Visiting Fellow Program

Analysis of CAREC Transport Corridors: Efficiency and Impact of the Participation of CAREC and Eurasian Countries Along the Routes in Regional Value Chains

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Scholars were encouraged to conduct research on CAREC integration topics and carry out comparative analyses between (sub)regions to obtain insights for promoting and deepening regional integration among CAREC member countries particularly, as anticipated in the CAREC 2030 strategy and stated operational priorities.

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Abstract

This study analyzes the comparative efficiency of the Central Asia Regional Economic Cooperation (CAREC) transport corridors and their impact on the participation of the CAREC and Eurasian countries along routes in regional value chains (RVCs); it explores the barriers and challenges to participation in RVCs in the CAREC region; and draws policy recommendations to enhance the efficiency of CAREC corridors and bolster the participation of countries along routes in RVCs. Data envelopment analysis (DEA) has been applied to analyze the comparative efficiency of the CAREC corridors during 2010 to 2020. A difference-in-differences method has been integrated into propensity score matching to avoid selection bias to analyze the participation of CAREC corridor economies along routes in RVCs. The study reveals that only Corridor 4 demonstrated efficiency over 2010 to 2020, while Corridors 1 and 5 exhibited consistent performance during 2010 to 2015. However, Corridors 3 and 6 were less efficient than the most efficient Corridor 4. Despite this, Corridors 3 and 6 displayed an increasing return to scale over 2010 to 2020, indicating that a proportionate rise in all inputs led to a greater proportionate increase in output. All the corridors can reorient their transit infrastructure through vigorous reforms and can learn significantly from the existing transit facilitation being carried out in Corridor 4. Empirical results underline the constructive impact of CAREC corridors on the participation in RVCs of countries along designated routes and underscore the multifaceted interplay of factors shaping the participation of CAREC corridor countries in RVCs. The CAREC transport corridor organizations must downsize operational costs to enhance the value of facilities provided by the corridors and realize the necessary valuable progress of functioning corridor efficiency by lowering transport costs and travel time. With lower trade transit costs, the CAREC transport corridors can be transformed into economic corridors to tap the novel trade opportunities that have emerged in the Eurasian countries. This requires CAREC economies to renovate manufacturing methods and acquire suitable export and investment opportunities.

Keywords: transport corridors efficiency, regional value chains, CAREC, Eurasian countries, policy implications

Table of Contents

Abstract iii
Abbreviations 3
1. Introduction 4
  1.1. Study rationale 4
  1.2. Problem statement 5
2. Methodology 5
  2.1. Efficiency measurement of CAREC transport corridors 5
    2.1.1. Variables 5
    2.1.2. Data sources 6
    2.1.3. Methodology to estimate efficiency 7
  2.2. RVC participation measurement 9
    2.2.1. Dependent variable and measurement 9
    2.2.2. Explanatory variables 9
    2.2.3. Control variables 10
    2.2.4. Data sources 10
    2.2.5. Methodological approach 10
3. Results and discussion 13
  3.1. Efficiency measurement of the CAREC transport corridors 13
  3.2. Analysis of CAREC Corridor Performance Measurement and Monitoring database 15
  3.3. Measurement of CAREC corridor participation in RVCs 17
    3.3.1. Descriptive statistics 17
    3.3.2. Common support assessment and ROC analysis 18
    3.3.3. Balancing test and matching validity assessment 19
    3.3.4. Empirical findings on participation in RVCs 20
    3.3.5. Impact of various factors on RVC participation 22
    3.3.6. Robustness analysis 23
4. Conclusion 23
5. Policy recommendations 24
  5.1. Improving the efficiency of CAREC transport corridors 24
  5.2. Bolstering the participation in RVCs 25
6. Limitations and future research direction 26
References 27

Figures

Figure 1: The kernel density graph of the PSM in the treatment group and control group 19

Tables

Table 1: Indicators and their definitions 6
Table 2: CAREC corridors and the regions/countries 7
Table 3: Main variables and indicators 10
Table 4: Estimates of efficiency scores across the CAREC transport corridors 13
Table 5: Estimates of return to scale across the CAREC transport corridors 14
Table 6: Descriptive statistics of variables 18
Table 7: Balancing test for propensity score matching 20
Table 8: Test for how well the model fits 20
Table 9: Effect of corridors on the RVC participation of countries along the routes 21

Abbreviations

ADB	Asian Development Bank
ASEAN	Association of the Southeast Asian Nations
BEC	broad economic category
CAREC	Central Asia Regional Economic Cooperation
COVID	COronaVIrus Disease
CRS	constant return to scale
DEA	data envelopment analysis
DID	difference-in-differences
DMU	decision making unit
DRS	decreasing return to scale
FDI	foreign direct investment
GDP	gross domestic product
GFCF	gross fixed capital formation
GPN	global production network
GVC	global value chain
IFS	international financial statistics
IMAR	Inner Mongolia Autonomous Region
IMF	International Monetary Fund
IRS	increasing return to scale
LR	likelihood ratio
NTB	non-tariff barrier
PRC	People's Republic of China
OECD	Organisation for Economic Cooperation and Development
PSM	propensity score matching
ROC	receiver operating characteristic
RPN	regional production network
RVC	regional value chain
SE	scale efficiency
TEU	20 ft equivalent unit
UN	United Nations
COMTRADE	commodity trade
US	United States
VRS	variable return to scale
XUAR	Xinjiang Uygur Autonomous Region

1. Introduction

Transport corridor efficiency is essential to guarantee the sustainable transition to market-oriented Central Asia Regional Cooperation (CAREC) economies via better regional connectivity. The analysis of transport corridors helps determine the potential efficiency and enhance system productivity to increase economic growth. Efficiency estimation improves the skills to determine the factors triggering transport corridor inefficiency and ways to enhance efficiency over the period. Efficient transport and trade connectivity can boost economic growth in the CAREC region through greater integration to regional and international production networks, which in turn generate novel economic opportunities, foster greater economic diversification, reduce transport costs and transit time, and integrate domestic and regional manufacturing centers and boost regional trade (Kalyuzhnova and Holzhacker, 2021).

Efficient CAREC transport corridors can foster greater trade flows and significantly improve economic affluence along the routes. The improved efficiency of CAREC transport corridors can bolster regional value chain (RVC) integration to regional and international markets. The increased efficiency of CAREC transport corridors can make RVCs highly resilient to external shocks owing to expanded trade linkages along the routes. However, there are immense disparities in the efficiency of the CAREC transport corridors across the regional economies. To improve the efficiency of the CAREC transport corridors, regional economies need to construct efficient road and rail connectivity as well as build quality flight connectivity. In addition, intraregional connectivity routes need to link the CAREC countries to seaports. The linkage of CAREC transport corridors via the People's Republic of China (PRC) and Pakistan can give strong connectivity to seaports.

Despite the significant economic growth and trade performance displayed by landlocked countries, the integration of firms into RVCs remained feeble, which calls for efficient and inclusive transport corridorsto address transport and trade barriers. The efficiency of transport corridors and constraints at border clearance points should therefore be addressed urgently to bolster the RVC integration of countries along routes and develop compatible trade facilitation and soft infrastructure. The improved efficiency of transport corridors can certainly enhance RVC integration and trade flows, thereby boosting economic growth in the CAREC countries. Therefore, it is imperative to analyze the performance efficiency of the CAREC transport corridors to remain competitive and integrate into RVCs and regional and global markets and to offer policy recommendations to enhance the gains from RVC integration and trade flows along the CAREC transport corridor routes.

1.1. Study rationale

In the CAREC region, little is written about transport corridor efficiency and RVC integration along the corridor routes. Sustainable economic development, improved trade flows, and robust RVC integration in landlocked CAREC countries require smoother transit via country corridor routes without constraint. However, the functioning of CAREC transit routes faces numerous practical limitations, which bring higher transportation costs and extended transit times, trigger inefficiencies among firms, and hamper supply chains. Quantitative research on the measurement of efficiency of transport corridors in CAREC economies is virtually absent, which requires a detailed analysis. The development of the CAREC transport corridors has attracted increasing attention for stronger regional cooperation and shared gains to participating countries along the routes. However, extant studies on evaluating the comparative efficiency of CAREC transport corridors and the impact of CAREC corridors on RVC participation of countries along the routes are non-existent. Therefore, this study is a modest attempt to analyze the corridor efficiency and impact on RVC participation.

1.2. Problem statement

The development of the CAREC corridors is centered on regional cooperation, dialog, participation, and mutual gains to participating economies along the routes to boost local economic activities and foster their participation in RVCs. However, the CAREC transport corridors face numerous barriers in leveraging trade and the participation of the CAREC economies in RVCs along the routes, which need to improve the efficiency of the transport corridors in regional economies. There are scant studies on the measurement of the efficiency of the CAREC transport corridors focusing on transport connectivity, trade facilitation, border clearance, transit collaboration, and transit operations in transit economies and RVC integration in countries along the routes. Therefore, this study analyzes the comparative efficiencies of the CAREC transport corridors to find the causes of CAREC transport corridor inefficiency, to establish the best performing CAREC transport corridor, and to investigate the impact of the CAREC corridors on the participation of the countries in RVCs along the routes. This study adds to extant literature from the perspective of both researchers and policymakers.

2. Methodology

2.1. Efficiency measurement of CAREC transport corridors

The administration of the CAREC transport corridors necessitates the application of suitable decision-making techniques to offer sufficient assistance for policy options. This study has applied a highly capable decision-making technique called data envelopment analysis (DEA) to analyze the performance efficiency of the CAREC transport corridors.

2.1.1. Variables

Landlocked countries have right of entry to and from the sea (UN-OHRLLS, 2013) including open transit via bordering nations through all transport modes, devoid of little constraint (Hummels and Schaur, 2013). Virtually, this basic right faced several intricacies in practice and consequently increased transport costs and transit delays (Lowe, 1990) and hampered RVC integration (World Bank, 2013). Djankov, Caroline, and Cong (2010) presented a lucid analysis of transport systems in landlocked developing countries and their reliance on exports. Greater efficiency of transport corridors requires improved trade transit infrastructure and robust trade facilitation strategy, which can significantly impact transportation and logistics costs and facilitate a smoother transit at border clearance points. Therefore, the enhancement and upkeep of trade transit infrastructure facilities are essential for highly efficient transport corridors and the cooperative use of transit facilities (Djankov, Caroline, and Cong, 2010). However, scant knowledge exists on the assessment of the CAREC transport corridor efficiency specifically focusing on road transport, border clearance procedures, trade facilitation, and transit practices. The empirical analysis of the efficiency of the CAREC transport corridors is virtually absent, which this study intends to accomplish through the application of DEA.

In this study, the selection of variables is based on Djankov, Caroline, and Cong (2010) and used with slight alterations in confirmation to Fanou and Wang (2018) through inclusion of the total documents required for export via road transport. In landlocked economies, the outdated and inept customs practices, deficient infrastructure, and lack of reliable transit facilities frequently entail larger transport and trade costs and time delays at border-crossing points. Higher transit cost and time delays influence export and obstruct the integration of domestic firms with RVCs. The selected input and output variables include certification prerequisites, customs practices, and administration procedures including time and road transport cost incurred for export along the routes. This study analyzes CAREC corridor efficiency for the period 2010 to 2020, restricted to road transport and export only.

The DEA efficiency analysis employs three inputs and one output. Table 1 shows that chosen inputs are transaction cost (measured in USD per TEU), transit time (measured in days), and number of documents to export via transportation.[1] The selected output is volume of exports[2] handled by each decision-making unit (DMU), measured in TEUs.

Table 1: Indicators and their definitions

Indicator	Definition
Documents to export	Quantity of official certificates needed by exporters to collect and present. Therefore, this indicates official difficulties faced by exporters. Increased document requirements simply imply that exporters spend larger amounts of time and money engaging in trade pursuits.
Days to export	Number of days needed to fulfil complete official processes linked to export and border procedures and delivering consignment. Smaller official processes point to more ease of export.
Cost to export	Money cost to export is expressed in USD charged for a 20 foot vessel.

Source: Author compilation

2.1.2. Data sources

Efficiency calculations have been conducted for six CAREC corridors, called DMUs in DEA, spanning 2010 to 2020 as shown in Table 2. The input data was sourced from the World Bank Business Database, while output data originated from the UN Comtrade database. The 'Doing Business' framework evaluates the time and cost linked to the export and import of standardized goods via transportation. Regarding exports, official procedures encompass everything from packing goods to their exit from the corridor, including border clearance procedures. Transport cost and travel time have not been included. Additionally, essential certificates needed for cross-border exports are considered.

[1]This analysis focuses exclusively on road transport, the primary mode of transportation in the context of CAREC countries. In addition, the data for transaction cost, transit time, and so on by rail and other transportation modes is largely unavailable for most of these countries.
[2]In this paper, the focus is on examining export efficiency only owing to the unavailability of essential input variables required for conducting an import efficiency analysis. The specific input variables selected from the World Bank Business Database for export efficiency analysis unfortunately are not available for import analysis, especially across all CAREC countries. Hence, the analysis is limited to examining export efficiency only.

Table 2: CAREC corridors and the regions/countries

Corridor	Countries
1	Europe—East Asia (Kazakhstan, Kyrgyz Republic, and XUAR)
2	Mediterranean—East Asia (Afghanistan, Azerbaijan, Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, Uzbekistan, and XUAR)
3	Russian Federation—Middle East and South Asia (Georgia, Afghanistan, Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan)
4	Russian Federation—East Asia (IMAR, Mongolia, and XUAR)
5	East Asia—Middle East and South Asia (Afghanistan, Kyrgyz Republic, Pakistan, Tajikistan, and XUAR)
6	Europe—Middle East and South Asia (Afghanistan, Kazakhstan, Pakistan, Tajikistan, Turkmenistan, and Uzbekistan)

Note: *IMAR: Inner Mongolia Autonomous Region; XUAR = Xinjiang Uygur Autonomous Region. Both are regions of the People's Republic of China.
Source: Author compilation

2.1.3. Methodology to estimate efficiency

DEA is a linear programming technique that applies several inputs and outputs to analyze the comparative efficiency of identical DMUs. DEA is applied to estimate efficiency in terms of the proportion of weighted aggregate of outputs to the weighted aggregate of inputs. Absolute efficiency is difficult to capture; this is estimated on assumed fact. Performance efficiency is calculated by linking DMUs to a situation with very similar input and output form. Using the input and output variables, DEA gives an integrated efficiency performance for each DMU, helping to identify efficient DMU and inefficient DMU. Inputs are the resources applied by DMU and outputs are the performance displayed by DMU.

The determination of the optimal performing CAREC corridor (specifically ranking as the most effective corridor) is accomplished using the modified DEA technique (Andersen and Petersen, 1993), which facilitates the ranking of efficient CAREC corridors by evaluating 'efficiency scores,' and is expressed mathematically as follows:

$$Max h_k(u,v) = \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}} forallk = 1, 2. \dots, n \quad (1)$$

Subject to:

$$\frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}} \leq 1, j = 1, 2. \dots, n \quad (2)$$

$$u_r > 0, r = 1, 2. \dots, s \quad (3)$$

$$v_i > 0, i = 1, 2. \dots, m \quad (4)$$

Where:

h_k = relative efficiency of *k*-th DMU;
y_{rj} = quantity of output *r* generated by DMU *j*;
x_{ij} = quantity of input *i* utilized by DMU *j*;
n = number of DMUs;
m = number of inputs;
s = number of outputs;

u_r = weight assigned to output *r*; and
v_i = weight assigned to input *i.*

Equation (1) is solved iteratively n times to gauge the relative efficiency of each DMU. Non-negative constraints in equation (3) and equation (4) are necessary to ensure that fractional equation (2) attains a value > than 0. Consequently, all input and output weights are assumed to be non-zero. Optimization of k-th DMU's efficiency is achieved through resolution of equation (1) and equation (2), resulting in values of h_k ranges from 0 to 1 and h_k = 1 signifies k-th DMU's efficiency in comparison to others, while values < 1 indicate inefficiency. When h_k tends towards 1, it implies a higher level of efficiency.

An alternative approach to address this issue involves utilizing a fractional linear programming model, called a CCR ratio model, and converting it into a linear programming model. The mathematical representation of this DEA model is as follows:

$$Max h_k(u,v) = \sum_{r=1}^{s} \mu_r y_{rk} \, for all k = 1, 2. \ldots, n \tag{5}$$

Subject to:

$$\sum_{i=1}^{m} v_i y_{rj} \ = 1 \tag{6}$$

$$\sum_{r=1}^{s} \mu_r y_{rj} - \sum_{j=1}^{m} v_i x_{ij} \leq 0, j = 1, 2, \ldots.. n \tag{7}$$

$$u_r \geq 0, r = 1, 2. \ldots, s \tag{8}$$

Where:

y_{rj} = quantity of output *r* generated by DMU *j*;
x_{ij} = quantity of input *i* to unit *j*;
h_k = relative efficiency of unit *k*;
n = number of DMUs under investigation;
m = number of inputs;
s = number of outputs;
μ_r = weight coefficient of output *r*;
v_i = weight coefficient of input *i*.

The k-th DMU's relative efficiency is determined by h_k in objective function. If h_k = 1, DMU k is relatively efficient, while a value < 1 implies inefficiency. In such cases, value of h_k signifies the proportion of inputs to be lower by DMU. Complete efficiency of DMU k is achieved only when the values of other DMUs indicate that its inputs or outputs cannot be enhanced without negatively impacting other inputs or outputs.

Two types of DEA paradigm include constant return to scale (CRS) method and variable return to scale (VRS) model. CRS method is appropriate if all DMUs are optimally functioning. However, a DMU may not work optimally owing to restricted competitiveness and economic problems and entail application of VRS method.

Application of CRS method is useful to capture technical efficiency, when scale efficiency of complete DMUs is functioning optimally, while VRS method is applied, when estimation of technical efficiency lacks impacts of scale efficiency. Technical efficiency estimated by applying CRS method can be separated into pure technical efficiency and scale efficiency (García Sánchez, 2009). Equation (9) shows the scale efficiency.

$$\text{Scale efficiency (SE)} = \frac{\text{CRS efficiency}}{\text{VRS efficiency}} \qquad (9)$$

DEA can be applied both as an input or an output adjustment. Input-adjusted technical efficiency method assumes output as constant and the share of expected decline in use of input is analyzed. Output-adjusted technical efficiency method avoids any alteration in input and share increase in use of output is analyzed (Cullinane and Wang, 2006). When CRS method is applied, DEA displays comparable outcomes in use of both the input and output, while application of VRS method portrays dissimilar results. This paper applied both CRS method and VRS method owing to the difficulty of measuring and guaranteeing steadiness of transport circumstances. CRS efficiency and VRS efficiency have been captured using an input-adjusted method with a goal to establish the prospect of lowering input and sustaining similar output level. DEA has been applied to analyze comparative efficiency of the six CAREC transport corridors for 2010 to 2020.

2.2. RVC participation measurement

Yeats (1998) applied the United Nations classification of broad economic categories (BECs) to capture country-level participation in GVCs over long period, wherein GVC participation was articulated as a segment of addition of export and import of transitional inputs in overall trade.

2.2.1. Dependent variable and measurement

In this study, the dependent variable is linked to the involvement of countries in RVCs within specific trade routes. This variable is assessed by applying the concept of gross value added RVC and its measurement. To facilitate this analysis, this study utilized trade data encompassing imports and exports, which has been sourced from the UN COMTRADE database and categorized according to the BEC classification system. The BEC classification method segregates products into distinct categories, including final goods, transitional goods, and primary goods intended for enduse (Kim et al., 2019). In this context, this study identified the fundamental category of intermediate products. The dependent variable refers to the proportion of total imports and exports of transitional goods linked to total trade.

2.2.2. Explanatory variables

The introduction of CAREC corridors is considered a primary explanatory variable in this study. The accurate measurement of this variable requires two critical dimensions: whether a country falls within the ambit of CAREC corridors and whether the period aligns with the implementation of the CAREC corridors. This study focuses on a set of 22 countries, encompassing 11 economies situated along the CAREC corridors—namely, Afghanistan, Azerbaijan, the PRC, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Pakistan, Tajikistan, Turkmenistan, and Uzbekistan—and 11 non-CAREC corridor economies in the Eurasian region, including Belgium, Finland, France, Germany, Hungary, Netherlands, Poland, Spain, the Czech Republic, Iran, and Turkey. In this context, 11 CAREC corridor countries serve as the treatment group (treated = 1), while 11 non-CAREC corridor countries form the control group (treated = 0).[3] The time frame of analysis spans from 1990 to 2020, encompassing both pre-CAREC corridor launch period and post-launch period.[4] Notably, 2001 serves as a reference year for the CAREC corridor launch (time = 0 for years up to 2000, and time = 1 for years from 2001 onwards). Consequently, the key explanatory variable is derived from the interaction between treatment status (treated) and temporal dimension (time). The estimation of coefficients of these interface terms provides insights into the net effect of CAREC corridors on the RVC participation of countries.

2.2.3. Control variables

This study also takes into account several control variables that play a pivotal role in the analysis. A comprehensive overview of these variables is given in Table 3.

Table 3: Main variables and indicators

Categories of variable	Variable	Indicators
Dependent variable	RVC	Percentage of quantity of intermediate goods trade to total trade
Explanatory variable	Treated × time	Dummy variable (0, 1)
Control variable	Market	Percentage of gross domestic product (GDP) growth per capita
	Urban	Percentage of urban population to total population
	Capital	Percentage of gross fixed capital formation (GFCF)to GDP
	Open	Percentage of net inflows of foreign direct investment (FDI) to GDP
	Public	Percentage of general government final consumption expenditure to GDP
	Resource	Ratio of agricultural raw materials, ores, and metal exports to total manufactured exports

Source: Author compilation

2.2.4. Data sources

The dataset utilized in this study has been procured from a diverse range of reputable sources, including the publications of the Asian Development Bank (ADB), CAREC Corridor Performance Measurement and Monitoring database, International Monetary Fund (IMF), International Financial Statistics (IFS) database, Balance of Payments databases, World Bank, and Organisation for Economic Cooperation and Development (OECD).

2.2.5. Methodological approach

To address any potential selection bias, this study has skillfully integrated a DID method into a PSM framework. This strategic integration enhances the robustness of the analysis. The application of DID facilitates a rigorous analysis of the impact of the CAREC corridors on the RVC participation of the CAREC economies. Further elaboration on this approach is presented in a subsequent section.

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[3] Here a distinction has been made between two groups by focusing on 22 countries: the CAREC and the non-CAREC countries, both of which are situated along this corridor. The CAREC countries serve as the treatment group, while the non-CAREC countries are treated as the control group. This differentiation allows us to assess the impact of the CAREC corridor on trade by comparing the experiences of these two distinct sets of countries.

[4] The CAREC Program is a partnership of 11 countries and is a proactive facilitator of practical, results-based regional projects, and policy initiatives critical to sustainable economic growth and shared prosperity in the region. Since its inception in 2001 and as of December 2021, the CAREC Program has mobilized USD41 billion in investments (https://www.carecprogram.org/?page_id=31).

i. Overcoming categorization complexities: A significant challenge arises when categorizing a country as either a CAREC corridor economy or a non-CAREC corridor economy simultaneously. To navigate this intricate issue, this study applied PSM in conjunction with DID. This combined approach offers a more nuanced understanding of the effect of the CAREC corridors on the participation of RVC economies along specified routes. This innovative methodology elicits meaningful insights that might have been obscured by traditional categorization techniques.

ii. Heteroscedasticity mitigation: To mitigate the potential impact of heteroscedasticity, this study has adopted a prudent approach in regression analysis. Specifically, this study has applied a natural logarithm transformation for all variables. This transformation not only achieves a more symmetrical distribution of data but also contributes to the stabilizing variance of variables, thereby enhancing the reliability of the regression results.[5]

This paper centers on policy evaluation, delving into the influence of the CAREC corridors on the engagement of economies along the designated routes in RVCs. To mitigate the potential sample bias, this study has integrated DID with PSM to gauge the impact of the CAREC corridors on the RVC participation of countries.

iii. PSM exercise: Regarded as an open cooperative policy, the CAREC corridor can be viewed as a natural or quasi-natural experiment. By contrasting the RVCs of CAREC corridor economies with non-CAREC corridor economies before and after the launch of the CAREC corridors, the study analyzes the effects of the CAREC corridor on countries' participation in RVCs along these routes. Nonetheless, a selection bias might be present when comparing the RVCs between the CAREC corridors and the non-CAREC corridor countries.

This bias stems from two primary questions: Is the selection of the CAREC corridor countries random? It is possible that there is a hidden signal in the decision to participate in the CAREC corridors, as noted by Lien et al. (2012). Furthermore, could differences in RVCs between the CAREC corridor countries and non-CAREC corridor countries be attributed to other unobservable and unchanging factors? To circumvent the potential impact of these variations on the ultimate findings, this study used the PSM method (Rosenbaum and Rubin, 1983) before engaging in DID analysis.

The PSM method seeks to estimate the erroneous impact for CAREC corridor countries. The propensity score has been estimated using a logit model by applying PSM estimation equation (10).

$$PS_i = P(treated_i = 1|X_i) = logit\ (h(X_i)) \qquad (10)$$

Following the successful PSM testing, a new treatment group and control group are established, and unmatched data is excluded.

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[5]Before transformation, the Breusch-Pagan/Cook-Weisberg test for heteroskedasticity generated a p-value of 0.000 with $chi^2(1)$ =566.13, which is less than the chosen significance value of 0.05 and indicates a statistically significant Chi-square test. This result indicates the presence of heteroskedasticity in the dependent variable in the regression analysis. After the log transformation, the heteroskedasticity test generated a p-value of 0.926 with $chi^2(1)$ =0.01. This test is no longer significant as the p-value is greater than our chosen 0.05 cutoff. This suggests that the log transformation has successfully eliminated problems with heteroskedasticity in the regression.

iv. DID method: DID stands as a prominent method for policy evaluation, adeptly isolating the 'time effect' from the 'policy process effect' and mitigating deviations attributed to unobservable time-related factors. According to demarcation between treatment and control groups, the DID model is expressed in equation (11).

$$Y_{i,t} = \beta_0 + \beta_1 treated_{i,t} + \beta_2 time_{i,t} + \beta_3 time_{i,t}\ x\ treated_{i,j} + \varepsilon_{i,t} \quad (11)$$

Here, $Y_{i,t}$ signifies participation in RVCs of countries during period t, $treated_{i,t}$ is treatment group dummy variable, $time_{i,t}$ is time dummy variable, $time_{i,t}$ x $treated_{i,t}$ represents interaction term, and $\varepsilon_{i,t}$ denotes random disturbance component, which includes all the factors that influence the outcome but are not explicitly included in the model.

v. PSM-DID Integration[6]: Utilizing DID alone might introduce selection bias, while relying solely on PSM could introduce a time effect. Hence, this study combines both methods—PSM and DID—culminating in an empirical model shown in equation (12):

$$Y_{i,t}^{PSM} = \beta_0 + \beta_1 treated_{i,t} + \beta_2 time_{i,t} + \beta_3 time_{i,t} \text{x}\ treated_{i,t} + \beta_4 x_{i,t} + \varepsilon_{i,t} \quad (12)$$

Here $Y_{i,t}^{PSM}$ represent participation in RVCs of countries after applying PSM during period t, $treated_{i,t}$ is treatment group dummy variable, $time_{i,t}$ is time dummy variable, $time_{i,t}$ x $treated_{i,t}$ represents interaction term, $x_{i,t}$, is propensity score, and $\varepsilon_{i,t}$ remains the error term, capturing unexplained variability in the outcome variable even after accounting for the treatment, time, interaction, and propensity score.

The approach begins with PSM to find comparable control groups closely aligned with treatment group from original control group. Subsequently, DID is applied to evaluate participation in RVCs between treatment and matched control groups. This dual-step procedure effectively addresses selection bias and time effects. A combination of PSM and DID yields more dependable, objective, and comprehensive findings.[7]

[6]In this paper, staggered DID has also been tried; this allows different treatment times for different treated groups. In the context of CAREC, it means that each country's 'treatment' starts when it joins CAREC. This is a more flexible approach that accounts for the fact that countries joined CAREC at different points in time. However, most of the CAREC countries started trading through the corridor only in 2021. Although, if cases vary for some countries, staggered DID can be used as a robustness check, as it better reflects the actual timing of the policy change (countries joining CAREC). However, it also indicates a potential issue: the number of treated samples (countries that join CAREC) can become relatively small compared to the control group (countries that do not join at the same time). This can lead to an unbalanced panel dataset, and this imbalance can affect the validity of the estimates. It is suggested that if the sample size of the treated group is too small to yield meaningful or statistically significant results, it may be necessary to stick with the static DID approach to address the timing of the treatment as detailed in Backer et al. (2022).

[7]For estimation, ATT (average treatment effect on the treated) measures have been used to understand how the corridor impacts the countries that are most directly involved (CAREC countries). This can help in assessing the corridor's impact on the countries it was primarily designed to benefit. It also assumes a common trend or parallel trends between the treated group (CAREC countries) and a control group (non-CAREC countries). This comparison group could be non-CAREC countries or CAREC countries before the corridor's implementation. Regarding the assumption of weak or strong ignitibility, DID analysis assumes that, in the absence of the treatment (the CAREC corridor), the treatment and control groups would have followed a similar trend also referred to as a 'parallel trends' assumption.

3. Results and discussion

3.1. Efficiency measurement of the CAREC transport corridors

The DEA analysis outcomes are presented in Table 4, which demonstratesthe comparative efficiency scores encompassing the CRS efficiency, VRS efficiency, and scale efficiency. These results highlight that only Corridor 4 maintained technical efficiency (CRS efficiency) throughout the study duration. Corridor 4 demonstrated high efficiency throughout in VRS efficiency as well as the scale efficiency. This reflects better hard and soft infrastructure along Corridor 4 as it transits through the regions of the PRC (IMAR, Mongolia, and XUAR). Corridor 5 displayed stronger technical efficiency from 2010 to 2015, after which it exhibited inefficiency, which needs policy attention. Corridor 1, Corridor 3, and Corridor 6 are the most inefficient CAREC transport corridors in terms of technical efficiency estimates from 2010 to 2020 and the technical efficiency of Corridor 2 remained lower but steady from 2010 to 2015 followed by significant inefficiency till 2020.

In terms of VRS efficiency, Corridor 4 also displayed significant efficiency throughout the study period, while Corridor 2 and Corridor 5 demonstrated efficiency from 2010 to 2015 followed by inefficiency thereafter. Corridor 1, Corridor 3, and Corridor 6 displayed inefficiency in terms of VRS efficiency for the entire period under study. In scale efficiency too, Corridor 4 revealed robust scale efficiency from 2010 to 2020, while Corridor 1 and Corridor 5 exhibited strong scale efficiency from 2010 to 2015 and afterwards Corridor 5 displayed scale inefficiency from 2016 to 2020. Therefore, Corridor 1 and Corridor 5 maintained strong scale efficiency in the initial years and subsequently transitioned into inefficiency. Corridor 1 demonstrated scale inefficiency from 2016 to 2018 and recovered thereafter to display efficiency in 2019 and 2020. Corridor 2, Corridor 3, and Corridor 6 demonstrated scale inefficiency, although fluctuating over 2010 to 2020.

Table 4: Estimates of efficiency scores across the CAREC transport corridors

Corridor	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
CRS Efficiency											
1	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.001
2	0.673	0.691	0.690	0.686	0.693	0.691	0.181	0.187	0.188	0.229	0.363
3	0.004	0.004	0.004	0.004	0.004	0.004	0.001	0.001	0.001	0.001	0.002
4	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
5	1.000	1.000	1.000	1.000	1.000	1.000	0.317	0.331	0.332	0.396	0.422
6	0.049	0.060	0.057	0.050	0.047	0.034	0.008	0.009	0.010	0.010	0.013
VRS Efficiency											
1	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.001
2	1.000	1.000	1.000	1.000	1.000	1.000	0.516	0.518	0.520	0.521	0.515
3	0.004	0.005	0.005	0.004	0.004	0.005	0.003	0.003	0.002	0.002	0.002
4	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
5	1.000	1.000	1.000	1.000	1.000	1.000	0.505	0.505	0.505	0.505	0.504
6	0.056	0.067	0.064	0.056	0.052	0.036	0.018	0.020	0.021	0.022	0.017
Scale Efficiency											
1	1.000	1.000	1.000	1.000	1.000	1.000	0.860	0.894	0.894	1.000	1.000
2	0.673	0.691	0.690	0.686	0.693	0.691	0.352	0.361	0.361	0.440	0.705
3	0.862	0.881	0.880	0.879	0.893	0.906	0.451	0.451	0.451	0.500	0.829
4	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
5	1.000	1.000	1.000	1.000	1.000	1.000	0.627	0.656	0.658	0.784	0.838
6	0.877	0.896	0.896	0.894	0.909	0.923	0.460	0.460	0.460	0.460	0.728

Note: 1.000 = Efficient
Source: Author estimates

Table 5: Estimates of return to scale across the CAREC transport corridors

Corridor	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	-	-	-	-	-	-	IRS	IRS	IRS	-	-
2	DRS	IRS	DRS	DRS	DRS	DRS	IRS	IRS	IRS	IRS	IRS
3	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS
4	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	IRS	IRS	IRS	IRS	IRS
6	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS

Note: - = Constant return to scale, DRS= Decreasing return to scale, and IRS = Increasing return to scale
Source: Author analysis

The efficiency classification, both in terms of VRS and CRS, has varied for a given corridor over 2010 to 2020. Comparing the corridors has facilitated an assessment of their relative scale efficiency. In CRS terms, when juxtaposed with the most efficient—Corridor 4—Corridor 1, Corridor 3, and Corridor 6 displayed the highest inefficiency in 2020. Notably, Corridor 5 remained efficient from 2010 to 2015, turning inefficient thereafter, but it still ranked ahead of all but the top-performing Corridor 4. This exception might be attributed to the novel transport system reforms introduced in Corridor 5. Nonetheless, countries situated within Corridor 1, Corridor 3, and Corridor 6 should consider transport system reforms, drawing lessons from the most efficient Corridor 4.

Table 5 shows the estimates of return to scale across the CAREC transport corridors. Concerning the VRS efficiency scores, the pre-eminent CAREC transport corridor, once again, was Corridor 4, whereas Corridor 1, Corridor 3, and Corridor 6 demonstrated the greatest inefficiency in 2020. Furthermore, apart from Corridor 5, Corridor 2 exhibited efficiency between 2010 and 2015, but saw a decline in efficiency thereafter. Notably, in 2020, Corridor 2 outperformed Corridor 5 in terms of the VRS efficiency score. Hence, the countries within Corridor 1, Corridor 3, and Corridor 6 should undertake transport system reforms, drawing insights from the exemplar of efficient performance displayed by Corridor 4. Additionally, lessons can be gleaned from the experiences of Corridor 2 and Corridor 5 to discern why these corridors transitioned into inefficiency over time. This inquiry could revolve around factors such as inadequate infrastructure (both the hard and soft infrastructure) or increased documentation requisites.

Table 4 further shows that Corridor 4 has displayed CRS over 2010 to 2020 and achieved optimal efficiency; therefore, any policy change is not expected to impact performance efficiency and entails the maintenance and persistence of existing policy initiatives to perform efficiently. Corridor 1 and Corridor 5 were functioning on optimal efficiency from 2010 to 2015, while Corridor 5 demonstrated IRS thereafter until 2020. This entails Corridor 5 to revisit policies to reorient them towards earlier policies, which guided this corridor to attain optimal efficiency from 2010 to 2015. Corridor 1 exhibited IRS from 2016 to 2018 after maintaining optimal efficiency from 2010 to 2015, again switching to attain optimal efficiency in 2019 and 2020, which entails Corridor 1 to maintain and sustain the current transit facilitation initiatives to remain at optimal scale. Corridor 6 displayed IRS over 2010 to 2020, which calls for improved transit facilitation measures to move towards optimal efficiency. Corridor 2 revealed DRS from 2010 to 2015, except 2011 wherein this corridor displayed IRS. During 2016 to 2020, Corridor 2 showed IRS, which demonstrates that this corridor can move towards optimal efficiency by embracing novel transit facilitation reforms. In brief, all the corridors can reorient their transit infrastructure through vigorous reforms and can learn significantly from the existing transit facilitation being carried out in Corridor 4.

This analysis reveals that only Corridor 4 demonstrated efficiency over 2010 to 2020, while two other corridors—namely, Corridor 1 and Corridor 5—exhibited a consistent performance during 2010 to 2015. However, Corridor 3 and Corridor 6 were less efficient in comparison to the most efficient, Corridor 4. Despite this, Corridor 3 and Corridor 6 displayed an IRS over 2010 to 2020, indicating that a proportionate rise in all inputs led to a greater proportionate increase in output, as depicted in Table 5. These trends could be attributable to the stable nature of inputs, with minimal variance observed in number of documents and time spent over the years.

The CAREC Corridor Performance Measurement and Monitoring (CPMM) database reveals that road cargos transported more than 30 million tons in 2020, about 60 percent of cumulative cargos via Corridor 4. Mongolia ventures to rehabilitate and construct roads with substantial financing to foster regional integration. The construction of new road led to a decline in transportation cost of 16.45 percent, while the speed without delay surged by 50 percent in 2014 over 2013. Mongolia transports coal to the PRC and minerals and ores to the IMAR via the border clearance points along Subcorridor 4a. Corridor 4, connecting Mongolia and the PRC, entails substantial financing to develop rail infrastructure for the cost-effective transportation of heavy items. Transit Mongolia (2008) aimed to improve transport transit connecting the PRC and the Russian Federation, and foster transport and trade facilitation for efficient imports and exports. The CPMM database related to Corridor 4 reveals that, during 2010 to 2020, road transit time surged from 3.8 hours to 4.8 hours, while road transport costs and transit costs declined immensely from USD2,023 to USD1,463 and USD334 to USD87. The road transport speed stayed almost constant and ranged between 33.3 km/h to 33.5 km/h during this period, while in 2018 it was considerably higher at 50.2 km/h. The PRC's exports consist of consumer and food goods, refined petroleum, and construction items to Mongolia via Corridor 4, while its imports constitute minerals and coal from Mongolia via Subcorridors 4a and 4c, and lumber from the Russian Federation via Subcorridor 4b. Mongolia's export consignments transit to Tianjin seaport via Subcorridor 4b.

Corridor 4 passes through three countries: Mongolia, the PRC, and the Russian Federation. IMAR and XUAR are regions of the PRC. Corridor 4 is thechief channel for trade and transit consignments between the bordering nations. Mongolia has strong trade collaboration with the PRC, which helped the PRC to develop novel energy markets and providedgreat prospects to enhance economic and cultural ties (Soni, 2018; Li, Tavitiyaman, and Chen, 2020). The CAREC corridors generated novel opportunities for trade cooperation between Mongolia and the PRC, and for bolstering regional integration despite the barriers (Murugesan, 2018) and challenges (Mavidkhaan, 2020), which have been tackled by bolstering economic cooperation, lowering trade barriers, and promoting trade. The PRC–Mongolia–Russian Economic Corridor has also boosted Mongolia–PRC economic cooperation and trade collaboration (Soni, 2018). The Observatory of Economic Complexity estimated that in 2021, the PRC's exports to Mongolia stood at USD2.5 billion, while Mongolia's exports to the PRC stood at USD7.6 billion, which reflects the strong bilateral trade between the two countries and the reforms in Mongolia's mining sector. The export structure disparities between Mongolia and the PRC are reportedly small (Enkhbold and Nomintsetseg, 2016), which demonstrates little export competitiveness and unrivaled gains between the two countries.

3.2. Analysis of CAREC Corridor Performance Measurement and Monitoring database

The following discussion is based on the CPMM data on road transport linked to trade facilitation indicators. In the CAREC corridors, the average time to cross the border surged from 2019 (12.2 hours) to 2020 (15.1 hours), while the average transport cost required to pass a corridor segment increased from 2019 (USD162) to 2020 (USD199) and the total transport cost incurred to cross the border averaged at USD901 (2019) and USD917 (2020). At Corridor 1, the average total cost to pass a corridor part stood significantly high in 2002 (USD1,788) from 2019 (USD1,092), while Corridor 3 and Corridor 4 also experienced a surge in average total cost, but slower than Corridor 1, whereas other corridors reported a decline. In 2020, Corridor 1 displayed the highest average speed with delay (69.5 km/h) and without delay (41.1 km/h) and Corridor 5 demonstrated the slowest speed without delay (28.4 km/h) and with delay (8.6 km/h).

In 2020, the average time to cross the border stood lowest (6.3 hours) through Corridor 4 and highest via Corridor 5 (40.2 hours), while Corridor 6 and Corridor 2 took 13.5 hours and 10.6 hours respectively. The average time spent in outbound road traffic for border-crossing has been estimated highest at 70.7 hours along Corridor 5 (Chaman) and lowest at 50.0 hours along Corridor 6 (Torkham) in 2020, similar to the 2019 ranking; however, in 2020 there was a surge in the average time experienced. In the case of inbound road traffic, the average time spent for border-crossing was estimated to be highest at 30.0 hours (Yallama) and lowest at 4.2 hours (Torkham) along Corridor 6. Corridor 6 experienced marginal declines in the average time spent, while other corridors displayed a surge. Corridor 5 and Corridor 4 took the maximum time (40.2 hours) and minimum time (6.3 hours) for the border-crossing in 2020, while Corridor 6 and Corridor 2 took 13.5 hours and 10.6 hours respectively. The longer average time spent to cross a border point was attributed to the pandemic-induced border closures and the extra hygiene demand.

Corridor 5 and Corridor 6 passing via Afghanistan, Pakistan, and Uzbekistan experienced considerable delays owing to pandemic measures and the high costs imposed by the surge in cargo charges and extra health and quarantine costs incurred by both the domestic overseas drivers at border-crossing points. Corridor 1 displays a rapid surge in the average cost to cross the border owing to a substantial hike in freight charges. The costs of loading and unloading cargo and the customs procedures at border-crossing points surged considerably. At Corridor 1, the loading and unloading expenses surged substantially to USD1,487 in 2020 from the previous average cost of USD316. Corridor 4, Corridor 5, and Corridor 6 also incurred additional costs on loading and unloading, including pandemic-induced hygiene and quarantine measures for both domestic and overseas trucks. The average cost stood substantially higher at USD4,755 and USD2,251 along Subcorridors 5b and 1b respectively,owing to higher cargo charges and the rise in border-crossing cost in particular sections. The border-crossing points along Corridor 1, passing through the PRC and Kazakhstan, were costly to transverse. The main reasons for transit delays and increased costs at border-crossing points included pandemic-induced measures, and expenses on health and isolation incurred by drivers. The estimated total transport cost surged highest at Corridor 1 and lowest at Corridor 4, while Corridor 2, Corridor 5, and Corridor 6 experienced a decline. The increase in total transport cost is attributed to a surge in cargo charges and the decline in total transport cost was owing to government assistance to lower working cost. The average speed without delay fell in 2020 (42.9 km/h) from 2019 (43.6 km/h), but the average speed with delay (22.7 km/h) continued constant owing to cumbersome customs clearance. In terms of speed, Corridor 1 and Corridor 5 remained efficient and inefficient respectively. Corridor 1 and Corridor 5 recorded the highest and lowest average speed without delay and with delay for road transport at, respectively, 69.5 km/h and 28.4 km/h, and 41.1 km/h and 8.6 km/h.

The following paragraphs reveal the corridor-wise performance by road transport in trade facilitation indicators. In Corridor 1, road transport incurred substantial time to cross the border at Subcorridor 1a along the PRC–Kazakhstan route and paid considerable additional fees at Subcorridor 1b to informal customs agents to avoid longer scrutiny and procedures. Transit costs also surged owing to pandemic-induced measures, which were eased subsequently by implementing modified border-clearance practices. In Corridor 2, road cargo time has been estimated at ten days along the Tajikistan and Uzbekistan routes and 13 days along the routes of Kazakhstan and the Kyrgyz Republic in 2020, of which about 50 percent of total cargo time was attributed to waiting, seeking access authorization, indemnity fees, and pandemic-induced measures. Cargo cost varied between

USD1,800 and USD2,150, besides extra charges levied on customs clearance procedures and tolls taxes, including informal expenses and additional fees for customs guides and exceptional authorization for heavy machinery and high-priced goods. In Corridor 3, more time and heavy charges were incurred at the Subcorridor 3a route for border-crossing in 2020. Despite the difference in distance of 15 km/h between Subcorridor 3a and Subcorridor 3b, the speed without delays estimated was fairly comparable; thus, the additional time spent in border-crossing influenced the costs. The pandemic-induced measures also delayed inbound traffic more than outbound traffic along Corridor 3.

Corridor 4 serves as a trade and transit corridor, which links Mongolia with the PRC and the Russian Federation through three subcorridors. Subcorridor 4a is used for Mongolia's coal exports to the PRC and operated successfully during the pandemic, despite restrictive measures and the increase in the cost of border crossing. Subcorridor 4b facilitates cross-border trade between Mongolia and the PRC and operates both the road and rail transport. The road consignments via Subcorridor 4b took less time and were cost-efficient and widely used to transport dangerous items banned through rail transport. However, the transfer of road freight to rail shipment and customs clearance and pandemic-related restrictions caused delays and increased cost at the border crossing; still, the road–rail choice is widely used owing to the improved safety of high-price machines and tools. Subcorridor 4c also facilitates cross-border trade between Mongolia and the PRC and operates more traffic than Subcorridor 4b, but was shut for cargo mobility owing to the pandemic measures.

The border-crossing time and speed of road cargos along Corridor 5 remained significantly higher than that of other corridors in 2020. The COVID-19 measures worsened the situation further and delayed the cargos owing to border closures, restrictions on working days, and the clearance of backlogged containers along Corridor 5. In Corridor 6, the average time, average cost, and speed without delay to cross the border stood at 8.7 hours, USD67.90, and 47 km/h respectively at Subcorridor 6a owing to fewer inspections, while the average time (6.1 hours) and speed without delay (38 km/h) to cross the border stood at comparatively less and the average cost was more (USD116.50) at Subcorridor 6b than at Subcorridor 6a. The average time (18.4 hours) and speed without delay (35 km/h) to cross the border were lower and the average border-crossing cost (USD200.90) was higher at Subcorridor 6c than at all subcorridors under Corridor 6. Subcorridor 6d takes a longer average time (32.7 hours) to cross the border compared to all subcorridors under Corridor 6.The average cost (USD137.70) to cross the border was higher than that of all subcorridors except Subcorridor 6c and the speed without delay (42 km/h) was estimated to be higher than all subcorridors except Subcorridor 6a.

The above analysis underscores the necessity for increased investment and extended implementation periods for CAREC transit transport services. Consequently, decision-makers must prioritize the selection and promotion of the appropriate infrastructure within suitable time frames, alongside policy reforms aimed at reducing documentation requirements, and transport and transit time and costs.

3.3. Measurement of CAREC corridor participation in RVCs

3.3.1. Descriptive statistics

Upon examining the descriptive statistics given in Table 6, it becomes evident that there is a range of values across the variables under consideration. Logarithmic mean value, which serves as an indicator of central tendency, varies across the spectrum of variables. Specifically, the lowest log interquartile range (IQR) value is noted in the context of 'participation in regional value chain,' at

0.645. Conversely, the highest log IQR value observed for 'market' is at 2.53. This difference in IQR underscores the diversity of the dataset and the varying degrees of influence these variables exert.

Table 6: Descriptive statistics of variables

Variable	Obs	IQR	Std. Dev.	Min	Max
lRVCs	681	0.41	0.459	2.303	7.654
treated x time	682	1.00	0.479	0	1
lmarket	682	2.53	1.632	-2.303	3.497
lcapital	682	0.30	0.320	0.956	4.064
lopen	682	1.53	1.403	-2.303	4.669
lurban	682	0.47	0.376	3.054	4.586
lpublic	682	0.47	0.310	1.775	3.768
lresource	682	1.64	1.136	-1.204	4.599

Source: Author estimates

Turning the attention to the measure of dispersion, the standard deviation offers valuable insights into the extent of variability within each variable. Remarkably, variable 'market' exhibits the highest standard deviation, signifying a considerable dispersion among its data points. On the contrary, variables 'public' and 'capital' display the least standard deviation, indicating a more tightly clustered distribution around their respective means.

A notable observation pertains to certain variables that manifest negative minimum log values, as observed in 'market, 'resource,' and 'openness.' This intriguing occurrence hints at the presence of pronounced differences among data points, with some falling below zero owing to logarithmic transformation. This phenomenon underscores a wide spectrum of values and their inherent variations.

Collectively, these descriptive statistics underscore the inherent heterogeneity within the dataset, shedding light on the diverse nature of the variables and the nuances that they contribute to the analysis. This information serves as a foundational understanding that informs subsequent analytical steps and the interpretation of results.

3.3.2. Common support assessment and ROC analysis

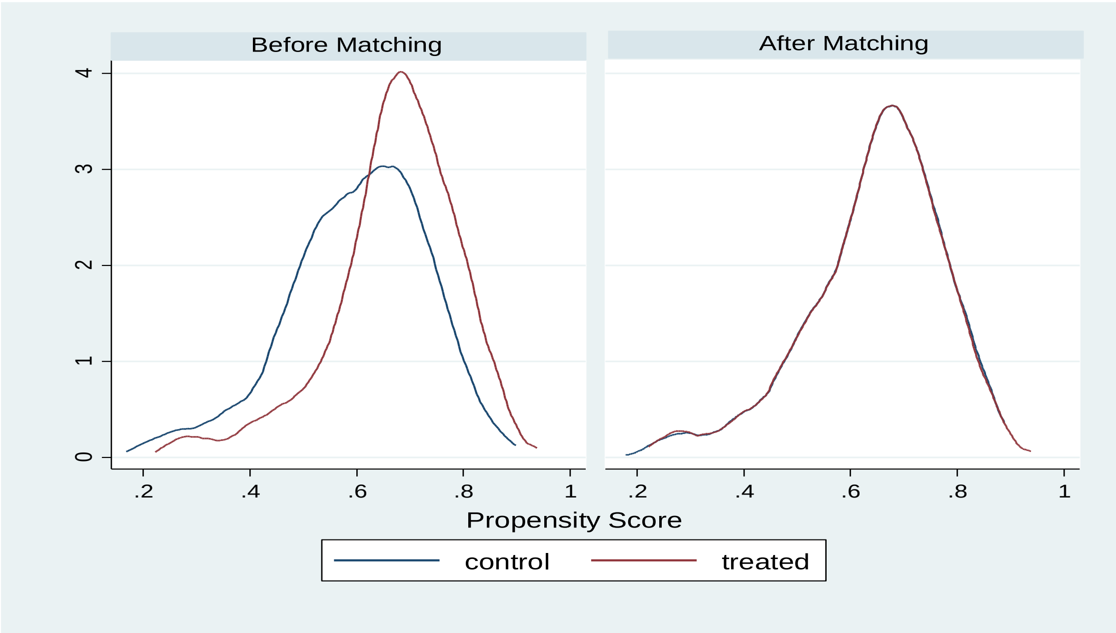
A pivotal aspect of the PSM method, as highlighted by Heckman et al. (1997), is the establishment of a common support hypothesis. To scrutinize this hypothesis, various testing methods come into play, including receiver operating characteristic (ROC) curve and graphical representations of empirical density functions.

Figure 1 provides insights into the examination of common support before and after one-to-three matching process. Kernel density function graphs presented in Figure 1 yields illuminating observations. Prior to matching, a discernible degree of non-coincidence is discernible within the common support range shared by the control group and the treatment group. Notably, the distribution of the control group exhibits a left-leaning and scattered pattern, accentuating the differences in probability density of propensity score values between two groups.

Conversely, following the one-to-three matching procedure, a transformation becomes evident. The probability density of propensity score values between two groups aligns more closely, as clearly depicted in the right-hand kernel density graph. This conformity indicates that differences in propensity score values have been considerably mitigated through the matching process.

In light of these insightful findings, a compelling conclusion can be drawn: the sample data has effectively surpassed the common support test. The transformation of density plots from disparate distributions to closely aligned patterns post-matching affirms that the data adheres to the fundamental premise of common support—a critical facet in ensuring the validity and reliability of subsequent PSM analysis.

Figure 1: The kernel density graph of the PSM in the treatment group and control group



Source: Author creation

3.3.3. Balancing test and matching validity assessment

Beyond establishing a common support hypothesis, it is imperative to subject the matching process to a balancing test for comprehensive validity. This study leverages the methodology introduced by Smith and Todd (2005) to rigorously assess the equilibrium achieved in the matching process. The outcomes of this balancing test are presented in Table 7 for evaluation.

Table 7 unequivocally demonstrates a substantial reduction in standard bias post-matching. This reduction underscores the effectiveness of the matching process in harmonizing the distribution of variables. Drawing insights from Rosenbaum and Rubin (1983), it is evident that both the chosen matching variables and the employed matching method stand on solid ground, contributing to the robustness of matching process.

Furthermore, the t-value post-matching exhibit number pronounced disparities between the treatment group and the control group. This observation signifies a commendable balance achieved between the groups. It is noteworthy that the application of the likelihood ratio (LR) chi^2value and the Ps R^2 reductions—16.77 from an initial 48.35 and 0.0550.055 from 0.0140.014, respectively—with an overall R value of 0.89, collectively strengthen the notion that the balancing test has led to a significant improvement in equilibrium between the groups.

Table 7: Balancing test for propensity score matching

Variable	Unmatched (U) and matched (M)	Mean		Bias %	|Bias|%	t-value	p>|t|	V(T)/V(C)
		Treated	Control					
lRVCs	U	3.0599	3.031	6.5		0.79	0.432	1.54*
	M	3.0599	2.985	16.8	-158.7	2.6	0.01	1.92*
lresource	U	2.5043	2.7118	-19		-2.29	0.023	1.74*
	M	2.5043	2.4111	8.5	55.1	1.25	0.21	1.64*
lurban	U	4.0544	3.9835	19		2.37	0.018	0.97
	M	4.0544	4.0758	-5.7	69.9	-0.96	0.337	1.72*
lmarket	U	0.51965	0.08371	26.6		3.36	0.001	0.88
	M	0.51965	0.45816	3.8	85.9	0.57	0.567	0.98
lcapital	U	3.2413	3.1574	25.3		3.3	0.001	0.54*
	M	3.2413	3.2395	0.5	97.8	0.09	0.925	0.92
lpublic	U	2.7631	2.8227	-19.4		-2.41	0.016	1.06
	M	2.7631	2.7546	2.8	85.7	0.4	0.69	0.94
lopen	U	1.0413	0.65003	28.3		3.51	0	1.12
	M	1.0413	0.78409	18.6	34.3	2.72	0.007	1.05

Note: *If the variance ratio falls outside [0.83; 1.21] for U and [0.83; 1.21] for M
Source: Author estimates

Table 8: Test for how well the model fits

Sample	Ps R^2	LR chi^2	p>chi^2	MeanBias	MedBias	B	R
Unmatched	0.055	48.35	0	20.6	19.4	56.8*	0.96
Matched	0.014	16.77	0.019	8.1	5.7	27.6*	0.89

Note: LR = likelihood ratio
Source: Author estimates

In culmination, the comprehensive findings from the balancing test consistently affirm the efficacy of the matching process. The discernible reduction in biases, alignment of t-values, and decreased values of LR and Ps R^2 collectively underscore the validity and reliability of the matching procedure shown in Table 8. This robust balancing lends further confidence to subsequent analyses, fostering more accurate and insightful outcomes.

3.3.4. Empirical findings on participation in RVCs

Using equation (3), the analysis provides estimates of the impact of the CAREC corridors on participation in RVCs of countries along the routes. The regression analysis is conducted with the application of cluster-robust standard errors. The comprehensive results of this analysis are displayed in Table 9, alongside estimation outcomes for unmatched data for the purposes of comparison.

Columns (1) and (2) within Table 9 delineate outcomes for unmatched data estimation, while the subsequent columns provide regression results for matched data. Specifically, columns (1) and (3) outline baseline outcomes, omitting any control variables, while columns (2) and (4) introduce primary explanatory variables into models presented in columns (1) and (3) respectively.

Table 9: Effect of corridors on the RVC participation of countries along the routes

Variable	DID		DID-PSM	
	(1)	(2)	(3)	(4)
Treated	0.0015*	0.0345*	0.0115**	0.052**
	(1.03)	(1.65)	(2.01)	(2.59)
Time	-0.0745	-0.0369	-0.0641*	-0.054*
	(-1.26)	(-0.53)	(-1.82)	(-1.59)
treated X time	0.0612	0.0779	0.0351*	0.0221*
	(0.83)	(1.08)	(1.02)	(1.14)
lopen		0.025*		0.0208**
		(1.94)		(2.13)
lpublic		0.017		0.0208
		(0.28)		(0.25)
lcapital		0.0698*		0.108**
		(1.3)		(2.47)
lmarket		0.00136*		0.0211*
		(0.11)		(1.06)
lurban		0.0193*		0.129**
		(1.27)		(2.21)
lresource		-0.0384**		-0.0739**
		(-2.28)		(-2.88)
_cons	3.068***	2.792***	3.069***	2.274***
	(73.47)	(7.45)	(55.36)	(3.99)
N	681	681	308	308
R^2	0.25	0.18	0.29	0.31

Note: t statistics in parentheses* p<0.01, **p<0.05, *** p<0.001
Bootstrapping in DID, and propensity score weights in DID-PSM
Source: Author estimates

The coefficient attributed to treatedi,t× timei,t captures the impact of the CAREC corridors on the participation in RVCs of countries along specified routes. The results obtained solely through DID approach reveal that coefficients associated with interaction terms lack statistical significance. However, a noteworthy shift occurs when the DID approach is coupled with the PSM method. This integration yields interaction term coefficients that are not only positive but also statistically significant. This transformation underscores the importance of employing the PSM method in conjunction with the DID method, accentuating the need for methodological synergy.

The contrasts between results before and after matching underscore the necessity of applying the PSM method as a precursor to the DID method. These outcomes distinctly portray that the introduction of the CAREC corridors has indeed led to an enhancement of participation in RVCs of countries along the routes. A noteworthy observation arises when comparing column (3) with column (4), upon incorporating control variables into regression, the effect of the CAREC corridors on the participation of the CAREC corridors countries in RVCs remains positively significant at a level of 10 percent. However, the significance level has diminished, accompanied by a considerable reduction in coefficient by 0.0130. This decline may potentially be attributed to a mediating role played by one or more control variables, influencing the overall effect.

In summary, the empirical results underline the constructive impact of the CAREC corridors on the participation in RVCs of countries along the designated routes. The integration of the PSM method with the DID approach enhances the statistical significance of findings, underscoring the intricate relationship between policy, methodological rigor, and influential factors. The incorporation of the control variables further enriches the understanding of the CAREC corridors' influence, shedding light on potential mediating mechanisms within this complex context.

3.3.5. Impact of various factors on RVC participation

Several factors, including market size, economic openness, material capital, and urbanization, distinctly exhibit a significantly positive influence on the participation of countries within the CAREC corridors in RVCs. The findings illuminate intriguing dynamics associated with these elements.

The results underscore the initial point that a growth in market size within the CAREC corridor countries leads to a discernible amplification in forward linkages compared to a parallel increase in backward linkages. This asymmetry implies that a larger market size prompts a stronger surge in demand for intermediate goods compared to their supply. Additionally, economic liberalization contributes to capital inflows, subsequently bolstering the trade volume of intermediate goods. It is notable that these capital inflows are likely allocated toward vital areas such as infrastructure development and the exploration of natural resources.

Remarkably, urbanization emerges as another factor with a significantly positive impact on the participation of CAREC corridor countries in RVCs. This relationship can be attributed to the substantial role of urbanization as a conduit through which these countries participate in RVCs. The interconnectedness between urbanization and participation is a compelling narrative within this context.

However, the presence of abundant natural resources brings about a notable divergence. While it would be anticipated that such resources could stimulate participation, the findings reveal a highly significant negative influence on RVC participation for countries along the CAREC corridor routes. This phenomenon suggests that heavy reliance on natural resource development may hinder active engagement in RVCs, possibly owing to resource-driven economic specialization that diverges from the RVC framework. Interestingly, under the PSM-DID analysis, the significance of this negative impact decreases, implying that countries endowed with natural resources may find participation in the CAREC corridors more appealing.

Conversely, the variable of public services does not exhibit significant influence even within the DID-PSM framework. This suggests that, within this analysis, public services do not significantly contribute to the participation in RVCs of countries along the CAREC corridor routes.

In conclusion, the empirical results underscore a multifaceted interplay of factors shaping the participation of CAREC corridor countries in RVCs. While certain variables such as market size, economic openness, material capital, and urbanization demonstrate positive influences, dynamics surrounding natural resources and public services reveal intricate nuances that warrant deeper exploration. This comprehensive understanding enriches the insights into the complex relationship between these variables and RVC participation, ultimately contributing to more informed policy considerations.

3.3.6. Robustness analysis

Drawing from an extensive panel dataset spanning from 1990 to 2020, encompassing 22 countries within the CAREC corridors, this study effectively establishes the capacity of the CAREC corridors to amplify the participation of these countries in RVCs. This assertion is rooted in empirical evidence gleaned from this temporal and geographic scope.

To fortify the dependability of research outcomes, this study embarks on a robustness test by transitioning from the standard matching method to the caliper matching approach. This method shares a conceptual affinity with the previously employed one-to-three matching technique. The rigorous calibration of this new approach unfolds as follows:

Initially, the caliper matching method is executed to harmonize samples, adhering to a stringent set of criteria. Subsequently, DID estimation is conducted using equation (4), based on outcomes of this calibrated matching procedure. It is noteworthy that the regression results derived from this calibrated approach correspond harmoniously with findings obtained from the preceding methodology. However, for the sake of brevity, these congruent outcomes are not expounded upon within this context.

By subjecting the research to this robustness test, the study strengthens the trustworthiness of the conclusions, validating the robustness of the impact of the CAREC corridors on the augmented participation of CAREC corridor countries in RVCs. This meticulous examination underscores the resilience of findings of this study across methodological variations, further reinforcing the significance of the CAREC corridor influence in shaping these economic interactions.

4. Conclusion

This study analyzed the efficiency of the CAREC transport corridors connecting transit ports along routes over 2010 to 2020. Analysis of the performance efficiency draws the following conclusions. Extant research on the application of DEA to estimate the efficiency of the CAREC transport corridors is non-existent. Therefore, this study has attempted to fill this knowledge gap. The application of DEA to measure transport corridor efficiency helps to rank efficient corridors with a target to offer policy options to improve ineffective transport corridors. The study also establishes the origins of inefficiencies such as larger transportation costs/transaction costs/travel time and offers policy recommendations for enhancing the efficiency of the CAREC transport corridors. The study draws significant policy implications to strengthen and foster the performance efficiencies of the CAREC transport corridors for policymakers and regional transport institutions working to develop and implement transport corridor strategies. This study of the participation of countries in RVCs contributes to knowledge about the significance of the CAREC corridors in enhancing the participation of CAREC corridor countries in RVCs. Analysis reveals the significance of the development of the CAREC corridors and draws the following implications. This is significant to encourage the countries to vigorously contribute to the development of the CAREC corridors and dynamically integrate into RVCs drawing on their own profuse resources. The CAREC corridor countries along the routes should nurture the penetrable and management capability on infrastructure investment to guarantee that their investments will successfully foster RVC participation.

5. Policy recommendations

5.1. Improving the efficiency of CAREC transport corridors

The efficient CAREC transport corridors have stronger execution of both the soft infrastructure and hard infrastructure than the others. The lagging CAREC transport corridors should initiate holistic reforms of their transportation systems for better performance efficiency. Attaining higher performance and better efficiency of the CAREC transport corridors and transit infrastructures entails tackling not only the physical barriers to trade, but also the administrative barriers. Border-clearance procedures, and the required customs and official documents should be simple, translucent, and harmonized. Novel digital technologies, trade facilitation, and modern customs clearance processes can be instituted with moderate investment to bolster soft infrastructure, which has immense potential to bestow a considerable reduction in transit transport costs and trade transit times. The collaborative engagement in institutional restructuring is needed to remove inefficient trade transit and customs processes for smoother border clearance. Capacity building of the relevant functionaries in novel customs and legal practices, and shared digital skills are imperative. In this context, regional cooperation in evolving a compatible transportation system for shared benefits cannot be overemphasized.

The following corridor-wise recommendations should be implemented to improve the efficiency of the comparatively inefficient CAREC corridors.

Corridor 1: The efficiency of customs clearance should be improved to reduce traffic disruption and delays at transit points caused by the physical verification of trucks, which requires a truck scanner system to enable smooth checking. The road cargo costs along the high-density Urumqi–Almaty route should be reduced to match the low road cargo charges at Corridor 4 along the PRC–XUAR route. Containerization in multimodal transport should be implemented to improve operational efficiency, which entails regulatory reforms. The viability of e-carriage of goods by road (e-CMR) should be explored and implemented, which requires digitalization and compatible laws and regulations. Both hard and soft infrastructure need to be developed and strengthened, which requires the capacity building of both technical and logistics manpower.

Corridor 2: Ambiguous transit practices along Corridor 2 require transparent consignment rules and fees through an official arrangement. The hazard of illegal cross-border trade from Afghanistan causes delays at customs clearance, which should be tackled by instituting the scheme of authorized economic operator (AEO) to shorten time at transit points. Green lanes should be developed to enable the trucks of the firms under AEO to transit border points without delay. Cargos should be given precedence over passenger vehicles to lower transit time at border transit points. High cargo traffic transit points should be made operational without any halt in functioning to lower the transit time at border clearance points.

Corridor 3: The common customs management along the border clearance point should be established to reduce delays incurred by stopping at a neutral region. Alternative shorter routes with improved hard and soft infrastructures should be developed from Georgia to Tajikistan via Turkmenistan, instead of Kazakhstan, to achieve cost-efficiency and lower time at transit clearance. Georgia should develop novel transit agreements focusing on lower transit charges with Tajikistan to achieve a cost-efficient transit as the current transit fee is substantially higher compared to that of a consignment from the Kyrgyz Republic and Uzbekistan at similar transit points. The Kyrgyz Republic needs substantial investment in cold chain development for steady exports of agricultural and horticultural products during all seasons and efficient transportation. Uzbekistan has magnetized substantial transit cargos, which caused delays at border-crossing points. Therefore, reducing time at border-crossing points requires digital scanners to be set up for accelerated scrutiny of consignments, an increase in the number of entrance roads to border-crossing points, and the speedy passing of consignment-designated green lanes.

Corridor 4: The customs clearance procedures along the Mongolia–PRC transit points should be improved to minimize delays for perishable items.

Corridor 5: Pakistan should execute a single window system for Afghanistan cargo to reducethe halt time at seaports. The reciprocal AEO scheme should be implemented by Pakistan to enhance the efficiency of transit trade with other corridor countries. International road transport (TIR) parks should be established along heavy traffic border-crossing points to lessen delays. Switching to rail transport can lower transport cost and increase the value of agricultural exports.

Corridor 6: In Tajikistan, the customs guide for TIR consignments should be substituted by digital technologies such as GPS to lower transit cost significantly. Digital stamping and smart scanners should be implemented to manage the transit of illegal consignments and reduce delays at border transit points. Tajikistan should allocate green lanes and the AEO scheme for Afghanistan's agriculture and horticulture consignments to lessen transit time at border-crossings. Turkmenistan should improve the technical and managerial capabilities of officials in modern logistics including supply chains and cold chains across transport modes to lower trade cost. Both hard and soft infrastructures at border-crossing points between Turkmenistan and Uzbekistan should be modernized and strengthened to reduce delays. A reciprocal AEO scheme should be implemented between bordering countries. Tajikistan and Uzbekistan need to develop cold chains for the cost-effective mobility of agricultural and horticultural products to enable them to maintain reliable exports.

5.2. Bolstering the participation in RVCs

There are considerable hurdles to be overcome to increase intraregional trade in the CAREC region and the development of RVCs. Industrial policy should be reoriented to boost industrialization in the CAREC countries and tap the potential of domestic manufacturing for greater intraregional trade flows. Increased domestic manufacturing will generate immense gains for local economies. Industrial policy should leverage a contemporary and prospective specialization which an individual country dominates or can potentially develop. This specialization can guarantee that the economy is cost competitive and/or production competitive in a regional and global context owing to strength of resources, technology, skills, workforce, or commendatory industrial strategies that support manufacturing in specific fields. Recognizing and exploiting this specialization can help economies to build specific practical plans for exports.

The CAREC countries can manufacture a broad range of modern products because they have a wide variety of specialized technical knowledge and skills. Greater intricacy in manufacturing generally embraces big value incorporation, which facilitates economies to seize higher manufacturing gains through value chain participation. Moreover, a surge in export products and export diversification can help countries enhance their trade potential with other regional economies. Increased export diversity and greater varieties of manufactured goods also significantly protect firms from distress in certain markets owing to price variations. Besides public investment in the development of industrial infrastructure, private investment including FDI should be considerably magnetized for industrial development.

Regional policy collaboration should be bolstered to accelerate intraregional trade and RVCs by amalgamating relative economic gains among CAREC member countries and increasing expertise in specific components of RVCs for particular goods. Robust trade policy can enhance intraregional trade, bolster RVCs, and generate economic growth and prosperity in the CAREC member countries. Redesigning the rules of origin can bolster regional trade integration hugely by influencing the preference of intermediate goods applied to manufacture goods. Regional economic cooperation can reduce tariffs for greater interregional trade; however, RVC integration entails manufacturing across the CAREC member countries. The non-tariff measures (NTMs) can avoid unfair trade practices; however, NTMs should not be applied as a protection measure, which hampers imports. There is a need to foster homogeneous standards and documentation across the CAREC region for better compliance. NTMs should also be strictly implemented to avoid their application as tariff barriers. Last, but not the least, the CAREC transport corridor organizations must downsize operational costs to enhance the value of facilities provided by the corridors and realize the necessity of functioning corridor efficiency by lowering transport costs and travel time. The bolstering of regional transport and trade infrastructure are essential to boost intraregional trade and RVCs in CAREC member countries. There is a need to simplify and establish complementary customs procedures, apply digital technologies, robust trade facilitation measures through suitable investors to achieve lower transit times and transport costs. In brief, the CAREC economies should renovate manufacturing and acquire suitable export and investment opportunities. New technologies are calling for manufacturing and RVCs to be transformed. In future, value chains are expected to be regional, which entails firms to relocate their manufacturing closer to demand and increasingly espouse digital technologies. Therefore, the capacity building of logistics and trade professionals should be implemented to foster stronger integration of firms into RVCs.

6. Limitations and future research direction

This study encapsulates the efficiency of the CAREC corridors confined to road transport and export only. In future research, analysis of CAREC corridor efficiency should focus on road and rail transport as well as exports and imports. The effective use of DEA entails adherence to certain stipulations. DEA does not assume a functional form linking inputs and outputs; however, DEA also has certain drawbacks. It offers results that are notably susceptible to estimation error, captures efficiency compared to best performance in a particular instance, and may not be applied to measure performance across different situations. DEA captures the comparative efficiency of a DMU and moves very slowly towards absolute efficiency. In DEA, every efficient DMU is allocated a similar mark (1.00), which helps to avoid subsequent ranking. This study used the adjusted DEA technique suggested by Andersen and Petersen (1993) to rank the best performing corridor with a score of 1.00 and super-efficiency score above 1.00. There are two major limitations in using DID and PSM in this research: this study has used a few country features as key explanatory variables; therefore, DID has not accounted for additional probable factors. Lastly, the different data sources used in this study have some missing values.

Economic development in CAREC corridor economies is considerably heterogeneous, which can have a significant impact on RVC participation. Therefore, future research should focus on more variables and derive more robust and rich data. New disruptions such as COVID-19 and the Russia-Ukraine conflict offer considerable opportunities to the CAREC member countries to participate in RVCs, which need to be explored in future research. Future research can explore how reforms in CAREC transport corridors lower trade transit costs and facilitate transformation of the CAREC transport corridors to economic corridors to tap the novel trade opportunities that have emerged in the Eurasian countries.

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