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Working Paper

Graph-based analysis of Armenia's connectivity in the EU- Asia trade network: Strategic role and limitations

Ordnungspolitische Diskurse, No. 2025-3

Provided in Cooperation with:

OrdnungsPolitisches Portal (OPO)

Suggested Citation: Atoyan, Vardan; Matevosyan, Diana (2025) : Graph-based analysis of Armenia's connectivity in the EU-Asia trade network: Strategic role and limitations, Ordnungspolitische Diskurse, No. 2025-3, OrdnungsPolitisches Portal (OPO), Erfurt

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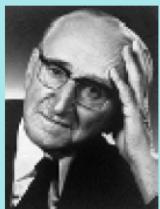
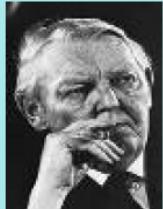
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Ordnungspolitische Diskurse

Discourses in Social Market Economy



**Vardan Atoyan &
Diana Matevosyan**

**Graph-Based Analysis of Armenia's Connectivity in the EU-Asia Trade Network:
Strategic Role and Limitations**

Diskurs 2025 - 3

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Vardan Atoyan & Diana Matevosyan

Abstract

The growing geopolitical tensions and regional instabilities in Eurasia raise urgent questions about the resilience of trade routes and infrastructure connectivity. This paper applies a graph-based approach to model the EU-Asia trade network and explores Armenia's potential as a transit hub within the framework of the Global Gateway strategy. The authors construct a weighted network of major regional players based on bilateral trade volumes, geographic distances, and route accessibility. In this network, nodes represent key countries, while edges capture trade relationships, with weights reflecting trade intensity and logistical characteristics. Using a set of graph-theoretical metrics, including degree centrality, betweenness centrality, closeness centrality, and eigenvector centrality, the authors assess the country's importance within the network, identifying its position as a potential chokepoint or facilitator of alternative trade routes. Stress-testing scenarios, including border closures, sanctions, or the reopening of previously closed borders, are simulated to evaluate the impact on trade flows and regional logistics. These scenarios simulate the dynamic nature of trade flows, considering disruptions that could reshape existing networks. Results indicate significant shifts in the network structure under stress, highlighting opportunities for Armenia to strengthen its strategic position as an alternative node in critical corridors.

Keywords: Graph, Logistic Network, Eurasian Corridors, Trade, Armenia.

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1. Introduction

In contemporary multipolarity, the Eurasian region has become an arena for competition and cooperation among countries aiming to enhance their transport connectivity and economic resilience. This article examines the Eurasian logistics network, including all major corridors and related regional routes. The connections between the countries in the region form a dense network of interactions, which can be represented and analyzed using graph theory methods.

The study aims to structurally analyze the network using graph metrics and model potential scenarios. The main objectives are:

- 1) Constructing a network of countries based on geographic location;
- 2) Calculating basic graph metrics;
- 3) Identifying key countries within the structure;
- 4) Simulating scenarios of changes in the network structure.

The proposed approach allows for expanding the analytical tools for evaluating logistics inter-connectivity in the region, providing both quantitative assessments and qualitative and visual means of interpretation.

Fagiolo, Reyes, and Schiavo (2010) were among the first to apply complex network theory to global trade, demonstrating that both topological and weighted metrics are essential to understanding the evolution and robustness of international trade systems. Their work highlighted the importance of centrality and clustering in sustaining trade dynamics. Building on this, De Benedictis and Tajoli (2011) introduced network measures to study the European trade system, emphasizing the role of geographical proximity and regional integration. Their findings confirm that countries with limited neighbors or closed borders exhibit consistently low centrality values, which weakens their integration into broader economic structures. More recently, Borgatti et al. (2018) and Serrano & Boguñá (2003) emphasized that resilience in trade and

transport networks is not only a matter of density but also of redundancy and accessibility. These concepts are particularly relevant for landlocked or politically isolated countries, where few connections increase systemic risk.

Barabási (2016) offers a comprehensive synthesis of network science, particularly how cascading failures and hub dependencies can impact global systems such as logistics and trade. Garlaschelli & Loffredo (2004) added a probabilistic dimension to trade network modeling through fitness-based approaches, which allow for prediction of tie strength based on country-level trade capacity. Ducruet and Notteboom (2012) investigated maritime container shipping networks and revealed how global trade centrality is closely tied to port infrastructure and shipping alliances — insights that indirectly affect landlocked countries like Armenia. Carrera et al. (2016) assessed infrastructure integration between Europe and Central Asia, finding that improved coordination could significantly reduce transport costs and increase interregional trade. Rodrigue et al. (2016) introduced the concept of “transport corridors as multilayered networks,” emphasizing governance, logistics nodes, and institutional cooperation. Simoes and Hidalgo (2011) introduced the Economic Complexity framework, linking a country’s export network structure to its development potential. Grassi et al. (2022) investigated trade resilience during global shocks (e.g., COVID-19), showing that countries with diversified and redundant trade links rebounded faster. Kim and Shin (2002) focused on regional trade agreements, finding they boost local centrality but sometimes reduce global openness. Blázquez et al. (2023) examined digital trade connectivity and the role of ICT infrastructure in expanding trade networks. Freund and Rocha (2011) analyzed how road quality and border delays shape trade flows in Africa, highlighting that trade connectivity is often more influenced by logistics performance than geography. Hidalgo and Hausmann (2009) introduced the Product Space concept, showing how trade networks evolve structurally as countries diversify toward more complex products.

In addition to academic studies, institutional reports offer valuable insights into the practical dimensions of network-based connectivity analysis. The Eurasian Development Bank (EDB, 2023) has published a comprehensive report titled The Eurasian Transport Network, which evaluates infrastructure, trade flows, and the potential of individual countries within pan-Eurasian corridors. The report identifies five major transit corridors and assesses their structural, political, and logistical bottlenecks. Armenia is highlighted as a strategically located country that, despite lacking direct access to the sea, could serve as an essential node in the North-South and East-West transit chains. However, the report also emphasizes that closed borders with Türkiye and Azerbaijan severely limit Armenia’s integration, echoing findings from network centrality analysis.

2. Methods:

The object of analysis is 19 Eurasian countries (Armenia, Georgia, Azerbaijan, Iran, Türkiye, EU, Moldova, Ukraine, Belarus, Russia, Kazakhstan, Kirgizstan, Uzbekistan, Turkmenistan, Tajikistan, Afghanistan, Pakistan, Mongolia, China), selected based on the Eurasian Development Bank report on Eurasian corridors (EDB, 2023). Since the modeled object represents a network, it was decided to use one of the common approaches for its modeling: a graph. For each pair of countries, the following parameters are considered: total trade volume in 2023 (in USD), border status (open, closed, under sanctions), and risk level (low, medium, high). The year 2023 was selected as the reference period, as many countries have not yet published complete trade statistics for 2024. The main data sources for trade volumes are UN Comtrade (United Nations, n.d.), TradeMap (International Trade Centre [ITC], n.d.), as well as official national sources (national statistical agencies, press releases).

The constructed network is represented as an undirected graph, where the nodes are the 19 countries and the edges represent trade connections between them. Each edge is labeled and parameterized based on border status and risk level:

- Border status effect on edge weight:
 - Closed border — weight = 0%
 - Open border — weight = 100%
 - Under sanctions — weight = 50%

(Sanctions imply the presence of restrictions between the two countries connected by the edge.)

- Risk level effect on edge weight:
 - Low risk — weight = 90%
 - Medium risk — weight = 65%
 - High risk — weight = 25%

The influence of border status and risk level (mainly political risk) on the weights was determined based on objective regional information and expert judgment adapted to the goals of this study.

The geographic coordinates of the countries were used to construct geo-referenced network visualizations. The NetworkX (NetworkX Developers, n.d.) library was employed for working with the graph structure, while GeoPandas (GeoPandas Developers, n.d.) and Matplotlib (Hunter, 2007) were used for visualization.

To study the network structure, the following methods and metrics were applied (Newman, 2010; Barabási, 2016; Wasserman & Faust, 1994):

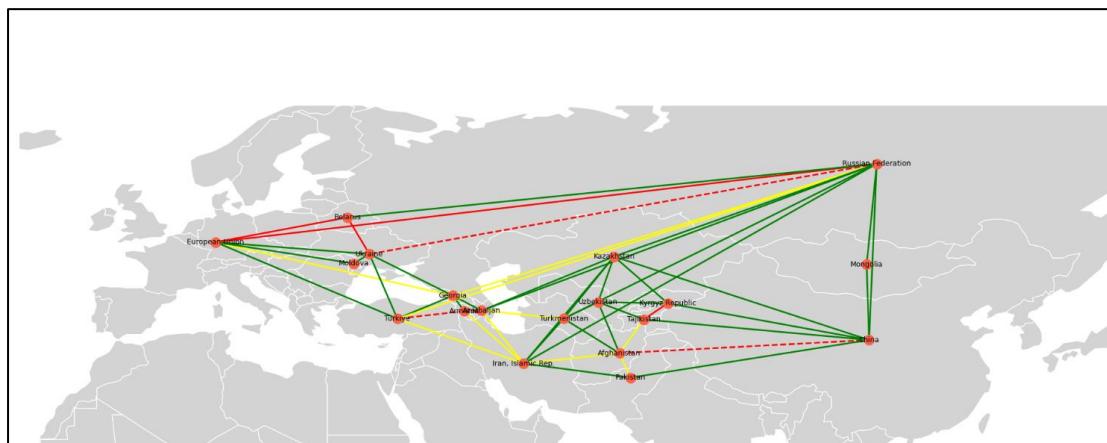
- Centrality metrics (Borgatti et al., 2018):
 - Degree Centrality;
 - Closeness Centrality;
 - Betweenness Centrality;
 - Eigenvector Centrality.
- Network properties (Jackson, 2008):
 - Connected components;
 - Average shortest path length;
 - Diameter of the graph.
- Algorithms for vulnerability and key node identification, including:
 - Simulation of node (country) removals from the network;
 - Scenario analysis of structural changes.

These methods allow for a comprehensive assessment of the robustness and resilience of the Eurasian logistics network under different conditions.

3. Results

The analysis begins with the construction of a baseline graph representing the Eurasian logistics network (figure 1).

Figure 1. The Eurasian logistics network



Source: Authors' calculations

Based on this graph, several key metrics were computed to assess the network's structure:

- **Connected Components:** The value equals 1, indicating that the graph is fully connected. This means the Eurasian network functions as a single integrated system, where any country (node) is reachable from any other.
- **Diameter:** The network diameter is 4, suggesting that at most four steps are required to travel between the two most distant countries in the network.
- **Average Shortest Path Length:** With a value of 2.05, this metric implies that, on average, a country needs to traverse two other countries to reach any other country within the network.
- **Geographic connectivity coefficient:** To realistically evaluate the cohesion of the Eurasian trade network, we calculate the geographic connectivity coefficient. This metric reflects the proportion of realized trade connections among all geographically feasible bilateral links—that is, between neighboring countries with the potential for trade. The coefficient equals 0.922, indicating that approximately 92% of all feasible geographic trade links are realized within the network.

Table 1. Main metrics of the Eurasian network graph

| Country | De-gree | Close-ness | Between-ness | Eigenvec-tor |
|--------------------|---------|------------|--------------|--------------|
| Armenia | 0.1111 | 0.4390 | 0.0049 | 0.0944 |
| Moldova | 0.1111 | 0.3529 | - | 0.0644 |
| Mongolia | 0.1111 | 0.4737 | - | 0.1208 |
| Pakistan | 0.1667 | 0.4500 | 0.0029 | 0.1447 |
| Belarus | 0.1667 | 0.4615 | 0.0107 | 0.1369 |
| Azerbaijan | 0.2222 | 0.5143 | 0.0169 | 0.2240 |
| Kyrgyz Republic | 0.2222 | 0.4390 | 0.0060 | 0.1706 |
| Tajikistan | 0.2222 | 0.4286 | 0.0049 | 0.1575 |
| Türkiye | 0.2778 | 0.5294 | 0.0582 | 0.2312 |
| Ukraine | 0.2778 | 0.4186 | 0.0264 | 0.1536 |
| Uzbekistan | 0.2778 | 0.4390 | 0.0147 | 0.2108 |
| Georgia | 0.3333 | 0.5143 | 0.0741 | 0.2328 |
| Turkmenistan | 0.3333 | 0.5625 | 0.0549 | 0.3028 |
| Afghanistan | 0.3333 | 0.5000 | 0.0502 | 0.2444 |
| European Union | 0.3333 | 0.5143 | 0.1009 | 0.2154 |
| Iran, Islamic Rep. | 0.3889 | 0.6000 | 0.1571 | 0.3081 |
| Kazakhstan | 0.3889 | 0.5806 | 0.0980 | 0.3330 |
| China | 0.3889 | 0.5625 | 0.1388 | 0.2768 |
| Russian Federation | 0.5556 | 0.6923 | 0.3570 | 0.4155 |

Source: Authors' calculations

Table 1 presents the centrality metrics, which offer insights into the strategic importance of individual countries within the logistics network.

- **Degree Centrality:** Reflects the number of direct connections a country has. This metric can be interpreted as a measure of integration within the network. According to the data, the most integrated countries are Russia, China, Kazakhstan, and Iran. Russia has a degree centrality of 0.5556, meaning it holds nearly half of all possible direct connections. In contrast, countries such as Armenia, Moldova, and Mongolia exhibit the lowest levels of integration. For Moldova and Mongolia, this can be attributed to their geographically isolated positions with a minimal number of neighbors. In Armenia's case, the limited connectivity is primarily due to closed borders.
- **Closeness Centrality:** Indicates how close a country is to all other countries in the network—that is, how quickly it can reach other nodes. Countries with the highest closeness centrality include Russia, Iran, Kazakhstan, China, and Turkmenistan. The least accessible countries in terms of network distance are Moldova, Ukraine, and Tajikistan.
- **Betweenness Centrality:** Measures the number of critical paths that pass through a given node, capturing a country's role as a mediator or bridge. The leading intermediary countries are Russia, Iran, China, and the EU. In contrast, Moldova and Mongolia have a betweenness centrality of 0, indicating they do not serve as intermediaries in any network paths.
- **Eigenvector Centrality:** Reflects a country's influence based on the influence of its neighboring countries. Higher values suggest that a country is strategically connected to other influential nodes. The top countries in terms of influential connections are Russia, Kazakhstan, Iran, and Turkmenistan. Countries with the lowest eigenvector scores include Moldova, Armenia, and Mongolia. In Armenia's case, the low score is largely due to subjective factors, namely its limited direct connections caused by closed borders.

4. Scenario Analysis

To identify network characteristics—weak and strong nodes and edges—several simulation scenarios were implemented. One group of scenarios focused on testing the connectivity level of edges, while the other targeted the role of nodes (countries). For each scenario, key graph metrics were recalculated to measure the scenario effect (Tables 2–9).

Scenario 1: Exclusion of routes with high-risk levels.

As shown in Table 2, the number of connected components remains 1, meaning the graph does not split and remains a single entity. However, the diameter increases by 1 (from 4 to 5), and the average shortest path length changes insignificantly, remaining around 2. Connectivity decreases by 7.8%. In terms of direct connections, Belarus is the most negatively affected, while Azerbaijan gains. Regarding distance from the network, the EU moves farther away, while Azerbaijan moves closer. As for the role as an intermediary or bridge, Belarus's role diminishes, while the roles of Pakistan, Turkey, and Azerbaijan increase.

Scenario 2: Removal of weak (vulnerable) connections.

Edges with a combined impact of risk level and border status less than or equal to 0.325 were removed from the network. This threshold was set assuming a sanctions effect of 0.5 and a medium risk level of 0.65, with the combined effect calculated as $0.65 \times 0.5 = 0.325$. The results of this scenario replicate those of Scenario 1.

Scenario 3: Russia exits the network.

The graph remains connected, but its diameter increases by 2 (from 4 to 6), and the rounded average shortest path becomes 3. Connectivity increases by 0.3%. In terms of direct connections, Mongolia is most affected, followed by Belarus and China. Georgia, Türkiye, Turkmenistan, Afghanistan, and the EU are almost equally negatively affected, while the remaining countries benefit equally.

Scenario 4: Simulation of border openings for Armenia and its neighbors.

Scenario 4 includes three sub-scenarios:

- 4.1: Opening of the Armenia–Türkiye border;
- 4.2: Opening of the Armenia–Azerbaijan border;
- 4.3: Opening of both borders.

As expected, border openings benefit the region and the overall network. To assess the overall network benefit, the change in connectivity can be considered: +2%, +2%, and +4%, respectively.

In sub-scenario 4.1, Armenia benefits the most in terms of direct connections (+50%), while Turkey's role as a connecting bridge increases by +32%.

In sub-scenario 4.2, both Armenia and Azerbaijan equally benefit in terms of direct connections, while Azerbaijan's role as a connecting bridge increases significantly (+144%).

In sub-scenario 4.3, Armenia gains the most in terms of direct connections, as expected, while Azerbaijan strengthens its role as a connecting bridge. It should also be noted that Georgia's role as a bridge weakens significantly (-37%) under this scenario.

Scenario 5: Identification of the most influential players in the network.

The purpose of Scenario 5 was to identify the most influential players whose removal would fragment the network. Computational tests confirmed that no single country acts as a critical hub—removing any individual node does not disconnect the network. However, further analysis of node pairs revealed structural vulnerabilities. In particular, the simultaneous removal of both Georgia and Iran leads to fragmentation, dividing the network into disconnected components. This highlights that network cohesion is dependent not on single central players, but on strategic combinations of countries that serve as transit bridges. Countries with relatively few direct connections (e.g., only two neighbors) can become isolated if both neighbors are removed, which in turn can trigger broader fragmentation.

Table 2: Comparison of metrics by scenario

| Scenario N | Connected Components | Diameter | Average Shortest Path | Connectivity |
|--------------|----------------------|----------|-----------------------|--------------|
| Scenario 1 | 1 | 5 | 2.19 | 0.84 |
| Scenario 2 | 1 | 5 | 2.19 | 0.84 |
| Scenario 3 | 1 | 6 | 2.48 | 0.93 |
| Scenario 4.1 | 1 | 4 | 2.05 | 0.94 |
| Scenario 4.2 | 1 | 4 | 2.05 | 0.94 |
| Scenario 4.3 | 1 | 4 | 2.04 | 0.96 |
| Scenario 5 | 2 | None | None | 0.89 |

Source: Authors' calculations

Table 3: Scenario 1: Main metrics of the graph

| Country | Degree | Closeness | Betweenness | Eigenvector |
|--------------------|--------|-----------|-------------|-------------|
| Armenia | 0.1111 | 0.4390 | 0.0040 | 0.1083 |
| Georgia | 0.3333 | 0.5143 | 0.1432 | 0.2246 |
| Iran, Islamic Rep. | 0.4444 | 0.6207 | 0.2074 | 0.3778 |
| Russian Federation | 0.5000 | 0.6429 | 0.3254 | 0.4042 |
| Azerbaijan | 0.2778 | 0.5455 | 0.0345 | 0.3069 |
| Türkiye | 0.2778 | 0.5294 | 0.1554 | 0.2190 |
| Turkmenistan | 0.3333 | 0.5294 | 0.0480 | 0.3376 |
| Afghanistan | 0.2778 | 0.4737 | 0.0492 | 0.2147 |
| Pakistan | 0.1667 | 0.4615 | 0.0087 | 0.1483 |
| European Union | 0.2222 | 0.4000 | 0.0523 | 0.1056 |
| Belarus | 0.0556 | 0.4000 | - | 0.0727 |
| Ukraine | 0.2222 | 0.4000 | 0.0523 | 0.1056 |
| Moldova | 0.1111 | 0.2951 | - | 0.0380 |
| Kazakhstan | 0.3889 | 0.5455 | 0.0973 | 0.3624 |
| China | 0.3333 | 0.5143 | 0.1131 | 0.2325 |
| Mongolia | 0.1111 | 0.4390 | - | 0.1145 |

| | | | | |
|------------------------|--------|--------|--------|--------|
| Kyrgyz Republic | 0.1667 | 0.4091 | 0.0035 | 0.1451 |
| Uzbekistan | 0.2778 | 0.4186 | 0.0240 | 0.2119 |
| Tajikistan | 0.1667 | 0.4000 | 0.0084 | 0.1185 |

Source: Authors' calculations

Table 4: Scenario 2: Main metrics of the graph

| Country | De-gree | Close-ness | Between-ness | Eigenvec-tor |
|---------------------------|---------|------------|--------------|--------------|
| Armenia | 0.1111 | 0.4390 | 0.0040 | 0.1083 |
| Georgia | 0.3333 | 0.5143 | 0.1432 | 0.2246 |
| Iran, Islamic Rep. | 0.4444 | 0.6207 | 0.2074 | 0.3778 |
| Russian Federation | 0.5000 | 0.6429 | 0.3254 | 0.4042 |
| Azerbaijan | 0.2778 | 0.5455 | 0.0345 | 0.3069 |
| Türkiye | 0.2778 | 0.5294 | 0.1554 | 0.2190 |
| Turkmenistan | 0.3333 | 0.5294 | 0.0480 | 0.3376 |
| Afghanistan | 0.2778 | 0.4737 | 0.0492 | 0.2147 |
| Pakistan | 0.1667 | 0.4615 | 0.0087 | 0.1483 |
| European Union | 0.2222 | 0.4000 | 0.0523 | 0.1056 |
| Belarus | 0.0556 | 0.4000 | - | 0.0727 |
| Ukraine | 0.2222 | 0.4000 | 0.0523 | 0.1056 |
| Moldova | 0.1111 | 0.2951 | - | 0.0380 |
| Kazakhstan | 0.3889 | 0.5455 | 0.0973 | 0.3624 |
| China | 0.3333 | 0.5143 | 0.1131 | 0.2325 |
| Mongolia | 0.1111 | 0.4390 | - | 0.1145 |
| Kyrgyz Republic | 0.1667 | 0.4091 | 0.0035 | 0.1451 |
| Uzbekistan | 0.2778 | 0.4186 | 0.0240 | 0.2119 |
| Tajikistan | 0.1667 | 0.4000 | 0.0084 | 0.1185 |

Source: Authors' calculations

Table 5: Scenario 3: Main metrics of the graph

| Country | De-gree | Close-ness | Between-ness | Eigenvec-tor |
|---------------------------|---------|------------|--------------|--------------|
| Armenia | 0.1176 | 0.4250 | 0.0077 | 0.1143 |
| Georgia | 0.2941 | 0.4474 | 0.1453 | 0.1627 |
| Iran, Islamic Rep. | 0.4118 | 0.5667 | 0.3703 | 0.3782 |
| Azerbaijan | 0.2353 | 0.5000 | 0.1337 | 0.2694 |
| Türkiye | 0.2353 | 0.4722 | 0.2263 | 0.1617 |
| Turkmenistan | 0.2941 | 0.4722 | 0.0387 | 0.3525 |
| Afghanistan | 0.2941 | 0.4595 | 0.0892 | 0.3144 |
| Pakistan | 0.1765 | 0.4474 | 0.0490 | 0.1960 |
| European Union | 0.2941 | 0.3864 | 0.1066 | 0.1123 |
| Belarus | 0.1176 | 0.2881 | - | 0.0474 |
| Ukraine | 0.2941 | 0.3864 | 0.1066 | 0.1123 |

| | | | | |
|------------------------|--------|--------|--------|--------|
| Moldova | 0.1176 | 0.2881 | - | 0.0474 |
| Kazakhstan | 0.3529 | 0.5000 | 0.2131 | 0.3821 |
| China | 0.2941 | 0.4048 | 0.1369 | 0.2354 |
| Mongolia | 0.0588 | 0.2931 | - | 0.0497 |
| Kyrgyz Republic | 0.2353 | 0.3953 | 0.0095 | 0.2491 |
| Uzbekistan | 0.2941 | 0.3953 | 0.0202 | 0.3243 |
| Tajikistan | 0.2353 | 0.3778 | 0.0159 | 0.2373 |

Source: Authors' calculations

Table 6: Scenario 4.1: Main metrics of the graph

| Country | De-gree | Close-ness | Between-ness | Eigenvec-tor |
|---------------------------|---------|------------|--------------|--------------|
| Armenia | 0.1667 | 0.4500 | 0.0040 | 0.1487 |
| Georgia | 0.3333 | 0.5143 | 0.0524 | 0.2559 |
| Iran, Islamic Rep. | 0.4444 | 0.6207 | 0.1704 | 0.3490 |
| Azerbaijan | 0.2778 | 0.5455 | 0.0209 | 0.2804 |
| Türkiye | 0.3333 | 0.5455 | 0.0768 | 0.2659 |

Source: Authors' calculations

Table 7: Scenario 4.2: Main metrics of the graph

| Country | De-gree | Close-ness | Between-ness | Eigenvec-tor |
|---------------------------|---------|------------|--------------|--------------|
| Armenia | 0.1667 | 0.45 | 0.004 | 0.1551 |
| Georgia | 0.3333 | 0.5143 | 0.0631 | 0.2525 |
| Iran, Islamic Rep. | 0.4444 | 0.6207 | 0.1577 | 0.3504 |
| Azerbaijan | 0.3333 | 0.5625 | 0.0412 | 0.3072 |
| Türkiye | 0.2778 | 0.5294 | 0.0585 | 0.2362 |

Source: Authors' calculations

Table 8: Scenario 4.3: Main metrics of the graph

| Country | De-gree | Close-ness | Between-ness | Eigenvec-tor |
|---------------------------|---------|------------|--------------|--------------|
| Armenia | 0.2222 | 0.4615 | 0.0057 | 0.1993 |
| Georgia | 0.3333 | 0.5143 | 0.0468 | 0.2619 |
| Iran, Islamic Rep. | 0.4444 | 0.6207 | 0.1518 | 0.3504 |
| Azerbaijan | 0.3333 | 0.5625 | 0.0393 | 0.3066 |
| Türkiye | 0.3333 | 0.5455 | 0.075 | 0.2682 |

Source: Authors' calculations

Table 9: Scenario 5: Main metrics of the graph

| Country | De-gree | Close-ness | Between-ness | Eigenvec-tor |
|---------------------------|---------|------------|--------------|--------------|
| Armenia | - | - | - | - |
| Russian Federation | 0.5000 | 0.6392 | 0.4589 | 0.4107 |
| Azerbaijan | 0.1875 | 0.4536 | - | 0.2397 |
| Türkiye | 0.1875 | 0.4395 | 0.0306 | 0.1513 |
| Turkmenistan | 0.3125 | 0.5208 | 0.1017 | 0.3284 |
| Afghanistan | 0.2500 | 0.4136 | 0.0292 | 0.2065 |
| Pakistan | 0.1250 | 0.3906 | 0.0069 | 0.1139 |
| European Union | 0.3125 | 0.4688 | 0.1333 | 0.1889 |
| Belarus | 0.1875 | 0.4395 | 0.0306 | 0.1513 |
| Ukraine | 0.2500 | 0.3430 | 0.0111 | 0.1173 |
| Moldova | 0.1250 | 0.3270 | - | 0.0646 |
| Kazakhstan | 0.3750 | 0.5409 | 0.0881 | 0.3970 |
| China | 0.3750 | 0.5409 | 0.1967 | 0.3334 |
| Mongolia | 0.1250 | 0.4395 | - | 0.1570 |
| Kyrgyz Republic | 0.2500 | 0.4261 | 0.0086 | 0.2673 |
| Uzbekistan | 0.3125 | 0.4261 | 0.0222 | 0.3024 |
| Tajikistan | 0.2500 | 0.4136 | 0.0156 | 0.2341 |

Source: Authors' calculations

5. Incorporation of Weighted Border Trade Data

In addition to structural network analysis, weighted trade data between geographically neighboring countries was considered to capture the economic significance of each connection. The dataset includes variables such as Border Status (open/closed), Risk Level, Trade Volume, and Weighted Trade Volume, where weights adjust the raw trade volumes based on the border's openness and associated geopolitical risk.

The total trade volume among geographically neighboring countries amounts to approximately 895 billion USD. After applying the weighting factors (border status and risk level), the weighted trade volume is reduced to approximately 708 billion USD, reflecting an average reduction of around 21% due to geopolitical and infrastructural factors. This demonstrates that, while physical connectivity remains, geopolitical risks and border closures significantly reduce the effective economic integration within the network.

6. Gyumri as a Multimodal Hub in the Eurasian Trade Network

Gyumri, the second largest city of Armenia after the capital Yerevan, is located close to the borders with Türkiye and Georgia and holds significant potential to serve as a multimodal logistics hub. Its position provides an alternative route within the TRACECA corridor and complements the ISTC corridor's north-south logic with a west-south connection: West(Europe, Türkiye)->Armenia(Gyumri-intermediate point)-> South(Iran)->One Belt One Road, offering an additional vector for diversification.

Table 10: SWOT Analysis of Gyumri as a Multimodal Hub

| | |
|--|---|
| Strengths: <ul style="list-style-type: none"> Strategic geographic location (near Georgia and Türkiye); Railway infrastructure connecting to Yerevan and Georgia; Shirak International Airport; Access to national and international road networks. | Weaknesses: <ul style="list-style-type: none"> Lack of large-scale logistics terminals; Limited digitalization of customs and logistics; Low level of logistics infrastructure investment. |
| Opportunities: <ul style="list-style-type: none"> Potential reopening of the borders, regional unblocking; Integration into Eurasian transport corridors; Development of multimodal logistics solutions through public-private partnerships (PPP); Growth of transit revenues, increased foreign investment, and strengthening Armenia's geopolitical role as a regional transport and logistics hub. | Threats: <ul style="list-style-type: none"> Geopolitical instability and continued closed borders with key partners; Strong competition from established regional hubs; Risk of underinvestment due to limited public and private funding; Workforce migration and shortage of qualified logistics and IT specialists. |

Source: Authors' elaboration.

7. Conclusion:

Russia emerges as the central leader across all centrality metrics. This suggests that Russia possesses a high number of direct links, is optimally located within the network to reach other countries quickly, plays a pivotal role as a bridge in regional connectivity, and maintains strategically influential connections. Other significant regional players include Kazakhstan, Iran, and China. On the other hand, countries such as Moldova, Mongolia, and Armenia consistently occupy peripheral positions in the network. In the cases of Moldova and Mongolia, this is primarily due to objective geographic limitations, such as a small number of neighboring countries or landlocked positions far from major corridors. Armenia, however, presents a different case.

Despite being landlocked, Armenia is strategically located at the intersection of North-South and East-West transit routes. Its peripheral role in the network is not a result of geography but rather of subjective constraints, particularly the closed borders with Türkiye and Azerbaijan. This significantly limits the number of its active connections and reduces its centrality.

Importantly, having few neighbors—whether due to geography or politics—makes a country more vulnerable, as it becomes more dependent on the stability and openness of a small set of connections. In Armenia's case, it is not the absence of maritime access that creates structural weakness, but the lack of integration into surrounding networks despite its strategic position.

In sum, Armenia's current peripheral status is not inevitable. If its closed borders were reopened, it could emerge as a key transit hub, enhancing not only its centrality but also improving the overall robustness and efficiency of the regional trade network. However, the issue of border reopening for Armenia should not be viewed solely through the lens of economics and trade. There are also broader challenges—political, security-related, and societal—that merit attention. Future research in this area could usefully focus on these dimensions as well.

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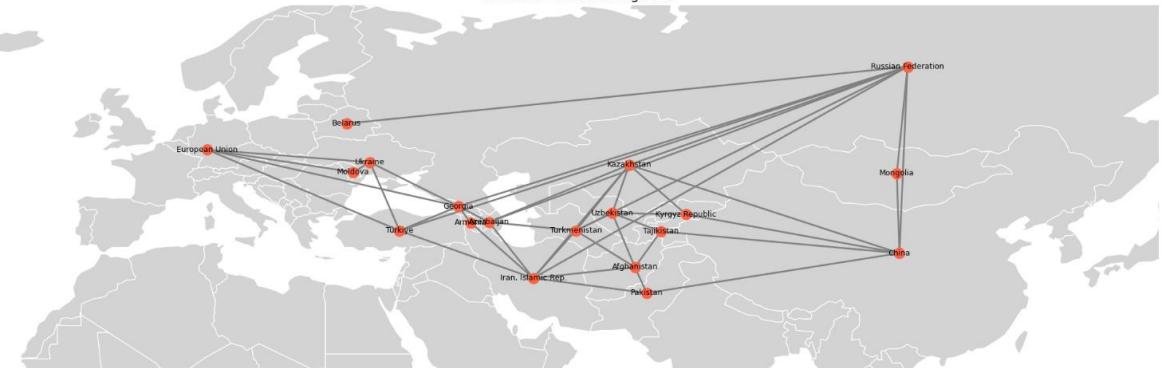
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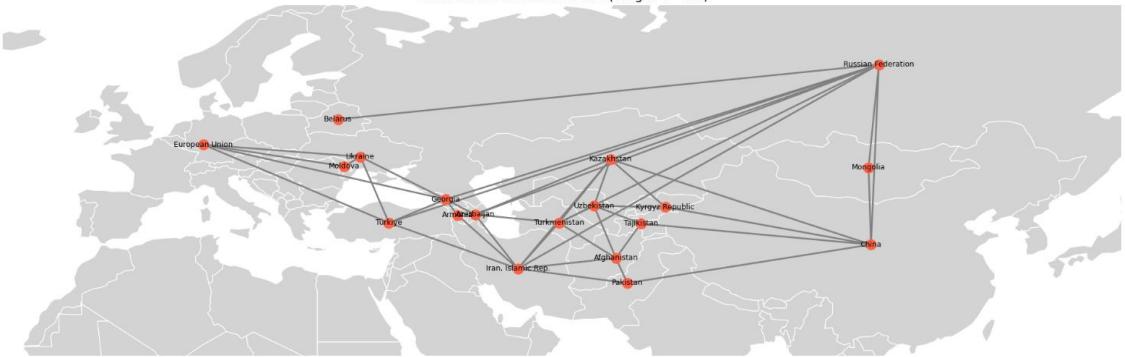
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Appendix: Scenario graphs

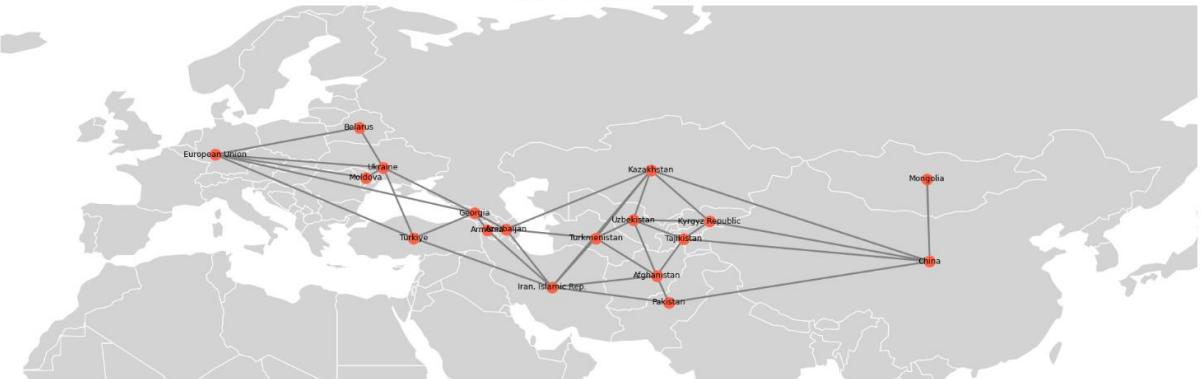
Scenario: 1. Without high risk



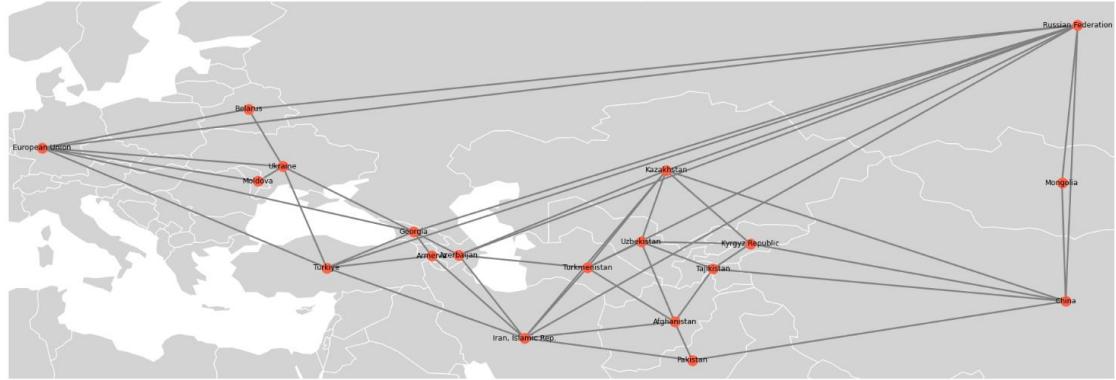
Scenario: 2. Without weak ties (weight <= 0.3)



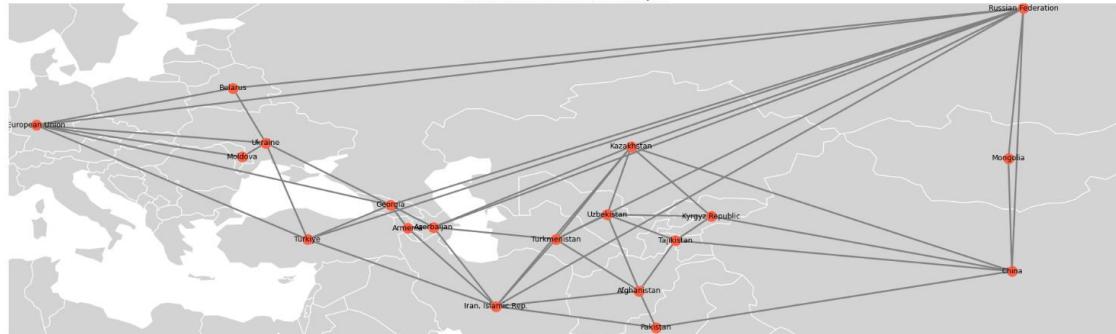
Scenario: 3. Without Russia



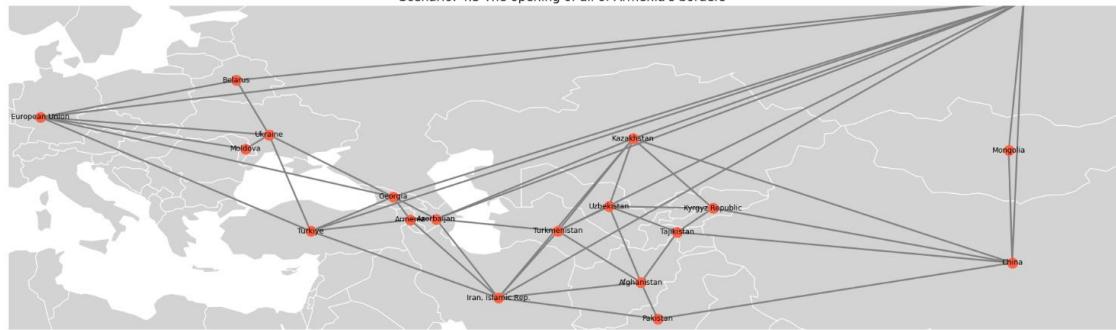
Scenario: 4.1 Armenia-Turkey



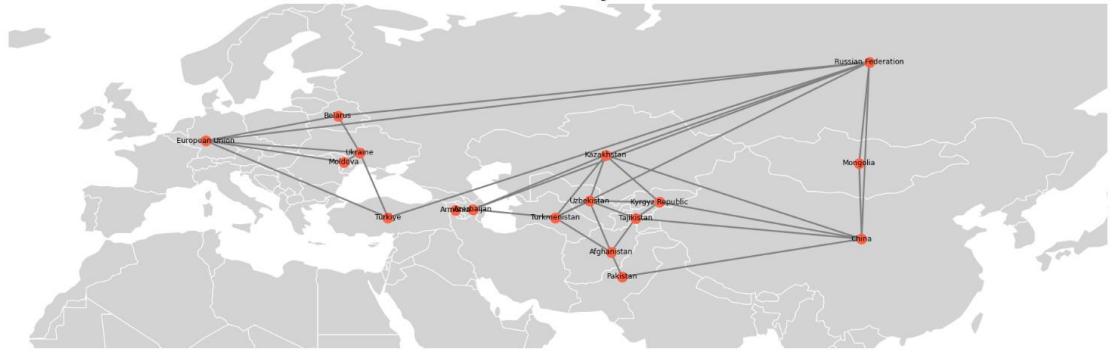
Scenario: 4.2 Armenia-Azerbaijan



Scenario: 4.3 The opening of all of Armenia's borders



Scenario: 5. Without Georgia and Iran



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