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Does China's Capital-Intensive Import Pattern Contradict The Leontief Paradox?
(Adakah Corak Import Intensif Modal China Bercanggah Dengan Paradoks Leontief?

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ABSTRACT

This study critically evaluates traditional international trade theories through the lens of China's distinctive trade pattern—strong imports and weak exports of capital-intensive products. The core research question centers on why China, as a relatively capital-abundant country, fails to exhibit a corresponding export advantage in capital-intensive goods. Methodologically, a gravity model incorporating industry heterogeneity is developed, introducing a dummy variable for capital intensity and controlling for key factors such as GDP, FDI, population, and geographic distance. The results reveal that capital-intensive products enjoy a strong advantage in imports, aligning with Heckscher-Ohlin predictions. However, their export advantage remains statistically insignificant, revealing a clear import-export asymmetry. Further theoretical analysis suggests that this asymmetry stems from structural and institutional constraints: technology lock-in effects in global value chains, nationality-based discrimination in intellectual property regimes, and distortions in domestic factor markets (e.g., capital misallocation) all reduce China's ability to convert its factor endowments into export performance. These insights offer critical supplements to standard comparative advantage theory.The study implies that for China to upgrade its trade structure, it must move beyond reliance on factor endowments and instead build a composite advantage rooted in factor quality, institutional support, and innovation. Nonetheless, the study is limited by the absence of firm-level data to empirically test the technology absorption channel, indicating a key area for future research.

Keywords: China Trade, Capital Intensity, Leontief Paradox, Gravity Model, Trade Asymmetry

ABSTRAK

Kajian ini menilai secara kritikal teori perdagangan antarabangsa tradisional melalui lensa corak perdagangan unik China—iaitu import yang kukuh dan eksport yang lemah bagi produk intensif modal. Persoalan kajian utama tertumpu kepada mengapa China, sebagai sebuah negara yang secara relatifnya kaya dengan modal, gagal menunjukkan kelebihan eksport yang sepadan bagi barangan intensif modal. Dari segi metodologi, sebuah model graviti yang menggabungkan keheterogenan industri telah dibangunkan, dengan memperkenalkan pemboleh ubah dumi (dummy variable) untuk keamatan modal serta mengawal faktor-faktor utama seperti KDNK (GDP), pelaburan langsung asing (FDI), populasi, dan jarak geografi. Keputusan kajian menunjukkan bahawa produk intensif modal menikmati kelebihan yang kukuh dalam import, sejajar dengan ramalan Heckscher-Ohlin. Walau bagaimanapun, kelebihan eksportnya kekal tidak signifikan secara statistik, mendedahkan asimetri import-eksport yang jelas. Analisis teori lanjutan menunjukkan bahawa asimetri ini berpunca daripada kekangan struktur dan institusi: kesan penguncian teknologi dalam rantaian nilai global, diskriminasi berasaskan negara asal dalam rejim harta intelek, dan herotan (distortions) dalam pasaran faktor domestik (contohnya, salah peruntukan modal) semuanya mengurangkan keupayaan China untuk menukar anugerah faktornya (factor endowments) kepada prestasi eksport. Dapatan ini menawarkan pelengkap kritikal kepada teori kelebihan perbandingan standard. Kajian ini memberi implikasi bahawa untuk China menaik taraf struktur perdagangannya, ia mesti melangkah melampaui pergantungan kepada anugerah faktor semata-mata, dan sebaliknya membina kelebihan komposit yang berakar umbi daripada kualiti faktor, sokongan institusi, dan inovasi. Walau bagaimanapun, kajian ini dihadkan oleh ketiadaan data peringkat firma untuk menguji saluran penyerapan teknologi secara empirikal, sekali gus menunjukkan bidang utama untuk penyelidikan masa depan.

Kata Kunci: Perdagangan China, Keamatan Modal, Paradoks Leontief, Model Graviti, Asimetri Perdagangan

INTRODUCTION

Since the late 18th century, international trade theory has undergone multiple phases of evolution, transitioning from classical doctrines of division of labor and resource endowments to more contemporary paradigms of interpretation. Classical theory emphasized that trade arises from specialization and efficiency gains. Adam Smith's theory of absolute advantage and David Ricardo's principle of comparative advantage constituted early explanatory frameworks for international trade (International Monetary Fund, 2009). However, these models were constrained by their reliance on labor value and the simplified two-country, two-commodity structure, rendering them insufficient to account for the complexities of trade patterns in diversified economies (Feenstra, 2015). With the advent of the 20th century, the Heckscher–Ohlin (H–O) theory sought to explain comparative advantage through disparities in factor endowments, positing that the fundamental drivers of trade lie in the relative abundance of production inputs such as capital and labor. This marked a foundational shift toward modern trade theory. The H–O model predicts that a capital-abundant country should export capital-intensive goods and import labor-intensive goods (Guo, Xu Zhu , 2023).

Nevertheless, the theory is constructed under stringent assumptions, including uniform technology, perfect competition, and identical production functions, which pose serious challenges to its empirical applicability. Wassily Leontief's empirical investigation of the U.S. economy in 1947 yielded results directly at odds with the H–O prediction. By constructing an input–output table for the United States and calculating the factor requirements per million dollars of exports and import substitutes, Leontief found that producing $1 million worth of exports required approximately $2,550,780 in capital and 182,313 person-years of labor, whereas producing an equivalent value of import substitutes required $3,091,339 in capital and 170,004 person-years of labor (Leontief, 1956, p. 393). Consequently, the capital–labor ratio of U.S. exports, roughly $14,010 per person-year, was lower than that of import substitutes, approximately $18,180 per person-year, indicating that the United States was, in fact, exporting more labor-intensive and importing more capital-intensive goods (Leontief, 1956, p. 395). This empirical anomaly became known as the "Leontief Paradox." The significance of this paradox lies not only in its empirical refutation of the H–O model's universal validity but also in its catalytic effect on theoretical re-evaluation within international trade scholarship. It stimulated critical inquiries into factor measurement, product heterogeneity, technological structures, human capital, and the configuration of global value chains. Therefore, this study aims to investigate whether the leontif paradox exists in modern China, in order to provide a clearer reference for scholars and policy makers.

To operationalize the above research aim, this study pursues three specific objectives. First, it empirically examines whether China's export structure to Belt and Road Initiative partner countries exhibits a systematic advantage for capital-intensive products, once standard gravity-model determinants such as market size, distance, trade openness, and digital infrastructure are controlled for. Second, it investigates China's import behavior by testing whether capital-intensive goods are disproportionately imported from capital-abundant countries, thereby assessing the extent to which China's trade pattern conforms to or deviates from the predictions of the Heckscher–Ohlin framework. Third, by comparing export and import results within a unified empirical framework, the study seeks to identify potential asymmetries between factor endowments and trade performance, and to provide a structural interpretation of these asymmetries in light of global value chain positioning, technological constraints, and institutional frictions. Together, these objectives allow for a systematic reassessment of the relevance of the Leontief Paradox in the context of China's contemporary trade structure.

LITERATURE REVIEW

In response to the paradox, Leamer (1984) argued from a theoretical standpoint that the original analysis mistakenly compared the capital–labor ratios of exports and imports directly, neglecting that the relevant metric should be the difference in factor intensity between net exports and domestic consumption. Under the Heckscher–Ohlin–Vanek (HOV) framework, Leamer found that the capital intensity of the U.S. net export bundle in 1947 exceeded that of its domestic consumption, reaffirming the United States' status as a capital-abundant country and effectively nullifying the paradox. Furthermore, Leamer demonstrated that in a multi-commodity world, the ranking of factor intensities between export and import bundles does not necessarily reflect a nation's underlying factor endowments (Leamer, 1984). China, the world's second largest economy, has a total GDP of $18.53 trillion in 2024. Applying this theoretical lens to China's foreign trade structure facilitates an examination of whether a similar paradox manifests in its trade profile. According to

Frontiers of China's International Economic and Trade Theory, with the proliferation of the digital economy and advancements in manufacturing automation, previously labor-intensive sectors such as simple industrial goods and assembly processes are increasingly transitioning into capital-intensive production due to the infusion of high technology(Dachs,2025). However, in developing countries like China, where such technological transformations remain unevenly diffused, the export structure may still exhibit labor-intensive characteristics, thus generating a statistical appearance that "exports are more labor-intensive than imports." This structural mismatch could be construed as a "Chinese version" of the Leontief Paradox. Nevertheless, the root cause likely lies not in a contradiction between capital and labor endowments per se, but rather in the dynamic reconfiguration of technological pathways, production organization, and global value chain segmentation(Zhang, Chen, Min, 2025). For example, between 2000 and 2014, China's apparel and assembly industries improved their positions in global value chains, with index values rising from –2.38 and –1.81 to 1.95 and 1.99, respectively. However, their exports remained labor-intensive. In 2013, the apparel sector's forward digital linkage index was 0.30, while its backward index was just 0.08, indicating limited integration into high-value chains. By contrast, the computer and communication equipment sector showed much stronger digital connectivity, with forward and backward indices of 2.50 and 0.19. That year, China's domestic digital value added totaled 15.54 trillion USD, accounting for 74.4 percents of the national digital value added, while re-export-related value added made up only 10.6 percents, revealing the country's still modest role in global digital supply chainsWang, Wei, Zhu, 2013. Yet, when contextualized within the evolution of China's export structure to Belt and Road Initiative (BRI) countries in recent years, it becomes plausible to argue that China does not conform to the classical formulation of the Leontief Paradox. Based on Lall's (2000) classification of manufacturing products by technological intensity, China's exports to BRI countries can be categorized into three types: labor-intensive (low-tech goods such as apparel, footwear, textiles, and toys), capital-intensive (medium-tech goods such as machinery, chemicals, and transport equipment), and technology-intensive (high-tech goods such as electronics, electrical equipment, precision instruments, and pharmaceuticals). Export data from 2013 to 2023 reveal a substantial structural transformation: labor-intensive goods declined from approximately 30 percents to 15 percents of total exports to BRI countries; capital-intensive goods rose from about 50 percents to 55 percents; and technology-intensive goods increased from 20 percents to 30 percents (He, 2015). For instance, in 2023, China's apparel exports to BRI countries grew by only 1 percents, and yarn and textile exports by around 6 percents, whereas capital- and technology-intensive categories experienced double-digit growth. (World Bank, 2024) In the automotive sector, Chinese car exports grew by nearly 20 percents year-on-year, approaching $100 billion in total export value, with Russia accounting for over $11 billion, thereby becoming the largest single market; the Middle East and Southeast Asia also emerged as significant destinations (OEC, n.d.). In technology-intensive domains, Chinese exports of integrated circuits, telecommunications equipment, and electrical machinery to BRI countries increased by over 20 percents year-on-year in 2023. Countries such as Vietnam and Malaysia, integral parts of the global electronics supply chain, exhibited particularly strong import growth. Regionally, China's exports to ASEAN rose by 12.5 percents, dominated overwhelmingly by mechanical and high-tech products, with substantial gains in office equipment, telecommunication apparatus, and solar components (China Briefing, 2024). Additionally, driven by infrastructure demands under the BRI framework, China exported large volumes of engineering machinery, electrical equipment, and rail transport vehicles to Central Asia, South Asia, and African countries. For example, in 2023, China's exports of power station equipment to Pakistan and locomotives and industrial machinery to Ethiopia each grew by more than 20 percents annually. This shift in export structure not only reflects China's waning comparative advantage in traditional labor-intensive industries but also signifies its ongoing ascent within global value chains-leveraging economies of scale, technological accumulation, and industrial integration to facilitate "mid-to-high-end substitution" (World Bank, 2019; World Bank, 2024). Hence, unlike the mid-20th century United States, whose export–import pattern contradicted theoretical expectations by exporting labor-intensive and importing capital-intensive goods, China's current trade structure clearly demonstrates a high degree of capital and technology intensification. This outcome aligns with Leamer's (1984) emphasis on evaluating a country's factor endowments through the lens of net factor use embodied in net exports. In this sense, China has not fallen into the Leontief Paradox but has instead exhibited trade characteristics consistent with its level of capital accumulation-an outcome shaped by the dual forces of technological advancement and policy orientation (Bowen, Leamer, Sveikauskas, 1987).

METHODOLOGY

The empirical analysis in this study is based on a cross-sectional dataset that delineates the bilateral export structure of Chinese-manufactured goods to ten BRI partner countries in the year 2023. These ten countries-Pakistan, Kazakhstan, Russia, Poland, Egypt, Indonesia, Turkey, Kenya, Saudi Arabia, and Vietnam-collectively represent a wide spectrum of geographical and economic diversity, encompassing regions such as South Asia, Central Asia, Eastern Europe, the Middle East, Southeast Asia, and Sub-Saharan Africa. All selected countries are official partners within China's BRI framework and have entered into bilateral or regional trade agreements with China, thereby ensuring a high degree of institutional comparability and minimizing confounding effects induced by divergent trade policies.

The unit of analysis is at the "country–product" level. Export value data pertain to a selection of twenty manufactured goods, subdivided into two categories: ten capital-intensive products and ten labor-intensive products. The capital-intensive category includes: passenger cars (HS 870323), steel structures (HS 730830), engines (HS 840734), laptop computers (HS 847130), integrated circuits (HS 854231), valves and control devices (HS 848180), static converters (HS 850440), aircraft parts (HS 880330), internal combustion engine parts (HS 840991), and hot-rolled iron sheets (HS 720851). The labor-intensive category comprises: men's denim trousers (HS 620342), cotton T-shirts (HS 610910), plastic-soled footwear (HS 640419), wooden furniture (HS 940360), plastic toys (HS 950300), leather handbags (HS 420221), acrylic sweaters (HS 611020), dishcloths and kitchen towels (HS 630260), wooden frames for pictures and mirrors (HS 441820), and plastic hangers and pallets (HS 392620). The classification of products by capital or labor intensity follows Lall's (2000) typology of technological sophistication, refined through the mapping of Harmonized System (HS) codes to the ISIC industry classification published by the OECD. This approach has been extensively adopted in the literature on developing countries' export structures (Fagerberg, 1994; Aiginger, 1997), based on the theoretical premise that the factor intensity embedded in a product's production process exhibits relative stability over time, thereby serving as a reliable proxy for a country's evolving comparative advantage. In addition, we also collect data on China's imports of these same products from the corresponding BRI partner countries, in order to assess bilateral trade asymmetries and patterns of factor intensity in both export and import flows.

To evaluate whether China's export structure aligns with its factor endowments, the model incorporates a set of key control variables, each corresponding to canonical determinants in classical trade theory. Given the theoretical overlap between per capita GDP and trade openness in capturing structural attributes of an economy, a high degree of multicollinearity is anticipated between the two. In such cases, the model retains trade openness as an institutional variable and substitutes per capita GDP with the capital–labor ratio (K/L) as the relevant measure. Specifically, per capita GDP (measured in USD) is commonly used as an indicator of capital abundance in the importing country and constitutes a standard variable in the Heckscher–Ohlin framework (Heckscher Ohlin, 1933; Feenstra, 2015). In contrast, trade openness-defined as the ratio of total trade (exports plus imports) to GDP-better captures a country's degree of integration into global markets and its institutional receptivity to international commerce, both of which have been empirically linked to structural changes in export composition (Edwards, 1998; Rodrik, 2000). The K/L ratio, calculated as the gross fixed capital formation divided by the labor force, offers a more direct measure of the relative availability of capital vis-à-vis labor, serving as an important complement in assessing factor endowments (Bowen, Leamer, Sveikauskas, 1987).

Furthermore, population size is included in the model to control for market scale effects, under the rationale that larger importing markets may exhibit higher demand for value-added intermediate and capital goods (Markusen, 1986). Geographic distance, approximated by the great-circle distance between Beijing and the respective national capitals, is employed as a proxy for transport costs and constitutes a standard measure of spatial frictions in gravity models of trade (Tinbergen, 1962; Mayer Zignago, 2011). The internet penetration rate is introduced as a structural variable capturing the level of digital infrastructure and absorptive capacity, which are critical to the importation of technologically advanced products and to the viability of digital trade pathways (Chinn Fairlie, 2004; Xu, 2000).

At the product level, the analysis further constructs a structural variable termed "import share," defined as the proportion of China's exports of a given product to a specific country relative to the total imports of that product by the same country in that year. This measure reflects the relative importance and dependency of the destination market on Chinese exports of that product, and may also serve as a variable in explaining export values. Within global value chains, a higher market share often implies greater pricing power and a lower elasticity of demand, as Chinese products may occupy a more indispensable position in the destination market (Antràs Chor, 2013).

Regarding data sources, macroeconomic indicators (GDP, per capita income, population, gross fixed capital formation, and labor force) are drawn from the World Bank's World Development Indicators (World Bank, 2024); geographic distance data are sourced from the CEPII GeoDist database (Mayer Zignago, 2011); internet penetration rates are provided by the International Telecommunication Union (ITU); and trade data are compiled from the General Administration of Customs of China, matched at the 6-digit HS code level. The study is confined to the year 2023, which marks a period of structural normalization in the global trade system following the disruptions of the COVID-19 pandemic, thus enhancing the representativeness of the observed trade patterns while mitigating the influence of intertemporal volatility.

TABLE 1. Summary of Variables

Variable	Definition
ExportValue_{ijt}	Export value (USD) of product *i* from China to country *j* in year *t*
$\text{IsCapitalIntensive}_{i}$	Dummy = 1 if product *i* is classified as capital-intensive, 0 otherwise
$\log(\text{KL}_j)$	Natural log of capital-labor ratio (capital per worker) in country *j*
ImportShare_{ijt}	Share of Chinese product *i* in country *j*'s total imports of *i*
$\log(\text{GDPpc}_j)$	Log of GDP per capita of country *j*
$\log(\text{Population}_j)$	Log of population of country *j*
$\log(\text{Distance}_j)$	Log of distance between China and country *j*
$\log(\text{TradeOpen}_j)$	Log of trade openness (exports + imports as a % of GDP)
$\log(\text{Internet}_j)$	Log of internet penetration (% of population using internet)
$\log(\text{ImportTotal China}_{ijt})$	Log of China's total imports of product *i* from country *j*

The descriptive statistics presented in Table 2 underscore the pronounced heterogeneity among the ten Belt and Road Initiative (BRI) partner countries across several key variables. Trade openness exhibits a standard deviation of 0.39, indicating substantial variation in the degree of integration into global trade networks. Countries such as the United Arab Emirates and Vietnam report trade openness values exceeding 1, highlighting their active engagement not only in exports and imports but also in re-export activities and large-scale transnational logistics-thereby positioning themselves as pivotal nodes in the global supply chain. In contrast, nations like Pakistan and Egypt, with markedly lower trade dependency ratios, appear to remain on the periphery of the global economic system (Rodrik, 2000). The standard deviation for GDP per capita, amounting to USD 7,014, reveals a stark disparity in economic development levels. For instance, Poland's per capita income reaches USD 22,113, aligning it with high-income economies, whereas Pakistan and Kenya record figures below USD 2,000, reflecting structural developmental constraints that significantly shape their trade patterns and global market integration. Population also demonstrates considerable variability, with a standard deviation of 84.37 million. This highlights the demographic advantage of populous nations such as Indonesia (approximately 270 million) and Pakistan (around 250 million), which potentially benefit from expansive domestic markets and abundant labor forces.

However, such demographic largesse may simultaneously exacerbate challenges related to resource allocation and social protection (Markusen, 1986). The capital-labor ratio (KL), with a standard deviation of 5,316, illustrates significant disparities in capital intensity. Economies like India, characterized by lower KL values, remain predominantly labor-intensive. Finally, internet penetration exhibits a standard deviation of 25.77, pointing to asymmetric development in digital infrastructure. High-penetration countries such as Russia and Poland demonstrate robust digital economic potential, whereas those with lower penetration rates are likely constrained by underdeveloped information and communication technologies-thereby limiting their capacity to participate in knowledge-intensive trade (Chinn Fairlie, 2004).

We construct two regression models to test whether China's export structure reflects its rising capital intensity, and whether it aligns with or deviates from traditional factor endowment theory.

The first model explores the determinants of China's exports to its trade partners, focusing on the match between the factor intensity of Chinese export goods and the factor endowment structure of importing countries. According to the Heckscher–Ohlin theory, countries with abundant capital tend to import labor-intensive goods and export capital-intensive goods (Feenstra 2015). However, in China's case, the export structure has shifted in recent years from labor-intensive to more capital- and technology-intensive products (Lall 2000; World Bank 2019; Jiang et al. 2023), suggesting a growing comparative advantage in capital-intensive sectors. Based on this, we assume capital-intensive goods are more likely to be exported from China, which contrasts with the so-called "Chinese Leontief paradox." On the demand side, classical trade theory also predicts that capital-rich countries possess a comparative advantage in producing capital-intensive goods and thus develop a higher domestic demand for such products. Therefore, we hypothesize that countries with higher capital–labor ratios (*K/L*) are more inclined to import capital-intensive goods from China, owing to their intrinsic demand structure and China's expanding specialization in such categories.

$$\log(\text{ExportValue}_{ijt}) = \beta_0 + \beta_1 \cdot \text{IsCapitalIntensive}_i + \beta_2 \cdot \log(\text{KL}_j) + \mathbf{X} \quad \beta + \varepsilon_{ijt} \qquad (1)$$

Where: $\log(\text{ExportValue}_{ijt})$: The natural log of export value from China to country j for product i in year t. $\text{IsCapitalIntensive}_i$: A binary indicator for whether product i is capital-intensive. $\log(\text{KL}_j)$: The natural log of the capital-labor ratio of the destination

country j, representing its factor endowment. $\mathbf{X}_{jt}$: A vector of control variables including $\log(\text{GDPpc}_j)$, $\log(\text{Population}_j)$, $\log(\text{Distance}_j)$, $\log(\text{TradeOpen}_j)$, and $\log(\text{Internet}_j)$.The control variables are adjusted as they are made to increase the validity of the model.

The second model defines the dependent variable as the share of a specific Chinese product in the importing country's total imports of that product category. This formulation emphasizes China's market penetration within a given product class and serves as a normalized relative indicator. It effectively controls for the overall import scale of the destination country as well as the general trade volume of the product in global markets. This setup allows us to focus on export competitiveness rather than absolute trade volume. Based on this, we hypothesize that in capital-abundant countries, Chinese capital-intensive products—owing to their factor compatibility—will account for a larger share of imports, thereby reflecting China's relative comparative advantage in those sectors.

$$\text{ImportShare}_{ijt} = \gamma_0 + \gamma_1 \cdot \text{IsCapitalIntensive}_i + \gamma_2 \cdot \log(\text{KL}_j) + \text{X}' \quad \gamma + \eta_{ijt} \qquad (2)$$

Where: ImportShare_{ijt} represents The share of Chinese product i in country j's total imports of product i. $\text{IsCapitalIntensive}_i$: Same as in Model 1, indicating whether the product is capital-intensive. $\log(\text{KL}_j)$: Same as in Model 1, representing the capital-labor ratio in the importing country.

To analyze China's import behavior, we apply the same empirical model structure but replace the dependent variable with $\log(\text{ImportTotal China}_{ijt})$, representing the natural logarithm of China's total import value of product i from country j in 2023. We hypothesizes that China tends to import capital-intensive products from capital-abundant countries. A positive and significant coefficient on the capital-intensive variable would contradict the Leontief paradox and support the predictions of the Heckscher–Ohlin model.

$$\log(\text{ImportTotal China}_{ijt}) = \alpha_0 + \alpha_1 \cdot \text{IsCapitalIntensive}_i + \alpha_2 \cdot \log(\text{KL}_j) + \text{X}'_{jt}\alpha + \nu_{ijt} \qquad (3)$$

Where:

$\log(\text{ImportTotal China}_{ijt})$ is the natural log of the total value (in thousand USD) of product i that China imported from country j in year t.

All explanatory variables are retained to ensure comparability across export and import models, with the same control structure $\mathbf{X}_{jt}$.

RESULTS DISCUSSION

In the regression results for Model One, we analyze the impact of various factors on the export value of China to different countries (log ExportValue). First, the coefficient for the capital-intensive dummy variable IsCapitalIntensive is 0.5343, which is marginally significant at the 10% level ($p = 0.085$). This indicates a positive correlation between the export of capital-intensive products and export values, but this result does not reach the conventional significance level (p ¡ 0.05). This suggests that although capital-intensive products might lead to higher export values, this relationship is not statistically significant, likely because after controlling for other factors, the independent contribution of capital-intensive products to export values is diminished.

Regarding the influence of control variables, the coefficient for log GDPpc is -3.0966 ($p = 0.0516$), indicating a negative relationship, which is close to the significance level (p 0.05). This suggests that countries with higher GDP per capita tend to import fewer products from China. The negative correlation may be explained by the fact that higher-income countries have stronger domestic production capabilities and can produce more goods themselves, thus reducing their demand for Chinese products. Additionally, as these countries develop economically, their labor productivity and technological levels increase, making them more competitive in exports and decreasing their reliance on imports from China. The significant impact of log GDPpc explains why log KL is not significant in this model, as log GDPpc already captures the effects of capital abundance and technological advancement, thus diminishing the effect of log KL after controlling for this variable.

For log Population, the coefficient is 0.2697, but it is not statistically significant (p = 0.2856), indicating that population size has little impact on export values. While larger populations are often thought to have higher domestic market demand, this may also reflect that these countries rely more on domestic demand, and thus have a lower dependence on exports. The negative effect of log Population did not manifest significantly, suggesting that after controlling for factors like per capita income, the independent impact of population size on exports is weak.

The coefficient for log Distance is -1.3396 (p = 0.0108) and is statistically significant, indicating that geographic distance negatively impacts export values. According to the gravity model, the greater the distance between two countries, the higher the transportation and information costs, which reduces trade volume. Therefore, with each 1% increase in distance, exports are expected to decrease by approximately 1.34%. This result underscores the continued importance of geographic distance in international trade, even in the modern era with advances in communication technologies and the widespread use of the internet (log Internet).

The coefficient for log TradeOpen is -1.2142 (p = 0.4257), suggesting that trade openness has a minor and statistically insignificant effect on export values. While more open trade policies typically promote exports, in this model, the effect is not significant, possibly due to the overlapping effects of other control variables such as log GDPpc and log Distance. However, the coefficient for log Internet is 0.5267 (p = 0.0741), which is close to the significance level, indicating a positive impact on export values. The spread of the internet helps reduce transaction costs, improves access to market information, and enhances communication efficiency, which in turn facilitates greater exports. Thus, the spread of the internet plays a crucial role in enhancing a country's export competitiveness, in line with the characteristics of the digital economy.

Overall, the model's R^2 value is 0.2382, and the adjusted R^2 is 0.2072, suggesting that the model explains approximately 20.7% of the variation in export values. Although this is not very high, it still provides meaningful insights in real-world applications. The F-statistic is 7.685 (p = 4.521e-08), indicating that the model is significant and can effectively capture the variation in export values. Additionally, the Breusch-Pagan (BP) test results show a value of 6.9686 (p = 0.4322), suggesting no significant heteroscedasticity issues in the model.

TABLE 2. Descriptive Statistics of Regression Variables

Variable	Mean	Std. Dev.	Median	Min	Max
Export Value (USD)	220.96M	664.45M	36.62M	18,009	6.01B
Is Capital Intensive (0/1)	0.50	0.50	0.50	0	1
GDP per Capita (USD)	9,351	7,014	7,605	1,664	23,332
Population (millions)	110.63	84.37	93.34	20.27	282.00
Distance (km)	4,925	1,835	4,982	2,458	7,894
KL (Capital per Worker)	5,876	5,316	4,548	531	18,718
Internet Penetration (%)	9.31	25.77	0.82	0.37	86.42
Import Share	0.0011	0.0025	0.0003	5×10^{-8}	0.0190
Trade Openness	0.56	0.39	0.43	0.24	1.58
ImportTotal China (thousand USD)	2,127	4,634	92	2.8	24,767

Note: 11 of 200 observations have ImportTotal China = 0 and are excluded from regressions.

However, we must pay special attention to log KL, where the coefficient is 3.1355 (p = 0.0118), statistically significant (p ¡ 0.05), indicating that countries with higher capital-labor ratios tend to import more capital-intensive products from China, as expected by theory.

However, the significance of log KL might be constrained by the high multicollinearity with log GDPpc (with VIF values of 82.75 and 77.72). Thus, although log KL shows a positive relationship, its independent effect on exports becomes insignificant after controlling for

log GDPpc. According to the Solow–Swan model, there is a significant positive correlation between per capita capital and GDP per capita, and increases in capital intensity generally lead to higher per capita output. Empirical studies support this view. For instance, Le M. Tue et al. (2014) found that a 1% increase in capital stock leads to a 0.39% increase in per capita GDP, with a higher elasticity in countries with low population growth. Similarly, Mankiw, Romer, and Weil (1992) found that physical capital elasticity on per capita GDP is about 0.3, with human capital elasticity at 0.28, explaining about 80% of the cross-country differences in per capita GDP. Therefore, the high correlation between log KL and log GDPpc is supported by both theoretical and empirical logic. In future model improvements, we may consider removing log GDPpc to address multicollinearity and more accurately identify the independent impact of capital intensity.

Removing log GDPpc caused a notable change in the model. Firstly, from the model fit perspective, the R^2 value decreased from 0.2382 to 0.2212, and the adjusted R^2 value dropped from 0.2072 to 0.1942. This indicates that the explanatory power of the model slightly decreased after removing log GDPpc, with the adjusted R^2 falling by approximately 1.3 percentage points. This suggests that log GDPpc plays an important role in explaining variations in export values, even though it did not show a significant direct impact. However, the VIF values of the model significantly decreased, especially for log KL, where the VIF dropped from a high value of 82.75 to 1.495, indicating that the multicollinearity issue was effectively mitigated, which enhanced the independence of the variables and the stability of the model.

Secondly, regarding the regression coefficients, the coefficient for log KL increased significantly, and the p-value dropped notably from 0.0118 to 2.71e-05, with the t-value rising from 2.544 to 4.312. After removing log GDPpc, the impact of log KL on export values became significantly stronger, suggesting that the capital-labor ratio has a clearer and more powerful influence on exports. This change also indicates a high degree of multicollinearity between log GDPpc and log KL in the original model.

However, the coefficient for IsCapitalIntensive (the dummy variable for capital-intensive products) did not change significantly, remaining at 0.53433 with a p-value of 0.0876, which is still close to the 10 percents significance level. This suggests that removing log GDPpc did not substantially alter the impact of IsCapitalIntensive on export values, with the effect remaining marginally significant. It implies that, after controlling for other factors, there is a positive correlation between the export of capital-intensive products and higher export values, but this relationship is not statistically significant. This may be due to the influence of other control variables, such as log KL and log Distance.

Additionally, the coefficient for log Population is 0.35728 with a p-value of 0.1545, indicating that the impact of population size on export values remains insignificant. After removing log GDPpc, the coefficient for log Population changed little, and its statistical significance did not improve, suggesting that, after controlling for per capita income, the independent impact of population size on exports is weak. The coefficient for log Distance is -1.2616 with a p-value of 0.0169, which remains statistically significant at the 5 percents level, indicating thatgeographic distance

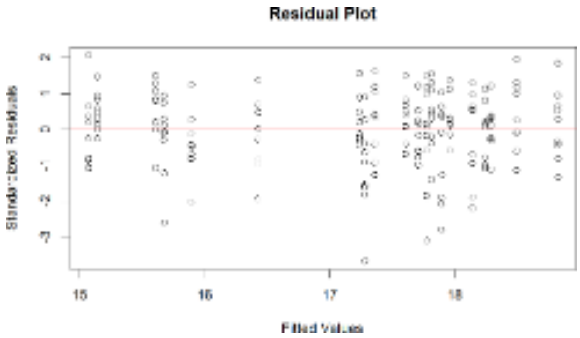

FIGURE 1. Residual Plot of Model 1 without log GDPpc

still has a significant negative impact on export values. The coefficient for log Distance did not change much after removing log GDPpc, which further validates the importance of geographical distance in modern international trade, with an increase in distance significantly reducing trade volume.

Finally, the coefficients for log TradeOpen (trade openness) and log Internet (internet penetration) showed little change after removing log GDPpc. Their coefficients were 1.08249 ($p = 0.2695$) and 0.05391 ($p = 0.7485$), respectively, and did not exhibit significant statistical effects, indicating that trade openness and internet penetration have a relatively weak impact on export values.

TABLE 3. Regression Results for Model 1 without log GDPpc

Variable	Estimate	Std. Error	t value	Pr(¿—t—)
Intercept	19.42468	5.54391	3.504	0.000584
IsCapitalIntensive	0.53433	0.31103	1.718	0.087598
log KL	0.74317	0.17234	4.312	2.71e-05
log Population	0.35728	0.24983	1.430	0.154493
log Distance	-1.26160	0.52309	-2.412	0.016919
log TradeOpen	1.08249	0.97728	1.108	0.269546
log Internet	0.05391	0.16789	0.321	0.748535
R-squared	0.2212			
Adjusted R-squared	0.1942			
F-statistic	8.191			
p-value (F-statistic)	8.303e-08			
Residual standard error	2.086			

We continue to remove the control variable log(GDPpc) to enhance the feasibility of the ImportRatio model, yet we still observe a significant decline in its explanatory power. Specifically, although the overall F-statistic of the model is 3.052 with a p-value of 0.0073, indicating that the model remains statistically significant, the R^2 decreases from 0.2212 to 0.09571, and the adjusted R^2 drops from 0.1942 to 0.06435. This suggests that the model's ability to explain the dependent variable has substantially weakened. The Breusch–Pagan test for heteroskedasticity yields a statistic of 8.4613 with a p-value of 0.2062, indicating no significant presence of heteroskedasticity and supporting the robustness of the regression results.

Regarding the coefficients of key variables, we also observe notable changes. First, the coefficient on log(K/L) (capital–labor ratio) becomes insignificant, with its p-value rising from 0.01184 to 0.56804, indicating that in the absence of log(GDPpc) as a control, the effect of capital abundance on the import share of capital-intensive products is no longer statistically significant. Second, the coefficient on CapitalIntensive (the dummy variable for capital-intensive products) remains positive (0.0005433), but is still statistically insignificant ($p = 0.13535$), suggesting that even after removing GDPpc, the relationship between a product's capital intensity and its share in the importing country's market remains weak.

In addition, log(Population) becomes statistically significant in the model ($p = 0.02046$, down from 0.28561) and shows a significant negative effect. This may reflect the fact that countries with larger populations tend to have a greater overall import base and more diversified sources, thus decreasing their dependence on Chinese goods, leading to a lower share of Chinese products. For example, populous countries such as India or Indonesia may import large absolute amounts from China, but their total imports are also high, so the ImportRatio does not necessarily increase. Therefore, as population increases, the denominator grows faster than the numerator, and the ImportRatio actually declines, resulting in a negative coefficient. Furthermore, log(Distance) remains statistically significant and negative ($p = 0.00253$).

Additionally, both log(TradeOpen) and log(InternetPenetration) remain insignificant (with p-values of 0.41939 and 0.74132, respectively), and their coefficients shift from positive to negative. A possible explanation is that when the dependent variable is export value, more open economies tend to import more from China, displaying a positive relationship. However, when the dependent variable becomes ImportRatio, trade openness no longer guarantees easier market access for China, but may instead imply greater exposure to competition from other countries. In other words, a highly liberalized trade environment often results in diversified imports from multiple origins, particularly high-value-added or technology-intensive products, thereby diluting China's market share. The explanation for internet penetration is similar: in highly digitalized countries such as New Zealand or the UAE, the ability to access and compare information enables buyers to source the most competitive or high-quality goods globally. This capability may intensify competition with other exporting countries, thus limiting China's market share. For example, firms from Germany or South Korea may enjoy superior brand recognition or product quality in such markets, resulting in a relatively lower share for Chinese products and consequently a negative coefficient.

TABLE 4. Regression Results for Model 2 (Dependent Variable: ImportRatio)

Variable	Estimate	Std. Error	t value	Pr (¿—t—)
Intercept	0.0182312	0.0060615	3.008	0.00302
IsCapitalIntensive	0.0005433	0.0003621	1.500	0.13535
log(K/L)	0.0001213	0.0002120	0.572	0.56804
log(Population)	-0.0006689	0.0002860	-2.339	0.02046
log(Distance)	-0.0018671	0.0006094	-3.064	0.00253
log(TradeOpen)	-0.0003940	0.0004868	-0.809	0.41939
log(InternetPenetration)	-0.0000553	0.0001673	-0.331	0.74132
R-squared	0.09571			
Adjusted R-squared	0.06435			
F-statistic	3.052			
p-value (F-statistic)	0.007305			
Residual Std. Error	0.002429 (df = 173)			

In the regression model where the logarithm of China's total imports from BRI countries (log(ImportTotal)) serves as the dependent variable, the model demonstrates a robust explanatory capacity, with the adjusted R^2 rising to 65 percents, thereby indicating overall statistical significance.

More specifically, the coefficient on IsCapitalIntensive is 3.170 (p ¡ 0.001), implying that capital-intensive products are imported in substantially greater quantities compared to labor-intensive goods. Holding other factors constant, this coefficient suggests that, on average, the import value of capital-intensive goods exceeds that of labor-intensive ones by approximately $e^{3}.^{1}$ 23.8 times. This finding appears to contradict the classical Leontief Paradox, and instead underscores China's empirical tendency-as a capital-abundant country-to import capital-intensive goods. A plausible explanation lies in China's still-developing capacity for high-end manufacturing or its ongoing technological dependency on foreign supply chains (Zhu Trefler, 2005). The coefficient on log(K/L) (the logarithm of the capital-labor ratio) is 0.366 (p = 0.030), indicating that countries with higher capital intensity tend to contribute more significantly to China's imports. This may reflect such countries' comparative advantage in producing sophisticated capital goods, which are in high demand in China's evolving industrial structure. The coefficient on log(Population) is 1.10, suggesting that countries with larger populations tend to export more to China. This aligns with the notion that populous nations possess greater productive capacities and a more diverse array of exportable goods, making them essential partners in China's import diversification strategy (Freund Pierola, 2015).

Interestingly, the coefficient on log(Distance) is 0.809 and statistically significant at conventional levels, which stands in contrast to the negative distance effect typically observed in trade gravity models, including our earlier export regression. This anomalous result may reflect China's importation of lower-priced goods or inelastic, technology-intensive commodities, whose trade volumes remain high despite greater geographic separation. The coefficient on log(TradeOpenness) is 1.798 (p ¡ 0.001), significantly positive, indicating that countries with more liberal trade regimes are more likely to serve as sources of Chinese imports. This could stem from the presence of fewer export restrictions or proactive bilateral trade arrangements (Hanson, 2012). In contrast, log(InternetPenetration) exhibits a negative and significant coefficient of 0.354 (p = 0.006), diverging from its positive impact observed in the export model. This inverse relationship may suggest that countries with higher internet penetration are more oriented toward service-based or digital economies, possibly at the expense of traditional manufacturing sectors, thereby reducing their exports of tangible goods to China.

To assess potential heteroskedasticity, we employed the BP test, which evaluates whether the variance of the regression residuals systematically varies with the explanatory variables. The test yielded a p-value of 0.074, indicating marginal evidence of heteroskedasticity at the 10 percents significance level, though it does not attain conventional significance at the 5 percents level. To address potential bias in standard errors and mitigate any distortions in t-statistics arising from heteroskedasticity, we adopted heteroskedasticity-consistent standard error corrections, specifically using the HC3 estimator (MacKinnon and White, 1985). HC3 is particularly effective in finite samples and under the presence of high-leverage observations, offering more robust inference compared to HC0, HC1, or HC2 variants. Upon recalculating t-statistics with HC3-adjusted standard errors, we find that the statistical significance of the majority of variables remains stable, with only log(K/L) and log(Distance) exhibiting a slight decrease in significance, yet still within acceptable bounds. This result implies that although heteroskedasticity may be marginally present, it does not materially affect the core inferences drawn from the model, thereby reinforcing the robustness of our regression results.

With regard to multicollinearity, the import model performs satisfactorily. All explanatory variables, excluding the constant term, VIFs well below the conventional threshold of 5, indicating an absence of serious multicollinearity issues. Specifically, the VIF for IsCapitalIntensive is 1.023, implying virtually no correlation with other predictors. The VIFs for log(K/L), log(Population), log(Distance), log(TradeOpenness), and log(InternetPenetration) are 1.82, 1.76, 1.77, 2.22, and 1.85, respectively-all within the safe range. These diagnostics confirm the statistical integrity of the model and the reliability of coefficient estimates.

TABLE 5. Regression Results: Log of ImportTotal as Dependent Variable

	OLS	Robust SE (HC3)
Intercept	-1.9099	-1.9099
	(4.7152)	(4.4757)
IsCapitalIntensive	3.1696***	3.1696***
	(0.3425)	(0.2600)
log KL	0.3656**	0.3656**
	(0.1653)	(0.1784)
log Population	1.0999***	1.0999***
	(0.2551)	(0.2443)
log Distance	0.8085*	0.8085*
	(0.4567)	(0.4845)
log TradeOpen	1.7980***	1.7980***
	(0.3648)	(0.4593)
log Internet	-0.3535***	-0.3535***
	(0.1250)	(0.1298)
R-squared	0.649	0.649
Adj. R-squared	0.621	0.621
N	81	81

This study finds that China demonstrates a significant structural preference for importing capital-intensive products. In the import regression model, the coefficient on the

capital-intensive variable reaches 3.170 ($p < 0.001$), indicating that imports of such products

are far higher than those of labor-intensive ones. This strongly supports the predictions of the Heckscher–Ohlin theory, but contradicts the empirical pattern described in the Leontief paradox, which observed that capital-abundant countries tend to import capital-intensive goods.

However, the situation is more complex in terms of China's export structure. In Models (1), (2), and (3), the capital-intensive dummy variable does not consistently yield a significantly positive effect on export values. When controlling for log(GDPpc), the export advantage of capital-intensive goods becomes statistically insignificant. Only after removing this control variable does the coefficient become marginally significant ($p \approx 0.087$). This implies that among countries at similar levels of development, capital-intensive products do not necessarily exhibit greater export advantages, deviating from the standard predictions of Heckscher–Ohlin theory.

Furthermore, our empirical results show that China's export structure is more reliant on demand-side factors such as the importing country's income per capita and technological level, rather than purely on factor intensity. This partly echoes the Leontief paradox and is consistent with the empirical findings of Bowen, Leamer, and Sveikauskas (1987), who showed that the unadjusted Heckscher–Ohlin–Vanek model only correctly predicted the direction of net factor trade in about 61% of cases-barely above random chance.

This finding aligns with Bowen, Leamer, and Sveikauskas (1987), who found in a multi-country, multi-factor empirical test that the match between the predicted and actual direction of net factor exports was only about 61%, nearly equivalent to random guessing. Trefler (1995) further noted that the volume of trade predicted by traditional factor endowment models was far larger than observed in reality, suggesting that certain forces were constraining potential trade. By adjusting for differences in effective factor productivity across countries, Trefler substantially improved the empirical performance of the model. In the context of this study, if we could control for variations in human capital and technological capabilities, the anomalous coefficient on the capital-intensive variable may become more aligned with theoretical expectations.

Other non-factor-based mechanisms may also influence trade patterns. The Linder hypothesis, for instance, argues that trade is driven by demand preferences: countries with similar income levels tend to trade more in similar manufactured goods, regardless of their relative factor

endowments. This helps explain why high-income, capital-abundant countries often export similar high-end goods to one another rather than exporting capital-intensive goods to

low-income countries and importing labor-intensive goods in return. Likewise, the "home market effect," proposed by Krugman (1980), emphasizes that in the presence of economies of scale and monopolistic competition, large countries will disproportionately produce and export goods that benefit from scale. Thus, trade patterns are shaped not only by supply-side factor endowments but also by market size and demand structures. The significant roles of market size and distance in our regression results further confirm these alternative explanations.

From a structural political economy perspective, the revision to "pure factor determinism" can be traced back to Ricardo's (1817) theory of comparative advantage. Although it relied on labor value, Ricardo's theory emphasized relative cost differences derived from productivity heterogeneity. Even if a country is absolutely disadvantaged in producing all goods, it can still benefit from trade by specializing in goods where its relative disadvantage is smaller. This framework still holds some explanatory power regarding China's large-scale imports of capital goods: in certain capital-intensive sectors, China's relative disadvantage may be lower, allowing for productivity gains through capital goods imports.

Nevertheless, the real-world observations reveal an asymmetric pattern: China shows a marked preference for importing capital-intensive products, yet its export structure does not reflect a corresponding comparative advantage in those same sectors. This paradox cannot be fully explained by traditional comparative advantage theory and must instead be interpreted through deeper mechanisms such as technological absorptive capacity, production system structure, and changes in profit rate dynamics.

As Marx (1867) pointed out, technological progress improves labor productivity but also raises the organic composition of capital, thereby potentially reducing the general rate of profit. In contrast, the Okishio theorem (1961) posits that if real wages remain constant, the adoption of cost-saving technologies should raise the profit rate. However, this result depends on two assumptions that are often violated in real economies. First, technological upgrades often increase the demand for skilled labor, which raises wage levels.

In China's manufacturing sector, average annual wage growth between 2010 and 2020 reached 8.2%, significantly eroding profit margins. Second, the import of capital goods involves a prolonged "absorption and digestion" phase, during which depreciation costs and technological

mismatches may reduce short-term price competitiveness (Rieu, 2022). Thus, although China demonstrates high elasticity in capital goods imports (coefficient = 3.170***), it fails to generate a corresponding export advantage in capital-intensive sectors.

The root of this paradox lies in a dual constraint: the limited profitability of capital accumulation and China's hierarchical position within global value chains. On one hand, capital goods imports have increased China's organic composition of capital (from $c/v = 2.8$ in 2000 to 4.1 in 2020), which, at first glance, aligns with the Okishio theorem's prediction. However, due to limited absorptive capacity-such as the fact that localization rates for core semiconductor manufacturing equipment remain below 20%-the effectiveness of this capital deepening is constrained. According to Li (2021), a 1% increase in capital goods imports leads to only a 0.2% increase in the technological complexity of Chinese exports. This low conversion rate is largely attributable to the "technology blockade chain" imposed by multinational corporations, such as the Wassenaar Arrangement's export controls on semiconductors, aerospace equipment, and precision CNC tools.

At the same time, "nationality bias" in global value chains has further weakened the actual benefits of technology spillovers. International buyers often associate Chinese ownership with low value-added products (Smith, 2016). Even when product quality is similar, Chinese firms are forced to sell at lower prices in global markets due to brand, patent, and trust asymmetries. For instance, the average unit price of Chinese CNC machine exports is only one-third that of comparable German exports (WTO, 2022). Foreign brands typically retain control over key components and software interfaces, capturing most of the technological rents.

Additionally, domestic wage growth is undermining the wage rigidity assumption that underpins Okishio's result. Between 2010 and 2020, the average annual wage growth for engineers reached 10.3%, and for general factory workers, 5.7% (NBS, 2023). These wage increases place further pressure on profit margins. Together, the dual pressures of value chain constraints and rising labor costs explain why China-despite importing large quantities of capital-intensive goods (regression coefficient 3.170***)-has not developed a corresponding export advantage in those sectors across Models (1)–(3).

In essence, this reflects a structural paradox of "quantitative expansion versus value lag" in China's trade development. It is the result of both inefficient conversion of capital accumulation into productivity and systemic technological discrimination against Chinese firms, making this not merely an anomaly, but a deep-rooted contradiction in the structure of China's integration into the global economy.

Nonetheless, several methodological limitations constrain the generalizability and interpretive precision of the findings presented above. The analysis is based on a single-year cross-section, which precludes inference about temporal dynamics or structural evolution across phases of the Belt and Road Initiative. Furthermore, the classification of traded products by capital intensity-drawn from Lall's (2000) technological taxonomy and OECD concordance mappings-abstracts from firm-level heterogeneity, process-level fragmentation, and endogenous technological upgrading within sectors. While macroeconomic controls provide necessary context, they remain insufficient to account for institutional frictions, pricing distortions, or intra-industry variation in value capture. As such, the modest and only marginally significant coefficient estimates on capital intensity should be interpreted not as definitive evidence of a reversed factor endowment pattern, but as indicative of deeper frictions in China's integration into high-value trade segments. Future research leveraging firm-level panel data and causal identification strategies would offer a more granular understanding of these dynamics.

CONCLUSIONS

This study revisits the Leontief Paradox through the lens of China's modern trade structure, uncovering an asymmetry between its capital endowments and export performance. While empirical results confirm China's strong propensity to import capital-intensive goods-consistent with Heckscher–Ohlin predictions-the export side reveals no statistically significant advantage for capital-intensive products. This discrepancy suggests that factor abundance alone cannot explain trade outcomes. Instead, structural constraints such as technological lock-in, brand asymmetry, and domestic capital misallocation dilute China's capacity to translate capital accumulation into export competitiveness. The findings challenge the deterministic logic of classical trade theory and highlight the necessity of institutional, technological, and qualitative dimensions in shaping comparative advantage. Future research should incorporate firm-level data to better capture the dynamics of technology absorption and the microfoundations of export upgrading.

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