MEASURING EFFICIENCY: DATA ENVELOPMENT ANALYSIS IN INTERNATIONAL RELATIONS

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Abstract: *Evaluating the performance of states, international organizations, and global policies remains a persistent challenge in the field of International Relations (IR). Traditional assessment methods often struggle to account for the complexity of inputs and outputs involved in international cooperation, diplomacy, and development. This paper explores the application of Data Envelopment Analysis (DEA)—a non-parametric efficiency measurement technique originally developed in operations research—as a tool for assessing the relative efficiency of international actors. By examining how DEA can be used to compare resource use and policy outcomes across multiple contexts, the study aims to demonstrate its value in identifying best practices and performance gaps. Through theoretical analysis and empirical case studies, this paper argues that DEA offers a systematic and replicable framework for evaluating efficiency in IR, providing insights often overlooked by conventional methods.*

Keywords: *Data Envelopment Analysis, DEA, International Relations, Efficiency, Performance evaluation, international actors, Relative efficiency, Decision-making units (DMUs)*

Introduction

In an increasingly complex and interconnected international system, evaluating the performance of states, international organizations, and transnational policies has become a central concern for scholars and practitioners alike. Whether assessing the effectiveness of foreign aid, the success of climate diplomacy, or the operational output of multilateral institutions, the challenge lies in identifying objective, comparable, and replicable methods to measure **efficiency**. Traditional evaluations often rely on qualitative or aggregated metrics that fail to capture the nuanced interplay between inputs (such as resources, diplomatic capital, or economic aid) and outputs (such as developmental outcomes, agreements reached, or conflict mitigation). As global challenges intensify, so too does the need for robust tools that can provide insight into the relative performance of international actors across a wide range of domains.

Data Envelopment Analysis (DEA), originally developed in operations research by Charnes, Cooper, and Rhodes (1978), is a non-parametric method for assessing the relative efficiency of decision-making units (DMUs) using multiple inputs and outputs. Unlike parametric approaches, DEA does not require a predefined functional form, making it especially suitable for evaluating performance in diverse, multi-dimensional contexts. While DEA has been extensively applied in sectors such as healthcare, education, and public administration, its potential in International Relations (IR) remains underexplored. This paper proposes that DEA can be a valuable methodological addition to the IR scholar’s toolkit, offering a means of quantitatively assessing how international actors use resources to achieve policy goals.

The primary aim of this study is to explore how Data Envelopment Analysis can be applied to the field of International Relations in order to assess the efficiency of states and institutions in pursuing foreign policy objectives, development goals, and multilateral cooperation efforts. Through both theoretical discussion and empirical examples, this paper examines the benefits and limitations of DEA as a framework for efficiency analysis in IR.

This investigation is guided by the following research questions:

1. In what ways can DEA provide meaningful insights into the performance of international actors?
2. How does DEA compare to traditional evaluation methods used in IR?
3. What are the methodological challenges and theoretical implications of applying DEA to IR contexts?

This paper argues that DEA provides a powerful framework for evaluating efficiency in international relations. By facilitating the comparative analysis of inputs and outputs across diverse actors and policies, DEA reveals insights often overlooked by conventional evaluation methods. In doing so, it enables a more nuanced understanding of how international actors translate resources into strategic and developmental outcomes.

Literature Review

Data Envelopment Analysis (DEA) was first introduced by **Charnes, Cooper, and Rhodes (1978)** as a method for evaluating the relative efficiency of decision-making units (DMUs) based on multiple inputs and outputs. The original CCR model assumed constant returns to scale and laid the groundwork for non-parametric frontier analysis. This model was later extended by **Banker, Charnes, and Cooper (1984)**, who developed the BCC model to account for variable returns to scale, allowing for greater flexibility in real-world applications where scale efficiency may vary. DEA has since evolved into a widely used analytical tool, especially in contexts where benchmarking performance across heterogeneous units is essential.

Beyond its origins in operations research and production analysis, DEA has been extensively applied in public policy domains, including healthcare, education, transportation, and environmental policy. These applications demonstrate DEA's capacity to handle multidimensional data and provide efficiency scores for organizations or systems whose inputs and outputs cannot be easily reduced to a single metric. In international contexts, DEA has been utilized to compare national education systems, public health outcomes, and the administrative efficiency of public institutions. Studies have shown that DEA can effectively benchmark performance, identify best practices, and inform resource allocation decisions (e.g., Thanassoulis et al., 2001; Emrouznejad & Yang, 2018).

Although DEA has gained traction in public administration and global development research, its application in core International Relations (IR) scholarship remains relatively limited. However, several studies demonstrate its potential. In the area of foreign aid evaluation, DEA has been employed to assess the efficiency of donor countries by comparing aid disbursements (inputs) against developmental outcomes (outputs) (e.g., Wane, 2004). Similarly, DEA has been used to evaluate the efficiency of military spending, particularly in NATO member states, by comparing defense budgets with strategic or security outcomes (e.g., Afonso & Aubyn, 2006). Climate policy is another emerging area in which DEA models have assessed countries' environmental performance by comparing carbon emissions and energy use against environmental investments.

Despite these promising applications, the integration of DEA into mainstream IR scholarship remains underdeveloped. Most studies employing DEA in international contexts do so from an economic or public administration perspective, with little engagement with IR theory or strategic considerations. There is a notable lack of theoretical integration, where efficiency analysis is not linked to foundational IR paradigms such as realism, liberal institutionalism, or constructivism. Furthermore, DEA is rarely applied to evaluate diplomatic networks, multilateral engagement, or strategic performance—domains central to contemporary IR. This methodological gap presents an opportunity to broaden the analytical tools available to IR scholars and policymakers by incorporating efficiency analysis into the evaluation of international behavior and institutional performance.

Theoretical Framework

Data Envelopment Analysis (DEA) is a non-parametric linear programming method used to assess the relative efficiency of *decision-making units* (DMUs) that convert multiple inputs into multiple outputs. In the context of international relations (IR), DMUs may include states, international organizations or transnational programs. DEA estimates the **efficiency frontier**—the set of best-performing units—against which all other units are compared.

Consider n decision-making units (DMUs), each using m inputs to produce s outputs. Let:

- x_{ij} = amount of input i used by DMU j

- y_{rj} = amount of output r produced by DMU j
- x_{i0}, y_{r0} = inputs and outputs of the DMU under evaluation (DMU_0)

The most basic form of DEA, the **CCR model** (Charnes, Cooper and Rhodes, 1978), assumes constant returns to scale. The efficiency of a DMU is calculated as the ratio of a weighted sum of outputs to a weighted sum of inputs:

$$\text{Efficiency}_o = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}}$$

Subject to:

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, \quad \text{for all } j = 1, \ldots, n \; u_r, v_i \geq 0$$

Where:

- u_r and v_i are the weights for outputs and inputs, respectively

To address situations where efficiency may vary with scale, the BCC model (Banker,

Charnes and Cooper (1984) incorporate variable returns to scale by adding a convexity constraint, allowing more realistic comparisons in settings where size matters (e.g., comparing large and small states or institutions).

BCC Model (Variable Returns to Scale)

Input-Oriented BCC Model : The objective is to **minimize inputs** while maintaining at least the observed output levels.

$$\begin{aligned}
\min_{\theta,\lambda} \quad & \theta \\
\text{s.t.} \quad & \sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta x_{i0}, \quad i = 1, \ldots, m, \\
& \sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{r0}, \quad r = 1, \ldots, s, \\
& \sum_{j=1}^{n} \lambda_j = 1, \quad \lambda_j \geq 0, \quad j = 1, \ldots, n.
\end{aligned}$$

Here:

- $\theta \in (0, 1]$ is the **pure technical efficiency score**.
- The constraint $\sum_{j=1}^{n} \lambda_j = 1$ imposes **variable returns to scale**.

Input-Oriented BCC Model: The objective is to **minimize inputs** while maintaining at least the observed output levels.

Output-Oriented BCC Model: The objective is to **maximize outputs** given the current input levels.

$$
\begin{aligned}
\max_{\varphi,\lambda} \quad & \varphi \\
\text{s.t.} \quad & \sum_{j=1}^{n} \lambda_j x_{ij} \le x_{i0}, \quad i = 1, \ldots, m, \\
& \sum_{j=1}^{n} \lambda_j y_{rj} \ge \varphi y_{r0}, \quad r = 1, \ldots, s, \\
& \sum_{j=1}^{n} \lambda_j = 1, \quad \lambda_j \ge 0, \quad j = 1, \ldots, n.
\end{aligned}
$$

where:

- $\varphi \ge 1$ measures proportional **output expansion**.

Output-Oriented BCC Model: The objective is to **maximize outputs** given the current input levels.

where:

Dual (Multiplier) Form of the Input-Oriented BCC Model

Dual (Multiplier) Form of the Input-Oriented BCC Model

$$
\begin{aligned}
\max_{u,v,u_0} \quad & \sum_{r=1}^{s} u_r y_{r0} + u_0 \\
\text{s.t.} \quad & \sum_{i=1}^{m} v_i x_{i0} = 1, \\
& \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} + u_0 \le 0, \quad j = 1, \ldots, n, \\
& u_r \ge 0, ; v_i \ge 0.
\end{aligned}
$$

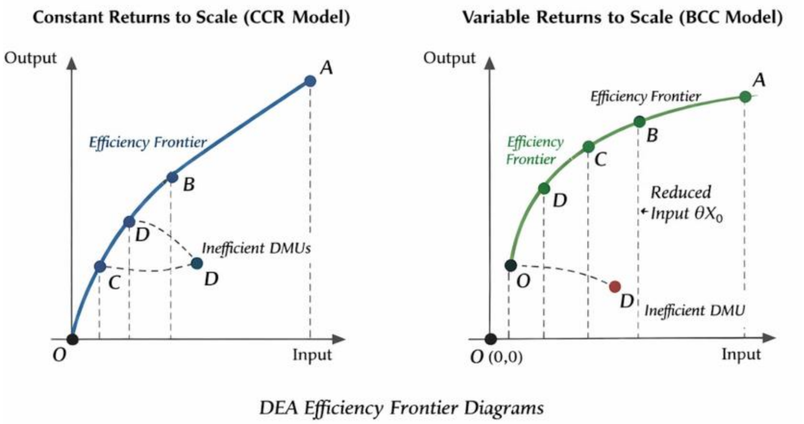


Рис. 1: DEA efficiency frontier diagrams (CCR vs. BCC

where:

- u_r and v_i are output and input weights,
- u_0 is a **free (unrestricted) variable** capturing scale effects.

Key Interpretation

- The **BCC efficiency score** measures **pure technical efficiency**, excluding scale inefficiency.
- Comparison with the CCR model allows decomposition into:

$$\text{Scale Efficiency} = \frac{\text{CCR Efficiency}}{\text{BCC Efficiency}}.$$

DEA thus provides a flexible, data-driven method for comparing efficiency across diverse units without requiring a pre-specified functional form—an important feature when applying it to the complexity of international systems.

In Figure 1, we compare the CCR and BCC DEA models. The left panel illustrates the CCR model (Constant Returns to Scale), where the efficiency frontier is a single ray from the origin, implying that outputs change proportionally with inputs; DMUs located on the frontier (e.g., A, B, C) are technically efficient, while interior points (e.g., D) are inefficient and could proportionally reduce inputs (or increase outputs) to reach the frontier. In contrast, the right panel presents the BCC model (Variable Returns to Scale), where the frontier is curved, allowing for increasing and decreasing returns to scale; efficiency is assessed conditional on scale, so an inefficient DMU (D) is projected to the frontier via an input contraction ωX_ω that reflects pure technical inefficiency rather than scale effects. The comparison highlights that CCR efficiency conflates technical and scale efficiency, whereas BCC isolates pure technical efficiency, making BCC more appropriate when countries (or DMUs) operate at heterogeneous scales—common in international trade analyses.

Linking DEA to International Relations Theory

While DEA originates in operations research, its application in IR invites theoretical engagement with key paradigms in the discipline:

- **Realism** emphasizes power and material capabilities as the primary drivers of international behavior. DEA can be used to assess the *efficiency of power projection*— for instance, how states convert military spending or diplomatic effort into strategic outcomes (e.g., deterrence, alliances, influence). From a realist lens, efficiency becomes a proxy for state capacity and survival in an anarchic system.
- **Liberalism** focuses on institutions, cooperation, and interdependence. DEA is well-suited to measuring the effectiveness of institutional mechanisms, such as the efficiency with which international organizations use financial and human capital to produce public goods (e.g., development, peacekeeping, health responses). It can also help evaluate how states contribute to and benefit from international regimes.
- **Constructivism** foregrounds the role of norms, identity, and discourse in shaping state behavior. While DEA is a quantitative method, it can be adapted to incorporate norm-based outputs, such as compliance with international agreements, soft-power initiatives, or normative leadership. In this context, DEA can help assess how states efficiently align their material capabilities with ideational goals.

By aligning DEA with these theoretical lenses, scholars can go beyond simple efficiency scores and interpret results within a broader conceptual framework, bridging the quantitative and qualitative dimensions of IR.

DEA offers practical value in international policy analysis by providing **benchmarking and optimization** tools. Policymakers and international organizations often operate under constraints—limited resources, competing priorities, and political pressures. DEA enables them to identify efficient performers, diagnose inefficiencies, and simulate scenarios for improving outcomes without necessarily increasing inputs.

For example, in **global governance**, DEA can help multilateral institutions assess which member states or programs are achieving the greatest impact per unit of investment. In **foreign aid**, it can inform the more strategic allocation of resources by identifying which donors deliver the most effective development outcomes. In **diplomacy**, it may help assess the productivity of diplomatic missions relative to their staffing, budgets, and international influence.

DEA introduces a rigorous, comparative, and multidimensional approach to performance evaluation in IR. Its integration with theoretical perspectives enhances both methodological robustness and conceptual depth, making it a valuable addition to the field's analytical toolkit.

Methodology

This study employs a comparative efficiency analysis using Data Envelopment Analysis (DEA) to evaluate the performance of selected international actors across policy domains. DEA is well-suited for this purpose, as it accommodates multiple input and output variables and allows for the identification of relatively efficient decision-making units (DMUs) without assuming a predefined production function. The research design is cross-sectional and comparative, focusing on how states or organizations utilize resources (inputs) to achieve international policy outcomes (outputs).

The objective is not to rank actors by absolute performance, but to identify which actors lie on the *efficiency frontier* and how others perform relative to this benchmark.

DEA Case Study in International Trade

In this DEA-based case study, each country is treated as a decision-making unit that transforms economic and structural resources—GDP, labor, and capital—into international trade outcomes, measured by exports and imports.

GDP reflects the overall economic capacity and production scale supporting trade activities. **Labor** encompasses the human resources engaged in production, logistics, and trade-related services, while capital comprises infrastructure, investment, and technological capabilities that facilitate participation in global markets.

On the output side, **exports** indicate a country's external competitiveness and ability to supply goods and services internationally, whereas **imports** reflect the depth of integration into the global economy and access to foreign inputs and technologies.

From an international relations perspective, a country is considered **trade-efficient** if it achieves relatively high export and import volumes given its economic size and factor endowments. Inefficiency suggests that existing economic resources are not fully translated into international trade performance, potentially due to trade policy barriers, weak institutions, limited connectivity, geopolitical constraints, or underdeveloped regional cooperation.

Thus, DEA results provide not only a measure of economic efficiency but also an indirect assessment of a country's effectiveness in leveraging international economic relations and trade diplomacy.

Data Description and DEA Input–Output Specification

This study employs **Data Envelopment Analysis (DEA)** as a non-parametric frontier technique to evaluate countries' relative trade efficiency. DEA is particularly appropriate for cross-country analysis in international economics, as it allows for the simultaneous consideration of multiple inputs and outputs without imposing a predefined functional form on the production technology. Each country is treated as a **Decision-Making Unit (DMU)** that transforms economic resources into trade outcomes.

The selection of inputs and outputs is guided by international trade theory, macroeconomic growth models, and prior empirical DEA applications in international relations and economics.

Input Variables: The input variables represent the productive capacity and resource endowments that underpin a country's ability to participate in international trade.

1. **Gross Domestic Product (GDP)** GDP is used as a proxy for overall economic size and production potential. In the context of trade efficiency, GDP reflects the scale of domestic economic activity, industrial capacity, and the ability to generate tradable goods and services. Larger economies typically possess broader production bases and more diversified export structures; however, DEA allows assessment of whether such scale advantages are translated efficiently into trade outcomes.

2. **Labor** represents the human input available for production and trade-related activities. It captures workforce size and, indirectly, the capacity for manufacturing, services,

logistics, and export-oriented industries. Including labor as an input aligns with classical and neoclassical trade theories, in which labor is a fundamental factor of production that influences comparative advantage.

3. **Capital** reflects the stock of physical and financial resources used in production, such as machinery, infrastructure, and investment assets. Capital accumulation enhances productivity, supports export competitiveness, and facilitates integration into global value chains. In the DEA, capital serves as a critical input capturing long-term investment capacity and structural economic strength.

Output Variables: The output variables measure **actual trade performance**, reflecting how effectively countries convert economic resources into international trade flows.

1. **Exports** represent a country's ability to supply goods and services to international markets. As a core indicator of outward trade performance, exports capture competitiveness, production efficiency, and global demand for domestic output. Higher export levels, given comparable inputs, indicate greater trade efficiency.

2. **Imports** reflect integration into the global economy and access to foreign goods, intermediate inputs, and technologies. From an efficiency perspective, imports signal a country's capacity to participate in international exchange and global value chains. Including imports as an output recognizes that efficient trade systems involve both export capability and effective sourcing from international markets.

Conceptual Interpretation in the DEA Context: Within the DEA framework, a country is considered efficient if it achieves relatively high levels of exports and imports relative to its GDP, labor, and capital endowments. Inefficiency, conversely, indicates unrealized trade potential—suggesting institutional, structural, logistical, or policy-related constraints that prevent the country from fully leveraging its economic resources in international trade. This input–output specification enables a **balanced assessment of trade efficiency**, accounting for both production capacity (inputs) and realized trade engagement (outputs), and provides a robust foundation for comparative analysis across countries and regions.

All input and output variables used in the DEA model are obtained from the World Bank's World Development Indicators (WDI) database, which provides standardized, internationally comparable trade statistics:

Sample Data for DEA Analysis (2024)

country	gdp	labor	capital	exports	imports
Bangladesh	4.501194e+11	77355168	1.381889e+11	4.708784e+10	7.344548e+10
China	1.874380e+13	773879678	7.473099e+12	3.753056e+12	3.219343e+12
India	3.909892e+12	607691498	1.168910e+12	8.274052e+11	9.183337e+11
Indonesia	1.396300e+12	143143940	4.069598e+11	3.097456e+11	2.846963e+11
Iran, Islamic Rep.	4.752521e+11	28574661	1.335799e+11	1.119289e+11	1.354975e+11
Japan	4.027598e+12	69382089	1.050562e+12	9.170437e+11	9.520416e+11
Kazakhstan	2.914803e+11	10285416	7.088095e+10	9.207035e+10	7.454369e+10
Korea, Rep.	1.875388e+12	29713473	5.631673e+11	8.318892e+11	7.554862e+11
Kyrgyz Republic	1.747826e+10	3196163	4.192528e+09	7.593079e+09	1.471802e+10
Malaysia	4.222270e+11	18264000	8.673690e+10	3.012213e+11	2.787605e

					+11
Pakistan	3.715700e +11	83643815	4.256903e +10	3.860781e +10	6.386551e +10
Philippines	4.616175 e+11	50979290	1.088056e +11	1.189747 e+11	1.851642e +11
Saudi Arabia	1.239805e +12	17168015	3.549347e +11	3.608973e 11	3.170117e +11
Singapore	5.473866e +11	3722265	1.198585e +11	9.785975e +11	7.860206e +11
Sri Lanka	9.896319e +10	8498980	1.859817e +10	1.968014e +10	2.227778e +10
Thailand	5.265177e +11	40623017	1.171136 e+11	3.688242e +11	3.511735e +11
Turkiye	1.359124e +12	36080817	4.256195e +11	3.746863e +11	3.673791e +11
Turkmenistan	5.138721e +10	2444797	9.063429e +09	9.030078e +09	5.735835e +09
Uzbekistan	1.149653e +11	13974298	4.260144e +10	2.617276e +10	4.364272e +10
Viet Nam	4.763882e +11	57133476	1.382558e +11	4.294841e +11	3.987741e +11

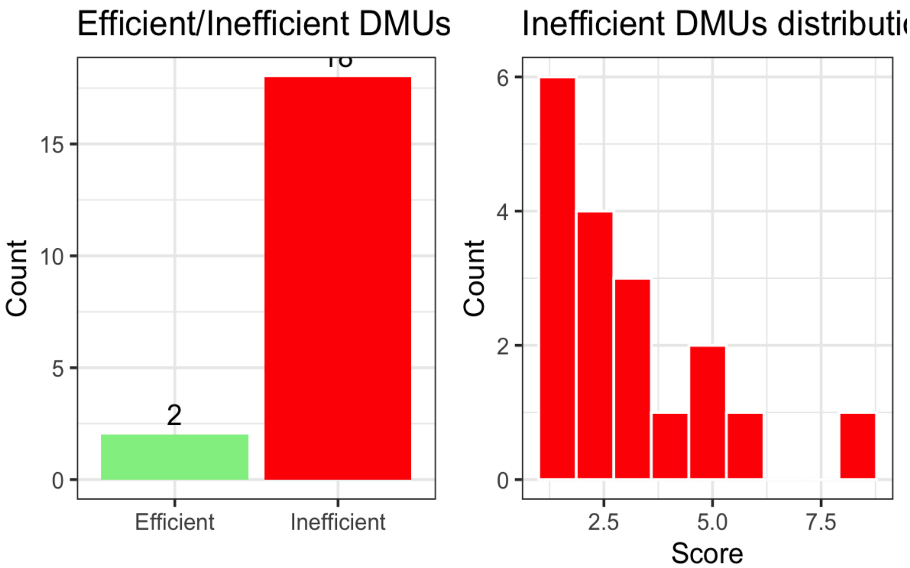
Analysis and Results

Figure 2 summarizes the classification of decision-making units (DMUs) into efficient and inefficient categories using the output-oriented DEA trade-efficiency model. Of the total sample, only two countries are identified as efficient, lying on the DEA frontier, while

18 **are classified as inefficient**. This pronounced imbalance indicates that the majority of Asian economies in the sample operate below the best-practice trade frontier, given their existing levels of economic inputs. The small number of efficient DMUs reflects the stringent nature of DEA benchmarking, where only countries that exhibit best-practice combinations of inputs and outputs are assigned full efficiency. These frontier countries serve as reference points for all inefficient DMUs and play a crucial role in defining the production possibility frontier. From an international relations perspective, this result suggests that trade efficiency is relatively rare, even among economically significant countries. Most states appear unable to fully convert their economic capacity into proportional trade outcomes, highlighting the importance of structural, institutional, and policy factors beyond mere resource endowments.

Figure 2. presents the distribution of inefficiency scores among the inefficient DMUs. The histogram reveals a right-skewed distribution, with a concentration of countries exhibiting moderate inefficiency and fewer countries exhibiting high inefficiency. Most inefficient DMUs cluster in the lower range of scores, indicating that while they do not operate on the efficiency frontier, their deviation from best practice is relatively limited. These countries may require incremental improvements in trade facilitation, export diversification, or institutional quality to approach the frontier. In contrast, a small subset of countries exhibits substantially higher inefficiency scores, suggesting more profound structural mismatches between inputs and trade outcomes. For these countries, inefficiency is likely driven by deeper constraints, such as limited integration into global value chains, weak logistics infrastructure, or restrictive trade policies. Addressing such inefficiencies would require comprehensive structural reforms rather than marginal adjustments.

Taken together, the two figures highlight that inefficiency is the dominant empirical outcome in the sample, but its severity varies considerably across countries. While only a few countries define



Distribution of Efficient and Inefficient DMUs

the efficiency frontier, most inefficient DMUs are not extremely distant from it, implying significant scope for improvement without expanding resource inputs.

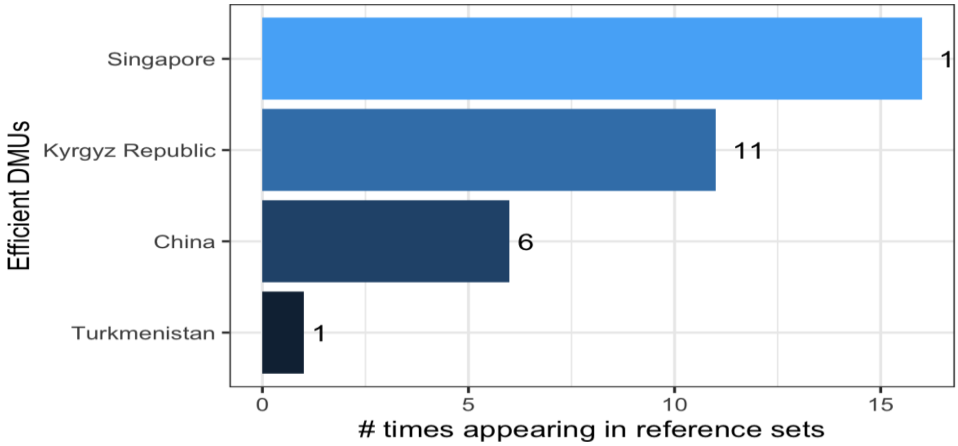
In policy terms, the results indicate that improving trade efficiency in Asia is less a question of increasing economic size and more a matter of enhancing the effectiveness with which existing resources are utilized. From an international relations standpoint, these findings underscore the role of trade governance, regional integration, and institutional coordination in shaping countries' relative performance in international trade.

The figure 3. shows how often each country appears in the **DEA** reference (peer) sets, meaning how frequently it serves as a benchmark for inefficient countries. **Singapore** appears most frequently, indicating that it represents a best-practice trade structure and is the dominant efficiency benchmark in the sample. The **Kyrgyz Republic** also appears often, suggesting that despite its smaller economic size, its trade performance is relatively efficient given its GDP, labor and capital endowments. **China's** moderate number of appearances reflects selective benchmarking—efficient in certain dimensions but not universally dominant across all comparisons. **Turkmenistan's** rare appearance implies limited benchmarking relevance, indicating that its trade outcomes are less efficient relative to its input endowments. Overall, higher frequencies signal stronger role-model status in international trade efficiency, rather than sheer economic size.

Figure 4. illustrates the **DEA peer (reference) network** derived from the output-oriented VRS trade efficiency model for Asian countries. In this network representation, **nodes correspond to countries**, while directed edges indicate benchmarking relationships generated by the DEA solution. Specifically, an arrow from country *i* to country *j* indicates that country *j* serves as a **reference (peer)** for country *i* in constructing the efficiency frontier.

Countries highlighted as **frontier or reference units** occupy central positions in the network and receive multiple incoming links from inefficient countries. These benchmark economies represent best- practice trade performers within the sample and define the production possibility frontier against which other countries are evaluated. In the present network, countries such as **Singapore, China and the Kyrgyz Republic** emerge as prominent reference nodes, indicating that their combinations of inputs

DEA reference sets



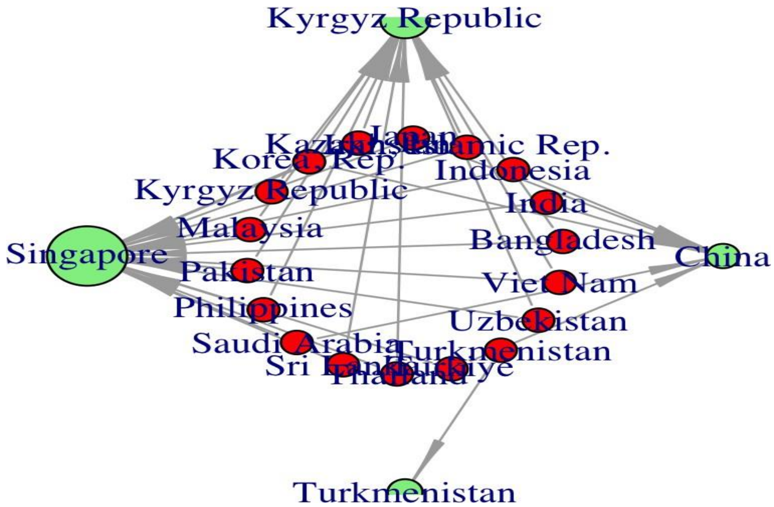


Рис. 4: Peer Reference Network and trade outputs are frequently used to benchmark less efficient peers.

The majority of countries appear as **peripheral nodes**, characterized by outgoing links directed toward one or more benchmark countries. This structure reflects the fact that inefficient countries are evaluated as convex combinations of efficient peers rather than being compared to a single benchmark. The density of outgoing links suggests that inefficiency is not driven by a single dominant performer but instead by multiple best-practice trade patterns within the region.

From an economic interpretation perspective, the peer relationships reveal **heterogeneous pathways to trade efficiency**. For example, some countries benchmark primarily against large, globally integrated economies, while others reference smaller but highly open economies. This implies that trade efficiency in Asia is not solely determined by economic size, but also by structural factors such as openness, export composition and integration into regional and global value chains.

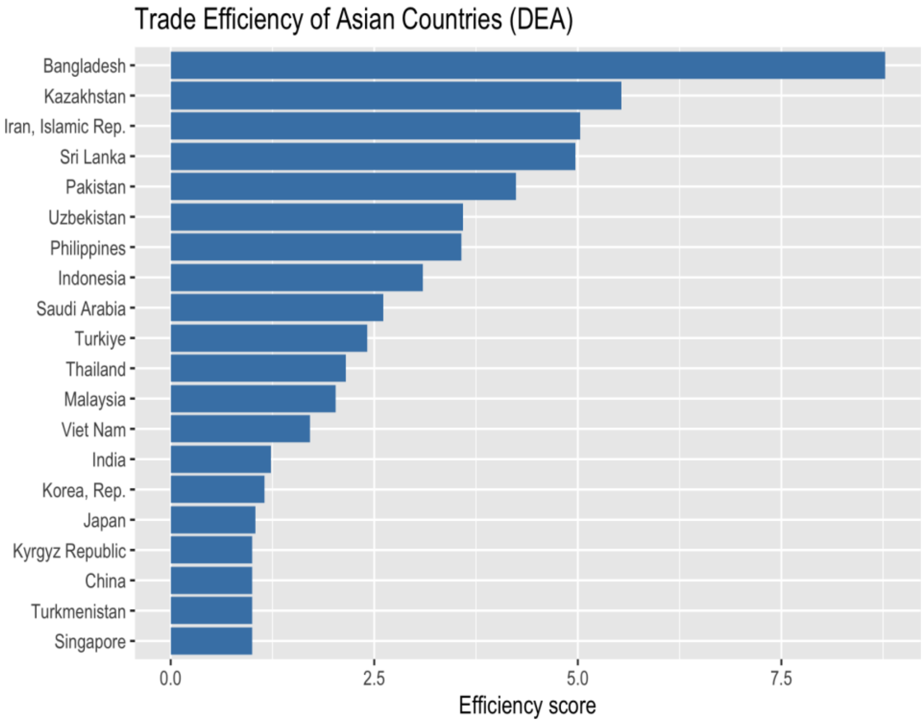
The network structure further highlights **regional clustering effects**. Several Central and South Asian economies share common reference countries, indicating similar trade inefficiency profiles and comparable adjustment paths toward the frontier. This finding suggests that policy learning and regional cooperation may play a role in improving trade efficiency through the diffusion of best practices.

Overall, the DEA peer network complements the efficiency score and slack analyses by providing qualitative insight into benchmarking relationships. While efficiency scores quantify the degree of inefficiency, the network identifies which countries serve as role models and how inefficient countries are positioned relative to the frontier. Together, these results enable a richer interpretation of trade performance and offer a basis for targeted, country-specific policy recommendations.

Figure 5. presents the results of the output-oriented DEA analysis of trade efficiency for selected Asian countries. The horizontal bars report relative efficiency scores derived from the DEA model, with higher values indicating greater trade performance relative to peer countries given comparable levels of economic inputs.

The results reveal substantial heterogeneity in trade efficiency across Asian economies. Countries such as Bangladesh and Kazakhstan appear at the upper end of the distribution, indicating that they achieve comparatively high trade outcomes relative to their input endowments. These countries can be interpreted as **best-performing reference units** within the sample, serving as benchmarks for other economies.

A middle group of countries—including **Iran, Sri Lanka, Pakistan, Uzbekistan and the Philippines**—exhibits moderate efficiency levels. These economies demonstrate reasonable trade performance but remain below the frontier defined by the most efficient peers. For these countries, DEA



Trade Efficiency of Asian countries

suggests the presence of **unrealized trade potential**, meaning that exports and imports could be expanded without a proportional increase in inputs such as GDP, labor force, or capital formation.

At the lower end of the efficiency distribution are countries such as **China, Singapore, Turkmenistan, and the Kyrgyz Republic**. Importantly, lower efficiency scores do **not** imply weak trade performance in absolute terms. Rather, they indicate that, relative to their substantial economic resources, trade outcomes are proportionally smaller than those observed in more efficient countries. In the DEA framework, these countries may face structural, policy or institutional constraints that limit the conversion of economic capacity into trade flows.

Trade Efficiency of Uzbekistan

The DEA-based analysis indicates that Uzbekistan operates below the trade efficiency frontier, suggesting the presence of unrealized trade potential relative to its existing economic resources. Although Uzbekistan does not emerge as an efficient decision-making unit (DMU), its efficiency score places it within the middle range of inefficient countries, implying that its deviation from best-practice performance is moderate rather than extreme.

Slack analysis reveals that Uzbekistan's inefficiency is **primarily output-driven**, rather than the result of excessive input usage. In particular, the presence of export and import slacks indicates that current levels of GDP, labor force, and capital formation could support substantially higher trade volumes if utilized more effectively. This finding suggests that Uzbekistan's trade inefficiency is not rooted in insufficient resources, but rather in structural and institutional constraints affecting trade performance.

The DEA peer reference network further clarifies Uzbekistan's position relative to benchmark economies. Uzbekistan is repeatedly benchmarked against Singapore, the Kyrgyz Republic and China, indicating that its optimal adjustment path toward the efficiency frontier is defined by a combination of high trade openness (Singapore), efficient utilization of limited resources

(Kyrgyz Republic) and **scale-based integration into global markets (China)**. This combination highlights that Uzbekistan's trade efficiency gap is not attributable to a single missing factor, but to the need for coordinated improvements across trade facilitation, market access and export diversification.

Importantly, Uzbekistan does not serve as a reference country for other DMUs, which implies that its current trade structure does not yet represent a best-practice model within the regional context. However, given its moderate inefficiency and proximity to the frontier, Uzbekistan appears to be a strong candidate for efficiency gains through targeted reforms, rather than through large-scale expansion of economic inputs.

From an international relations perspective, the results suggest that Uzbekistan's trade performance could be significantly enhanced by strengthening regional trade integration, improving logistics and customs efficiency, and deepening participation in global and regional value chains. Such measures would allow Uzbekistan to convert existing economic capacity into greater international trade outcomes, thereby improving its relative position in the regional trade efficiency landscape.

Overall, the DEA findings indicate that Uzbekistan's trade inefficiency is reversible and policy- sensitive. By aligning trade governance and international economic strategy with the practices of its most relevant benchmark countries, Uzbekistan has the potential to move closer to the efficiency frontier without requiring proportional increases in resource endowments.

Comparative DEA Model Specifications for International Relations

This study employs a set of complementary Data Envelopment Analysis (DEA) model specifications to evaluate multiple dimensions of state performance in international relations. Rather than relying on a single efficiency metric, the analysis adopts a comparative modeling strategy that reflects the multidimensional nature of international power, encompassing economic diplomacy, soft power, diplomatic engagement, security provision, development-driven influence and composite state power. Each model treats countries as decision-making units (DMUs) and assesses how efficiently national resources are transformed into internationally relevant outcomes.

Таблица 2: Comparative DEA Model Specifications for International Relations Analysis with Data Sources

Model	Inputs	Outputs	IR_Focus	Interpretation	Sources
Model A: Trade Efficiency	GDP; Labor force; Capital formation	Exports; Imports	Economic diplomacy and trade performance	Efficiency of converting economic capacity into trade outcomes	WDI; OECD
Model B: Soft Power & Engagement	GDP; Education expenditure; Population	International students; Tourism arrivals; Cultural exchanges	Soft power and public diplomacy	Efficiency of generating international attractiveness	WDI; UNESCO; UNWTO
Model C: Diplomatic Network	GDP; Government expenditure	Embassies abroad; Treaties signed; IO memberships	Bilateral and multilateral diplomacy	Efficiency of diplomatic presence and engagement	WDI; UN Treaty Collection; MFA
Model D: Security & Defense	Military expenditure; Armed forces personnel	Defense readiness; Peacekeeping missions	Security studies and defense economics	Efficiency of translating military resources into security outcomes	SIPRI; UN Peacekeeping
Model E: Development & Influence	GDP; Human capital index	FDI inflows; ODA provision; GVC participation	Development diplomacy and emerging powers	Efficiency of converting development into global influence	WDI; OECD; UNCTAD
Model F: Composite State Power	GDP; Population; Military expenditure	Trade volume; Diplomatic network size; Soft power indicators	Overall international power and influence	Balanced efficiency of economic, demographic, and military power	WDI; SIPRI; OECD; UN

Comparative DEA Model Specifications for International Relations Analysis with Data Sources

Model A focuses on **trade efficiency** and captures the economic diplomacy dimension of international relations. By specifying gross domestic product, labor force and capital formation as inputs, and exports and imports as outputs, this model evaluates the capacity of states to translate economic potential into trade performance. Efficiency shortfalls in this framework indicate unrealized trade potential arising from market access barriers, structural competitiveness constraints or suboptimal trade policy design.

Model B examines **soft power and international engagement efficiency**, emphasizing non- coercive forms of influence. Inputs such as economic size, education expenditure and population are related to outputs reflecting international attractiveness, including international student mobility, tourism inflows and cultural exchanges. This specification is particularly relevant to analyzing public diplomacy strategies and states' ability to convert domestic social and educational investments into international visibility and appeal.

Model C addresses **diplomatic network efficiency**, evaluating how effectively states deploy economic and governmental resources to build and sustain international diplomatic presence. Outputs such as embassies abroad, international treaties, and memberships in international organizations reflect both bilateral and multilateral engagement. Inefficiency in this model suggests underdeveloped diplomatic networks relative to available national resources.

Model D is designed to assess **security and defense efficiency**, a core concern in international relations and security studies. Military expenditure and armed forces personnel are treated as inputs, while outputs capture security outcomes such as defense readiness and participation in peacekeeping missions. This model enables a comparative assessment of how effectively military resources contribute to the provision of security and international stability.

Model E evaluates **development and the efficiency of global influence**, focusing on how domestic development translates into external economic and political impact. Inputs include economic size and human capital, while outputs encompass foreign direct investment inflows, official development assistance provision, and participation in global value chains. This framework is particularly suitable for studying emerging powers and development diplomacy.

Model F provides a composite perspective on state power efficiency by integrating economic, demographic, and military resources on the input side with a broad set of outputs that reflect trade performance, diplomatic reach, and soft power. This advanced specification captures the balanced use of national power across multiple domains and offers an overarching assessment of a state's efficiency in international influence.

Across all specifications, the models rely on internationally comparable data from authoritative sources, including the World Bank's World Development Indicators, SIPRI, OECD, UN agencies, and related international databases. The use of output-oriented DEA with variable returns to scale ensures that cross-country heterogeneity in size and capacity is appropriately accounted for. Taken together, the comparative DEA framework provides a systematic and multidimensional assessment of efficiency in international relations, enabling both cross-model robustness checks and policy-relevant interpretations.

Conclusion

This policy brief applies Data Envelopment Analysis (DEA) to evaluate international trade efficiency across Asian countries, with particular emphasis on Uzbekistan's regional performance. DEA assesses how effectively countries transform key economic inputs—GDP, labor, and capital—into trade outcomes measured by exports and imports, offering a multidimensional alternative to traditional trade indicators.

The results show that trade efficiency in Asia is not driven by economic size alone. Several smaller economies emerge as efficiency benchmarks, demonstrating that institutional quality, trade facilitation, logistics, and regional integration play a decisive role. For Uzbekistan, the findings suggest that despite growing economic capacity, trade outcomes remain below potential, indicating scope for efficiency gains through improved export diversification, customs procedures, and deeper participation in regional value chains.

From a policy perspective, DEA identifies peer benchmark countries that provide practical models for reform. Targeted alignment with best-performing Asian economies—particularly in trade infrastructure, regulatory efficiency, and trade diplomacy—

can enhance Uzbekistan’s international trade efficiency without requiring proportional increases in resource inputs.

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