The Shrinking Globe: Structural Evolution and Globalization of the International Migration Network (1990–2024)

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Abstract. International migration forms a complex network of relationships between countries that evolves over time. In this work, we analyze the structure and evolution of the global migration system between 1990 and 2024 by modeling the stocks from the *UN International Migrant Stock* dataset as a directed and weighted graph, where nodes represent countries and edges capture migrant volumes between origin–destination pairs.
Using network science tools, we characterize global topological properties, community structure, and centrality, and evaluate four hypotheses regarding the determinants of migration: geographic proximity, cultural and linguistic affinity, economic asymmetry, and forced crises.
The results reveal a system undergoing progressive globalization: regional communities persist but lose cohesion, migration corridors increasingly span traditional boundaries, and geographic proximity declines in relative importance as a primary determinant. In contrast, linguistic similarity emerges as the most stable and consistent cultural factor throughout the entire period. Forced migration constitutes the most pronounced structural exception: in the presence of political or humanitarian crises, geography regains prominence and drives large-scale displacements toward neighboring countries, regardless of other factors.
Overall, these findings characterize a global migration system that is heterogeneous, hierarchical, and evolving, whose dynamics reflect a combination of long-term structural forces and short-term disruptive shocks.

Keywords: international migration · network science · migration networks · network analysis · network dynamics

1 Introduction

International migration is a central phenomenon in global social, economic, and political dynamics. Over recent decades, the number of people living outside their

country of birth has steadily increased [16], giving rise to a complex network of relationships between origin and destination countries [6,15].

Modeling migration systems as graphs enables the characterization of structural properties — such as community formation, indirect connections, and asymmetries in migrant stocks — that are not evident in purely statistical analyses [6,15,13]. Network science approaches make it possible to identify concentration patterns, regional modularity, and countries playing central roles within the global migration system [12].

In this work, we analyze international migration using the *UN International Migrant Stock 2024* dataset[5], which contains estimates of global migrant stocks for the 1990–2024 period. We characterize the structure and evolution of the international migration network through network science tools, analyzing global topological properties, centrality patterns, and community structure. Unlike previous studies, this work provides longitudinal evidence of a transition toward a more integrated migration system, identifies linguistic affinity as the most stable cultural factor throughout the period, and characterizes forced migration as a structural disruption in which geographic proximity regains a dominant role.

To evaluate these findings, the study analyzes four hypotheses using network metrics and socioeconomic data:

- H1: Geographic dominance. Migration predominantly occurs toward neighboring countries.
- H2: Cultural and linguistic affinity. Migration patterns are associated with cultural affinity, shared language, and historical colonial ties.
- H3: Economic asymmetry. Migration flows are associated with economic disparities and the search for better living conditions.
- H4: Forced migration. Political conflicts and humanitarian crises generate distinct migration patterns characterized by massive displacement toward neighboring countries.

The paper combines global structural analysis, regional and cultural dynamics in Africa, economic asymmetry in Argentina, and forced migration crises to provide a multidimensional perspective on the evolution of the international migration system.

2 Related Work

International migration has traditionally been studied from the perspectives of demography, economics, and social sciences using statistical models and aggregate analyses of migration flows and stocks. Network science has emerged as a complementary approach capable of capturing systemic complexity and structural properties often overlooked by conventional statistical analyses, including

[5] The *International Migrant Stock 2024* dataset is available at: https://www.un.org/development/desa/pd/content/international-migrant-stock

heterogeneous degree distributions, flow concentration, community formation, and link asymmetry.

In particular, [6] introduced the concept of the *International Migration Network* and showed that migration networks exhibit characteristic properties of complex systems, providing foundational evidence for Hypothesis 1. Similarly, [1] developed methods to estimate bilateral migration flows from migrant stock data, contributing significantly to the understanding of global migration dynamics.

Previous studies identified geographic proximity, colonial ties, and development disparities as major determinants of the modular organization of migration networks [2,4]. In parallel, research on large-scale social networks has shown that interaction structures can reveal socioeconomic and spatial behavioral patterns [9,10]. These findings support Hypotheses 2 and 3 concerning the role of cultural affinity and economic asymmetry in shaping migration patterns.

Finally, the association between forced migration and armed conflicts has been extensively documented [3], showing that displacement magnitude is strongly associated with conflict intensity and that most forced migration is directed toward neighboring countries, supporting Hypothesis 4.

Unlike previous studies, this work provides longitudinal evidence on the joint evolution of these determinants between 1990 and 2024 within a unified network science framework.

3 Data and Network Construction

Migrant stock. The *UN International Migrant Stock* dataset provides official estimates of international migrant stocks between 1990 and 2024, following the criteria established by the United Nations: an international migrant is defined as any person residing in a country other than their country of birth or citizenship for a minimum period of 12 months, regardless of legal status [16]. The data are organized as bilateral matrices indicating the stock of migrants born in country i and residing in country j, with estimates available for eight temporal snapshots between 1990 and 2024.

Auxiliary datasets. Several additional datasets were used to enrich the analysis. Population data were obtained from the *UN World Population Prospects*[6]. Geographic and administrative information about countries was obtained from the *UNHCR GIS Core Database*[7]. GDP per capita data were obtained from the *World Development Indicators*[8]. Geographic, administrative, and land-contiguity information, as well as linguistic and historical-colonial links between countries, were

[6] United Nations (2024). World Population Prospects. https://population.un.org/wpp/

[7] United Nations High Commissioner for Refugees (2024). GIS Core Database. https://www.unhcr.org/gis

[8] World Bank (2024). World Development Indicators. https://databank.worldbank.org/source/world-development-indicators

obtained from the CEPII *GeoDist* database [11]. Data on forced displacement and humanitarian crises were obtained from UNHCR[9].

Project repository. The original dataset and the auxiliary datasets were adapted and structured to facilitate analysis. Based on this framework, both data processing and most of the visualizations presented in this work were developed in Python. To further explore the methodology or reproduce the study, the source code and supplementary materials are publicly available in the project repository: https://github.com/RexCaecos/evolucion_redes_migratorias

Data reliability. Data quality and completeness vary considerably across countries. Most countries include records aggregated under the category "others", reducing graph density and limiting the interpretability of certain results, particularly in regions affected by refugee flows or limited statistical capacities. The analysis suggests that the observed density (see Table 1) is partially explained by these limitations and not exclusively by the actual structure of the migration system.

Network construction. Using bilateral migrant stock data, we construct a directed and weighted network $\mathcal{G} = (\mathcal{V}, \mathcal{E})$, where $\mathcal{V}$ is the set of countries and $\mathcal{E}$ is the set of directed links between country pairs. Each directed edge $(i, j) \in \mathcal{E}$ represents the number of migrants born in country i and residing in country j, with weight w_{ij} corresponding to the size of that migrant stock. The network is represented by a weighted adjacency matrix $W = (w_{ij})$.

4 Structural Analysis of the International Migration Network

Global network properties. Table 1 summarizes the main structural metrics of the network for the extreme years of the analyzed period.

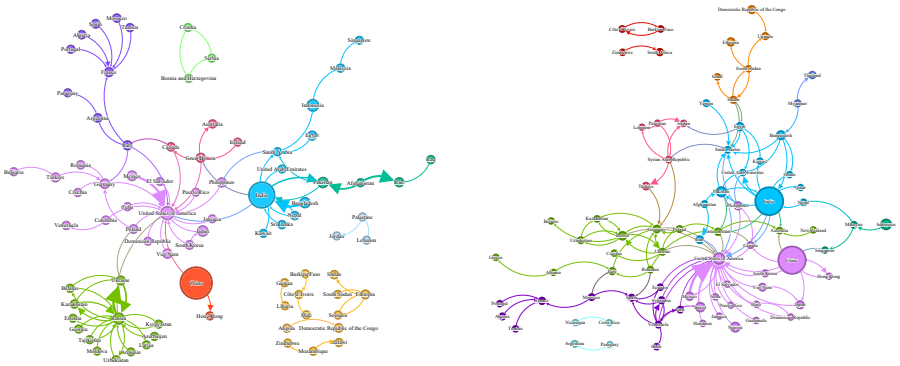
Table 1. Global properties of the international migration network.

Metric	1990	2024
Nodes	201	201
Edges	7,369	8,390
Density	0.1833	0.2087
Reciprocity	0.4315	0.4176
Binary clustering (BCC)	0.7038	0.7333
Average path length	2.017	1.962
Modularity (Infomap)	0.5812	0.4603

[9] United Nations High Commissioner for Refugees (2024). Refugee Data Finder. https://www.unhcr.org/refugee-statistics

Small-world structure. The network exhibits typical small-world properties [17]: high clustering coefficients (BCC > 0.70) combined with short average path lengths (≈ 2.0). This indicates that, despite the modular organization into regional communities, any pair of countries is connected through only a few intermediaries, a result consistent with [5].

Progressive globalization: decreasing modularity. The modularity detected by Infomap decreases between 1990 and 2024 (from 0.5812 to 0.4603), suggesting an evolution toward a less regionalized and more globally interconnected system. The simultaneous increase in density (from 0.1833 to 0.2087) and in the number of edges (7,369 to 8,390) provides evidence of the expansion of migration corridors crossing traditional regional boundaries.



(a) 1990 (b) 2024

Fig. 1. Evolution of the international migration network between 1990 and 2024. Each node represents a country (node size is proportional to population), and each edge represents a migration corridor weighted by migrant stock.

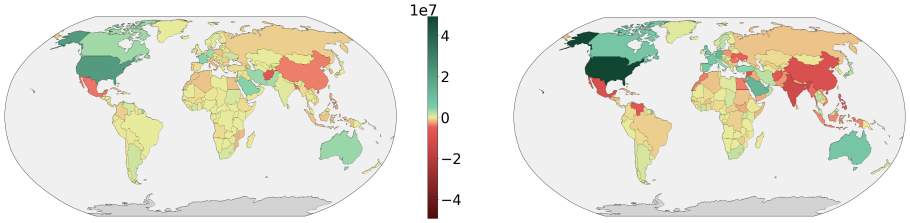
Persistent regional cohesion. Despite the globalization trend, the binary clustering coefficient increases from 0.70 to 0.73, indicating that local cohesion within regional communities remains high. Globalization operates heterogeneously: while certain corridors become increasingly globalized, regional communities preserve intense internal migration patterns. This duality is consistent with the notion of *"glocal"* connectivity proposed by [4].

Degree and weight distributions. The degree and weight distributions reveal strong structural heterogeneity consistent with the heavy-tailed distributions observed in other complex systems [12]. Concentration is particularly pronounced: the Mexico–United States corridor accounts for approximately 3.75% of the global migrant stock, and the thirty largest corridors concentrate nearly 27% of the total. This hierarchical topology provides structural validation for Hypothesis 3: migration flows systematically converge toward high-income hubs, with the United States consolidated as the main net receiver, hosting 52.4 million immigrants

in 2024. This result shows that the network is organized neither randomly nor purely geographically, but rather according to a gradient of economic asymmetry.

When flows are normalized by population, additional migration corridors with lower absolute volume but high relative impact emerge, as well as countries with high emigration rates, with India, China, Mexico, and Venezuela being the largest migrant-sending countries in 2024.

Centrality and structural roles. The network exhibits strong directionality in migration patterns, with well-defined corridors reflecting historical, geographic, economic, and political factors. This asymmetry is manifested in the divergence between immigrant and emigrant stocks among the main nodes: countries such as the United States, Germany, and Saudi Arabia concentrate large stocks of foreign-born populations from multiple origins, whereas Mexico, India, and the Philippines display diversified emigrant stocks toward high-income destinations (see Figure 2).



(a) 1990 (b) 2024

Fig. 2. Net migration balance by country in 1990 and 2024, defined as the difference between immigrant stock and emigrant stock. Positive values (green) indicate net receiver countries, while negative values (red) indicate net sender countries. The scale is shared between both maps and, for 2024, ranges between −13,733,480 and 49,243,534.

Community detection. Infomap [14] detected 13 modules with a codelength of 5.0378, capturing the asymmetry of migration corridors through random walks on the directed network.

The largest Infomap communities exhibit clear geographic and historical coherence. Community 2 (41 countries) groups Western Europe and its historical colonial sphere; Community 1 (35 countries) connects the United States with its main migration origins in Latin America and East Asia; Community 3 (24 countries) reflects the Anglophone Commonwealth space; and Community 4 (22 countries) captures the Persian Gulf–South Asia corridor. Similar patterns are observed in the remaining detected communities and are consistent with previous studies identifying geographic proximity, colonial ties, and development disparities as the main determinants of the community structure of the global migration network [2,6].

5 Neighboring Countries Migration (Hypothesis 1)

When analyzing geography as a determining factor in human mobility, considering only countries with land borders — and excluding Oceania — we observe that neighboring countries continue to be one of the primary migration destinations, still accounting for approximately 36% of global mobility. However, the analysis reveals a structural shift: although migration was historically concentrated within contiguous border regions, destinations have become increasingly heterogeneous over time, reflecting the ongoing globalization process. This transformation can be broadly observed in Figure 3, which shows a progressive attenuation in the intensity associated with the proportion of neighboring-country migration over time.

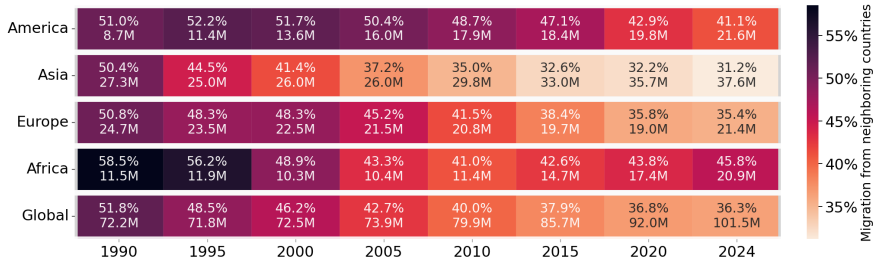


Fig. 3. Distribution and relative weight of neighboring-country migration. The percentage indicates the relative weight of neighboring-country migration over total migration in each region, while the absolute values represent the total number of neighboring migrants (in millions). For example, in 1990, 51% of migrants in the Americas moved toward neighboring countries, corresponding to 8.7 million people.

In Europe and Asia, the levels observed in 1990 were exceptionally high due to political transformations and conflicts, such as the dissolution of the Soviet Union and the Afghan crisis, where geographic proximity operated as the main shock-absorption mechanism, generating massive displacements toward neighboring countries and consolidating corridors such as Russia–Ukraine, Bangladesh–India, and Afghanistan–Iran/Pakistan. Europe also stands out as the only region with an initial peak in 1990 that has not been reached again since.

In contrast, the Americas exhibit sustained growth associated with the consolidation of historical migration axes such as Mexico–United States, as well as the emergence of more recent flows, including the Venezuela–Colombia corridor (H3). Africa, meanwhile, maintained relatively stable levels until 2015, after which intraregional mobility accelerated significantly. It is the region where migration remains most strongly structured around neighboring countries, confirming that in contexts with lower levels of global infrastructure, geography remains the primary determinant of mobility.

Overall, neighboring-country migration has lost relative weight due to the diversification of destinations, decreasing from 51.8% of the global migrant stock in 1990 to 36.3% in 2024. However, its structural role has evolved: from being primarily a physical constraint to becoming an emergency response mechanism

during regional crises. Geographic proximity remains relevant as the first escape route (H1), while digital and economic connectivity increasingly enables migration beyond traditional border regions toward nontraditional destinations in contexts of voluntary migration.

6 Cultural and Linguistic Affinity (Hypothesis 2)

To understand the mechanisms underlying the global transition described in previous sections, the analysis focuses on Africa, where persistent regional blocs and colonial legacy make it possible to evaluate the role of cultural proximity (H2). Unlike the dynamism observed in transatlantic corridors, the African migration network exhibits stable regional communities strongly influenced by linguistic proximity and colonial history rather than purely economic factors.

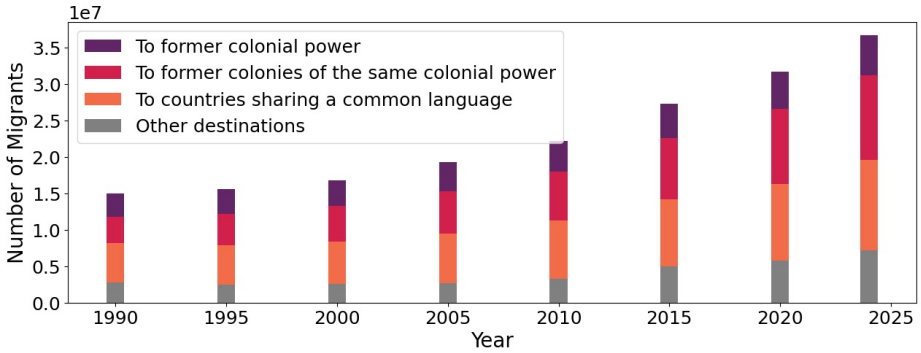


Fig. 4. Evolution of migration destinations according to historical-cultural ties. Migration flows originating in Africa toward European powers and toward African countries sharing colonial links or linguistic affinity.

The evidence suggests differentiated effects depending on the type of cultural-historical tie. Migration toward former colonial powers (Figure 4) shows a declining contribution over time (21% in 1990 versus 15% in 2024) and low structural dominance, indicating that direct colonial legacy has limited explanatory power in the current African migration system.

In contrast, flows toward countries sharing a common language consistently account for the largest proportion of migrants (82–89%) and remain highly stable over time. However, this category overlaps substantially with migration between former colonies of the same European power, suggesting that "common language" captures a broader cultural and institutional affinity rather than a purely linguistic effect. The evidence therefore supports H2 in a broad sense, although language cannot be isolated as an exclusive mechanism.

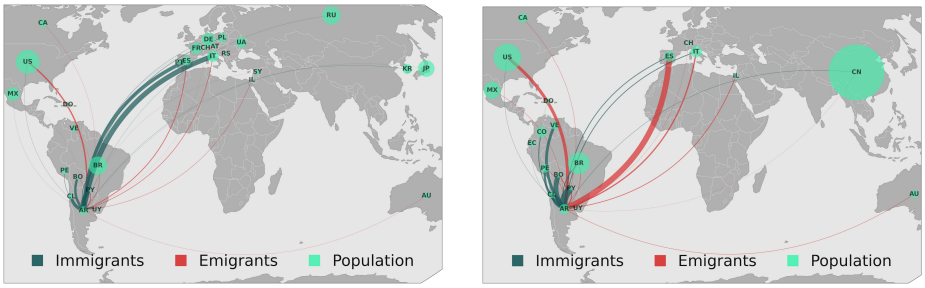
Community detection using the Louvain algorithm identified ten regional blocs with an average cohesion of 0.552, confirming a strong intraregional structure and also supporting H1 in the African context: geographic proximity remains a primary determinant of mobility under high border frictions.

While the Argentine case discussed in Section 7 shows that economic asymmetry can reverse migration directions, the African case demonstrates that culture and geography act as structural anchors preserving the morphology of the network despite globalization pressures.

7 Economic Asymmetry (Hypothesis 3)

To evaluate H3, we analyze the correlation between the direction of migrant stocks and the GDP per capita differential between origin and destination country pairs. The Argentina–Spain case constitutes the most illustrative migration corridor of the analyzed period: a corridor characterized by strong linguistic and historical ties in which increasing economic asymmetry completely reversed the direction of migration stocks, making it possible to isolate the economic effect from other cultural determinants.

During the 1990–2024 period, Spain, the United States, and Italy were the main migration destinations for Argentine migrants, while Italy, Paraguay, and Bolivia accounted for most immigration into Argentina. Figure 5 illustrates the evolution of these corridors for the extreme years of the period.



(a) 1990 (b) 2024

Fig. 5. The figures show the origins and destinations accounting for 95% of migration flows centered on Argentina. Migration from Spain → Argentina decreased from 234,460 migrants in 1990 to 54,371 migrants in 2024, while migration from Argentina → Spain increased from 51,118 migrants in 1990 to 390,798 migrants in 2024.

The Argentina–Spain corridor constitutes the main scenario for validating H3. The comparison between the 1990 and 2024 snapshots reveals a complete reversal in the direction of the migration corridor. In 1990, although Spain already exhibited a higher GDP per capita than Argentina (a 3.2x gap[10]), the network still reflected the inertia of historical European-origin migration flows: the nodes maintained a relationship inherited from the major European migrations of the twentieth century.[11]

[10] Source: https://datos.bancomundial.org/indicador/NY.GDP.PCAP.CD

[11] Economic theories such as those proposed by [8] suggest that the emergence of a massive migration flow requires more than a country simply being wealthier; the

By 2024, however, we observe the breakdown of this historical inertia and the consolidation of a massive outward migration flow from Argentina to Spain. This transition demonstrates that when economic asymmetry combines with conditions of state fragility and recurrent crises, a strong pull effect emerges that reconfigures the topology of the network, replacing historical ties with a logic driven by the search for structural well-being in economically higher-ranked nodes.

8 Forced Migration (Hypothesis 4)

Unlike labor or economically motivated migration, forced or survival migration is driven by war, persecution, disasters, or various forms of crisis in the country of origin. [7] identify three empirical regularities in these processes: **(i)** the magnitude of displacement is primarily determined by the intensity of the conflict; **(ii)** economic opportunities and political freedoms do not determine the choice of destination country; and **(iii)** most emigration is directed toward neighboring countries and/or destinations with large communities of compatriots. The datasets used in this work do not record internal displacement, and therefore this dimension falls outside the scope of the analysis.

To evaluate H4, we analyze three crisis cases with documented migration impact during the study period: Syria (2011), Venezuela (2015), and Ukraine (2022). For each country, we evaluate the increase in emigration following the onset of the crisis, identify the main destinations before and after the crisis, and quantify the proportion of emigration directed toward neighboring countries once the effects of the crisis become visible in migration variables. The results are presented in Table 2.

The three cases confirm the structural pattern proposed in H4. In Syria, the proportion of emigrants relative to the total population increased from 5.6% in 2010 to 30.8% in 2015, with a simultaneous increase in neighboring-country emigration from 57.8% to 78.4%, providing evidence of the geographic reorientation of the system during crises.

In Venezuela, emigration increased from 2.5% in 2015 to 29.2% in 2024, while the neighboring-country proportion rose from 5.0% to 42.5%, reflecting the consolidation of the Venezuela–Colombia corridor as a major destination corridor.

Taken together, these cases demonstrate that during political or humanitarian crises, the migration system undergoes abrupt reconfiguration: geographic proximity regains its dominant role independently of the cultural and economic factors structuring voluntary migration. This behavior constitutes the most pronounced structural exception within the system and complements the pattern observed

economic gap must cross a critical threshold, often combined with a loss of stability in the origin country. The Argentine case illustrates this mechanism precisely: it was not the 1990 gap itself that generated the migration flow, but rather its sustained deepening combined with successive economic and political crises.

Table 2. Crises and emigration in Syria, Venezuela, and Ukraine.

Country	Year	Population	Emigrants	% emigrants	% neighboring
Syria	2010	22,482,000	1,265,490	5.6	57.8
	2015	19,424,000	5,981,013	30.8	78.4
	2020	21,049,000	8,651,760	41.1	74.2
	2024	24,672,000	8,927,084	36.2	69.6
Venezuela	2015	30,573,000	754,933	2.5	5.0
	2020	28,444,000	5,443,604	19.1	38.5
	2024	28,405,000	8,282,023	29.2	42.5
Ukraine	2020	44,680,000	4,353,031	9.7	53.3
	2024	37,860,000	9,769,216	25.8	48.4

in Section 5, where geography operates as the first escape route in response to regional shocks.

9 Conclusions

In this work, we analyzed the structural evolution of the international migration network (1990–2024) and showed that the system evolved from a fragmented structure toward a highly interconnected small-world architecture. Using network science tools, we characterized global topological properties, community structure, and centrality patterns, and evaluated four hypotheses concerning the determinants of international migration.

The main finding is that the global migration system has become progressively more integrated, although this globalization process is not uniform: while some migration corridors expand beyond traditional boundaries, regional communities preserve high internal cohesion. Long-range connectivity therefore coexists with persistent proximity-based ties.

The analysis of voluntary migration reveals differentiated determinants. Geography has lost relative importance, although neighboring countries still account for 36% of global mobility in 2024. At the same time, economic asymmetry increasingly explains migration directions. The Argentina–Spain corridor illustrates this process, showing how a growing income gap combined with institutional fragility completely reversed a historically consolidated migration flow. In Africa, linguistic affinity emerges as the most stable cultural factor, while the direct colonial legacy follows a declining trajectory.

Forced migration follows a different logic: during political or humanitarian crises, geographic proximity regains a dominant role independently of economic and cultural factors. The cases of Syria, Venezuela, and Russia–Ukraine illustrate this abrupt geographic reorientation toward neighboring countries.

Overall, the results suggest that the global migration system is shaped by the dynamic interaction between geography, culture, and economic asymmetry, with

distinct behaviors between voluntary and forced migration. Future work includes incorporating machine learning methods to estimate missing migration data and developing longitudinal analyses with higher temporal resolution.

References

1. Abel, G.J., Sander, N.: Quantifying global international migration flows. Science **343**(6178), 1520–1522 (2014). https://doi.org/10.1126/science.1248676
2. Akbari, H.: Exploratory social-spatial network analysis of global migration structure. Social Networks **64**, 181–193 (2021). https://doi.org/10.1016/j.socnet.2020.09.007
3. Castles, S., de Haas, H., Miller, M.J.: The Age of Migration: International Population Movements in the Modern World. Palgrave Macmillan, 5 edn. (2014)
4. Danchev, V., Porter, M.A.: Neither global nor local: Heterogeneous connectivity in spatial network structures of world migration. Social Networks **53**, 4–19 (2018). https://doi.org/10.1016/j.socnet.2017.06.003
5. Davis, K.F., D'Odorico, P., Laio, F., Ridolfi, L.: Global spatio-temporal patterns in human migration: A complex network perspective. PLOS ONE **8**(1), e53723 (2013). https://doi.org/10.1371/journal.pone.0053723
6. Fagiolo, G., Mastrorillo, M.: International migration network: Topology and modeling. Physical Review E **88**(1), 012812 (2013). https://doi.org/10.1103/PhysRevE.88.012812
7. Fransen, S., de Haas, H.: Trends and patterns of global refugee migration. Population and development review **48**, 97–128 (2022). https://doi.org/10.1111/padr.12456
8. Hatton, T.J., Williamson, J.G.: Global Migration and the World Economy: Two Centuries of Policy and Performance. MIT Press, Cambridge, MA (2005)
9. Leo, Y., Karsai, M., Sarraute, C., Fleury, E.: Correlations and dynamics of consumption patterns in social-economic networks. Social Network Analysis and Mining **8**(1), 9 (2018)
10. Luo, S., Morone, F., Sarraute, C., Travizano, M., Makse, H.A.: Inferring personal economic status from social network location. Nature Communications **8**(1), 15227 (2017)
11. Mayer, T., Zignago, S.: Notes on CEPII's distances measures: The GeoDist database. Working Paper 2011-25, CEPII (2011)
12. Newman, M.E.J.: Networks: An Introduction. Oxford University Press (2010)
13. Pitoski, D., Lampoltshammer, T., Parycek, P.: The complex network patterns of human migration at different geographical scales: network science meets regression analysis. Applied Network Science **9**(1), 35 (2024). https://doi.org/10.1007/s41109-024-00635-1
14. Rosvall, M., Bergstrom, C.T.: Maps of random walks on complex networks reveal community structure. Proceedings of the National Academy of Sciences **105**(4), 1118–1123 (2008). https://doi.org/10.1073/pnas.0706851105
15. Tranos, E., Gheasi, M., Nijkamp, P.: International migration: A global complex network. Environment and Planning B: Urban Analytics and City Science **42**(1), 4–22 (2015). https://doi.org/10.1068/b39042
16. United Nations: International migration 2024: Highlights. UN DESA Population Division (2024), https://www.un.org/development/desa/pd/content/international-migration
17. Watts, D.J., Strogatz, S.H.: Collective dynamics of 'small-world' networks. Nature **393**, 440–442 (1998). https://doi.org/10.1038/30918