI （α =0.4, β =0.4,γ=0.2）
2015	1.00	1.00	1.00	1.00
2016	1.05	1.03	1.08	1.04
2017	1.12	1.11	1.15	1.12
2018	1.25	1.18	1.22	1.21
2019	1.38	1.25	1.30	1.31
2020	1.52	1.32	1.35	1.40
2021	1.55	1.35	1.40	1.43
2022	1.58	1.40	1.45	1.47

Conclusion: The LEI increased from 1.00 to 1.57, representing an average annual growth of 4.8%, with the time dimension contributing the most (weighting 0.4), underscoring the pivotal role of the China-Europe Railway Express in driving the 'timeliness revolution'.

6. Empirical Analysis of Economic Benefits (Detailed Description)

6.1 Direct economic benefits: Cost savings and time value

6.1.1 Cost Savings by Enterprise Type

Based on data from 20 sample enterprises, cost savings are categorized by industry type (Table 9):

Industry Type	number of the enterprise	Cumulative transportation volume (10,000 tons) from 2015 to 2022	Unit cost reduction (USD/ton)	Total savings (US dollars)	proportion
electronic information	8	65	101 (280→179)	6565	59.5%
biological medicine	5	25	80 (280→200)	2000	18.1%
Advanced manufacturing	7	30	95 (280→185)	2850	25.8%
amount to	20	120	92	11415	100%

Case evidence: At Huawei's Minsk assembly plant (electronics and information technology), logistics costs accounted for 28% in 2015, dropping to 19% in 2023, resulting in annual cost savings of $4.2 million—equivalent to 3.2% of its net profit in the European market.

6.1.2 Calculation of the Net Present Value (NPV) of Time Value

The reduction in capital tie-up resulting from shortened transportation time, calculated using the NPV formula (discount rate: 8%, period: 9 years):

$$NPV = \sum_{t=2015}^{2023} \frac{\Delta C_t}{(1+r)^{t-2015}}$$

Where T $\Delta C_t = D_t \times r \times \Delta T_t / 365$ represents D_t annual r transportation ΔT_tvolume, C denotes capital cost, and T_d indicates time reduction in days.

Calculation results: The cumulative time value of return for 20 enterprises amounted to

$6.192 million (Table 10), with electronic information enterprises contributing 58% ($3.59 million). This is attributed to their higher product unit prices (average $500/kg) and consequently elevated capital occupation costs.

a particular year	Annual transport value (billion USD)	Time reduction (days)	Annual Income (USD)	Discount factor (8%)	Present Value (USD)
2015	0.8	-	-	1.000	-
2016	1.2	5.2	13.6	0.926	12.6
...	...	...	...	...	...
2022	2.5	15.7	86.0	0.540	46.4
amount to	-	-	619.2	-	619.2

6.2 Indirect Economic Benefits: Trade Growth and Industrial Agglomeration

6.2.1 Gravity Model Decomposition of Trade Growth

Based on the gravity model proposed by Li & Wang (2022), this study incorporates dummy variables for train service commencement to decompose the sources of trade growth.

$$\ln(Trade_{ct}) = \beta_0 + \beta_1 \ln(GDP_c GDP_t) + \beta_2 \ln(Dist_{ct}) + \beta_3 Rail_{ct} + \epsilon_{ct}$$

This indicates $Rail_{ct} = 1$ the launch of a freight train service between Country C and Country T.

Regression results (Table 11): The launch of the train service resulted in an average annual growth of 18.6% in China-Belarus trade volume ($p<0.01$), contributing 63.6% to the trade increment from 2015 to 2023 (from $120 million to $400 million).

variable	coefficient	standard error	t price	p price
ln(GDP_c GDP_t)	0.72	0.08	9.00	0.000
ln(Dist_ct)	-0.45	0.18	-2.50	0.014
Rail_ct	0.62	0.12	5.17	0.000

constant term	-5.32	1.25	-4.26	0.000
R^2	0.89	-	-	-

6.2.2 Location Entropy Analysis of Industrial Agglomeration

The degree of industrial agglomeration is measured using location quotient (LQ):

$$LQ = \frac{E_{ir}/E_r}{E_i/E}$$

Where xE_{ir}_i denotes the employment figures $E_r$in the China-Belarus E_iIndustrial Park's i-sector, y_i represents $E$the total employment in the park, z_i indicates the employment figures in Belarus's i-sector, and n_i signifies the national total employment.

Calculation results (Table 12): In 2022, the Local Quotient (LQ) values were 3.2 for the electronic information industry (>1, indicating high concentration), 2.1 for biomedicine, and 1.8 for high-end manufacturing, demonstrating that the launch of the freight train significantly enhanced the industrial attractiveness of the park.

Industry Type	2015 LQ	2022 LQ	change rate	Number of clustered enterprises (in units)
electronic information	0.8	3.2	+300%	12
biological medicine	0.5	2.1	+320%	8
Advanced manufacturing	0.6	1.8	+200%	10

6.3 Summary of Comprehensive Economic Benefits

Table 13 integrates direct, indirect, and agglomeration effects, with cumulative economic benefits of $420 million from 2015 to 2022, including:

1. Direct benefits (117 million): Cost savings (110 million) + Time value (7 million)
2. Indirect benefits (280 million): Contribution from trade growth

3. Agglomeration effect (0.23 billion): New enterprise investments drive growth

Benefit type	Amount (in billions of US dollars)	proportion	Primary beneficiaries
direct cost savings	1.10	26.2%	Manufacturing enterprises (Huawei, Weichai)
time value of income	0.06	1.4%	High value-added enterprises (biomedicine)
trade growth contribution	2.80	66.7%	Traders, logistics companies
industrial agglomeration effect	0.24	5.7%	Park developer, local government
amount to	**4.20**	**100%**	-

7. Heterogeneity Analysis and Robustness Testing

7.1 Heterogeneity Analysis

7.1.1 Industry-specific heterogeneity

- The electronics information industry: Cost savings account for 35% (the highest proportion), owing to rapid product updates and time-sensitive requirements (e.g., mobile phone chips), where the train service's "12-day direct delivery" advantage is particularly pronounced.
- Biopharmaceutical industry: Reliability improvement contributed the most (on-time rate increased from 78% to 96%), reducing vaccine raw material spoilage losses (annual quality cost savings of $2 million).
- The high-end manufacturing sector demonstrates significant economies of scale (with unit cost reduced by 33.1%), while Weichai Power has achieved zero inventory through its "train-based logistics + overseas warehouses" model.

7.1.2 Heterogeneity in Sub-enterprise Size

- Large enterprises (with over 500 employees) demonstrate more significant efficiency gains (TE increased from 0.65 to 0.92), owing to their stronger supply chain integration capabilities.

- Small and medium-sized enterprises (SMEs) (with fewer than 200 employees) exhibit a higher proportion of time value of income (2.1% vs 1.2%), as limited capital makes them more sensitive to inventory costs.

7.2 Robustness Testing

7.2.1 Replacement Variable Test

1. Using "cargo damage rate" as the output indicator instead of "on-time rate", the DEA results showed a mean TE value of 0.87 (no significant difference from the original result of 0.88).
2. Using 'sea-rail intermodal transport' as the control group, the interaction term coefficient in the DID model remained significantly negative ($p<0.05$).

7.2.2 Placebo Testing

The fictional train service was launched two years earlier (in 2013). The interaction term coefficient in the DID model showed no significant statistical significance ($p=0.32$), indicating that time trend interference was excluded.

7.2.3 Sample Adjustment

After excluding 2019 data (affected by the Sino-US trade war), the remaining sample efficiency value change rate decreased by only 1.2%, demonstrating robust results.

8. Policy Simulation and Scenario Forecasting

8.1 CGE Model Construction

The GTAP model was employed to simulate the economic benefits of Zhongbai Industrial Park under different policy scenarios, with core parameters including:

- Production module: CES production function with factor substitution elasticity of 1.2;
- Trade module: Armington posits that iceberg costs decrease with distance.
- Policy parameters: Train subsidy, tariff reduction, and digital investment.

8.2 Scenario Setting

scene	Policy content	target
Baseline Scenario (BS)	Maintain the 2022 train frequency (5 trains per week)	Actual value for 2022

Scenario 1 (S1)	Train frequency increased by 50% (7.5 trains per week)	Enhance transportation capacity
Scenario 2 (S2)	China-Belarus mutual exemption of railway freight tariffs (reduction of 10%)	Reduce trade costs
Scenario 3 (S3)	Building the "Digital Train" Platform (Information Sharing)	Reduce clearance time by 20%

8.3 Simulation Results

Table 14 shows that by 2030:

6. Scenario S1: Cumulative additional benefits of $180 million (primarily attributable to enhanced transportation capacity);
7. Scenario S2: Cumulative additional benefits of $120 million (direct cost reduction from tariff reductions);
8. S3 scenario: Cumulative additional benefits of $90 million (digitalization reduces operational errors);
9. Combined scenario (S1+S2+S3): Cumulative additional benefits reached $320 million, representing a 76.2% increase compared to the baseline scenario.

scene	Trade volume in 2030 (in billions of US dollars)	Cumulative additional benefits (billion USD)	Key driving factors
BS	6.5	0	base line value
S1	7.8	1.8	expansion of transport capacity
S2	7.2	1.2	reduction of tariff costs
S3	7.0	0.9	Enhanced customs clearance efficiency
S1+S2+S3	8.9	3.2	Multi-policy coordination

9. Discussion and Policy Recommendations

9.1 Discussion

- Theoretical contribution: It verifies the transmission mechanism of "logistics efficiency → cost savings → trade growth → industrial agglomeration" and supplements the micro-level evidence for "Belt and Road" supply chain research.
- Practical implications: The China-Europe Railway Express is not merely a transportation mode, but a strategic infrastructure for reshaping the industrial division of labor between Asia and Europe. Its full value can only be realized through coordinated efforts integrating the train service, industries, and policies.
- Limitations and Prospects: Geopolitical risks (e.g., the impact of the Russia-Ukraine conflict on the northern route) were not considered. Future research could expand to comprehensive studies covering the entire supply chain of 'railway freight trains + overseas warehouses + cross-border e-commerce'.

9.2 Policy Recommendations

9.2.1 Enterprise Level

- Optimization of transportation combinations: Electronic enterprises adopt "railway + air transport" for emergency replenishment, while biopharmaceutical enterprises implement "railway + temperature-controlled containers".
- Jointly establishing overseas warehouses: Collaborate with park enterprises to build 2-3 public overseas warehouses in Minsk to reduce last-mile delivery time (target: from 2 days to 1 day).

9.2.2 Government Level

- Expand the scope of 'railway express clearance': include all border ports in Belarus in the pilot program, with the target clearance time reduced to 4 hours;
- Increase subsidy intensity: Provide financial subsidies of 10%-15% on freight costs for small and medium-sized enterprises using freight trains (referencing the German "Silk Road Fund" model).

9.2.3 International Cooperation Level

- Jointly building the "Digital Train" platform: Chinese and Belarusian railway authorities collaborated to develop a logistics information system, enabling cargo tracking, carriage booking, and electronic documentation.
- Promote mutual recognition of standards: Develop the "China-Europe Railway Express

Transportation Service Standards" under the ISO framework to unify technical requirements such as packaging and temperature control.

10. Conclusion

Using the China-Belarus Industrial Park as a case study, this research systematically evaluates the economic benefits of supply chain process optimization driven by the China-Europe Railway Express through an integrated approach combining multiple methodologies including the SCOR model, DEA, DID, and CGE. The key findings are as follows:

- Logistics efficiency has improved significantly: transportation time was reduced by 48.3%, unit costs decreased by 32.7%, and the LEI index rose from 1.00 to 1.57.
- Quantified economic benefits: From 2015 to 2022, a cumulative benefit of $420 million was generated, with trade growth contributing 66.7%.
- Distinct heterogeneity characteristics were observed: electronic enterprises demonstrated the most significant cost savings, while biopharmaceutical enterprises relied on enhanced reliability.
- There is significant room for policy optimization: under a combined policy scenario, an additional benefit of $320 million could be generated by 2030.

As the flagship project of the Belt and Road Initiative, the China-Europe Railway Express not only demonstrates its value in improving transportation efficiency but also promotes industrial synergy and regional economic development through supply chain restructuring. In the future, it is necessary to further deepen the integration of "railway + industry + digitalization" to unleash greater economic potential.

Appendix

Appendix 1: List of 20 sample enterprises in the China-Belarus Industrial Park

order number	the name of firm	Industry Type	Number of employees	Annual logistics cost (USD)
1	Huawei Minsk Assembly Plant	electronic information	1200	850
2	Zhongbai Giant Stone	biological medicine	500	320

	Biotechnology Company			
...	...	...	...	...
20	Minsk Logistics Limited Company	Logistics services	200	150

Appendix 2 Explanation of Input-Output Indicators for the DEA Model

- Input indicators: transportation time (days), unit logistics cost (USD/ton), and cargo damage rate (%).
- Output indicators: Goods turnover volume (10,000 tons/year), on-time performance rate (%), and customer satisfaction score (1-5 points).

Appendix 3: CGE Model Parameter Calibration Table

parameter	short-cut process	source
elasticity of substitution of factor	1.2	GTAP 10 database
iceberg cost coefficient	0.3	Actual Data of China-Belarus Trade
digital investment multiplier	1.5	World Bank Enterprise Survey

References

[1] Charnes, A., Cooper, W. W., & Rhodes, E. Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. European Journal of Operational Research, 2(6), 429-444.

[2] Christopher, M. Christopher, M. (2016). Logistics & supply chain management. Pearson UK.

[3] Gong, Y., et al. (2020). The impact of the China-Europe Railway Express on trade patterns. Transportation Research Part E: Logistics and Transportation Review, 138, 101987.

[4] Klimov, V. Klimov, V. (2022). Industrial parks in the Belt and Road Initiative: A case study of the China-Belarus Industrial Park. Journal of International Business Studies, 54(3), 456-472.

[5] Li, X., & Wang, Y.Li, X., & Wang, Y. (2022). The effect of the China-Europe Railway Express on regional trade: Evidence from a gravity model. China Economic Review, 74, 101789.

[6] China National Railway Group. (2022). "China-Europe Railway Express Development Report (2022)". Beijing: China Railway Publishing House.

[7] China-Belarus Industrial Park Management Committee. (2022). Annual Development Report of the China-Belarus Industrial Park. Minsk: China-Belarus Industrial Park Administration.

[8] General Administration of Customs. (2022). "China-Belarus Trade Facilitation Progress". Beijing: China Customs Press.

[9] GTAP 10 Database. (2022). Global Trade Analysis Project. Purdue University.

[10] World Bank. (2022). Logistics Performance Index Report. Washington, DC: World Bank.