

Porat, Idan; Benguigui, Lucien

Conference Paper

World migration degree: Global migration flow in directed networks

54th Congress of the European Regional Science Association: "Regional development & globalisation: Best practices", 26-29 August 2014, St. Petersburg, Russia

Provided in Cooperation with:

European Regional Science Association (ERSA)

Suggested Citation: Porat, Idan; Benguigui, Lucien (2014) : World migration degree: Global migration flow in directed networks, 54th Congress of the European Regional Science Association: "Regional development & globalisation: Best practices", 26-29 August 2014, St. Petersburg, Russia, European Regional Science Association (ERSA), Louvain-la-Neuve

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World Migration Degree

Global migration flow in directed networks

Idan Porat*, Lucien Benguigui**

*Architecture and Town Planning Faculty
Technion - Israel Institute of Technology

idan.prt@gmail.com

Phone: +972.54.2295577

Fax: +972.4.8294071

**Solid State Institute and Physics Department,
Technion - Israel Institute of Technology
32000 Haifa Israel

Abstract

In this article we analyze the migration flow of destination and source countries (2006-2010) and focus on directed network degree dispersion of the two phenomena. Degree represents the connectivity of a country to the global migration network, and plays an important role in defining migration processes and characteristics. Global analysis of directed migration flow degree dispersion offers a potential improvement in understanding of the differences in the network pattern between source and destination countries. In regard to immigration networks, we found that it is possible to classify countries into three classes: high degree, with global representation; low degree and massive migration with local representation; and low degree representing specific migration links. Emigration networks, on the other hand, were found to be homogeneous with a constant relationship between emigration, degree and populations.

Key Words

Immigration, Emigration, Migration flow, Directed Networks, Network Degree

1. Introduction

Migration is an important aspect of human society. It has existed throughout history, but in modern times it takes a new form, scope and scale. Developments in transportation and, more recently, globalization have increased migration to such an extent that today it affects almost all the countries in the world. Migration affects not only societies but also world economy, labor, mobility, environment and politics (Castles, 2010; Cohen, 1995; Koser, Laczko, 2010), and therefore, understanding its scope and dynamics is essential for understanding the world that we all lives in.

While there is intense and vast research on migration as a social and geographical phenomena and a vast literature relating to these topics, global migration network as a spatio-temporal analysis is rather a new and limited research topic due to shortage of reliable and comprehensive global data (Davis et al., 2013; Fagiolo, 2013). In recent years, data collection at a global scale and in a fine resolution of source and destination countries level is evolving (Davis et al., 2013; Fagiolo, 2013; Ratha and Shaw, 2007; World Bank Factbook, 2011), and the “big picture” of world migration characteristics is beginning to be examined. Global migration studies relate to the global patterns of migration in regional scale and in several time periods. These studies are innovative and groundbreaking, however there are several issues which need further investigation: first, to separate temporal migration flows in specific time frame in order to look at present migration phenomena without the bias of past migration stocks; second, to separate the analysis of migration to destination countries and from source countries in a global directed network in order to look at the two phenomena separately and identify differences.

This study relates to the global flow of migrants from source and to destination countries between the years 2006-2010. According to World Bank data source of bilateral migration, in 2006 there were 204 million people that lived outside their home country; in 2010 this number increased to 216 million (Ratha and Shaw, 2007; updated with additional data for 71 destination countries as described in the Migration and Remittances World Bank Factbook, 2011). In the four years 2006-2010, the world experienced migration flow of 12 million people. In this study we focus on that flow of migrants and on the unique directed relationship between source and destination countries.

2. Migration Dynamics

Studies of modern migration focus mainly on two approaches that are often presented together: a description of the phenomenon itself, in particular between two countries (from source to destination), and a discussion of a specific case study with its unique aspects such as differences between the countries in wage, health, rights, education or other services. Case studies such as the most reported migration waves between Mexico and the USA (e.g. Massey, Goldring and Durnad, 1994; Massey & Taylor, 2004), highlight three elements: social capital, human capital and market consolidation - these factors combined with the mutual border generate the migration. Spain has experienced a migration wave from Latin American and South American countries during the last decade (Durand and Massey, 2010). This wave has been interpreted as resulting from mutual culture, social networks, and Spanish migration policies (Sandell, 2006). Israel experienced a wave of immigration from the former Soviet Union at the beginning of the 1990s when the Soviet Union experienced political change (Alterman, 2002). It brought one million migrants (one-fifth of the country's population) in less than a decade, and then subsided.

Studies including Cohen's *Cambridge Survey of World Migration* (1995), Zolberg's "Migration Theory for a Changing World", Hatton and Williamson's *Global Migration and the World economy: two centuries and Policy and Performance*, Castles & Millers', (2008) *The Age of Migration: International Population Movements in the Modern World*, Hatton, Williamson, *global migration and world economy*, (2005) and also the works of Li (2008), Massey et al., (1993); Massey & Taylor, (2004) and others present studies of migration in different regions of the world as well as the theoretical, economic, geographical, and psychological context, social and political aspects and also geographic and ethnic **relationships** between specific source and destination countries (Rainer, 2007; Taylor, 1999). In many cases, migration between two countries can only be explained by migration system theories (Kritz et al., 1992, Castels & Miller, 2008) that analyze source and destination and their relationship, e.g. the former colonialist relationship between France and Algeria, mutual trade interests in commonwealth countries - the UK, South Africa, Australia, New Zealand - or military involvement between Korea and the USA. Middle Eastern countries are powerful migration magnets, but only from specific sources; each of them forms a close migration network separate from the global network, and with specific social characteristics (Okruhlik & Conge, 1997; Shah & Menon, 1999; Ratha & Shaw, 2007; Nasra & Shah, 1999).

According to chain migration theory, migration dynamics usually begin with a link (even a weak link) of social networks between migrants and their community in the homeland (De Hass, 2010a,b; Massey, 1990; MacDonald and MacDonald, 1964). This social network is the facilitator and broker of knowledge regarding opportunities, transportation and employment in destination countries. McKenzie and Rapoport (2007) suggest a model of acceleration of migration followed by its decline. According to this model, migration may start due to any trigger, even random one. In most cases a migration emerges and then declines, but in some cases (again, possibly a random process) it becomes a mass migration, which may continue for some time but ultimately will also decline. However, there is a difference between relating to bilateral migration from the ethnographic perspective and the global network perspective (Davis et al., 2013; Fagiolo, 2013). The global network analysis approach can provide complementary knowledge on the spatial pattern of increasing interconnectivity and resilience of global migration processes.

In the present work, we analyze a directed network of source and destination migration flows. This approach is focused on the difference between the flows from source countries to destination countries in a global migration network. We use the network concepts of degree (the number of links) and strength/weight (the number of migrants per link) for the analysis of global distribution of degree and weight in a directed migration network, consisting of immigration and emigration separately. We consider and compares both these aspects of the phenomenon in all countries for which there are reliable data sets and statistics.

Social systems can be described as a network of connections (Castles & Miller, 2008). A network is a concept of connections of various extents, from a single person's net of several agents, to a vast and growing network of millions. According to Graph Theory, networks are measurable both quantitatively and qualitatively (Strogatz, 2001) as a system of nodes and links that may represent social, commercial, transportation, ecological or any other type of connection. Such flexibility enables use of networks in life sciences and social sciences as well as in mathematics.

The present study deals with the degree of nodes and weight of links. Degree D of a specific node is the number of links to it, and measures the involvement of the node and/or its connectivity to the network. The weight/strength of a link is the number of people passing through this link. The weight/strength W of a node is the number of migrants who come to or leave this node from all the linked countries, or the sum of the strengths of all those links. Thus a node is characterized by two numbers - degree and weight. In other words there are four

alternative options: low degree low weight countries, low degree high weight countries, high degree low weight countries and high degree high weight countries. Each category has a different level of connectivity to a global migration network.

2. Results

2.1. Data base

A bilateral migration matrix of the University of Sussex (Persons et al., 2005; Ratha and Shaw, 2007) was published by the World Bank and updated in the Migration and Remittances Factbook 2011, for the years 2006 and 2010. This data set can be accessed at these links¹. In this database, migrants are defined as people who do not live where they were born (Ratha and Shaw, 2007). The matrix covers migration data on 226 countries and territories (source and destination) and is a unified data source for these countries, including national census, population registration, national statistical bureaus and secondary sources for countries with limited migration information. The data were verified by world and regional migration models and techniques to assess missing data, and the database includes migrants according to current distribution, both registered and un-registered, i.e. it is a mixture of heterogeneous data with disparities across countries, differences of definition, classification, and other lacunae, a collection of shared data between countries. The resultant bilateral migration matrix is the fullest and most up-to-date set of data, and is the most useful for modeling world migration (Parsons et al., 2005; Ratha & Shaw, 2007).

To estimate migration flows between the years 2006-2010, we subtracted the 2010 matrix from the 2006 matrix. This process yield a new matrix that indicate the flow of migrants during the four years period and the change in number of migrants in each country. Each cell in the new matrix represents the number of migrants who moved from country A to country B during the years 2006-2010. The subtract action is not automatic and needs intervention because this mathematical act can provide positive and negative results which needs different attitudes. A

<http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTDECPROSPECTS/0,,contentMDK:22759429~pagePK:64165401~piPK:64165026~theSitePK:476883,00.html>¹
<http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTDECPROSPECTS/0,,contentMDK:21154867~pagePK:64165401~piPK:64165026~theSitePK:476883,00.html>

positive number of migrants indicate a positive flow of migration from A to B, however negative number are much more difficult to understand. Negative migrant number in a cell may indicate migrants who return to their home country (and therefore are not migrants anymore) or migrants which moved to a third county C (in this case these migrants will be counted in the A to C cell). Therefore in the analysis of migration flow we considered only positive results and ignored negative numbers. Furthermore, we did not consider countries with total W less than 1000 or with D smaller than 4. These criteria are somewhat arbitrary, but they permit elimination of countries whose involvement in the global migration phenomenon is so weak that statistically we cannot verify their migration flow. This resulted in a matrix of 88 destination countries that received immigrants during this period, and 108 source countries from which emigrants left (see Appendix 1). These two systems do not mirror one another since the matrix is not symmetric.

2.2 Degree and weight statistics

We present statistics for degrees (D) and weight (W) for the destination and source countries, using the log-log Rank Size representation (Zipf) as well as histograms. Degree and weight are sorted by decreasing values, ranking R for a given size (S) or value. In Figure 1a we plotted $\log W$ vs. $\log R$ for destination, and in Figure 1b for source countries. There is a marked similarity between weight distributions for destination and source countries, and the histograms are also similar with a large decrease for low values of W. However a closer inspection of the curves $W(R)$ and $\text{Log}W(\text{Log}R)$ of the destination countries shows a break at about $W = 32000$. Although it is possible to fit the destination countries curve by summing two exponentials, this break can be interpreted as indicating separation between countries with $W > 32000$ and those with $W < 32000$. The log-log plot fit of the source countries is expressed as: $y = 5.7(2.14 - x)^{0.15}$

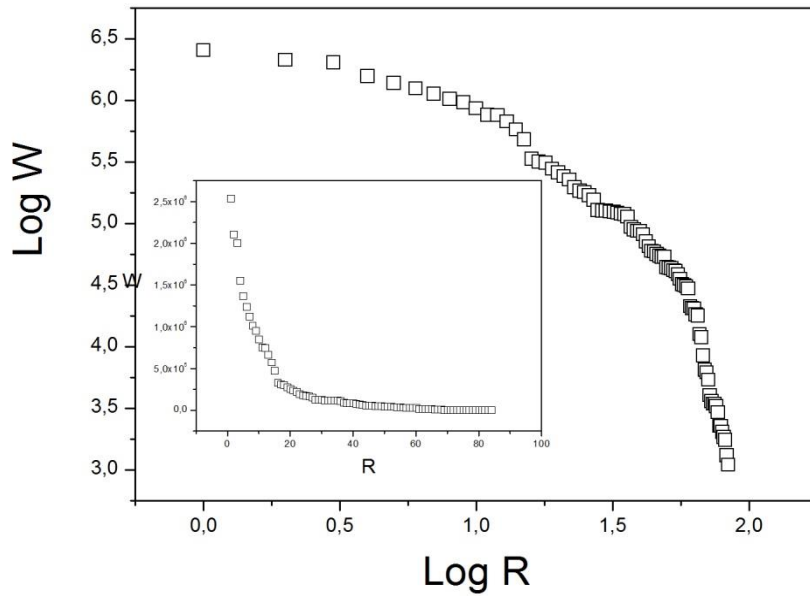


Fig. 1a: W versus R (destination countries) in a log-log plot. The insert shows the curve W vs. R in linear plot to indicate the division into two parts

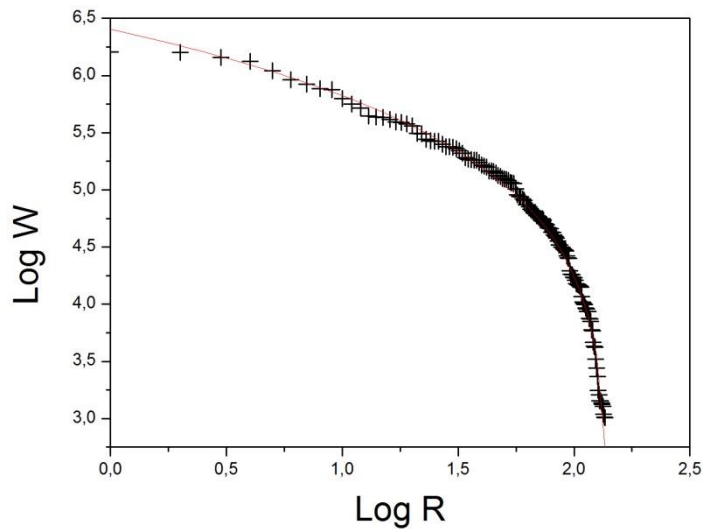


Fig. 1b: W vs. R (for source countries) - log-log plot

From the same representation for the degrees (Figs.2a and 2b), the large difference in distributions of destination degrees and source degrees is evident. The source distribution is homogeneous since all the countries are associated on the same curve, except for five countries with higher values of D. Also the histogram of degree distribution for the source countries shown in Fig.3 is very near a Gaussian distribution (see the continuous curve).

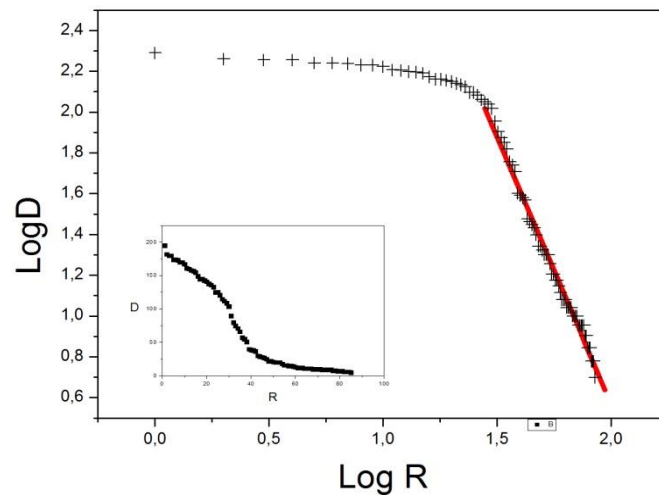


Fig. 2a: D vs. R (destination countries) curve - log-log plot. The insert shows the curve D(R) in linear coordinates. There is a clear break in D(R) at about D = 100. For D < 100 the log-log curve is a straight line

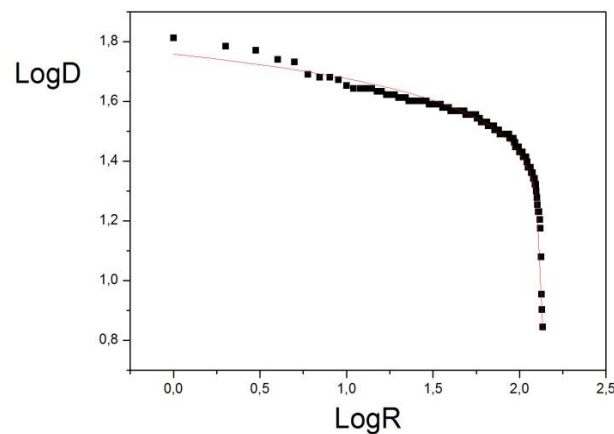


Fig.2b: D vs. R (source countries) curve - log-log plot

On the other hand, it seems clear, that the log-log curve for destination countries is compounded of two parts, i.e. countries with degree larger than 100, and those with degree smaller than 100. For the latter ($D < 100$), the Rank-Size curve is a power law, i.e. $\text{Log}D = 5.81 - 2.62 \log R$, or D is proportional to $R^{-2.62}$. The histogram of destination degrees (Fig.4) also shows division of the countries into two groups - those with $D > 100$ and those with $D < 100$.

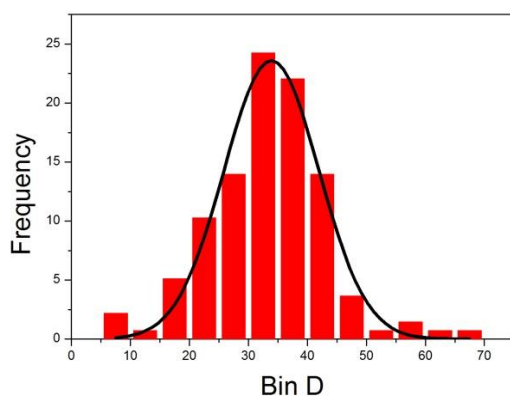


Fig. 3: Histogram of degree distribution for the source countries. The continuous line is a Gaussian figure

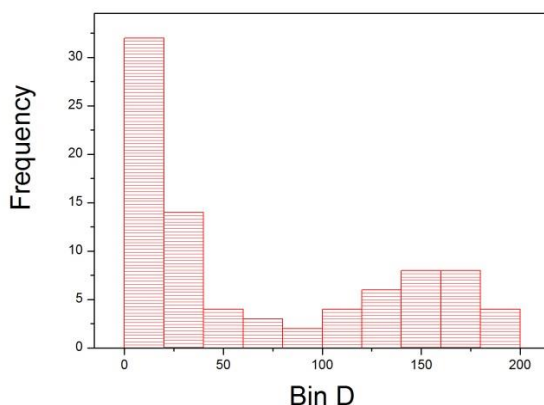


Fig. 4: Histogram of degree distribution for destination countries, illustrating the two groups, those with low D and those with high D

These results are interesting because they show major difference between the out links distribution (source countries) and in links distribution (destination countries). The almost normal distribution of out links may relate to the randomly dynamics of the immigration process; while the power law distribution of the out links may only explain the low degree ($D < 100$) emigrant countries, and the high degree is still unclear. In the next sections we will try to delve in to the relationship between source and destination countries.

2.3. Characteristics of destination countries

The weight and degree parameters represent two aspects of destination countries' migration, namely the flow of migrants and the connectivity of the network. Figure 5 (D vs. W) shows clearly the two groups of countries already observed in $\log D$ vs. $\log R$, i.e. those with large and those with small degree. In view of the above results, we propose to divide the low-D group

into two subgroups. Subgroup A ($D > 100$) includes most of the European countries, the New World (USA, Canada, Australia, New Zealand), and some Latin-American countries. Subgroup B comprises countries with $D < 100$ and $W > 32000$. This group essentially includes African, Middle East and ex-Soviet Union countries. Group C comprises countries with low D and low W , and includes African, Asian and some Latin-American countries.

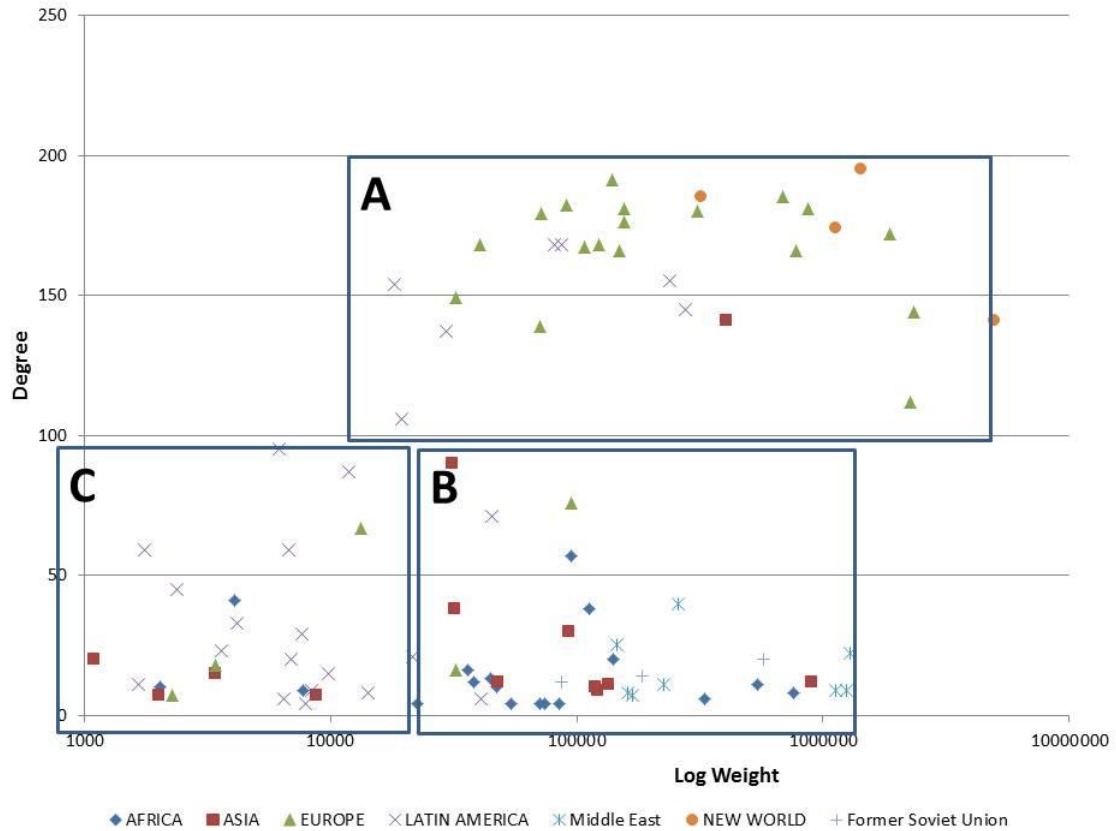


Fig. 5: W vs. D for destination countries, classified in three groups according to values of W and D

The distribution to three groups help to identify the difference between OECD countries (mostly located in group A) which are high connected and have high levels of immigration; and groups B and C which represent the developing countries and a more targeted immigration pattern.

2.4 Characteristics of the source countries

Source countries are those from which migrants depart. Degree ranges from 5 to 66, i.e. far more concentrated than that of the distribution countries. According to migration data in 2006-2010, 108 countries experienced positive emigration of more than 1000 emigrants, and are included in this analysis.

Analysis of degree versus weight of source countries shows generally positive correlation; a totally different pattern from that of destination degree and weight. Figure 6 plots weight versus degree and show a positive correlation between them. There is also a positive correlation between migration weight and population, i.e. bigger countries sent out more migrants via more out-links. In other words, countries of high weight also have high degree and high population. The Figure also presents countries according to geographic location, but it is not possible to distinguish groups in this figure as we did for destination countries. It seems that source countries which send large numbers of emigrants, such as India, Mexico, Poland, Bangladesh and the UK, have low similarity in their attributes; and it may be possible to say that emigration is a global phenomenon and immigration is a conditional phenomenon.

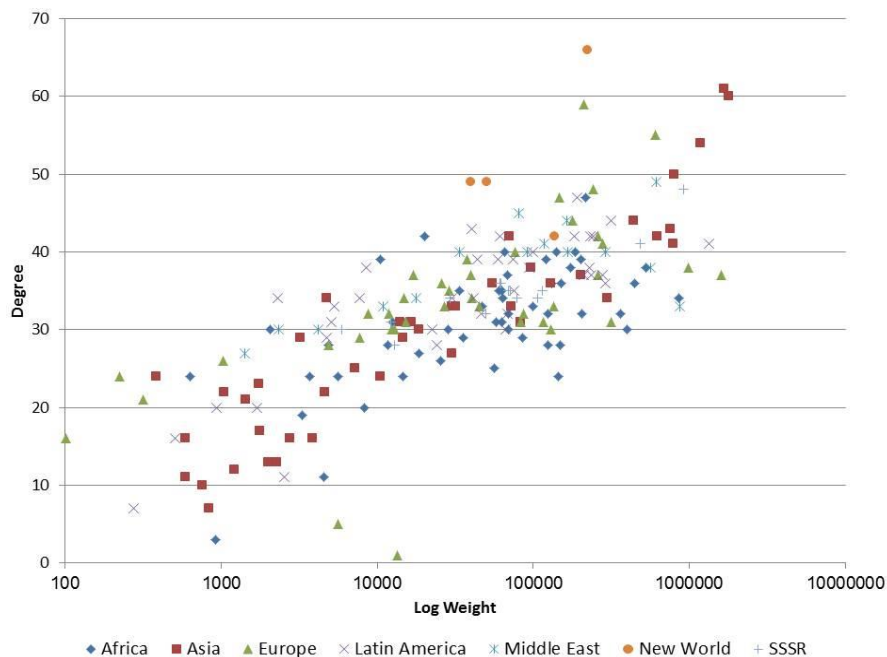


Fig. 6: W versus D for source countries. Note the positive trend of the points for all the countries

3. Discussion and Conclusion

We have proposed a new approach to typologies of the world migration flow phenomenon as a directed network, and have tried to compose a general picture by evaluating both countries as sources of migrants and countries as receivers of migrants. We employed two parameters: degree (D) - the number of links of a country with the rest of the world; and weight (W) - the number of migrants to and from a country. We confined our research to countries with at least 4 links and at least 1000 migrants, disregarding countries that have very low influence on the phenomenon. The weights and degrees are completely different for each migration system.

Global migration flow analysis in directed networks reveals a few important differences between the different directions of the network. Source countries (N=136) represent a regular weight distribution and a normal degree distribution with a mean of 37 out links. It is remarkable that the degree distribution of source countries is Gaussian, indicating some universality in the emigration phenomenon. The motivations for people to leave their country vary from country to country and from one social class to another etc. Nevertheless, on the whole, the source countries form a coherent system with their own characteristics - there is a general trend for degree and weight to increase in their population, so that the number of migrants per link is not very different from country to country. Figure 7 (histogram of the migrant number per link) shows that 50% of the links are between 500 and 1500, indicating that emigration is largely common to the 136 countries under review.

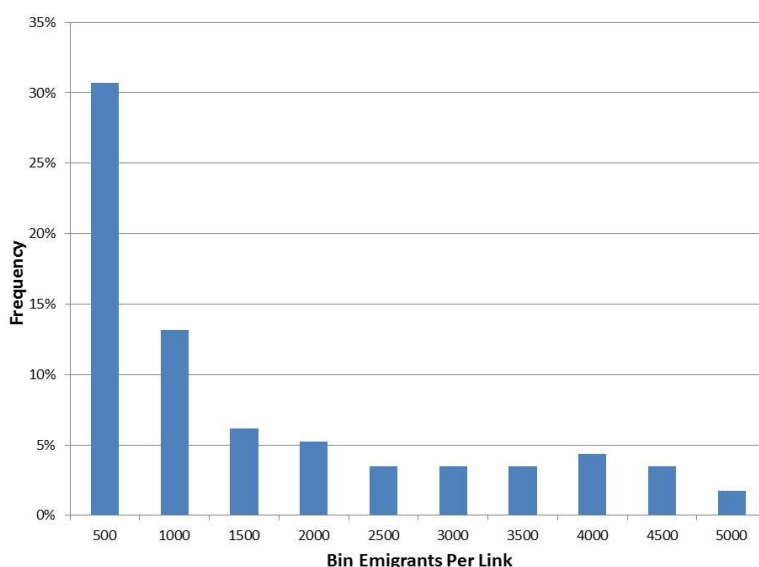


Fig. 7: Distribution of number of migrants per link for source countries

For destination countries (N=85), the weight distribution is less regular and the degree distribution is divided to a power law in low degree countries and linear for high degree countries with a mean of 63. Destination countries fall into three groups according to degree and weight: Group A - large D and large W; Group B - small D and large W; and Group C - small D and small W. There are the two main strategies of migration to destination countries: a) strong dependence on high degree, representing a “global world” of high network connectivity; and b) dependence on low degree, representing a “local world” strategy of limited specific links. Both have equal numbers of immigrants, comprising 50% of migrants to destination countries during the analysis period. This means that the immigration process is restricted to a relatively small number of countries, but many countries contribute to the process. Conversely, emigration is much more frequent in several countries but is directed to relatively few countries. These two findings are evidence of the asymmetries aspect of the migration phenomenon.

We emphasize that migration is essentially a global and general process involving countries of all sizes, from very small countries like Panama, to very large like the United States. This indicates that questions about the origins and/or dynamics of the process, or about national policies can be asked for all countries. Perhaps there are parallels between countries that are not considered "migration countries". Perhaps a much larger view is required. Finally, it is evident that countries that are often regarded purely as receptors of migrants are also sources of migration, e.g. United Kingdom. In the period covered by the present analysis, 1.6 million people migrated to the UK, while 0.6 million British migrated abroad.

Migration literature focuses mainly on characteristics of strong links, because these links are largely responsible for migration flows. However, degree also has value in the analysis of migration as a global directed network, and may characterize the level of connectivity of a country to the migration network and define migration typologies.

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| Country | Source | | Destination | | |
|--------------------------|--------|--------|-------------|--------|---------------------|
| | Weight | Degree | Weight | Degree | Destination Cluster |
| American Samoa | 4545 | 11 | 7740 | 9 | C |
| Andorra | | | 3411 | 18 | C |
| Antigua and Barbuda | 4768 | 29 | 2384 | 45 | C |
| Armenia | 29206 | 34 | 86316 | 12 | B |
| Argentina | 190440 | 47 | | | B |
| Aruba | 1707 | 20 | 6432 | 6 | C |
| Australia | 39775 | 49 | 1424520 | 195 | A |
| Austria | 39625 | 37 | 95249 | 76 | B |
| Bahamas, The | 5101 | 31 | 1759 | 59 | C |
| Bahrain | 4189 | 30 | 145783 | 25 | B |
| Bangladesh | 621407 | 42 | | | |
| Barbados | 7762 | 34 | 1648 | 11 | C |
| Belgium | 17060 | 37 | 685651 | 185 | A |
| Belize | 2305 | 34 | 6144 | 95 | C |
| Benin | 60140 | 35 | | | |
| Bolivia | 277872 | 37 | 29421 | 137 | A |
| Brazil | 316006 | 44 | 45161 | 71 | B |
| Bulgaria | 259846 | 37 | | | |
| Burkina Faso | 361435 | 32 | | | |
| Burundi | 62549 | 31 | | | |
| Cambodia | 30235 | 33 | 31833 | 38 | B |
| Cameroon | 63056 | 35 | | | |
| Canada | 50506 | 49 | 1132317 | 174 | A |
| Cape Verde | | | 2025 | 10 | C |
| Cayman Islands | | | 19519 | 106 | A |
| Central African Republic | 4850 | 28 | 4064 | 41 | C |
| Chile | 74422 | 39 | 86824 | 168 | A |
| Colombia | 230818 | 42 | 7667 | 29 | C |
| Comoros | 5569 | 24 | | | |
| Costa Rica | 8488 | 38 | 40749 | 6 | B |
| Côte d'Ivoire | 863328 | 34 | 540747 | 11 | B |
| Croatia | 86370 | 32 | 32384 | 16 | B |
| Cuba | 40242 | 43 | 9800 | 15 | C |
| Cyprus | 4904 | 28 | 32394 | 149 | A |
| Czech Republic | 40499 | 34 | | | |
| Denmark | 25695 | 36 | 107015 | 167 | A |
| Dominica | 30278 | 34 | | | |
| Dominican Republic | 60831 | 42 | 275174 | 145 | A |
| Ecuador | 210608 | 37 | 239476 | 155 | A |
| El Salvador | 229745 | 38 | 21428 | 21 | C |

| | | | | | |
|----------------------|---------|----|---------|-----|---|
| Equatorial Guinea | 14672 | 24 | | | |
| Fiji | | | 1091 | 20 | C |
| Finland | 12952 | 30 | 40532 | 168 | A |
| France | 212141 | 59 | 870961 | 181 | A |
| Gabon | 3689 | 24 | 44939 | 13 | B |
| Gambia | 12544 | 31 | | | |
| Germany | 241714 | 48 | 775001 | 166 | A |
| Guatemala | 236051 | 37 | 6720 | 59 | C |
| Guinea-Bissau | 11670 | 28 | | | |
| Guyana | 41280 | 34 | 8390 | 9 | C |
| Haiti | 290692 | 36 | 3581 | 23 | C |
| Honduras | 183635 | 42 | | | |
| Hungary | 44936 | 33 | 71014 | 139 | A |
| Iceland | 8757 | 32 | 13302 | 67 | C |
| India | 1681028 | 61 | | | |
| Iran, Islamic Rep. | 291618 | 40 | 168326 | 7 | B |
| Ireland | 26828 | 33 | 309105 | 180 | A |
| Israel | 116885 | 41 | 257138 | 40 | B |
| Italy | 146520 | 47 | 2274517 | 112 | A |
| Jamaica | 43777 | 39 | | | |
| Japan | 70706 | 42 | 403889 | 141 | A |
| Kazakhstan | 62369 | 36 | 574998 | 20 | B |
| Korea, Dem. Rep. | 31812 | 33 | 134127 | 11 | B |
| Kuwait | 17653 | 34 | 1241355 | 9 | B |
| Lesotho | 145615 | 24 | | | |
| Liberia | 124454 | 32 | 47269 | 10 | B |
| Libya | 10442 | 39 | | | |
| Luxembourg | 15190 | 31 | | | |
| Macao, China | 2769 | 16 | | | |
| Macedonia, FYR | 115760 | 31 | | | |
| Madagascar | 3228 | 29 | | | |
| Malaysia | 129205 | 36 | 897489 | 12 | B |
| Malta | 7766 | 29 | 2262 | 7 | C |
| Mauritania | 100038 | 33 | 95095 | 57 | B |
| Mauritius | 124551 | 28 | 36136 | 16 | B |
| Mexico | 1333128 | 41 | 81046 | 168 | A |
| Mongolia | 18485 | 30 | | | |
| Mozambique | 206007 | 32 | 38381 | 12 | B |
| Nepal | 71881 | 33 | 121002 | 9 | B |
| Netherlands | 178577 | 44 | 149561 | 166 | A |
| Netherlands Antilles | | | 4156 | 33 | C |
| New Caledonia | | | 8709 | 7 | C |
| New Zealand | 136466 | 42 | 319143 | 185 | A |
| Nicaragua | 59498 | 39 | 11816 | 87 | C |
| Niger | 68887 | 32 | | | |

| | | | | | |
|--------------------------------|--------|----|---------|-----|---|
| Nigeria | 216230 | 47 | 141520 | 20 | B |
| Northern Mariana Islands | | | 47744 | 12 | B |
| Norway | 14840 | 34 | 139625 | 191 | A |
| Oman | 2341 | 30 | 225609 | 11 | B |
| Palau | 2012 | 13 | 2013 | 7 | C |
| Panama | 5283 | 33 | 18203 | 154 | A |
| Peru | 241815 | 42 | | | |
| Philippines | 797260 | 50 | 31345 | 90 | C |
| Poland | 988053 | 38 | 122516 | 168 | A |
| Portugal | 258468 | 42 | 154901 | 176 | A |
| Russian Federation | 919610 | 48 | 183337 | 14 | B |
| Rwanda | 69136 | 30 | 332536 | 6 | B |
| Saudi Arabia | 33750 | 40 | 1291582 | 22 | B |
| Senegal | 202299 | 39 | | | |
| Singapore | 54463 | 36 | 118371 | 10 | B |
| Solomon Islands | 1429 | 21 | 3407 | 15 | C |
| South Africa | 186308 | 40 | 756675 | 8 | B |
| Spain | 76364 | 40 | 2338397 | 144 | A |
| St. Vincent and the Grenadines | | | 6902 | 20 | C |
| Sudan | 150786 | 36 | 112813 | 38 | B |
| Sweden | 37563 | 39 | 155634 | 181 | A |
| Switzerland | 28807 | 35 | 90456 | 182 | A |
| Syrian Arab Republic | 163002 | 44 | | | |
| Tanzania | 33440 | 35 | | | |
| Thailand | 97356 | 38 | 93134 | 30 | B |
| Turkey | 276684 | 41 | 71282 | 179 | A |
| United Arab Emirates | 10863 | 33 | 1121843 | 9 | B |
| United Kingdom | 607102 | 55 | 1876670 | 172 | A |
| United States | 223827 | 66 | 4987459 | 141 | A |
| Venezuela, RB | 100055 | 40 | | | |
| Virgin Islands (U.S.) | | | 14224 | 8 | C |
| West Bank and Gaza | 872913 | 33 | 160453 | 8 | B |