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Internal Migration in Rhineland-Palatinate - The evolution of the migration network

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Abstract. The understanding of migration flows is an important research area for various disciplines, such as infrastructure and transportation planning. Instead of statistical analyses of in- and out migrations of individual communities, this work uses complex network analyses to analyze the evolution of the internal migration network in 2012-2021 between association communities in the federal state of Rhineland-Palatinate. The results show peculiarities in some years, which might be related to a high level of international migration.

Keywords. *Internal Migration; Complex Network Analysis; Spatial Data*

1 Introduction

Migration is one of the most important forms of human mobility. Understanding migration connections is important for various areas, especially for spatial planning. The understanding of migration, as well as its spatial patterns and causes, makes an important contribution to understanding urbanization, re-urbanization, sub-urbanization, or counter-urbanization since migration is often a driver of these effects. The work presented herein provides an overview of the development of internal migration between the various association municipalities in the federal state of Rhineland-Palatinate (RLP) in Germany from 2012 to 2021. Internal migration is analyzed as a network consisting of the municipalities as nodes and the migration flows between them as edges. This representation generates an additional perspective that expands the existing analyses. While these approaches mainly rely on statistical analyses of in- and out-migration flows of the individual municipalities, the network-based approach facilitates the study of the properties of the migration network. Statistical analyses of migration movements in RLP by the Rhineland-Palatinate State Statistical Office (RLPSSO) show a strong population growth since 2011. However, this is not due to a high birth rate but rather to high numbers of immigrants, especially from abroad. In addition to this international migration, internal migration in RLP shows different migration patterns depending on age. It is primarily the urban communes that benefit from the immigration of young people between 20 and 35, while middle-aged and older adults leave the urban communes for the rural districts. However, this migration does not lead to rejuvenation but rather to the aging of the local population, although

it often includes the migration of the children of middle-aged adults. Since 2012, more people have migrated from urban communes every year than the other way around. It should be noted that in the case of international migration, the strong increases in asylum seekers, especially in 2015, were often initially recorded in Trier and then distributed among the districts. This procedure led to a distortion of external and internal migration. However, the pattern of increasing internal migration from the urban communes to the districts remains unaffected.[11] The data basis for the analysis presented herein is the migration flows between the association municipalities in the federal state of RLP from 2012 to 2021. The data was provided by the RLPSSO ((c) Rhineland-Palatinate State Statistical Office; Reproduction and Dissemination, also excerpts, are permitted provided the source is cited). The data set Administrative Areas 1: 250,000 (VG250-EW) (© GeoBasis-DE / BKG 2022) from the Federal Agency for Cartography and Geodesy (BKG) is used to represent the data spatially.

2 Results

Using the python libraries NetworkX and CDlib [12], the analyses of the migration network are carried out on macroscopic (topology of the whole network)[5, 6], mesoscopic (community and core structure)[2, 3, 1], and microscopic levels (centralities)[7, 9, 8, 10] to enable the most complete representation of the changes in the network over time.

Macroscopic Analysis: At the macroscopic level, abnormalities are particularly evident around 2015. This period has been affected by strong international immigration. Figure 1 shows the migration rates over the district borders for the state RLP divided into Germans (red '>'), foreigners (blue '<'), and total (green 'x'). Statistical analyses by the RLPSSO also showed that the years 2014 and 2015 were significant for the average values of internal migration in the 2011 - 2020 period. In 2012, more than half of the urban communes and districts still had deficits in internal migration. In 2015, apart from the independent city of Trier, all administrative districts showed internal migration surpluses due to the peculiarity mentioned at the beginning. In 2020, only 11 urban communes or districts had deficits in their internal migration balances.[11] In line with these analyses, the highest number of edges in the undirected networks examined herein is in 2016. In that year the number of edges increases by around 10% from 2012 (6546 edges) to 2016 (7251 edges) and falls continuously in the following years until 2020. In 2021, there is another increase in the number of edges. Although the networks consist of 170 nodes, they show a low diameter of two, which could indicate the existence of hub municipalities that share migration connections with all other cities. A similar pattern to the number of edges can also be seen in the number of degrees in most association municipalities. The highest value for the median degree is also in 2016 (approx. 80). We calculate the global parameters transitivity, density, and degree correlation, with and without considering the total migration flows as weight. All parameters show a similar trend in the undirected networks (Figure 1). The internal migration network in the RLP shows a high complexity. The highest density value is 0.505 in 2016. So, more than half of all possible migration links exist between any two municipalities in the network. The course of transitivity suggests that migration flows are not concentrated on single hubs, e.g., because of the distribution of international migrants from Trier to the surrounding rural areas, but also between the surrounding areas. Interestingly, this development reverses after 2016 and only increases again in 2021. We also calculate the degree correlation to analyze the assortativity in the networks (Figure 1 bottom left chart). Overall, the degree correlation is at a low level. The results show that in 2016, the network becomes more disassortative. Indeed, the highest value for a negative correlation is -0.119. The effect could be due to increased urban-rural connections where residents from

urban communes with higher degrees migrate to rural municipalities with lower degrees. We also include the total migration flows as weights for the analysis of the assortativity (Figure 1 middle left chart). The results show that considering the weight, correlation values are even smaller. The year 2015 is conspicuous but in the opposite direction, making the network more non-assortative (-0.04).

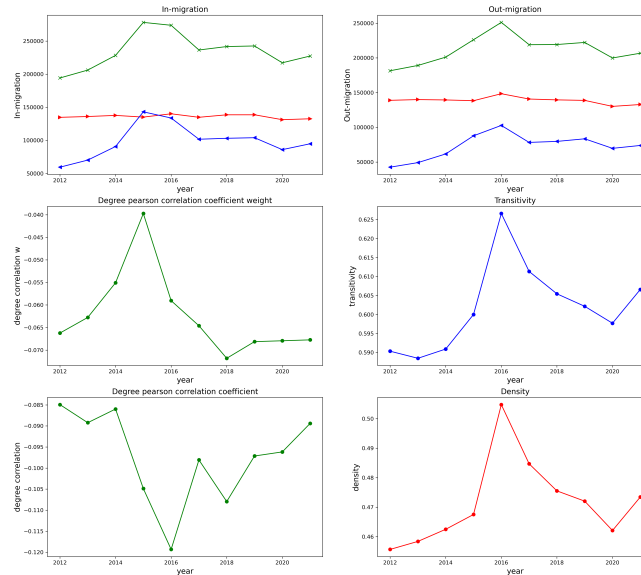


Figure 1: Migration rates (over district borders) for the state of RLP (© Federal Statistical Office of Germany, 2024.) and global parameters for the same period

Mesoscopic Analysis: An analysis of the community structure using the well-known Louvain algorithm and the total migration flows as a weight for the undirected network reveals a community structure with five to seven communities. Each of the five permanent communities contains one of the urban communes with the highest population, Mainz, Koblenz, Trier, Ludwigshafen, or Kaiserslautern, and surrounding municipalities which fits the urban-rural migration pattern mentioned in the first section. Although the modularity drops in 2015 and 2016 from about 0.6 to 0.5, there is no major change in the community structure in 2015 or 2016. **Microscopic Analysis:** Further analyses using degree-based centralities of the directed networks also show insightful results. Figure 2 shows the out-degree centrality for the directed networks. The urban communes with the highest population are also the nodes with the highest out-degree centrality. In addition to the trend of migrations from the urban communes to the districts, the destinations of the urban leavers are also dispersed. What is also interesting is the increase in the out-degree centrality of individual association municipalities in individual years. The municipality of Ingelheim, west of Mainz has a particularly high out-degree centrality in 2014/2015. This also applies to the municipality of Hermeskeil near Trier from 2015 to 2020.

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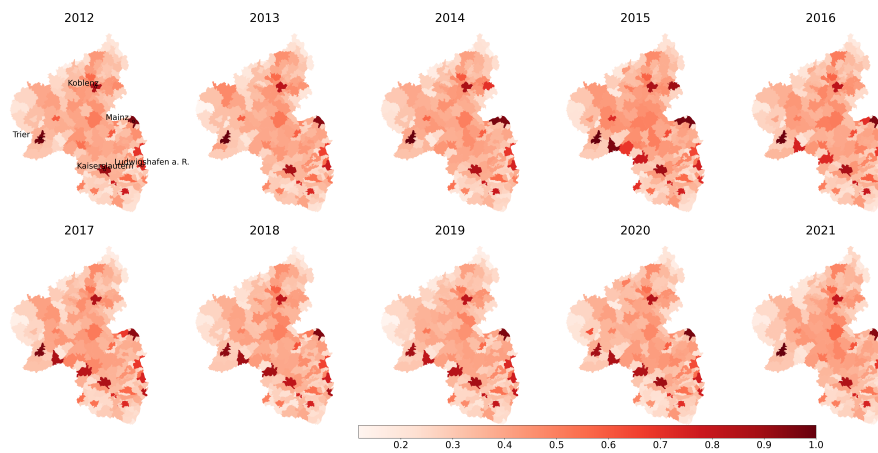


Figure 2: Out-Degree-Centrality

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