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Article

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Cogent Economics & Finance

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Suggested Citation: Bastanifar, Iman; Omid, Ali; Khan, Kashif Hasan (2024) : A recursive networking economic analysis of international economic corridors: IMEEC and INSTC, Cogent Economics & Finance, ISSN 2332-2039, Taylor & Francis, Abingdon, Vol. 12, Iss. 1, pp. 1-18, <https://doi.org/10.1080/23322039.2024.2363457>

This Version is available at:

<https://hdl.handle.net/10419/321505>

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To cite this article: Iman Bastanifar, Ali Omid & Kashif Hasan Khan (2024) A recursive networking economic analysis of international economic corridors: IMEEC and INSTC, Cogent Economics & Finance, 12:1, 2363457, DOI: [10.1080/23322039.2024.2363457](https://doi.org/10.1080/23322039.2024.2363457)

To link to this article: <https://doi.org/10.1080/23322039.2024.2363457>



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Published online: 26 Jun 2024.



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A recursive networking economic analysis of international economic corridors: IMEEC and INSTC

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ABSTRACT

The expansion of the International North-South Transport Corridor (INSTC) and the introduction of the India-Middle East-Europe Economic Corridor (IMEEC) are of great significance in terms of both politics and trade. This article aims to analyze the methodological shortcomings of traditional models and suggests a new model to evaluate the potential trade benefits of these corridors. The study discusses the reasoning for combining recursive analysis with GIS-network analysis in the logistical planning of international corridors. The authors have used a shopping time model that integrates distance and political risk index (PRI). They have then employed dynamic programming to assess and compare the changing opportunity cost (OPC) of retaining money. The findings suggest that the development of these corridors would provide differing degrees of benefits to different nations, with India being the country that would earn the greatest advantage by joining the IMEEC. Nevertheless, Iran enjoys the most significant benefits in comparison to other members of the INSTC. India stands to benefit somewhat more from its participation in the INSTC compared to the IMEEC.

IMPACT STATEMENT

This study offers a pioneering analysis of the economic effects of international trade routes, with a specific emphasis on the India-Middle East-Europe Economic Corridor (IMEEC) and the International North-South Transport Corridor (INSTC). The research proposes a novel approach that combines recursive dynamic programming with network planning. It introduces a new value function that aims to maximise the expected discounted value of future utility for corridor members. This new function considers trade distance and improves upon the traditional model of opportunity cost of holding money. Empirical study provides compelling evidence of the considerable advantages that member nations, namely Iran, Azerbaijan, Russia, and India, experience as a result of the INSTC and IMEEC. Specifically, the INSTC effectively mitigates macroeconomic volatility for Iran, Azerbaijan, and Russia, while the IMEEC offers huge benefits for India. The results emphasise the significance of trade corridors in promoting economic stability, offering policymakers a fresh standard for evaluating the cost-effectiveness and economic advantages of international trade infrastructure investments. Furthermore, the incorporation of a flexible shopping time model emphasises the influence of the duration of transactions on the potential loss of benefits from keeping money, providing a thorough comprehension of how the distance of trade impacts economic well-being. This research has significant implications for international economic policy and infrastructure development. It provides guidance to policymakers on how to optimise trade routes and improve economic stability. Additionally, it paves the way for future research in recursive economic modelling, which aims to develop strong economic policies in a globally interconnected market.

ARTICLE HISTORY

Received 13 February 2024

Revised 9 May 2024

Accepted 29 May 2024

KEYWORDS

Recursive; networking; shopping time; economic corridors; INSTC; IMEEC

JEL

C61, E43, R42

REVIEWING EDITOR

Goodness Aye, University of Agriculture, Makurdi Benue State, Nigeria

SUBJECTS

Econometrics; Development Economics; Political Economy

1. Introduction

Domestic and international transportation infrastructure plays a pivotal role in driving economic growth and development. According to the export-led growth theory, export and import activities, based on

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comparative advantages, are critical factors for a country's economic prosperity (Quium, 2019). Nowadays, countries around the world strive to improve goods movement and facilitate trade by establishing international commercial corridors. These corridors encompass various transportation modes, including sea, rail and road, to promote the seamless movement of cargo. Transportation corridors, by furnishing reliable and efficient services, have played a crucial role in facilitating the transfer and movement of diverse loads. This, in turn, stimulates economic development and attracts investment across different regions (Saidi et al., 2020). The primary objective behind establishing international trade corridors is to connect production and consumption centers within and between different countries. Economic corridors further enhance industrial and commercial infrastructure by creating industrial and construction clusters, thereby attracting investment and fostering regional economic development. In the era of globalization, corridors have evolved into fundamental cornerstones of regional economic integration (Kuroda et al., 2007) and exert both direct and indirect impacts on well-being (Venables, 2007).

Over the past two decades, two international routes have garnered significant global recognition: the International North-South Transport Corridor (INSTC) and the India-Middle East-Europe Economic Corridor (IMEEC). INSTC (refer to Figure 1) constitutes a comprehensive transportation network spanning approximately 7200 km (4500 miles), incorporating shipping, rail and road routes. Its primary objective is to facilitate the efficient movement of goods between India, Iran, Azerbaijan, Russia, Central Asia and Europe (Khan & Koch, 2024). The corridor is designed to cater to the transportation of goods from India, Iran, Azerbaijan and the Russian Federation *via* ships, railways and roads. Its overarching goal is to bolster trade connectivity among key cities such as Mumbai, Moscow, Tehran, Baku, Bandar Abbas, Astrakhan and Bandar Anzali.

In September 2023, in India, the G-20 meeting introduced the proposal for the IMEEC (Figure 2). This corridor aims to improve connectivity and promote economic integration between Asia, the Persian Gulf and Europe. The envisioned route would stretch from India to Europe, passing through the United Arab Emirates, Saudi Arabia, Jordan, Israel and Greece. IMEEC's primary goal is to boost economic development by facilitating trade and connectivity across these regions.

The main objective of this analysis is to demonstrate the various possible advantages for each country involved in these corridors, taking into account the escalating political tensions in the Middle East caused by the Israel-Gaza and Russia-Ukraine conflicts. The ongoing conflict between Russia and Ukraine

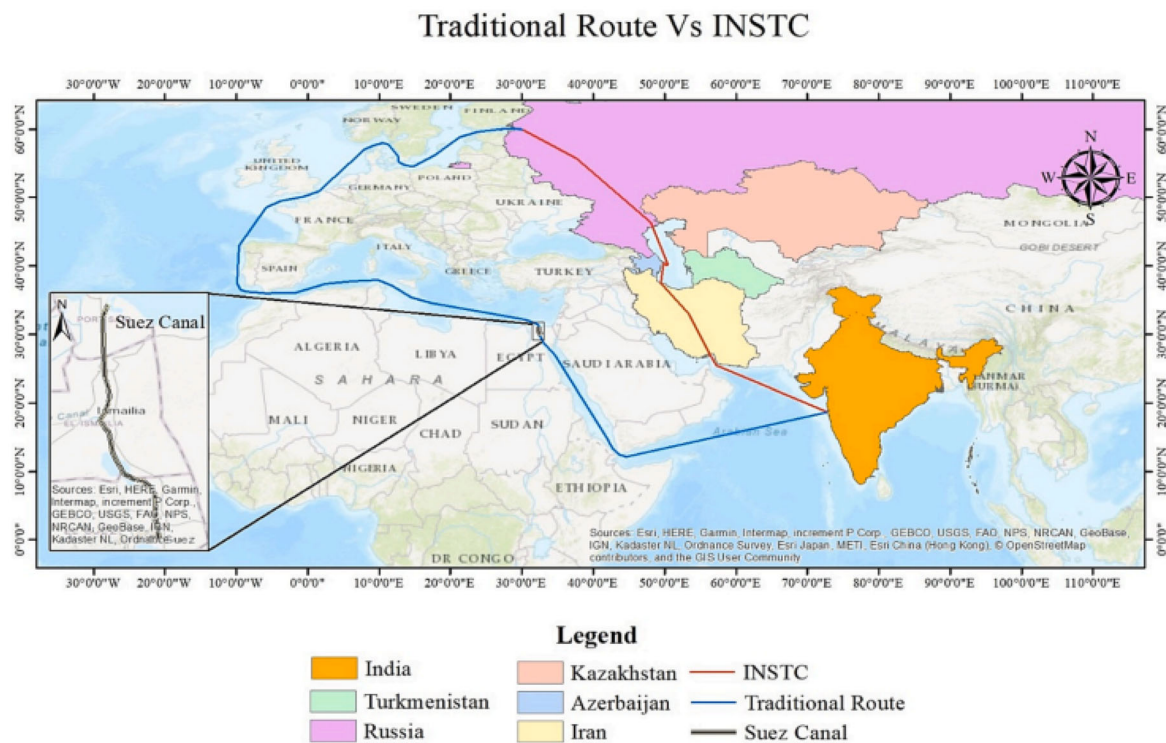


Figure 1. Traditional Sea Route (*via* Suez Canal) vs. INSTC Route (*via* Chabahar Port in Iran). Source: Khan et al. (2023).

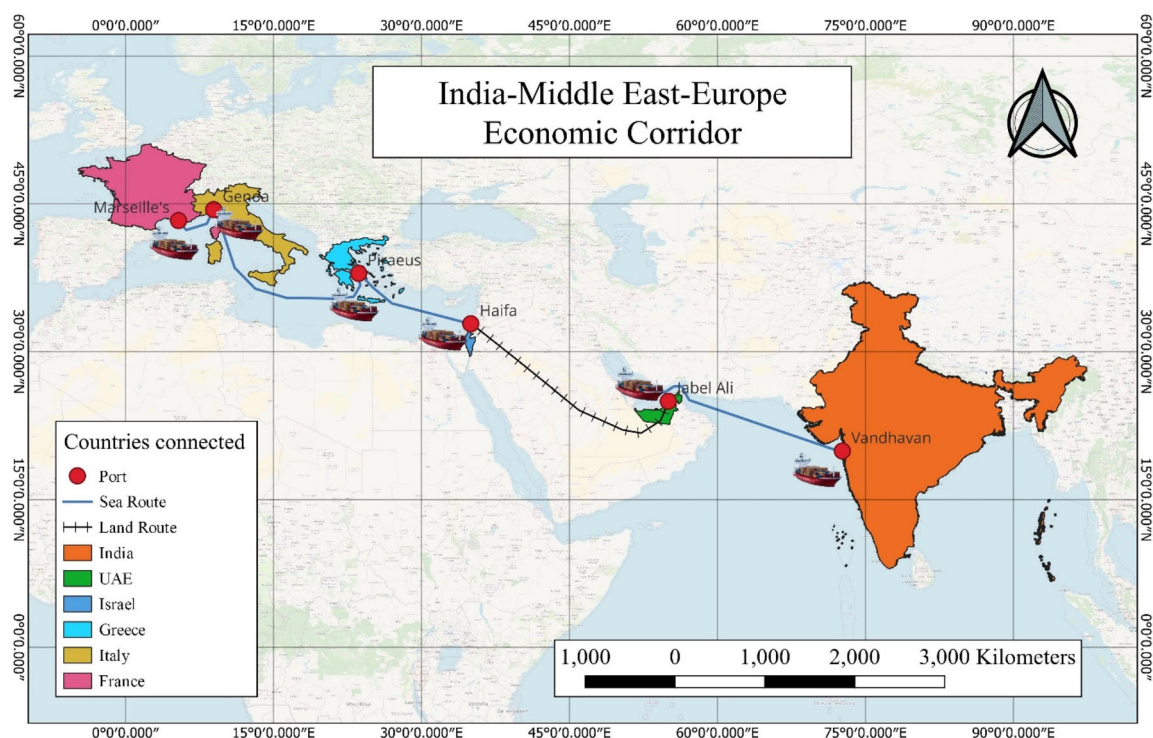


Figure 2. The India-Middle East Europe Economic Corridor (IMEEC).

Source: Khan *et al.* (2024).

has significant implications for the INSTC, while the Israel-Gaza conflict has a direct influence on the IMEEC. The presence of these tensions will heighten the likelihood of establishing the corridors. Consequently, the countries' political vulnerabilities have not been overlooked.

The political risk index (PRI) provides an overall measure of risk for a specific country, taking into account 17 risk components such as turmoil, financial transfers, direct investment and export markets (<https://worldpopulationreview.com/country-rankings/political-risk-index-by-country>).

Despite the political risk, conventional methods of analyzing the economic corridors have some problems. Traditional methods employ two distinct approaches. First, some authors, including Emadzadeh *et al.* (2007), Kunaka and Carruthers (2014), and Nasir *et al.* (2016), have utilized Cost-Benefit analysis to estimate and examine the impact of establishing a corridor. Second, several studies employ the gravity model (GM), as demonstrated in Bergstrand (2019), or GM in conjunction with geographical information system (GIS) analysts, as seen in Stanojevic and Jovancai (2015), Onifade *et al.* (2021) and Jamagidze (2022), to analyze the economic impact of corridors. Many of these studies use econometric methods such as time series or panel data in GMs without addressing the Lucas (1976), which emphasizes the influence of changes in economic policy on individuals' behavior.

Furthermore, these kinds of studies should address the issue of time inconsistency in an optimal plan. The time inconsistency problem posits that agents have varying preferences over time, and the decision maker's expectations are a crucial variable influencing present decisions. Consequently, techniques relying on past information, such as optimal control, may be inadequate for analyzing the impact of economic policies (Tabellini, 2005). In addressing those methodological drawbacks, the recursive approach known as "Recursive Macroeconomic Theory" was introduced in 2000 by Nobel laureate Thomas Sargent. According to the recursive approach, time allows for breaking down a dynamic problem into two parts: choosing between utility today and tomorrow. The core idea is to develop a method that describes the current state of a system or project and predicts its future state. This method contrasts with optimization techniques or econometric time series, which analyze the behavior of a decision-maker using past information (Ljungqvist & Sargent, 2018). Pioneers in the application of recursive methods to solve problems in macro and monetary economics include Stokey *et al.* (1989).

The main macroeconomic and monetary function that utilizing the recursive method is the examination of the welfare cost of inflation, as outlined by Robert Lucas (2000). He emphasized the role of the opportunity

cost (OPC) of holding money or the welfare cost of inflation as a crucial macroeconomic criterion for the decision-making rules of a social planner. According to the welfare cost of inflation criterion, a reduction in the OPC of holding money results in a decrease in inflation and an increase in social welfare. Robert Lucas (2000) posited that the interest rate solely influences the OPC of holding money, but recent studies (Cao et al., 2021) contradict this by finding that variables such as age can also influence the welfare cost of inflation.

Therefore, this article's investigation of the impact of distance on the welfare cost of inflation, using the recursive dynamic programming method for corridor economic analysis, is feasible. The authors employ a new value function aimed at maximizing the expected discounted value of future utility for the members of IMEEC and INSTC. Additionally, the authors consider the role of trade distance as a variable to illustrate the impact of corridors on the welfare of their members. Theoretically, distance influences transaction time. A dynamic shopping time model is implemented to illustrate how distance affects the expected discounted value of future utility for IMEEC and INSTC members. The shopping time model is used to calculate OPC of holding money when the time of trade is important. This article uses the shopping time model to calculate OPC, taking into account both trade distance and political risk.

Empirically, the authors have integrated network planning into a dynamic shopping time model to calculate trade distances among countries. By solving the new value function, the authors have established a novel criterion for analyzing the OPC of holding money, differing from the one utilized by Robert in 2000. Furthermore, the authors demonstrate how this criterion is employed to assess the cost-effectiveness of IMEEC and INSTC. Accordingly, this study delves into the OPC of holding money when distance is a factor in trades, utilizing a recursive networking model, and seeks to determine which IMEEC and INSTC member countries will experience greater advantages by being part of the IMEEC and INSTC corridors.

2. IMEEC and INSTC: History and importance

The INSTC is a 7200-km (4500 mile) multi-mode network comprising ship, rail, and road routes designed for freight transportation between India, Iran, Azerbaijan, Russia, Central Asia and Europe. Iran, India and Russia formally signed the INSTC in St. Petersburg on 16 May 2002, establishing it as a new trade corridor to strengthen economic ties between India, Central Asia and Eastern Europe. The corridor's objective is to link the container port east of Mumbai in India, traverse Iran's Chabahar and Anzali ports, proceed to Azerbaijan's Astara Khan, and culminate in Russia's Saint Petersburg. The strategic significance of Chabahar port has grown due to India's efforts to circumvent Pakistan's Gwadar port. Additionally, the rivalry between India and China, both emerging Asian powers, to establish connections with Central Asia, Russia, and Europe's markets underscores the North-South corridor's importance. Compared to alternative routes, a significant advantage of this corridor is its ability to reduce distance by 40% and transportation costs by 30% compared to the Suez Canal (Noorali and Ahmadi, 2022).

India's investment in Chabahar and its successful exemptions from U.S. sanctions during the Trump administration underscore the corridor's importance for emerging global economic powers. The completion of this project would significantly enhance Iran's geopolitical position, addressing one of its weaknesses: the lack of deep ports. Traditional southern ports like Bandar Abbas cannot accommodate ships of 250,000 tonnes, making the development of Chabahar's ocean port symbolically significant for both Iran and India.

The North-South corridor consists of three branches: the western branch, which passes through the Rasht-Astara route; the eastern branch, which enters Iran from Kazakhstan and Turkmenistan; and the central branch, which traverses the Caspian Sea. The eastern branch of this Corridor has been operational since October 2022. The central branch connects the beneficiary countries, particularly Russia, through Iranian ports in the Caspian Sea, notably Anzali. The western branch, which will be activated with the launch of the Rasht-Astara railway, passes through the Republic of Azerbaijan and from there, to Russia. In early 2023, Moscow and Tehran signed an agreement to expedite the construction of the railway, with Russia providing 1.6 billion euros (\$1.75 billion) in financing for its completion within 48 months (Sabena, 2023). While this Corridor's three central founding countries recognize its strategic importance and its symbolic impact on the entire region, more practical action must be taken to activate it. Since 2018, the Chabahar port development project, which aims to connect India to Russia, Afghanistan, and Central Asia by sea and rail, has remained suspended. The appointed operator of Chabahar port, 'India Global Ports', has been unable to deliver the project due to US sanctions against Iran. The Russian government now believes it is necessary to address the logistical problems caused by the

sanctions imposed by the West following the Russia-Ukraine war in 2022. As a result, it is eager to strengthen transportation cooperation with China, India, Southeast Asia and the Persian Gulf. Therefore, the operationalization of the INSTC holds significant strategic importance for Russia (Evgeny *et al.*, 2022).

While the North-South Corridor project is still in progress, India is also assuming leadership in another corridor known as IMEEC. On the sidelines of the Group of 20 meeting in September 2023 in India, US President Joe Biden announced the launch of the IMEEC a burgeoning multifaceted commercial route, holds promise in altering trade dynamics among the Indian Ocean region, the Middle East and Europe by forging trading connections along Eurasia's southern periphery. This emerging interconnectedness signifies a strategic pivot for India, with substantial geopolitical ramifications potentially altering its position within the Eurasian economic framework. IMEEC seeks to establish a railway network linking the UAE and Israel, traversing through Saudi Arabia and Jordan. Consequently, Israel's Haifa port would be tasked with facilitating the transit of Indian merchandise to European nations (Khan *et al.*, 2024). Biden said it was a 'real big deal' that would bridge ports across two continents and lead to a 'more stable, more prosperous and integrated Middle East'. He emphasized that it would unlock 'endless opportunities' for clean energy, clean electricity and laying cable to connect communities (TRT World, 2023). According to estimates, utilizing the IMEEC route could reduce travel time from Mumbai to Europe by 40% compared to the Suez Canal, leading to a 30% cost reduction (Ahmed, 2023).

By supporting India's relationship with the West through funding from the UAE and Saudi Arabia, Washington aims to undermine India's ties with China and Russia in the Shanghai Cooperation Organization (SCO) and Brazil, Russia, India, China and South Africa (BRICS). Additionally, it seeks to counter China's One Belt and One Road initiative by promoting India's advancement and replacing India's European exports with those from China. With a trade volume of \$709 billion, China has emerged as the European Union's largest trading partner, surpassing the value of \$671 billion in trade between Europe and the United States in 2020 (BBC News, 2021). While the US aims to reassure its traditional Arab partners about its continued presence in the region, energy-rich Gulf countries are adjusting their global relations with emerging powers, potentially to the detriment of Washington. China's increasing influence coincides with India's economic struggle to establish stable partnerships in the Middle East and Europe, making this competition appealing to the US, which favors India in this emerging rivalry.

The two corridors are similar in that India is one of their partners. Both corridors avoid crossing the Bab El-Mandeb Strait, the Red Sea and the Suez Canal. In addition, both corridors have strategic political goals. The North-South Corridor facilitates India's access to Central Asia, the markets of Iran, the Caucasus, and Russia. INSTC plays a vital role in the Russian economy in the current situation where the West is isolating Russia. At the same time, India can play a balancing role against the Chinese BRI Corridor. However, the IMEEC is more relevant for Washington's strategic goals in the Middle East and containing China. Therefore, it is imperative to compare these two corridors in order to evaluate their probable trade payoffs.

3. Literature review

The preceding section makes it evident that corridors offer tangible benefits. However, because economics is the science of allocating resources to unlimited needs, a project stakeholder must employ methods capable of effectively assessing the economic justification of a project and comparing it with alternative options. Notably, there are some issues with the economic analysis methods applied to international corridors. Cost-benefit analysis, a fundamental method in engineering economics for cost-effectiveness analysis, integrates the time value of money and cash flows to evaluate the economic value of an activity (Blank & Antony, 2012). This method requires summing up all expected costs and revenues within a specific time frame to establish a decision rule for accepting or rejecting a project. While this provides managers with information about the details of costs and revenues, it falls short in illustrating the interplay among critical factors such as the interest rate, OPC of holding money, distance, trade costs and time. These factors are essential in determining the monetary value of costs and benefits. Studies like David *et al.* (2018) observe that this limitation continues even when other social and environmental factors are considered.

Another area of study is the application of the GM, which systematically incorporates distance influence into its methodology. For instance, Cai (2021) employed the doubly constrained GM (DCGM) to estimate destination matrices of interregional trade, utilizing maximum entropy principles and

parameters established by Wilson in 1967 and 1970. Khan *et al.* (2023), Azmi *et al.* (2024) and Khan *et al.* (2024) investigated trade potentials between India and Caspian countries, as well as among India and member countries of the INSTC and the IMEEC, employing a combination of GIS and the GM. Notably, no comparative study between IMEEC and INSTC has been conducted thus far. Furthermore, these studies primarily focus on delineating distance and other variables. Consequently, while these variables' parameters elucidate past events, they may not be suitable for informing future social policy, thus raising concerns regarding Lucas's critique (1976) and the issue of time inconsistency in planning.

Additionally, GMs in econometric analysis typically lack derivation from an optimality process. Recursive theory, a mathematical optimization approach characterized by time-invariant equilibrium decision rules that determine actions based on a limited set of variables, offers a promising alternative. Not only does it enable comprehensive analysis of all economic risks and uncertainties, but it also facilitates the examination of a social planner's present and future policies. Recursive theory has been further developed in macroeconomics by Lars and Sargent in 2018 in their book titled 'Recursive Macroeconomics'. Various recursive models are utilized to address theoretical inquiries across diverse economic fields, such as monetary and financial economics, economic growth and labor economics. However, there exists a notable gap in bridging networking and recursive modeling within the realm of economics.

Furthermore, social criteria should be considered based on the optimality conditions extracted by recursive equilibriums to analyze the impact of a policy or an event. The OPC of holding money is a criterion based on the optimality condition. It can be used as a social criterion for analyzing the impact of a policy or event, such as establishing a corridor. This criterion is a measure of economic stability. The greater the OPC of holding money in an economy, the more significant the gap between investment and saving, and the more instability we experience.

Milton Friedman, in his book titled 'the optimum quantity of money and other essays' published in 1969 argued that the sole way to increase the social welfare of society is by bringing the interest rate down to zero, thereby reducing the OPC of holding money to zero (Walsh, 2017, p. 61). In the literature on the welfare cost of inflation, it is posited that a decrease in the OPC of holding money leads to a reduction in the cost of inflation (Lucas, 2000). Hence, a project stakeholder is urged to exert efforts to diminish the cost of inflation by lowering the OPC of holding money. While some studies have attempted to apply a recursive approach in spatial analysis, such as Jin *et al.* (2013) and Yoon *et al.* (2015), a study explicitly analyzing the effect of corridor distances using a recursive model has yet to be conducted. This study aims to fill this gap and stands as a pioneer in this endeavor. Logistics network planning (LNP), allowing any project stakeholders to make decisions about factors like locations, transportation modes and other amenities (Aura *et al.*, 2021), presents an opportunity to integrate a recursive approach into the analysis of dynamic economic corridors. This integration serves to mitigate Lucas's criticism and address the time inconsistency of an optimal plan.

4. Model

4.1. Recursive analysis

$$u(c, m, l) = v\{c, l\} \quad (1)$$

In a shopping time model, the utility function of a household relies on consumption (c) and leisure (l). The representation of leisure (l) is given by $l = 1 - n - n^s$, where n denotes the time spent in the market, and n^s signifies the time allocated to shopping or transactions (Walsh, 2017). Time is normalized to one. The shopping time is dependent on both consumption and money holding, and this relationship can be expressed as $n^s = g(c, m)$. It is assumed that this function increases with consumption and decreases with accurate money balances, which can be denoted as $g_c > 0$ and $g_m \leq 0$.

$$l_{tc} = [1 - n_t - n^{(c_s)}] \quad (2)$$

l_{tc} , is the leisure time, $n^{(c_s)}$ is shopping time.

The model was extended by integrating the distance factor into shopping time. The rationale is that as the distance in a trade increases, the corresponding cost in terms of money also rises. However, concerning shopping time, it is argued that distance (d) amplifies trade costs by extending

transaction or shopping time (g). This distance can be geographical, ideological, or cultural, all of which could elongate transaction time. Consequently, distance is introduced into the model to precisely account for its impact

$$n^{(c_s)} = d_t, g(c, m) \quad (3)$$

In the model, $d_t = \frac{\sum_{i,j=1}^n x_{ti} - x_{tj}}{\sum_{i,j=1}^n x_{i+j}}$, distance risk of transaction (DRT). x_{ti} and x_{tj} are two distance parts between two countries, such as ports or capitals and x_{i+j} is the distance aggregation of all countries involved in a special transaction environment, such as a corridor. Therefore, this index should be between zero and one. $0 < d < 1$ If $d = 1$, there is no partner for trade because the formula turns to $d_t = \frac{\sum_{i,j=1}^n x_{ti}}{\sum_{i=1}^n x_i}$. So, there is no corridor, indeed. If $d = 0$, no distance between countries is not a real factor in our world, as each trade has its own distance.

Since trade is influenced by political consideration, we should take in to account political risk of the trade. This will enhance the dynamics impacts of the corridors consider competing corridors and trade patterns.

In order to apply a metric assessing for the level of political risk, author applies PRI. This index is between zero and one and measures different components such Corruption, International Conflict and unrest and Environmental Factors by countries.

<https://worldpopulationreview.com/country-rankings/political-risk-index-by-country>

Since political considerations among countries impact the trade, this influence is demonstrated in Equation (6) by incorporating the PRI. In this paper the authors apply the absolute value of the difference in PRI (\overline{PRI}) between two countries in 2021.

According to Equation (6), it is assumed that any political considerations that heighten the political risk between two countries, also increase the time of trade, serving as a proxy for trade cost. Therefore, two countries with the highest score (one) and the lowest score (zero) on PRI, cannot engage in trade with each other. Therefore when \overline{PRI} equals to one, there is no economic corridor in this situation.

For example, if country imposes a sanction on another country or closes a certain routes of trade, it increases transaction cost. So, when \overline{PRI} increases (from zero to one), consequently, the cost of trade in the shape of time-distance-cost (TCD) increases.

Now, by replacing Eq. (3) in (2), the new leisure time is specified as follows in a utility function:

$$u(c, m, l) = v\{c, 1 - n - g(c, M)(d_t \overline{PRI}_t)\} \quad (4)$$

The shopping time model is now adjusted for DRT as well as PRI. The authors call this new version of the model, TCD.

Equation (4) indicates an intertemporal utility function. for a representative household

$$\sum_{j=0}^{\infty} \beta^j v[c_{t+j}, 1 - n_{t+j} - g(c_{t+j}, m_{t+j})d_t \overline{PRI}_t] \quad 0 \leq \beta \leq 1 \quad (5)$$

The discounting factor is shown by β indicates the time preference of a household, and c_t is time t per capita consumption.

Subject to:

$$A_t = \tau_t \cdot N_t + \frac{(1 + i_{(t-1)}^g)B_{(t-1)}^g}{P_t} + \frac{M_{(t-1)}}{P_t} \quad (6)$$

A_t is a non-human wealth. τ_t is transfer payment. B is total debt of a government. i_{t-1}^g is the government bond yield. P_t is the price index. M_{t-1} is a stock of international money. If there is a trade between two countries i_{t-1}^g is the weighted interest rate that is adjusted by real factors (such as the share of real gross product per capita (RGDP) of the two countries)

$$Y_t + (1 - \delta)K_{(t-1)} + A_t \geq C_t + K_t + \frac{M_t}{P_t} + \frac{B_t^g}{P_t} \quad (7)$$

Y_t is the aggregate production function. $Y_t = F(K_{t-1}, N_t, \theta_t)$.

K_{t-1} is the aggregate stock of Capital at the end of period $t-1$. N_t is population. θ_t is technology. $\tau_t N_t$ is the aggregate real value of any lump-sum transfers or taxes and, δ is the depreciation rate of

physical Capital. According to the assumption "H", $P_t = (1 + \pi_t)P_{t-1}$ and $N_t = (1 + n)N_{t-1}$. Dividing both sides of the budget constraint (6) and (7) by population (N_t).

$$\frac{A_t}{N_t} = a_t = \tau_t + \frac{(1 + i_{t-1}^g).B_{t-1}^G}{(1 + \pi_t)(1 + n)P_{t-1}.N_{t-1}} + \frac{M_{t-1}}{(1 + \pi_t)(1 + n)P_{t-1}.N_{t-1}} \quad (8)$$

Or

$$a_t = \tau_t + \frac{(1 + i_{t-1}^g).b_{t-1}^g}{(1 + \pi_t)(1 + n)} + \frac{m_{t-1}}{(1 + \pi_t)(1 + n)} \quad (9)$$

Now, the per capita budget constrain becomes:

$$y_t + \frac{(1 - \delta)}{(1 + n)}k_{t-1} + a_t \geq c_t + k_t + m_t + b_t^g \quad (10)$$

$W(a_t, k_{t-1})$ is the value function or ¹Bellman's equation

$$\begin{aligned} w(a_t, k_{t-1}) &= \max [v(c, 1 - n_t - g(c_t, m_t)d_t \overline{PRI}_t) + \beta E_t w(a_{t+1}, k_t)] \\ &= \max [vc, 1 - n_t - g(c_t, m_t)d_t \overline{PRI}_t] \\ &+ \beta E_t w \left[\tau_{t+1} + \left(\frac{(1 + i_t^g)b_t^g}{(1 + \pi_{t+1})(1 + n)} + \frac{m_t}{(1 + \pi_{t+1})(1 + n)} \right), \left(y_t + \frac{1 - \delta}{1 + n}k_{t-1} + a_t - c_t - m_t - b_t^g \right) \right] \end{aligned} \quad (11)$$

By deriving Equation (13) (Value function) in terms of d , it is determined that the final value of the change in distance is equal to the negative of the shopping time, $\frac{\partial W}{\partial d_t} = -g \cdot \overline{PRI}_t$. In other words, a one unit change in distance may result in a one unit increase or decrease in trade time, as it depends on the \overline{PRI}_t . This implies that any potential decrease in TCD (or risk of transaction time) relies on increasing society's wealth's marginal value through DRT changes.

If we eliminate k_t and a_{t+1} from the expression for the value function, the necessary first-order conditions for labor, consumption, actual money holdings, real bond holdings are obtained:

$$\begin{aligned} \frac{\partial W(a_t, k_{t-1})}{\partial n_t} &= \frac{\partial v}{\partial l_t} \cdot \frac{\partial l_t}{\partial n_t} + \beta E_t \frac{\partial W(a_{t+1}, k_{(t)})}{\partial k_t} \cdot \frac{\partial k_t}{\partial f} \frac{\partial f}{\partial n_t} = 0 \\ &\Rightarrow -v_l + \beta E_t \frac{\partial W(a_{t+1}, k_{(t)})}{\partial k_t} f_n = 0 \end{aligned} \quad (12)$$

$$\begin{aligned} \frac{\partial W(a_t, k_{t-1})}{\partial c_t} &= \frac{\partial v}{\partial c_t} + \frac{\partial v}{\partial l_t} \frac{\partial l}{\partial g} \frac{\partial g}{\partial c_t} d_t \overline{PRI}_t - \beta E_t \frac{\partial W(a_{t+1}, k_{(t)})}{\partial k_t} \cdot \frac{\partial k_t}{\partial c_t} = 0 \\ &\Rightarrow v_c - v_l g c d_t \overline{PRI}_t - \beta E_t \frac{\partial W(a_{t+1}, k_{(t)})}{\partial k_t} = 0 \end{aligned} \quad (13)$$

$$\begin{aligned} \frac{\partial W(a_t, k_{t-1})}{\partial m_t} &= \frac{\partial v}{\partial l_t} \frac{\partial l}{\partial g} \frac{\partial g}{\partial m_t} d_t \overline{PRI}_t + \beta E_t \left[\frac{\partial W(a_{t+1}, k_{(t)})}{\partial a_{t+1}} \frac{\partial a_{t+1}}{\partial m_t} + \frac{\partial W(a_{t+1}, k_{(t)})}{\partial k_t} \frac{\partial k_t}{\partial m_t} \right] = 0 \\ &\Rightarrow -v_l g m d_t \overline{PRI}_t + \beta E_t \left[\frac{\partial W(a_{t+1}, k_{(t)})}{\partial a_{t+1}} \frac{1}{(1 + \pi_{t+1})(1 + n)} - \frac{\partial W(a_{t+1}, k_{(t)})}{\partial k_t} \right] = 0 \end{aligned} \quad (14)$$

$$\begin{aligned} \frac{\partial W(a_t, k_{t-1})}{\partial b_t^g} &= \beta E_t \left[\frac{\partial W(a_{t+1}, k_{(t)})}{\partial a_{t+1}} \cdot \frac{\partial a_{t+1}}{\partial b_t^g} + \frac{\partial W(a_{t+1}, k_{(t)})}{\partial k_t} \cdot \frac{\partial k_t}{\partial b_t^g} \right] = 0 \\ &\Rightarrow \beta E_t \left[\frac{\partial W(a_{t+1}, k_{(t)})}{\partial a_{t+1}} \cdot \frac{1 + i_t^g}{(1 + \pi_{t+1})(1 + n)} - \frac{\partial W(a_{t+1}, k_{(t)})}{\partial k_t} \right] = 0 \end{aligned} \quad (15)$$

Removing $\frac{\partial W(a_{t+1}, k_{(t)})}{\partial a_{t+1}}$ in Equation (14) by (15), replacing $\beta E_t \frac{\partial W(a_{t+1}, k_{(t)})}{\partial k_t} = \frac{v_l}{f_n}$ finally, Equation (16) is extracted.

$$-g_m f_n = \frac{i_t^g}{1 + i_t^g} \frac{1}{d_t \overline{PRI}_t} \quad (16)$$

In a shopping time model, the left side represents the OPC of holding additional money, which serves as a social welfare criterion in a society. This cost is expressed as the ratio of the marginal utility of holding money to the marginal consumption of a representative household, equivalent to the OPC of holding money in the utility function (Dean, 1993). According to Equation (16), social welfare in a society would be optimal if the OPC of holding additional money became zero. As the DRT as well as PRI are important factors, it can demonstrate how network analysis can be utilized to calculate the DRT and PRI.

4.2. Network analysis in logistical strategic planning (IMEEC and INSTC)

Network analysis is a powerful GIS tool for analyzing transportation facilities and geographic connectivity. This tool allows the visualization and identification of geographic routes such as ports, railways, and highways (Jones et al., 2010; Black et al., 2004).

Figure 3 shows the basic information based on the Network analysis tool of GIS to calculate distance or DRT for IMEEC.

Figure 4 also shows the basic information based on the GIS network analysis tool to calculate distance or DRT for INSTC.

4.3. Data and parameters

To calculate Equation (18), we require the weighted interest rate i^g and the DRT. Table 1 provides the data sources and country abbreviations. The weighted RGDP is represented by i^g , which necessitates both the interest rate (i) and RGDP per capita. Table 1 presents the references for these variables. The interest rate values for each country are depicted in Figure 5, while the latest available data for RGDP per capita, based on constant 2011 US dollars, are for 2021. This information was obtained from the World Bank's website, and 2021 was the most recent year for which data was available.

Figure 5 displays the interest rates of various countries. The members of INSTC have higher interest rates than the members of IMEEC. Consequently, they face a greater OPC than the members of IMEEC.

Figure 6 indicates the PRI for members of INSTC and IMEEC. Generally, members of IMEEC have higher PRI than INSTC. Since countries with higher scores experience lower levels of risk, <https://world-populationreview.com/country-rankings/political-risk-index-by-country>) generally, based on PRI, IMEEC members politically are in better situation than the INSTC.

Based on the network analysis in the previous section, the port distance for members of IMEEC is calculated from Vadhavan port to Jebel Ali (Dubai), Haifa port (Israel), Piraeus harbor (Athens), Marseille's port (France) and the port of Genoa (Italy). For the members of INSTC, the capital distance between two countries is used as a measure of distance. Tables 2 and 3 provide information about the distance and how the Risk of Transaction (DRT) is calculated.

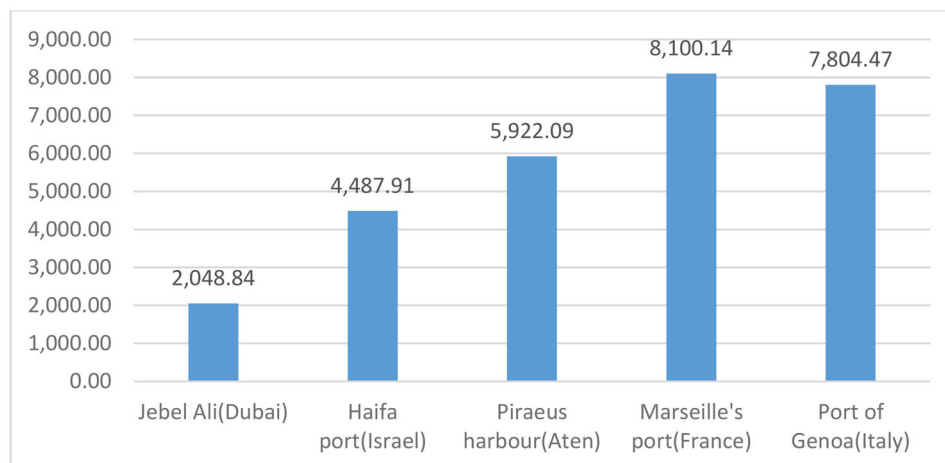


Figure 3. Distance from Vadhavan Port (KM).
Source: calculated by authors.

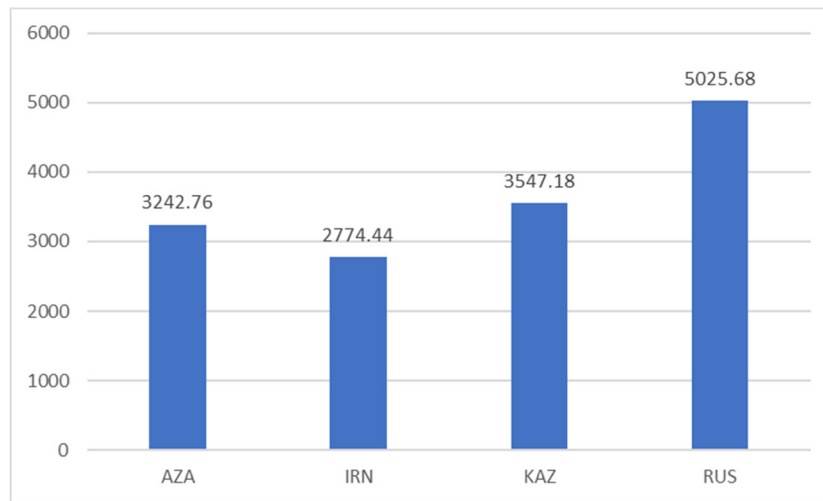


Figure 4. Distance (Mumbai to the Capital in km).

Source: Khan et al. (2023).

Table 1. Source of data.

Data and abbreviations	Reference
<i>i</i>	https://tradingeconomics.com/country-list/interest-rate .
Distance from Vadhaven port (km)	https://www.worldometers.info/geography/largest-countries-in-the-world/
Distance (Mumbai to the Capital in km)	Khan et al. (2023).
RGDP per Capita	https://wits.worldbank.org/CountryProfile/en/country/by-country/startyear/LTST/endyear/LTST/indicator/NY-GDP-PCAP-PP-KD
Azerbaijan = AZE	https://www.nationsonline.org/oneworld/country_code_list.htm
France = FRA	https://www.nationsonline.org/oneworld/country_code_list.htm
Greece = GRC	https://www.nationsonline.org/oneworld/country_code_list.htm
India = IND	https://www.nationsonline.org/oneworld/country_code_list.htm
Iran, Islamic Republic of = IRN	https://www.nationsonline.org/oneworld/country_code_list.htm
Israel = ISR	https://www.nationsonline.org/oneworld/country_code_list.htm
Italy = ITA	https://www.nationsonline.org/oneworld/country_code_list.htm
Kazakhstan = KAZ	https://www.nationsonline.org/oneworld/country_code_list.htm
Russian Federation = RUS	https://www.nationsonline.org/oneworld/country_code_list.htm
United Arab Emirates = UAE	https://www.nationsonline.org/oneworld/country_code_list.htm
Political Risk Index (PRI).	https://worldpopulationreview.com/country-rankings/political-risk-index-by-country
DRT = Distance Risk of Transaction	Authors
OPC = opportunity cost for holding additional money	Authors

Source: Prepared by Authors.

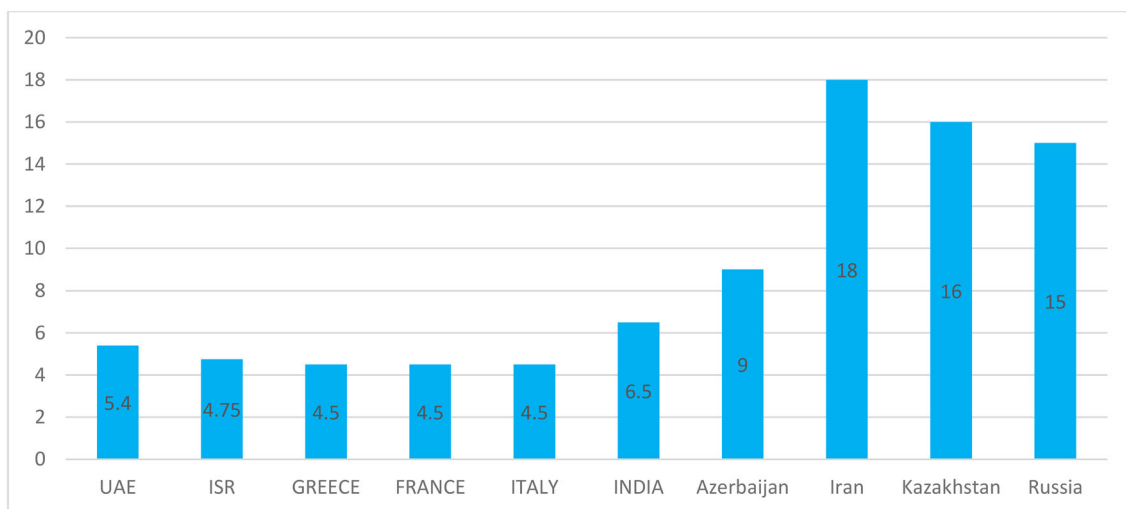


Figure 5. Interest rate of the countries in 2023.

Source: <https://tradingeconomics.com/country-list/interest-rate>.

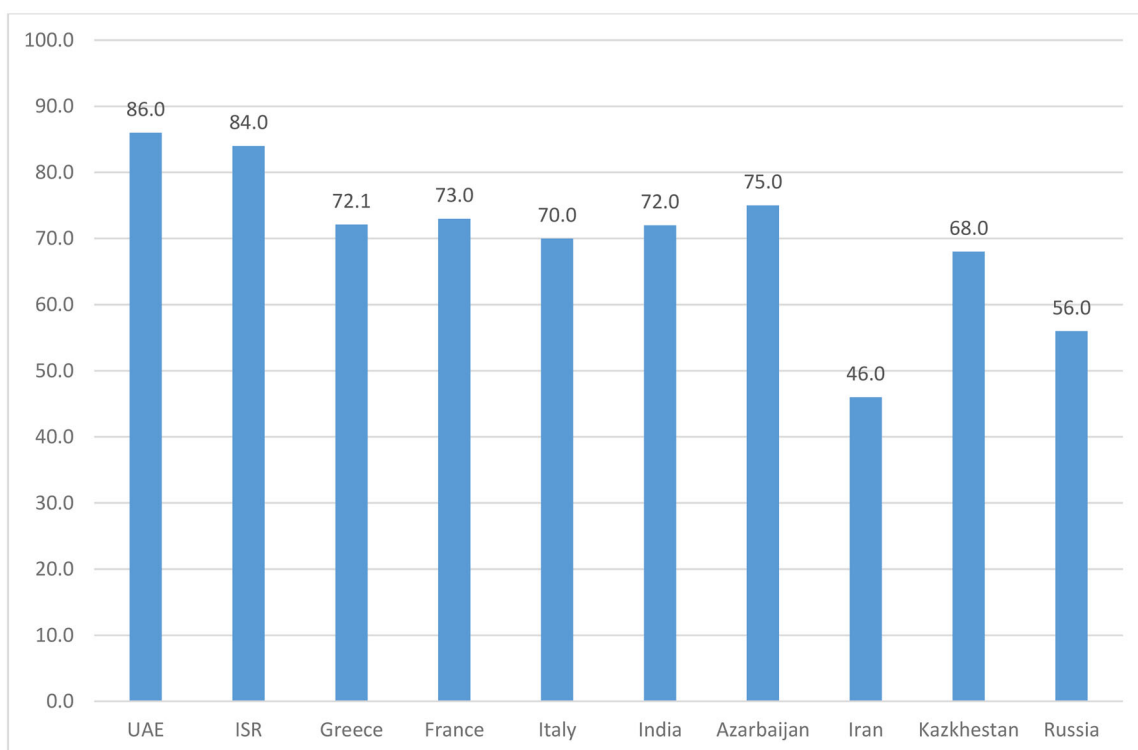


Figure 6. PRI.

Source: <https://worldpopulationreview.com/country-rankings/political-risk-index-by-country>).

Table 2. DRT and PRI for IMEEC countries.

Ports of IMMEC	Distance from Vadhavan port (km)	Port trade between two countries	DRT%	PRI _t %	$\frac{1}{d_t, PRI}$
Jebel Ali (Dubai)	2,048.84	IND-UAE	7.22	14.00	0.01
Haifa port (Israel)	4,487.91	IND-ISR	15.82	14.00	0.00
Piraeus harbor (Aten)	5,922.09	IND-GRC	20.88	0.10	0.48
Marseille's port (France)	8,100.14	IND-FRA	28.56	1.00	0.04
Port of Genoa (Italy)	7,804.47	IND-ITA	27.52	2.00	0.02
Vadhavan port (India)	0	UAE-ISR	8.6	2.00	0.06
Total	28,363.44	UAE-GRC	13.66	13.90	0.01
		UAE-FRA	21.33	13.00	0.00
		UAE-ITA	20.29	16.00	0.00
		ISR-GRC	5.06	11.90	0.02
		ISR-FRA	12.74	11.00	0.01
		ISR-ITA	11.69	14.00	0.01
		GRC-FRA	7.68	0.90	0.14
		GRC-ITA	6.64	2.10	0.07
		FRA-ITA	1.04	3.00	0.32

Source: Calculated by authors.

Table 3. DRT and PRI for INSTC countries.

Countries	Distance (Mumbai to the Capital in km)	Capital between two countries	DRT	PRI _t %	$\frac{1}{d_t, PRI}$
AZA	3242.76	IND-AZE	22.23	3.00	0.01
IRN	2774.44	IND-IRN	19.02	26.00	0.00
KAZ	3547.18	IND-KAZ	24.31	4.00	0.01
RUS	5025.68	IND-RUS	34.45	16.00	0.00
IND	0	AZA-IRN	3.21	29.00	0.01
Total	14,590.06	AZA-KAZ	2.09	7.00	0.07
		AZA-RUS	12.22	19.00	0.00
		KAZ-IRN	5.30	22.00	0.01
		KAZ-RUS	10.13	12.00	0.01
		IRN-RUS	15.43	10.00	0.01

Source: Calculated by authors.

Table 4. OPC before establishing the IMEEC.

Country	Interest rate%	OPC before IMEEC
UAE	0.054	0.051
ISR	0.0475	0.045
GRC	0.045	0.043
FRA	0.045	0.043
ITA	0.045	0.043
IND	0.065	0.061

Source: Author's calculations.

Table 5. OPC before establishing INSTC.

Country	Interest rate%	OPC before INSTC
AZA	0.09	0.08
IRN	0.18	0.15
KAZ	0.16	0.14
RUS	0.15	0.13
IND	0.065	0.061

Source: Author's calculations.

Table 2 shows how distance is used as a parameter for IMEEC countries. Each port in each country can facilitate trade between five countries. Therefore, there are different DRT for port trades between two countries. Some examples illustrate the risk calculation using the formula for DRT. For example, the DRT for UAE-ISR is the difference between the ports of Jebel Ali (Dubai) and Haifa port (Israel) divided by the 'Total'. Another example is for the IND-UAE. The DRT for IND-UAE is the difference between the ports of Jebel Ali (Dubai) and Vadhavan port (India) divided by the 'Total'.

Table (2) also indicates that the \overline{PRI}_t for each trade. For example, thanks to information in Figure 6, \overline{PRI}_t , which is the absolute value differences of PRI for trade between India and United Arab Emirates (IND-UAE), is 14%.

Table 3 illustrates how distance is utilized as a parameter for INSTC countries. Capitals in each country facilitate trade between four countries, resulting in different DRT values for capital trade between two countries. The calculation of the risk using the provided formula for DRT is demonstrated through some examples. For instance, the DRT for AZA-ISR is calculated by taking the difference between the Capital of AZA from Mumbai and the Capital of IRN from Mumbai, divided by the 'Total' value. Similarly, for the IND-AZE example, the DRT is determined by taking the difference between the Capital of AZA from Mumbai and the Capital of IND from Mumbai (which is zero in this case) and dividing it by the 'Total' value.

4.4. Results

In order to calculate the benefits of the members of the two corridors, OPC must be calculated before and after the construction of the two corridors. According to Equation (16), $\frac{\beta}{1+\beta}$, d_t and \overline{PRI}_t should be considered for calculation OPC before and after the construction of the two corridors. Since it was mentioned in the model section, if the two variables \overline{PRI}_t and d_t were equal to one, there would be no economic corridors, the optimal OPC before establishing a corridor for IMEEC and INSTC occurs when the DRT and \overline{PRI}_t is equal to one. Therefore, to calculate the OPC before the corridors, the expression $\frac{\beta}{1+\beta}$ from Equation (18) is required. The results of these calculations are presented in Tables 4 and 5.

Based on this criterion, it is evident that member countries of INSTC have a higher optimal OPC due to the higher interest rates they experience. Consequently, members of IMEEC experience greater economic well-being compared to members of INSTC.

Figure 7 indicates the OPC information among the members of the IMEEC and INSTC before establishing the corridors. It is crystal clear that members of the IMEEC experience fewer OPC than members of the INSTC.

In the following, the calculation method of OPC after the construction of the corridor is explained.

To calculate the OPC of countries after the establishment of corridors, we require the inverse value of the \overline{PRI}_t . DRT. The OPC after the corridors are built can be observed in Tables 6 and 7. In Tables 2 and 3, the DRT values as well as \overline{PRI}_t for port trade and capital distance between the two countries are

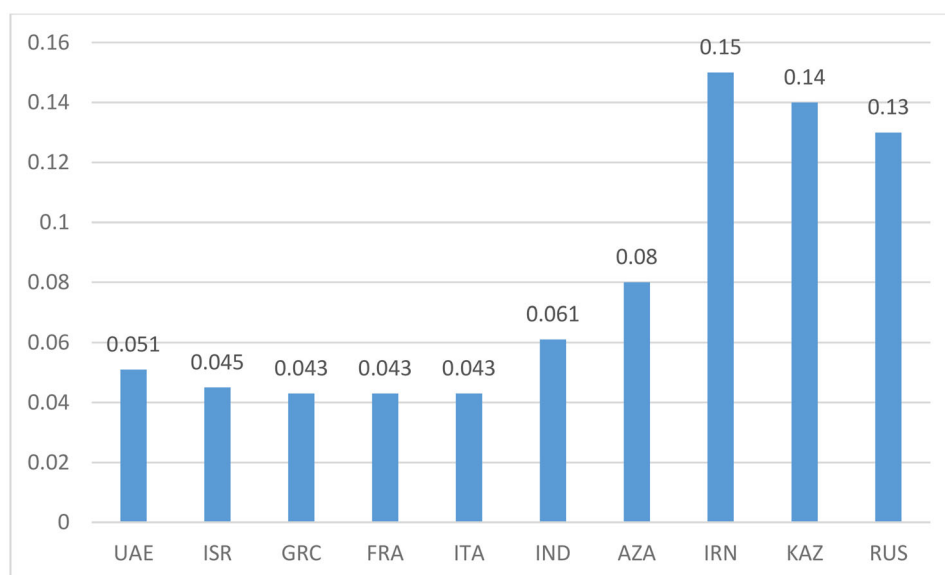


Figure 7. OPC of the members corridors before establishing.

Source: Calculated by authors.

Table 6. Weighted Interest after establishing the IMEEC.

Ports of IMMEC	Interest rate	RGDP per capita	% RGDP in Total Group	Trade by ports	weighted Interest rate(i^g)	$\frac{i^g}{1+i^g}$
UAE	0.054	69733.7938	0.30	IND-UAE	0.02	0.02
ISR	0.0475	42409.476	0.18	IND-ISR	0.01	0.01
GRC	0.045	29548.0389	0.13	IND-GRC	0.01	0.01
FRA	0.045	44993.1259	0.19	IND-FRA	0.01	0.01
ITA	0.045	42055.5424	0.18	IND-ITA	0.01	0.01
IND	0.065	6677.18503	0.03	UAE-ISR	0.02	0.02
Total	–	235417.162	1	UAE-GRC	0.02	0.02
				UAE-FRA	0.02	0.02
				UAE-ITA	0.02	0.02
				ISR-GRC	0.01	0.01
				ISR-FRA	0.02	0.02
				ISR-ITA	0.02	0.02
				GRC-FRA	0.01	0.01
				GRC-ITA	0.02	0.02
				FRA-ITA	0.02	0.02

Source: Author's calculations.

provided. To determine the interest rate for each column, the authors consider the impact of the Real Gross Domestic Product (RGDP) per capita of the two countries on each other. Let's take the example of IND-UAE. The authors aggregate the product of UAE's interest rate (0.054) with UAE's contribution to the total RGDP in the group (0.30). They also multiply the interest rate of IND (0.065) by IND's contribution to the total RGDP (0.03) in the group. As a result, the weighted interest rate (i^g) for IND-UAE becomes 0.02.

To calculate the columns of the optimal OPC of trade by ports and capital between two countries, the authors can multiply the column $\frac{i^g}{1+i^g}$ by the column \overline{PRI}_t . DRT. Table 7 provides the OPC by ports. If the authors wish to aggregate the related ports with a country, they would need to calculate the OPC after the corridor for each country. For example, to calculate the OPC for the UAE, the authors would integrate the OPC values for IND-UAE, UAE-ISR, UAE-GRC, UAE-FRA and UAE-ITA.

The exact process for the INSTC and analysis of the results in Table 8 has been conducted.

Figure 8 indicates the OPC information among the members of the IMEEC and INSTC after establishing the corridors. It is crystal clear that members of the INSTC experience fewer OPC than members of the INSTC.

According to Figure 8, Since OPC for both members of corridors decrease, compare to the information of Figure 7, all countries benefit from establishing the corridors.

Table 7. OPC after establishing the IMEEC.

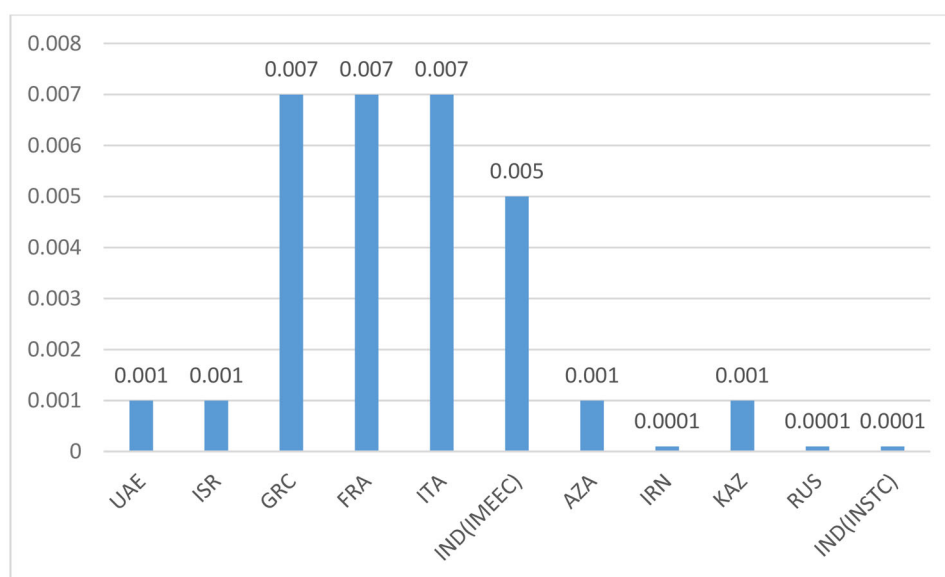
Ports of IMMEC	Trade by ports among countries	OPC after corridor trade by ports	Country	OPC after corridor for countries
Jebel Ali (Dubai)	IND-UAE	0.000	UAE	0.001
Haifa port (Israel)	IND-ISR	0.000	ISR	0.001
Piraeus harbor (Athen)	IND-GRC	0.005	GRC	0.007
Marseille's port (France)	IND-FRA	0.000	FRA	0.007
Port of Genoa (Italy)	IND-ITA	0.000	ITA	0.007
Vadhavan port (India)	UAE-ISR	0.001	IND	0.005
	UAE-GRC	0.000		
	UAE-FRA	0.000		
	UAE-ITA	0.000		
	ISR-GRC	0.000		
	ISR-FRA	0.000		
	ISR-ITA	0.000		
	GRC-FRA	0.001		
	GRC-ITA	0.001		
	FRA-ITA	0.006		

Source: Author's calculations.

Table 8. OPC after establishing the INSTC.

Capital	Trade by Capital	OPC after corridor by trade	Country	OPC after corridor for countries
AZA	IND-AZE	0.000	AZA	0.001
IRN	IND-IRN	0.000	IRN	0.0001
KAZ	IND-KAZ	0.000	KAZ	0.001
RUS	IND-RUS	0.000	RUS	0.0001
IND	AZA-IRN	0.000	IND	0.0001
	AZA-KAZ	0.001		
	AZA-RUS	0.000		
	KAZ-IRN	0.000		
	KAZ-RUS	0.000		
	IRA-RUS	0.000		

Source: Authors' calculations.

**Figure 8.** OPC of the members corridors after establishing.

Source: Calculated by authors.

Table 9. Difference between OPC before and after establishment of each corridor.

Country (IMEEC)	Benefit(percent)	Country (INSTC)	Benefit(percent)
UAE	0.05	AZA	0.079
ISR	0.038	IRN	0.15
GRC	0.036	KAZ	0.139
FRA	0.036	RUS	0.130
ITA	0.036	IND	0.061
IND	0.056		

Source: Authors' calculations.

By comparing the OPC before and after the establishment of the corridors, the benefits for each country in Table 9 can be observed.

5. Discussion and conclusion

The findings based on the right side of Equation (16) suggest that the OPC of holding money depends on the interest rate and is influenced by the \overline{PRI}_t .DRT. When the \overline{PRI}_t .DRT, increases, the OPC of holding money decreases, resulting in a lower cost of inflation as a measure of social welfare.

This implies that Milton Friedman's idea that a zero interest rate is necessary for a zero OPC of money cannot be accepted in an international trade environment where transaction risk exists. Instead, the findings indicate that expanding trade through economic corridors can reduce the marginal cost of society. A decrease in the \overline{PRI}_t .DRT leads to a lower OPC of holding money and an increase in social welfare, without directly impacting the interest rates of the countries involved. Furthermore, promoting trade through economic corridors can help eliminate the inefficiency caused by favorable interest rates and the gap between private and social marginal costs. By accepting more transaction risk through the construction of new corridors, a social planner facing higher interest rates can enhance the social welfare of society.

Equation (16) highlights another crucial point, which is that the varying distances considering political risk of trade involved in international transactions among countries with different interest rates result in different OPCs of holding money. As a result, member countries of IMEEC and INSTC, which experience different interest rates, would accrue varying advantages. In this analysis, we assume that none of the countries have reduced their interest rates. However, the DRTs have enhanced social welfare by reducing the overall OPC of holding money. This implies that the efficiencies gained through reduced transaction risks and improved trade opportunities have positively impacted social welfare, regardless of the varying interest rates among the member countries. By reducing the OPC through the establishment of economic corridors, the DRTs is mitigated, leading to increased social welfare. This highlights the potential benefits of trade facilitation and the importance of considering the impact of transaction risks when assessing the advantages of international trade agreements and corridor development.

Based on the information presented in Figure 8 and Table 9, we can conclude that the optimal OPC after establishing corridors for all the countries studied is lower compared to the scenario where no corridors are created. This indicates that the countries included in this research, which are members of IMEEC and INSTC, would benefit from the establishment of these corridors. According to the rankings provided, among the members of IMEEC, India, UAE, Israel, Greece, France and Italy are the countries that would benefit the most from the corridors, in that order. For the members of INSTC, Iran and Kazakhstan stand out as the countries that would enjoy the most significant advantages. Russia, India and Azerbaijan are expected to receive fewer benefits compared to Iran and Kazakhstan. The establishment of corridors can help reduce the gap between the actual balance of money and consumption for countries with higher interest rates. It also offers an opportunity for these economies to achieve a more stable and steady state, leading to overall economic stability.

Based on the information provided in Table 9, it is expected that India would benefit more from the membership in the IMEEC compared to the INSTC. The table indicates that a one percent increase in the completion of the IMEEC (Km) corridor results in a 5.6% reduction in macroeconomic instability and the gap between the actual balance of money and consumption in India. On the other hand, completing the INSTC corridor reduces macroeconomic instability in India by 6.1%. From an economic perspective, this suggests that the INSTC holds a slight advantage over the IMEEC for India. The IMEEC membership would contribute more significantly to reducing macroeconomic instability and narrowing the gap between the actual balance of money and consumption in India. Additionally, based on the results presented in Table 9, each 1% effort to complete the INSTC corridor can reduce macroeconomic instability by 15%, 13.9% and 13% for Iran, Azerbaijan and Russia, respectively. This indicates that the INSTC corridor has a more substantial impact on reducing macroeconomic instability for both Iran, Azerbaijan and Russia compared to India. In summary, the findings suggest that India would benefit a bit more from the INSTC membership compared to the IMEEC membership. The INSTC shows a slight advantage over the IMEEC in terms of reducing macroeconomic instability and narrowing the gap

between the actual balance of money and consumption in India. Furthermore, the completion of the INSTC corridor has a more significant impact on reducing macroeconomic instability for Iran, Azerbaijan and Russia.

Limitation

Contrary to some other nations, the interest rate of Turkmenistan could not be found on reliable resources like <https://tradingeconomics.com/country-list/interest-rate>. Consequently, despite being a member of INSTC, this country was excluded. The model utilized interest rate, DRT, and Political risk to compute OPC and illustrate the fluctuations in trade between India and other members of corridors. However, future studies can enhance the development of other variables. The PRI index is exclusively utilized to assess political risk inside each specific corridor. This can be extended to encompass both domestic and international political risks. The model selected Vadhavan port due to its natural draft of 20 m, which enables it to accommodate and manage sizable vessels and container ships. The port is fully prepared to accommodate the increased demand resulting from the IMEEC. Additionally, future studies can incorporate Mundra or Jawaharlal Nehru as well.

There was a lack of a definitive scientific criterion to ascertain the effect of the conflict between Hamas and Israel on the cost or delay in building IMEEC.

Recommendations

With the expansion of studies on different routes of the IMEEC in the future, it would be possible to analyze the effect of corridors on various destinations for DRT through land routes for the IMEEC. Examining specific conflict criteria or shocks and their resilience can provide valuable insights.

Note

1. The Bellman equation is a requisite condition in mathematical optimisation, named after Richard Bellman's contribution to the development of a novel method for solving dynamic programming (Avanish, 1990). This strategy is commonly employed in recursive models in both macroeconomics and monetary economics. Several instances of economic modelling employing recursive techniques may be found in the research conducted by Stokey et al. (1989). To gain further insights into the application of Bellman's equation in optimising shopping time, readers are encouraged to refer to Iman's publications from 2023 to 2024.

Author contributions

Iman Bastanifar: Conceptualization, Methodology, Data curation, Investigation, Validation Formal analysis, Writing – original draft, Writing – review & editing.

Ali Omid: Formal analysis, Investigation, Resources, Writing – original draft

Kashif Hasan Khan: Formal analysis, Investigation, Resources, writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration.

Disclosure statement

There is no any conflict of Interest between authors.

Funding

This study has not been funded by any organization or individual.

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Data availability statement

Data for the study are obtained from publicly available sources and can also be made available upon request.

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