Faculty of Business and Economics

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Pannon Management Review

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Pannon Management Review

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ASYMMETRIES ON MOBILITY NETWORKS (PMR 2021/4)

Linking network theory and economic models is always a challenging task. At the same time, linking network and economic models can make it possible not only to describe the network properties but also to explain them with economic models. In this study, we introduce a novel indicator for measuring the asymmetry of weighted networks and we define an economic null model that can capture and explain this indicator in different structural levels. Economic null models are proposed to explain the asymmetry in static and in dynamic network analysis. In the proposed application and occupation mobility network, the mediating and retaining role of institutions has been examined via asymmetries on mobility networks.

Introduction and literature review

Although the social network analysis (SNA) is looking back (at least) two decades, there are a lot of applications from social science (Lubbers et al., 2020) from neural sciences (Girvan – Newman, 2002), even till to cosmology (Krioukov et al., 2012). This epoch-making theory is just slightly used in economic and business studies and until recent years these studies are rather than descriptive. One of the reasons for barely using social networks in economic studies may be that the theory of SNA simplifies economic phenomena too much. For example, costs of links (such as transactional costs, traveling costs, shipping costs) are usually cannot be neglected in the case of analysis of supply chain networks, company ownership networks, or networks of foreign trade relations. Novel studies already use distance dependency models to describe (Barthélemy, 2011) and explain (Gadár et al., 2018) the links between players (i.e. nodes in a network). However, distance can be only a proxy for explaining transaction costs. Namely, part or all of the transaction costs can be independent of distance.

The understanding of the migratory behavior of higher education customers has been considered of crucial importance to the managers of institutions, and to policymakers that attempt to promote regional integration or regulate the supply of higher education. The socioeconomic and cultural characteristics of regions are important determinants of migratory behavior. Intuitively, districts with a larger population in the relevant age group tend to have greater outgoing flows in absolute terms (Dotti et al., 2013). They also tend to have greater incoming (Beine et al., 2014) as the abundance of educational services is positively correlated with population size. Regions with lower unemployment and greater economic opportunities also tend to attract and keep a greater absolute number of students (Dotti et al., 2013), as the latter often anticipate remaining in the region once they graduate. Students also moved by consumption motives, and so regions with greater opportunities for rich sociocultural experiences are likely to be more attractive (Franklin – Faggian, 2014). However, such regions also tend to be more densely populated and, therefore, costlier to live in. The characteristics of the institutions are also found to affect flows. Measures of the quality of the institution are usually introduced to capture this. Quality is often measured by proxies such as the employability of graduates (Sá et al., 2012; Lourenco – Sá, 2019), teacher to student ratios (Sá et al., 2004), the proportion of honors students (Dotti, 2013), research intensity (Adkisson – Peach, 2008) or the place in international rankings (Ciriaci, 2014).

The mobility network is one of the great opportunities to combine network and economic science theories. We propose an economic-network approach to model application and occupation mobility via network asymmetries and revealed preferences.

Methodology

Data employed

Several specific data sources are involved in the study. One of the main databases is the Hungarian central system for tracking graduates' careers (HCSTGC). HCSTGC includes all the anonymous graduated employees' residence location (subregion-NUTS4), the city of their higher education institution (HEI), the county and the subregion of their workplace, and starting salary, who earned their absolutism or graduation between intervals 01/09/2014–31/01/2015. Among them, the research focuses on those who got a job until May 2016. This represents 47,165 graduate students. The next applied database is the student application database (2006–2017),

which contains anonymous data from the applicants and the HEIs. The last included data sources are already found in all countries in the European Union (such as in Eurostat), and most countries in the world. Gross Domestic Income per capita (GDI/cap) of a location (subregion) between 2006–2017 comes from the Hungarian Central Statistical Office (HCSO). From the Hungarian National Employment Service, the mean of the salary for all the 19 counties and the capital city (Budapest) was gathered for the years 2015 and 2016.

Applied models

The mobility network can be described as a directed graph is an ordered pair $G = (V, E)$ comprising: where V is a set of vertices (also called nodes i.e. locations); $E \subseteq \{(x, y) \mid (x, y) \in V^2 \wedge x \neq y\}$ a set of edges (also called arcs) which are ordered pairs of distinct vertices (i.e., an edge is associated with two distinct locations in a mobility graph). And the number of movements between locations is associated with the edges. **E** s the adjacency matrix of the graph G, where the elements of the matrix indicate whether pairs of vertices are adjacent or not in the graph.

Denote e_{ij} as the matrix element of the adjacency matrix **E** of the mobility graph G. We used a gravity-like economic null model to estimate the matrix elements of the adjacency matrix.

$$p_{ij}^{\mathrm{ECO}} = \gamma d_{ij}^{\delta} \prod_{k:=1}^{N} m_{i_k}^{\alpha_k} m_{j_k}^{\beta_k}, \tag{1}$$

where m_{i_k} is a k-th economic value, such as gross domestic product (GDP), gross domestic income (GDI), or other economic quantity of the location of the node i. d_{ij} is the distance between location i and location j. α, β, δ are the importance parameters of locations and the distance between locations. They estimated by regression analysis.

We consider a directed weighted network specified by the (non-negative) weight matrix **E**, where e_{ij} indicates the weight of the directed from node i to j node. In case of no connection from i to j, $e_{ij} = 0$. **E** can be specified as the sum of symmetric (**P**) and skew-symmetric matrix **Q**, where $\mathbf{P} = \frac{1}{2}\left(\mathbf{E} + \mathbf{E}^T\right)$, $\mathbf{Q} = \frac{1}{2}\left(\mathbf{E} - \mathbf{E}^T\right)$.

The asymmetry matrix is A=P/Q. And the null model of matrix element can be specified as follows:

$$a_{ij} = \frac{e_{ij} - e_{ji}}{e_{ij} + e_{ji}} \sim \rho_{ij}^{\mathrm{ECO}} = \frac{p_{ij}^{\mathrm{ECO}} - p_{ji}^{\mathrm{ECO}}}{p_{ij}^{\mathrm{ECO}} + p_{ji}^{\mathrm{ECO}}} \ . \tag{2}$$

The asymmetry matrix can be transformed into a preference matrix: for example, eA is a multiplicative preference matrix, therefore, if the asymmetry matrix can be modeled via economic models, the preference of application can also be explained.

Results

Predicting asymmetries on application mobility

The way is to combine gravity-based economic models and null models from the network science and the revealed preferences are to model asymmetry with economic null models (see Eq. (2)). Table 1 shows the parameter estimation Eq. (2). The results of the gravity models in Table 1 have shown that a more preferred HEI, which has a higher number of applicants, has a lower unemployment rate, higher GDI per capita and better rank position (smaller rank order value) in faculty excellence. The results show us, that a HEI is more preferred if the prospects of living there are more favorable (higher GDI per capita, lower unemployment rate) and there are better HEIs, which is in line with the results of gravity models (see Table 1). Nevertheless, this model also shows that the differences in the importance of faculty excellence of HEIs are increasingly evened out.

Variables	Coefficients	2011	2013	2014	2015	2016	2017
GDI/capi / GDI/capj	$\tau_1 = \alpha_1 - \beta_1$	0,056	0,048	0,042	0,016	0,027	0,105
URi / URj	$\tau_2 = \alpha_2 - \beta_2$	–0,043	–0,035	–0,031	–0,005	–0,019	–0,026
RANK(HEIi) / RANK(HEIj)	$\tau_3 = \alpha_3 - \beta_3$	–0,106	–0,081	–0,071	–0,062	–0,042	–0,047
	R^2	0,606	0,528	0,478	0,476	0,438	0,485
	$\bar{R}^2$	0,606	0,528	0,478	0,475	0,437	0,485

Table 1 Results of asymmetries
Source: own editing

Where a good fit is found for asymmetry, it is worth comparing the real and modeled values. In this case, we can answer the question of how well the order of preference formed based on the application and the order modeled based on economic, unemployment, faculty excellence data correlate with each other (see Table 2). Since the asymmetry matrix can be transformed to a preference matrix, the revealed preferences can be estimated. Therefore, all applications and, more importantly for institutions, all first-place applications can be estimated.

Revealed preference order	Estimated preference order	HEI	GDI/cap (HUF)	ÚR (%)	RANK (HEI)	Applicants	Estimation of applicants	All applications
1	1	ELTE	1 929 477	4,12	1	15 339	13 461	44 213
2	3	DE	1 542 460	9,10	3	12 552	10 437	39 965
3	2	SZTE	1 528 263	6,18	2	11 953	10 653	37 603
4	6	PTE	1 555 151	8,03	6	10 803	9 212	34 045
5	7	BCE	1 929 477	4,12	8	9 605	8 263	28 383
6	18	BGF	1 929 477	4,12	41	7 388	5 778	28 274
7	10	SZIE	1 696 694	4,67	13	8 056	7 583	26 884
8	9	BME	1 929 477	4,12	11	8 580	6 858	23 165
9	5	NYME	1 392 972	2,07	3	6 582	6 232	19 524
10	14	ME	1 484 443	11,94	9	5 308	5 005	17 189

Table 2 Estimation of application preference
Source: own editing

The impacts of asymmetries on occupation mobility

Combining network science methods with gravity models the impact of HEIs can be further investigated. The asymmetry on occupation mobility can be calculated for the subregions, and they can be ranked. Table 3 shows the top 10 most attractive subregions.

Rank	NUTS-4	Is there any HEI	Graduated		Graduated	
			incoming	outgoing	incoming	outgoing
			employers*		employers*	
1	Budapesti	Yes	17 656	4 163	68 672	66 263
2	Gödöllői	Yes	2 148	300	3 624	3 305
3	Győri	Yes	742	778	6 348	5 045
4	Székesfehérvári	Yes	619	887	4 850	4 389
5	Veszprémi	Yes	407	579	3 727	3 679
6	Kecskeméti	Yes	439	642	4 369	4 051
7	Tatabányai	Yes	348	350	2 806	2 679
8	Szegedi	Yes	708	1 140	5 976	5 204
9	Pécsi	Yes	549	1 096	5 510	5 150
10	Egri	Yes	407	723	3 107	2 620

* without loops, it means the source and the host location must be different.

Table 3 Top 10 most attractive subregions for freshly graduated employers (2015)
Source: own editing

In line with the former results, it is not surprising, that at first, ten subregions have (at least one) HEI. It resonates to the former results, and highlight the role of the HEI. Only the first two subregions have a positive balance of graduated employers. The first one is the capital town of Hungary, the second one is also located next to the Budapest. The other subregion already has a negative balance. While if only all peoples' mobility is considered, this balance is positive in the first top subregions. Nevertheless, the lack of freshly graduated employers can make a problem for the subregion already in the medium term.

Summary and conclusion

The data-driven career tracking offers new insight for scholars to analyze the application and occupation mobility. This database represents the whole population of graduated employers and the applicants, therefore more reliable models can be proposed. This database even important for potential applicants to choose a HEI. A pilot web page is already accessible in https://www.diplomantul.hu (retrieved: 29/04/2019), where potential

applicants can see the potential salaries by occupation categories and the added values of HEIs. Nevertheless, it is a good research question, that how it further reinforces the asymmetry that already exists in the mobility networks.

The combination of network and economic models, on one hand, can cross-validate the results and offers a technique for model triangulation. On the other hand, the economic models can explain the formation and the properties, such as asymmetries of mobility networks. Besides, the combination offers a better explanation and estimation of revealed application preferences. Explaining network properties with economic models can open new horizons because it is possible to move from descriptive statistics on network properties to explanatory models and thus we can better understand the mechanism of the formation of networks.

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