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139

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Wage Assortativity in Internal Migration Networks in England and Wales

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Introduction

People may move within their country of residence for several reasons, including for employment, education or for friends and family. The study of these reasons is one that goes back to 1885 with the publication of Ravenstein's Laws of Migration[1]. The application of network analysis techniques to this area of research has thus far been limited, particularly in attempting to understand the extent to which migration decisions relate to the features of the areas being moved from and to.

We use migration data from the Office for National Statistics for the United Kingdom, which quantifies the number of people moving between pairs of Local Authorities in England and Wales at each year of age to measure the assortativity of migration with respect to median weekly wages and the pay gradients along which migration occurs.

Methods

In this study we consider the migration network to be a directed, weighted network $G(V,E)$ consisting of a set of vertices V representing local authorities and a set of edges E representing migration of people between pairs of vertices. For any $i \neq j$ in V, let e_{ij} represent a directed edge from vertex i to vertex j. As G is weighted, w_{ij} represents the number of people migrating from local authority i to local authority j, while s_i can be understood to represent the median weekly pay in Great British Pounds of an individual resident in local authority i in the year 2019.

Quantifying Migration Efficiency

A range of measures of have been developed in recent years to understand the characteristics of internal migration. The Migration Efficiency Ratio (MER) is the ratio of net migration in an area to the total inward and outward migration in area, shown in **Equation 1**:

$$MER_i = 100\left(\frac{\sum_{j=1}^{N} w_{ji} - \sum_{j=1}^{N} w_{ij}}{\sum_{j=1}^{N} w_{ji} + \sum_{j=1}^{N} w_{ij}}\right) \tag{1}$$

Where w_{ij} represents the number of people migrating from local authority i to local authority j. The migration efficiency ratio was calculated for all local authority districts in England and additionally for the age groups described below:

$G_{0\text{-}18}$	Birth to the end of secondary education
$G_{19\text{-}21}$	University education
$G_{22\text{-}25}$	Post-university period
$G_{26\text{-}35}$	Early-career period
$G_{36\text{-}45}$	Mid-career period
$G_{46\text{-}65}$	Late-career period
$G_{66\text{-}89}$	Retirement

Quantifying Migration Gradients

We define the 'migration gradient' as the weighted average difference in vertex values for those migrating from one local authority to another (**Equation 2**).

$$F_i^{out} = \frac{\sum_{j=1}^{N} w_{ij}(s_j - s_i)}{\sum_{j=1}^{N} w_{ij}} \tag{2}$$

$$F_{all}^{out} = \frac{\sum_{i,j \in V} w_{ij}(s_j - s_i)}{\sum_{i,j \in V} w_{ij}} \tag{3}$$

where F_i^{out} is the average difference in median pay between destination and origin local authorities for those migrating from local authority i. Similarly, national migration gradients F_{all}^{out} were calculated based on the overall weighted average of outgoing migration across all local authorities, shown in **Equation 3**. The outward migration pay gradients were calculated for all local authority districts in England and Wales and across all ages, and then subsequently applied to the age group networks described above.

Quantifying Migration Assortativity

Yuan et al. (2021) describe a method by which to measure assortativity in weighted and directed networks measured in terms of the weighted in-degree or out-degree of source and target nodes[2]. The method can be extended to other nodal attributes, such as in our case the median weekly pay in a local authority. The assortativity of G was calculated according to **Equation 4** for each year of age.

$$\rho(G) = \frac{\sum_{i,j \in V} w_{ij}[(s_i - \bar{s}_{sou})(s_j - \bar{s}_{tar})]}{W \sigma_{sou} \sigma_{tar}} \tag{4}$$

where: $\rho(G)$ is the assortativity of G, $\bar{s}_{sou}$ is the weighted average of all source vertex values, σ_{sou} is the weighted standard deviation of all source vertex values and W is the sum of all edge weights.

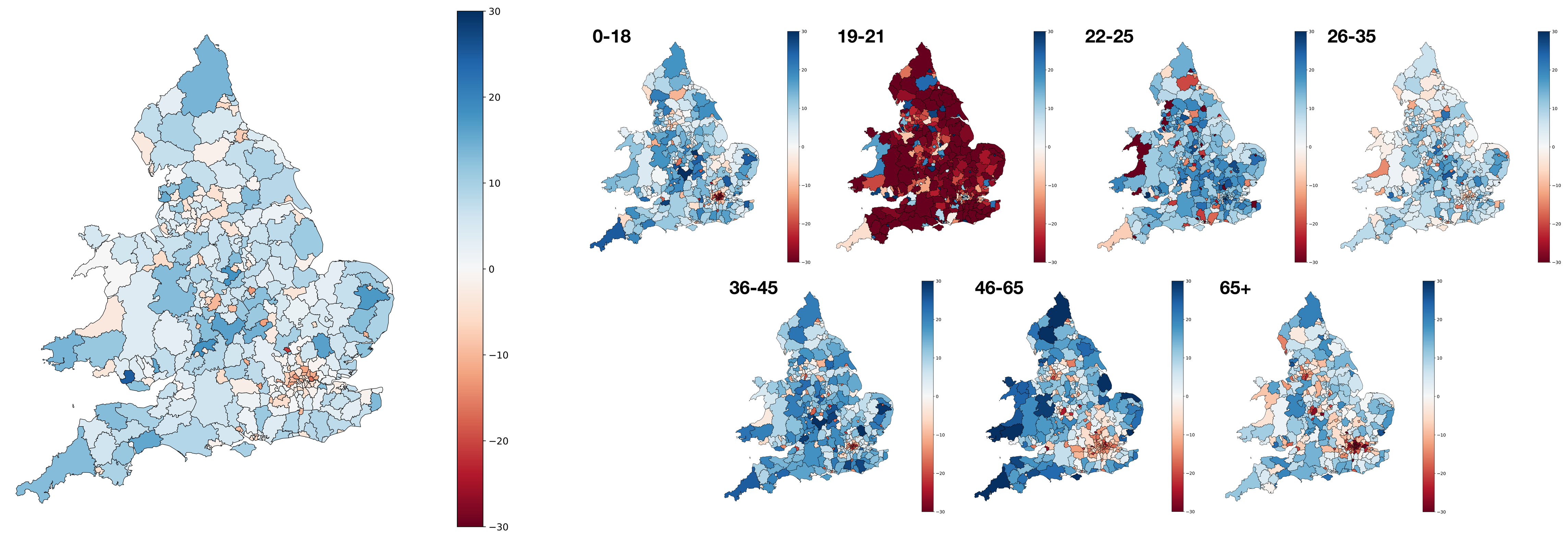

Figure 2: The Migration Efficiency Ratio for all local authorities across all ages all local authorities in England and Wales (left) and for each of the seven subgroups by age (right).

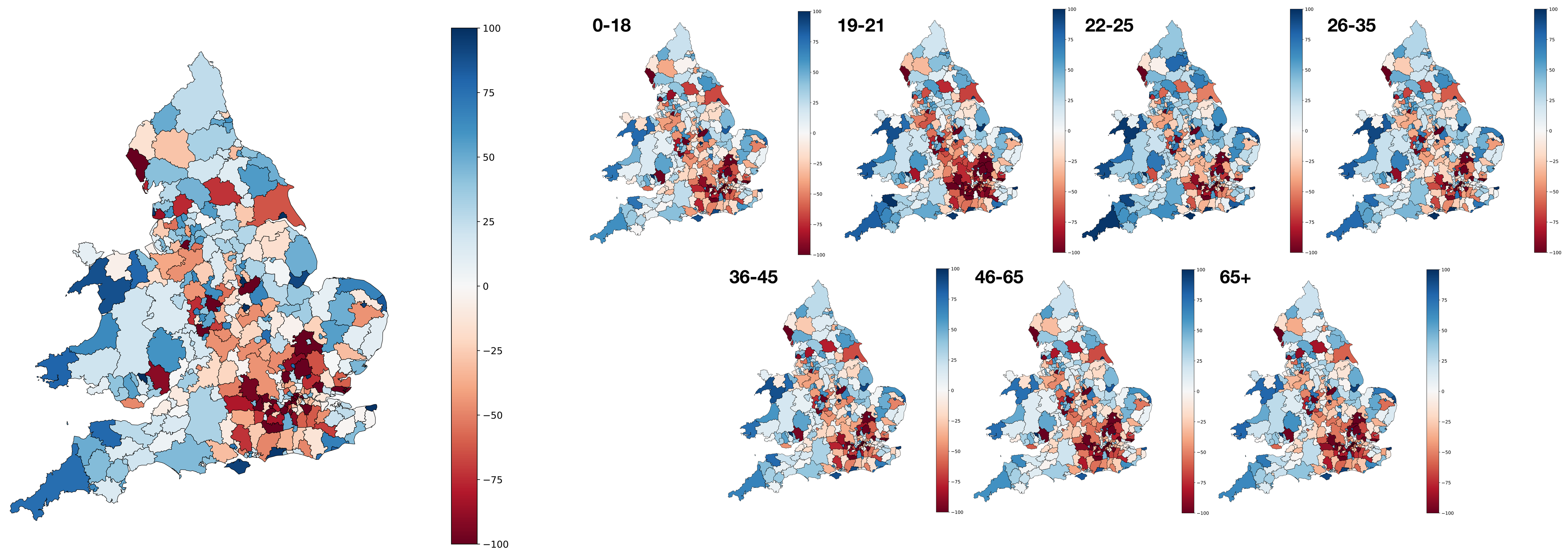

Figure 3: The Migration Gradient for weekly median pay for outward moves for all local authorities across all ages in GB £ per week (left) and for each of the seven subgroups by age (right).

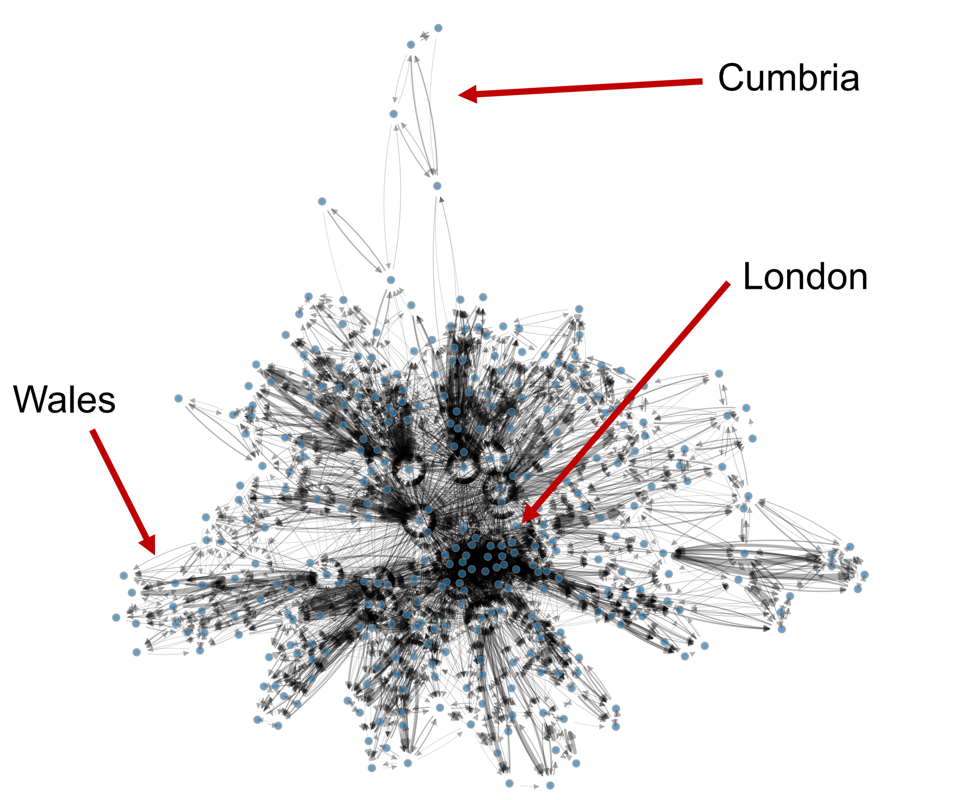

Figure 1: Visualisation of the weighted directed mobility network. Only edges representing 100 instances of migration or more are included using the Force Atlas algorithm. The underlying geographic structure of the network is reproduced.

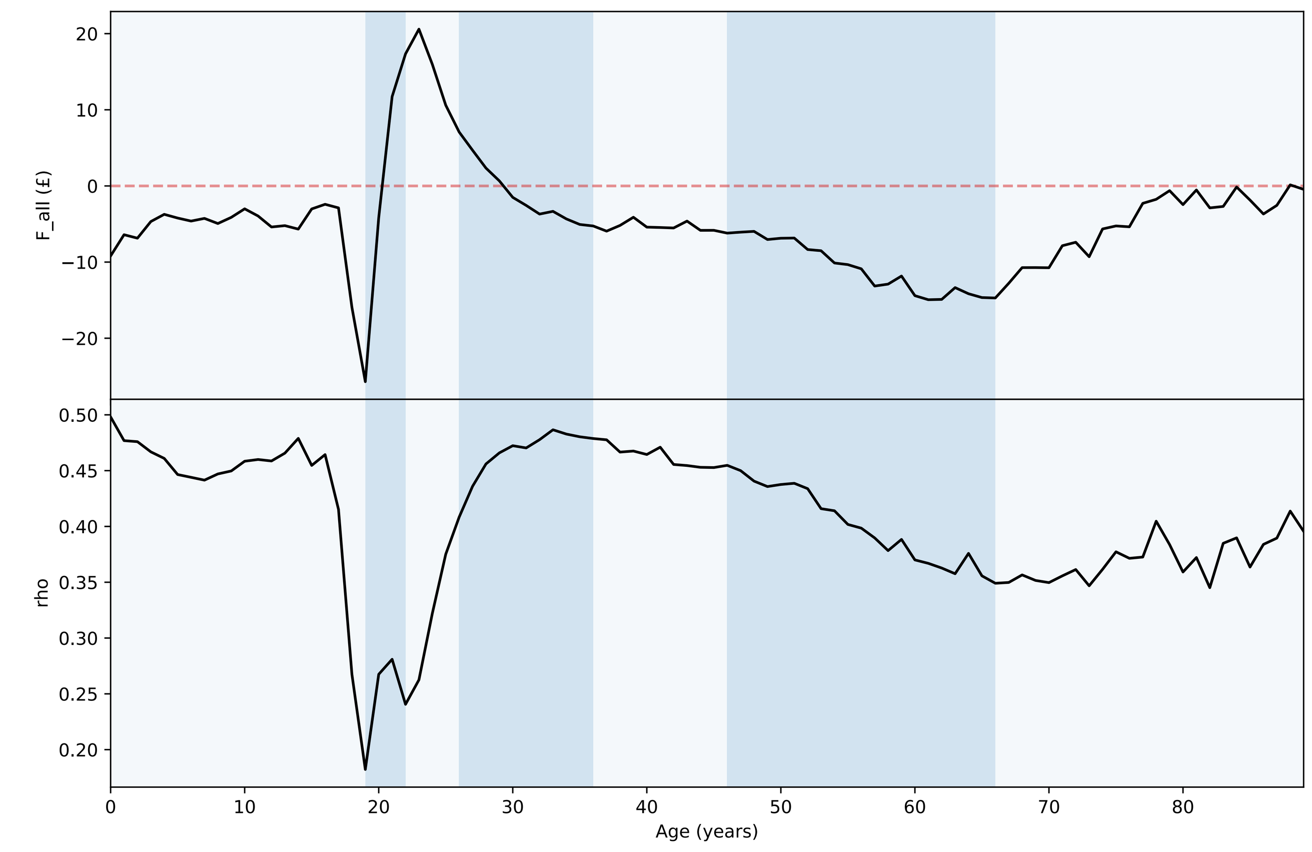

Figure 4: Top: Values of the average migration gradient for each year of age for median pay in GP £ per week. Bottom: Overall assortativity coefficient for each year of age. Colour bands indicate different age groups corresponding to different life stages

Results

A total of 3,081,533 migration events were identified between 333 Lower Tier Local Authorities in England and Wales in the year 2019, as visualised in **Figure 1**. The most common ages at which migration occurred were between the ages of 19 and 23 years, collectively accounting for 23.3% of all moves (**Figure 2**).

Figure 3 shows the migration gradient for each local authority in England and Wales. Dark blue areas indicate regions where those moving outwards move towards areas with the greatest increase in median pay, compared to red areas who have the most negative migration gradient.

Figure 4 shows the overall migration gradient (top) and assortativity (bottom) for each year of age. Assortativity is generally high, at between 0.35 and 0.55 for most ages, except for the period from 18 to 23 years, where less assortative migration occurs. This coincides with markedly negative migration gradients at ages 18 and 19, followed by positive migration gradients until the age of 30 years.

Conclusions

Migration between local authorities in England and Wales is common and varies in its frequency at different ages.

For all ages, migration is assortative in terms of median weekly wages, with the period of the late teens to early twenties being the least strongly assortative.

This coincides with negative migration gradients with respect to weekly wages in the migration of teenagers to university, and positive migration gradients at the end of university age and early working life.

Collectively this work provides a new way in which to apply network analysis methods to understand the motives underlying internal migration at a local and national level, and across our lifetimes.

1. E. G. Ravenstein. The laws of migration. Journal of the Statistical Society of London, 48(2):167–235, 1885.
2. Yelie Yuan, Jun Yan, and Panpan Zhang. Assortativity measures for weighted and directed networks. Journal of Complex Networks, 9(2):cnab017, May 2021.

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