A universal university ranking from the revealed preferences of the applicants

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“The ranking never lies.”

(Stan Wawrinka, who won three Grand Slam tournaments in tennis)

Abstract

A methodology is presented to rank universities on the basis of the applicants’ revealed preferences. We exploit a crucial feature of the centralised admissions system to higher education in Hungary: a student is admitted to the first programme where the score-limit is achieved. This makes it possible to derive a partial preference order of each applicant. Our approach integrates the information from all students participating in the system, does not require any preliminary selection of criteria, and is essentially independent of ad hoc weights, while it is able to reflect even non-measurable college characteristics. The suggested procedure is implemented for ranking faculties in the Hungarian higher education between 2001 and 2016. We demonstrate that the ranking given by the least squares method has favourable theoretical properties such as size invariance and bridge player independence, is robust with respect to the aggregation of preferences, and performs well in practice.

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1 Introduction

The global expansion of higher education has created an increasing demand for the comparison of universities and has inspired the development of ranking systems or league tables around the world (Dill and Soo, 2005; Usher and Savino, 2007). These rankings are usually based on the composition of various factors, namely, they are indices with a number of moving parts, which the producer – usually an academic institution, a government, a magazine, a newspaper, or a website – is essentially free to set. This approach is widely criticised for its sensitivity (Saisana et al., 2011; Olcay and Bulu, 2017), similar measures have been called “mashup indices” on the field of development economics (Ravallion, 2012). Nevertheless, college ranking remains a transparent tool of fair evaluation for the public despite the lack of consensus in the appropriate methodology.

The current paper proposes a new higher education ranking from the applicants’ revealed preferences. Our method is based on pairwise comparisons. Universities play matches against each other, and an institution defeats another in a match if it is preferred by a student to the other. Thus each applicant provides a tournament, and the suggested procedure aggregates all information into a common preference matrix in order to derive a ranking. This approach is essentially parameter-free, independent of an arbitrary choice of factors and component weights, and may reflect all characteristics of a university that are observed by the applicants even if they are non-measurable. Furthermore, it has a straightforward motivation as we are able to implicitly weight all features by the degree to which the students collectively care about them (Avery et al., 2013).

We exploit administrative data in Hungary, a country which has a centralised system of admissions to higher education designed such that the derivation of revealed preferences is relatively obvious. This dataset has been used recently to analyse college choices (Telcs et al., 2015), to identify mistakes in a strategically simple environment (Shorrer and Sóvágó, 2018), and even to rank the universities (Telcs et al., 2016). However, some crucial assumptions of the latter paper have been criticized (Csató, 2013a, 2016).

Our approach somewhat follows Avery et al. (2013), where the authors implement a ranking of U.S. undergraduate programs using a national sample of high-achieving students. But our dataset covers every Hungarian student applying for higher education in their home country across 16 years (2001-2016), which makes possible to derive more specific results, and we focus on the theoretical rather than the statistical analysis. Kóczy and Strobel (2010) have suggested a similar method for journal ranking.

The key to our methodology is the derivation of the aggregated preference matrix. After that, any well-known scoring procedures can be applied to rank the objects (Chebotarev and Shamis, 1998, 1999; Palacios-Huerta and Volij, 2004; Slutzki and Voliju, 2005; González-Díaz et al., 2014; Kittı, 2016; Bubboloni and Gori, 2018), keeping in mind that there does not exist a perfect solution as impossibility results show (Csató, 2018c,d).

Nonetheless, it will be suggested to apply the least squares method, also known as the Potential Method (Čaklović and Kurdija, 2017), or as the Logarithmic Least Squares Method on the field of pairwise comparison matrices (Bozóki et al., 2010). Csató (2015) gives an overview of its origin and an interpretation on graphs. González-Díaz et al. (2014) and Čaklović and Kurdija (2017) discuss the axiomatic properties of the method, mainly with positive conclusions, despite that Csató and Rónyai (2016) present a potential failure of it. Csató (2018a) and Csató (2018b) provide characterizations in the case of complete preference lists. Lundy et al. (2017) prove that the least squares scores are equal to the preference vector calculated from the spanning trees of the network, while Bozóki and
Tsyganok (2017) extend this result to our incomplete data. The least squares method has a growing list of successful applications, including ranking historical Go (Chao et al., 2018) and tennis players (Bozóki et al., 2016), teams in Swiss-system chess tournaments (Csató, 2013b, 2017), or the participating countries of the Eurovision Song Contest (Čaklović and Kurdija, 2017). It is used in international price comparisons by the OECD (Éltető and Köves, 1964; Szulc, 1964), to evaluate movies on a subset of Netflix data (Jiang et al., 2011), and for obtaining an alternative quality of life ranking (Petróczy, 2018).

It seems that the suggested methodology can be applied in several other fields where applicants should reveal some preferences and a centralised allocation mechanism creates incentives for truthfulness such as the student-optimal deferred acceptance algorithm (Gale and Shapley, 1962; Dubins and Freedman, 1981). Besides Hungary (see the detailed discussion in Subsection 3.3), college admission is organised basically along these principles in Chile (Ríos et al., 2014), Ireland (Chen, 2012), and Spain (Romero-Medina, 1998). School choice often shows similar characteristics, too, like in New York, Hungary, Finland, Amsterdam (Biró, 2017). Allocation of graduates according to their preferences in a centrally coordinated way is typical in certain professions, including residents (junior doctors) in the UK and US, teachers in France, or lawyers in Germany (Biró, 2017). Biró (2017) provides a comprehensive review of matching models under preferences.

The article proceeds as follows. Section 2 describes the data. Our methodology is detailed in Section 3, and Section 4 presents the results. Some concluding thoughts are offered in Section 5.

2 Data

In Hungary, the admission procedure of higher education institutions has been organised by a centralised matching scheme at a national level since 1996 (Biró, 2008, 2011). At the beginning of the procedure, the students submit their ranking lists over the fields of studies of particular faculties they are applying for. A single application in a given year consists of the following data:

- Student ID;
- Position according to the student’s preference order;
- Faculty / School of a higher education institution;
- Course;
- Level of study (BSc/BA, MSc/MA, Single long cycle);
- Form of study (full-time training, correspondence training, evening training);
- Financing of the tuition (state-financed: completely financed by the state, student-financed: partly financed by the student).

For example, the record

\[
\begin{bmatrix}
158 & 2 & \text{PTE–AOK Medicine} & O & N & A
\end{bmatrix}
\]
means that the student with the ID #158 applied at the second place (2) for the faculty
PTE–AOK, course Medicine in level \( O \) (Single long cycle giving an MSc degree), form \( N \)
(full time), financed by the state (\( A \)). In the following, the faculty, course, level of study,
form of study, and financing of the tuition (e.g. PTE–AOK, Medicine, \( O, N, A \)) will be
called a programme.

After that, the students receive scores at each of the programmes they are applied for,
on the basis of their final grades at secondary school and entrance exams. The scores of
an applicant can differ in two programmes, for example, when the programmes consider
the grades from different sets of subjects.

Finally, a government organisation collects all ranking lists and scores, and a centralised
algorithm determines the score-limits of the programmes. A student is admitted to the first
programme on her list where the score-limit is achieved, and it is not possible to overwrite
this matching by any participant. The score-limits are good indicators of the quality and
popularity of the programmes, they highly correlate with the applicants’ preferences and
with the job market perspectives of the graduates (Biró, 2011).

Our dataset contains almost all applications between the 2001 and 2014: for students
who have a preference list with more than six items, only the first six programmes plus
the one where she is admitted (if there exists such a programme) were recorded. The 2015
and 2016 data do not have this limitation.

3 Methodology

First, the theoretical background of our analysis will be presented.

3.1 Ranking problems and scoring methods

Let \( N = \{X_1, X_2, \ldots, X_n\} \) be the set of objects on which the preferences of the agents are
being expressed, and \( A = [a_{ij}] \in \mathbb{R}^{n \times n} \) be the preference matrix such that \( a_{ij} \in \mathbb{R} \) is a
measure of how object \( X_i \) is preferred over \( X_j \). \( a_{ii} = 0 \) is assumed for all \( X_i \in N \).

The pair \((N, A)\) is called a ranking problem. The set of ranking problems with \( n \) objects
\((|N| = n)\) is denoted by \( \mathcal{R}^n \).

There exists a one-to-one correspondence between preference matrices and directed
weighted graphs without loops: if object \( X_i \) is preferred to object \( X_j \) with an intensity
of \( a_{ij} \), then the graph \( G \) contains a directed edge from node \( X_i \) to node \( X_j \) which has a
weight of \( a_{ij} \), and vice versa.

The aim is to derive a ranking of the objects from any ranking problem \((N, A)\), for
which purpose scoring methods will be used. A scoring method \( f: \mathcal{R}^n \rightarrow \mathbb{R}^n \) is a function
that associates a score \( f_i(N, A) \) for each object \( X_i \) in any ranking problem \((N, A) \in \mathcal{R}^n \).

It immediately induces a ranking of the objects in \( N \) (a transitive and complete weak
order on the set of \( N \times N \)) by \( f_i(N, A) \geq f_j(N, A) \Rightarrow X_i \succeq X_j \), that is, object \( X_i \) is at
least as good as \( X_j \) if its score is not smaller.

A ranking problem \((N, A)\) has the skew-symmetric results matrix \( R = A - A^T \in \mathbb{R}^{n \times n} \),
and the symmetric matches matrix \( M = A + A^T \in \mathbb{R}^{n \times n} \), where \( m_{ij} \) is the number of
comparisons between \( X_i \) and \( X_j \) whose outcome is given by \( r_{ij} \).

Let \( e \in \mathbb{R}^n \) denote the column vector with \( e_i = 1 \) for all \( i = 1, 2, \ldots, n \).

Perhaps the most straightforward measure for the goodness of the objects is the sum
of their net preferences.
Definition 3.1. Row sum: Let \((N, A) \in \mathcal{R}^n\) be a ranking problem. The row sum score \(s_i\) of object \(X_i \in N\) is given by \(s_i = Re\).

It is clear that the row sum score does not take into account the “popularity” of the objects which can be a problem as the volatility of row sum for objects with a high number of comparisons is usually significantly higher than the volatility of row sum for objects with a low number of comparisons.

This effect can be handled by some normalisation. Denote the degree of node \(X_i\) in the graph \(G\) by \(d_i = \sum_{X_j \in N} m_{ij}\). Introduce the diagonal matrix \(D^- = \begin{bmatrix} d_i^{-1} \end{bmatrix} \in \mathbb{R}^{n \times n}\) such that \(d_i^{-1} = 1/d_i\) for all \(i = 1, 2, \ldots, n\) and \(d_i^{-1} = 0\) if \(i \neq j\).

**Definition 3.2. Normalised row sum**: Let \((N, A) \in \mathcal{R}^n\) be a ranking problem. The normalised row sum score \(p_i\) of object \(X_i \in N\) is given by \(p_i = D^- s = D^- Re\).

Furthermore, a preference over a “strong” object is not necessarily equal to a preference over a “weak” object. It can be taken into account by considering the entire structure of the comparisons.

The Laplacian matrix \(L = [\ell_{ij}] \in \mathbb{R}^{n \times n}\) of the graph \(G\) is given by \(\ell_{ij} = -m_{ij}\) for all \(i \neq j\) and \(\ell_{ii} = d_i\) for all \(i = 1, 2, \ldots, n\).

**Definition 3.3. Least squares**: Let \((N, A) \in \mathcal{R}^n\) be a ranking problem. The least squares score \(q_i\) of object \(X_i \in N\) is given by \(Lq = s = Re\).

The Laplacian matrix \(L\) is a singular matrix, its rank equals \(n - k\), where \(k\) is the number of (weakly) connected components in the graph \(G\). Consequently, the system of linear equations in Definition 3.3 does not have a unique solution. This can be ensured by adding the equation \(\sum_{X_i \in K} q_i = 0\) for each connected component of nodes \(K \subseteq N\) (Kaiser and Serlin, 1978; Chebotarev and Shamis, 1999; Bozóki et al., 2010; Čaklović and Kurdija, 2017).

An extensive analysis and a graph interpretation of the least squares method, as well as an overview of its origin, is provided in Csató (2015).

### 3.2 Axioms

In the following subsection, some axiomatic properties are presented for the ranking of the objects in order to illustrate the differences between the scoring methods.

**Axiom 1. Size invariance**: A scoring method \(f : \mathcal{R}^n \rightarrow \mathbb{R}^n\) is said to be size invariant if \(f_i(N, A) = f_j(N, A)\) holds for any ranking problem \((N, A) \in \mathcal{R}^n\) which have two different objects \(X_i, X_j \in N\) such that \(a_{ik} = \alpha a_{jk}\) and \(a_{ki} = \alpha a_{kj}\) for all \(X_k \in N \setminus \{X_i, X_j\}\), furthermore, \(a_{ij} = a_{ji} = 0\).

Size invariance means that if there exists two objects \(X_i, X_j\) with exactly the same preference structure against any third object \(X_k\), but one of them is \(\alpha\) times “larger”, then they should have the same rank.

**Proposition 3.1.** The row sum method violates size invariance.

The normalised row sum and least squares methods satisfy size invariance.

**Proof.** Row sum: It can be checked that \(s_i = \alpha s_j\) for two different objects \(X_i, X_j \in N\) such that \(a_{ik} = \alpha a_{jk}\) and \(a_{ki} = \alpha a_{kj}\) for all \(X_k \in N \setminus \{X_i, X_j\}\), furthermore, \(a_{ij} = a_{ji} = 0\).
Normalised row sum: $d_i = \alpha d_j$ also holds for two different objects $X_i, X_j \in N$ such that $a_{ik} = \alpha a_{jk}$ and $a_{ki} = \alpha a_{kj}$ for all $X_k \in N \setminus \{X_i, X_j\}$, furthermore, $a_{ij} = a_{ji} = 0$.

Least squares: It follows from $m_{ik} = \alpha m_{jk}$ for all $X_k \in N$ if there are two different objects $X_i, X_j \in N$ such that $a_{ik} = \alpha a_{jk}$ and $a_{ki} = \alpha a_{kj}$ for all $X_k \in N \setminus \{X_i, X_j\}$, furthermore, $a_{ij} = a_{ji} = 0$.

**Definition 3.4. Bridge vertex:** Let $(N, A) \in \mathcal{R}^n$ be a ranking problem. An object set $\emptyset \neq B \subseteq N$ is called bridge vertex if there exists $N_1, N_2 \subseteq N$ such that $N^1 \cup B \cup N^2 = N$, $N_1 \cap N_2 = \emptyset$, and $m_{ij} = 0$ for all $X_i \in N_1$ and $X_j \in N_2^2$, furthermore, $m_{ik} = m_{\ell k}$ for all $X_i \in N_1$ and $X_k, X_\ell \in B$.

**Remark 3.1.** The concept of bridge vertex is a common generalisation of bridge player (when $|B| = 1$) (González-Díaz et al., 2014) and macrovertex (when $N^2 = \emptyset$) (Chebotarev, 1994; Csató, 2018c).

**Axiom 2. Bridge vertex independence:** A scoring method $f : \mathcal{R}^n \rightarrow \mathbb{R}^n$ is said to be bridge vertex independent if $f_i(N, A) \geq f_j(N, A) \iff f_i(N, A') \geq f_j(N, A')$ holds for all $X_i, X_j \in N^1$ in the case of any two ranking problems $(N, A), (N, A') \in \mathcal{R}^n$ with a bridge vertex $B$ such that $a_{\ell k} = a'_{\ell k}$ for all $\{X_k, X_\ell \} \cap N^1 \neq \emptyset$.

Bridge vertex independence means that the order of objects in the set $N^1$ is independent of the preferences between the objects outside $N^1$.

**Remark 3.2. Macrovertex independence** (Chebotarev, 1994; Csató, 2018c) is a particular case of bridge vertex independence when $N^2 = \emptyset$.

**Axiom 3. Bridge vertex autonomy:** A scoring method $f : \mathcal{R}^n \rightarrow \mathbb{R}^n$ is said to be bridge vertex autonomous if $f_i(N, A) \geq f_i(N, A') \iff f_i(N, A') \geq f_i(N, A')$ holds for all $X_k, X_\ell \in B \cup N^2$ in the case of any two ranking problems $(N, A), (N, A') \in \mathcal{R}^n$ with a bridge vertex $B$ such that $a_{ij} = a'_{ij}$ for all $\{X_i, X_j\} \cap (B \cup N^2) \neq \emptyset$.

Bridge vertex autonomy requires the order of objects to remain the same in the set $B \cup N^2$ if only the preferences inside $N^1$ change.

**Remark 3.3.** Bridge vertex autonomy is an extension of macrovertex autonomy (Csató, 2018c), which demands that $N^2 = \emptyset$.

**Proposition 3.2.** The row sum and normalised row sum methods satisfy bridge vertex independence and bridge vertex autonomy.

**Proof.** Bridge vertex independence: It can be seen that $s_i(N, A) = s_i(N, A')$ and $d_i(N, A) = d_i(N, A')$ hold for all $X_i \in N^1$ in the case of any two ranking problems $(N, A), (N, A') \in \mathcal{R}^n$ with a bridge vertex $B$ such that $a_{\ell k} = a'_{\ell k}$ for all $\{X_k, X_\ell \} \cap N^1 \neq \emptyset$.

Bridge vertex autonomy: It can be checked that $s_k(N, A) = s_k(N, A')$ and $d_k(N, A) = d_k(N, A')$ hold for all $X_k \in (B \cup N^2)$ in the case of any two ranking problems $(N, A), (N, A') \in \mathcal{R}^n$ with a bridge vertex $B$ such that $a_{ij} = a'_{ij}$ for all $\{X_i, X_j\} \cap (B \cup N^2) \neq \emptyset$.

**Proposition 3.3.** The least squares method satisfies bridge vertex independence and bridge vertex autonomy.

**Proof.** Bridge vertex independence: Consider the linear equations for an arbitrary object $X_k \in B$ and $X_\ell \in N^2$.

$$d_k q_k - \sum_{X_i \in N^1} m_{ik} q_i - \sum_{X_\ell \in B} m_{\ell k} q_\ell - \sum_{X_h \in N^2} m_{kh} q_h = s_k;$$

(1)
\[ d_g q_g - \sum_{X_i \in B} m_{g_t} q_t - \sum_{X_h \in N^2} m_{gh} q_h = s_g. \] (2)

Note that \( m_{ki} = m_{k'i} = \bar{m}_i \) for all \( X_i \in N^1 \) and \( X_k, X_l \in B \) since \( B \) is a bridge vertex. Sum up the \(|B|\) equations of type (1) and the \(|N^2|\) equations of type (2), which leads to:

\[ \sum_{X_i \in N^1} \bar{m}_i \left( \sum_{X_k \in B} q_k - |B|q_i \right) = - \sum_{X_i \in N^1} s_i. \] (3)

Take also the linear equation for an arbitrary object \( X_i \in N^1 \):

\[ d_i q_i - \sum_{X_j \in N^1} m_{ij} q_j - \sum_{X_k \in B} \bar{m}_i q_k = s_i. \] (4)

\( \sum_{X_k \in B} q_k \) can be substituted from equation (3) into the \(|N^1|\) equations of type (4). This system consists of \(|N^1|\) equations and the same number of unknowns. It should have a unique solution since it has been obtained by pure substitution of formulas. As the coefficients of the system do not depend on the preferences outside the object set \( N^1 \), the weights of these objects are the same in the ranking problems \((N, A)\) and \((N, A')\).

**Bridge vertex autonomy:** Similarly to the proof of bridge vertex independence, \( \sum_{X_k \in B} q_k \) can be substituted from equation (3) into the \(|N^1|\) equations of type (4). This system consists of \(|N^1|\) equations and the same number of unknowns. It should have a unique solution, from which \( q_i(N, A) \) and \( q_i(N, A') \) can be obtained for all \( X_i \in N^1 \), respectively.

Introduce the notation \( \Delta q_i = q_i(N, A') - q_i(N, A) \) for all \( X_i \in N \). \( \sum_{X_i \in N^1} s_i(N, A) = \sum_{X_i \in N^1} s_i(N, A') \) holds because only the preferences inside the object set \( N^1 \) may change, so equation (3) implies that

\[ \sum_{X_k \in B} \Delta q_k = \sum_{X_i \in N^1} \bar{m}_i \Delta q_i = \beta. \] (5)

It will be shown that \( \Delta q_k = \Delta q_g = \beta/|B| \) for all \( X_k \in B \) and \( X_g \in N^2 \). Since the system of linear equations \( Lq = s \) has a unique solution after normalisation, it is enough to prove that \( \Delta q_k = \Delta q_g = \beta/|B| \) satisfies equations of types (1) and (2). The latter statement comes from \( d_g = \sum_{X_i \in B} m_{g_t} + \sum_{X_h \in N^2} m_{gh} \) as there are no preferences between the objects in sets \( N^1 \) and \( N^2 \).

Take an equation of type (1) and note that \( s_k(N, A') - s_k(N, A) = 0 \) because only the preferences inside the object set \( N^1 \) may change:

\[ d_k \Delta q_k - \sum_{X_i \in N^1} \bar{m}_i \Delta q_i - \sum_{X_t \in B} m_{k_t} \Delta q_t - \sum_{X_h \in N^2} m_{kh} \Delta q_h = 0. \] (6)

Since \( d_k = \sum_{X_i \in N^1} \bar{m}_i + \sum_{X_t \in B} m_{k_t} + \sum_{X_h \in N^2} m_{kh} \), with the use of the assumption \( \Delta q_k = \Delta q_g = \beta/|B| \) for all \( X_k \in B \) and \( X_g \in N^2 \), we get

\[ \sum_{X_i \in N^1} \bar{m}_i \beta - \sum_{X_i \in N^1} \bar{m}_i \Delta q_i = 0, \] (7)

which holds due to the definition of \( \beta \) in equation (5). It completes the proof. □

**Axiom 4.** *Bridge player independence* (González-Díaz et al., 2014): A scoring method \( f : \mathcal{R}^n \rightarrow \mathbb{R}^n \) is said to be bridge vertex independent if \( f_i(N, A) \geq f_j(N, A) \iff f_i(N, A') \geq f_j(N, A') \) holds for all \( X_i, X_j \in (N^1 \cup B) \) in the case of any two ranking problems \((N, A), (N, A') \in \mathcal{R}^n \) with a bridge vertex \(|B| = 1\) such that \( a_{k\ell} = a'_{k\ell} \) for all \( \{X_k, X_l\} \cap N^1 \neq \emptyset \).
According to bridge player independence, in a hypothetical world consisting of two set of objects connected only by a particular object called bridge player, the relative rankings within each set of objects are not influenced by the preferences among the objects in the other set.

**Proposition 3.4.** *The least squares method satisfies bridge player independence.*

*Proof.* See González-Díaz et al. (2014, Proposition 6.1). 

Similarly to macrovertex independence and macrovertex autonomy, it has been attempted to generalise bridge player independence in a way that the extended property is satisfied by the least squares method without success.

Now an illustration is provided for the three scoring methods and the four axioms.

Figure 1: Preferences between the objects in Example 3.1

![Figure 1: Preferences between the objects in Example 3.1](image)

**Example 3.1.** Consider the ranking problem \((N, A) \in \mathcal{R}^5\) shown in Figure 1, where the directed edges represent the preferences with their weights written on near the start of the arrow, and their thickness is proportional to the strength of the preferences.

The preference, the results, and the matches matrices are as follows:

\[
A = \begin{bmatrix}
0 & 0 & 6 & 6 & 0 \\
0 & 0 & 10 & 10 & 0 \\
12 & 20 & 0 & 6 & 7 \\
12 & 20 & 6 & 0 & 0 \\
0 & 0 & 5 & 0 & 0 \\
\end{bmatrix}, \quad R = \begin{bmatrix}
0 & 0 & -6 & -6 & 0 \\
0 & 0 & -10 & -10 & 0 \\
6 & 10 & 0 & 0 & 2 \\
6 & 10 & 0 & 0 & 0 \\
0 & 0 & -2 & 0 & 0 \\
\end{bmatrix}, \quad \text{and}
\]

\[
M = \begin{bmatrix}
0 & 0 & 18 & 18 & 0 \\
0 & 0 & 30 & 30 & 0 \\
18 & 30 & 0 & 12 & 12 \\
18 & 30 & 12 & 0 & 0 \\
0 & 0 & 12 & 0 & 0 \\
\end{bmatrix}.
\]

Objects \(X_1\) and \(X_2\) satisfy the conditions of the axiom size invariance: \(X_2\) is \(\alpha = 5/3\) times larger than object \(X_1\). It remains true even if the preferences between the other three objects (the green and black directed edges) change. For the sake of visibility, the favourable preferences of objects \(X_1\) and \(X_2\) are indicated by blue, and their unfavourable preferences by red colour.
Objects $X_3$ and $X_4$ form a bridge vertex with $N^1 = \{X_1, X_2\}$ and $N^2 = \{X_3\}$. It holds even if the preferences in the object set $B \cup N^2 = \{X_3, X_4, X_5\}$ (the green and black directed edges) change. Furthermore, only the sum of total preferences with the objects $X_1$ and $X_2$ should remain the same, that is, weights can be redistributed on the blue and red edges between the same nodes.

Finally, object $X_3$ is a bridge player with $N^1 = \{X_1, X_2, X_4\}$ and $N^2 = \{X_5\}$.

| Object | Row sum | Norm. row sum | Least squares |
|--------|---------|---------------|---------------|
| $X_1$  | −12     | −20/60        | −1/6          |
| $X_2$  | −20     | −20/60        | −1/6          |
| $X_3$  | 18      | 15/60         | 1/6           |
| $X_4$  | 16      | 16/60         | 1/6           |
| $X_5$  | −2      | −10/60        | 0             |

The scores according to the three methods are shown in Table 1. The sum of row sum and least squares scores are equal to 0, but this condition does not hold for the normalised row sum scores.

Size invariance implies that objects $X_1$ and $X_2$ have the same rank. As Proposition 3.1 shows, this is satisfied only by the normalised row sum and least squares methods. Therefore, it is difficult to argue for the application of row sum scores.

According to bridge vertex independence, $X_1 \sim X_2$ should remain even if the preferences between the other three objects (the green and black directed edges) change.

Compare the normalised row sum and least squares scores. The first favours object $X_4$ over $X_3$, but the sole difference between them is that $X_3$ has some extra preferences with object $X_5$, which seems to be a weak reason to distinguish between the strength of $X_3$ and $X_4$. This is provided by the axiom bridge player independence.

Finally, bridge player autonomy ensures that this tied rank of $X_3$ and $X_5$ is not influenced by the possible existence of direct preferences between the objects $X_1$ and $X_2$.

**Proposition 3.5.** The row sum and normalised row sum methods violate bridge player independence.

**Proof.** Consider the ranking problem $(N, A) \in \mathcal{R}^n$ of Example 3.1.

Let $(N, A')$ be the ranking problem such that the preference matrix $A'$ is the same as $A$ except for $a'_{35} = 3 < 7 = a_{35}$. Then $s_3(N, A') = 14 < 16 = p_4(N, A')$, while $s_3(N, A) = 18 > 16 = p_4(N, A)$, showing the violation of bridge player independence by the row sum method.

Let $(N, A'')$ be the ranking problem such that the preference matrix $A''$ is the same as $A$ except for $a''_{35} = 10 > 7 = a_{35}$. Then $p_3(N, A'') = 7/25 > 16/60 = p_4(N, A'')$, while $p_3(N, A) = 15/60 < 16/60 = p_4(N, A)$, showing the violation of bridge player independence by the normalised row sum method.

Table 2 summarises the findings of the axiomatic analysis. It turns out that the least squares method shares the advantages of the other two procedures, while it is the only one satisfying bridge player independence. Hence, at this stage from theoretical reasons, we can suggest applying the least squares method for ranking in similar problems.
3.3 Derivation of the preference matrix

Our central assumption is that the applications of a student partially reveal her true preferences. This is not true in the case of every school choice mechanism (Abdulkadiroğlu and Sönmez, 2003). The Hungarian centralised matching scheme applies the Gale-Shapley algorithm at its core (Biró et al., 2010; Biró and Kiselgof, 2015; Ágoston et al., 2016), its college-oriented version until 2007, and the applicant-oriented variant since then (Biró, 2008). In the applicant-oriented Gale-Shapley algorithm (Gale and Shapley, 1962), students cannot improve their fate by lying about their preferences (Dubins and Freedman, 1981). While the college-oriented version does not satisfy this property, the difference of the two versions is negligible in practice, and a successful manipulation requires a lot of information, which is close to impossible to obtain for an applicant (Teo et al., 2001).

Naturally, the whole preference list of an applicant remains unknown. The exact rules governing the length of the rankings changed several times between 2001 and 2016. In the first years, there was no limit on the number of applications from a given student, but they were charged for each item after the first three. In recent years, it has been allowed to apply for at most five (six in 2016) places for a fixed price such that the state-financed and student-financed versions of the same programme count as one.

As a consequence, the applications of a student reveal only a part of her preferences. In the presence of such constrained lists, Haeringer and Klijn (2009, Proposition 4.2) show that – when the centralised allocation rule is the student-optimal Gale-Shapley algorithm – the applicant can do no better than selecting some programmes among the acceptable ones and ranking them according to the true preferences. Thus, it is assumed for a student that:

1. She prefers an object to any other objects having a worse position on her list of applications;

2. Her preference between an object on her list of applications and an object not on her list of applications is unknown;

3. Her preference between two objects not on her list of applications is unknown.

Telcs et al. (2016) do not follow our second and third assumptions, so Haeringer and Klijn (2009, Proposition 4.2) implies that the individual choices derived by them are not guaranteed to reflect the true preferences of the applicants, in contrast to our model. For example, unranked objects cannot be legitimately said to be less preferred than any of the

2 The actual algorithm is a heuristic that is close to the Gale-Shapley algorithm because of the existence of some specialities like ties or common quotas (Biró et al., 2010; Biró and Kiselgof, 2015; Ágoston et al., 2016). Consequently, it remains strategy-proof only essentially, for example, when the applicants believe they have no chance to influence the score-limits.
ones on the list, since a student may disregard a programme when she knows that she has no chance to be admitted there.

The rules of the centralised system make possible that the same object appears more than once on the list of a student. For instance, if courses are compared, then both the state-financed and the student-financed versions of a particular course may be present. Then we preserve only the first appearance of the given object and delete all of the others. This ensures that each applicant can have at most one preference between two different objects. Furthermore, only the preferences concerning the first appearance of a given object reflect the true preferences of the applicant adequately. Assume that she prefers faculty $A$ to $B$, so her list contain a particular programme of faculty $A$ at the first place and the same programme of faculty $B$ at the second place. Faculty $A$ also offers another programme, which is not the favourite of the student but she applies for it because, for example, she can achieve the score limit with a higher probability. Then it cannot be said that faculty $B$ is preferred to faculty $A$ in any sense.

It is worth noting that the financing of the tuition may somewhat distort the picture. Suppose that an applicant prefers faculty $A$ to faculty $B$. Both faculties offer the same programme in state-financed and student-financed form such that the score-limit of the former is above the score-limit of the latter as natural. The applicant knows that she has no chance to be admitted to the state-financed programme of faculty $A$, however, she wants to avoid paying the tuition, therefore her list contains the state-financed programme of faculty $B$ at the first place, the student-financed programme of faculty $A$ in the second, and the student-financed programme of faculty $B$ in the third position. Then our methodology concludes that faculty $B$ is preferred to faculty $A$, which is opposite to the true preferences of the applicant. Consequently, it may make sense to differentiate between the two forms of financing, that is, to derive preferences for the state-financed and student-financed programmes separately. Nevertheless, applying for both the state-financed and student-financed versions of the same programme has no financial costs, so probably few students employ this strategy.

Following these ideas, one can determine the preference matrix of any student. In order to aggregate them, a weighting scheme should be chosen. At first sight, it might look that all contributions are equal, so each student should have the same weight, which will be called the unweighted problem. In the unweighted preference matrix $A^\text{UW}$, the element $a_{ij}^\text{UW}$ gives the number of applicants who prefer object $X_i$ to object $X_j$.

On the other hand, some students have a longer list of applications, hence, there is more information available on their preferences. Then the unweighted version essentially weights the students according to the number of preferences they have revealed (Čaklović and Kurdija, 2017). The equal contribution of each applicant can be achieved by introducing the weight $w_i = 1/k$ for student $i$ if she has given $k$ preferences after the truncation of objects appearing more than once. This will be called the weighted problem. In the weighted preference matrix $A^W$, each applicant, who has revealed at least one preference, increases the sum of matrix elements by one.

Another solution can be the moderately weighted problem when the weight for student $i$ is $w_i = 1/\ell$ if she has given a (truncated) preference list of $\ell$ objects. In the moderately weighted preference matrix $A^{\text{MW}}$, each applicant, who has revealed at least one preference concerning object $i$, increases the sum of matrix elements in the $i$th row and column by one.

Finally, with respect to the form of financing, the adjusted unweighted $\hat{A}^\text{UW}$, weighted $\hat{A}^W$, and moderately weighted $\hat{A}^{\text{MW}}$ preference matrices can be defined, respectively, by
obtaining the state-financed and student-financed unweighted, weighted, and moderately weighted preference matrices separately as above, and aggregating them in a corresponding way.

The methodology above allows for the comparison of any types of objects: higher education institutions (universities or colleges), faculties, courses, etc. It is also possible to present rankings specific to various types of students. In the current paper, the ranking of Hungarian faculties will be discussed, as revealed collectively by all applicants participating in the system.

**Example 3.2.** Consider a student with the following list of applications:

\[
\begin{bmatrix}
1 & \text{SE–AOK} & \text{Medicine} & O & N & A \\
2 & \text{PTE–AOK} & \text{Medicine} & O & N & A \\
3 & \text{DE–AOK} & \text{Medicine} & O & N & K \\
4 & \text{SE–AOK} & \text{Medicine} & O & N & A \\
5 & \text{SE–FOK} & \text{Dentistry} & O & N & K
\end{bmatrix}
\]

As the objects are the faculties, SE–AOK appears twice, from which the second is deleted. The preferences of the student over the four faculties are as follows:

- SE–AOK $\succ$ PTE–AOK;
- SE–AOK $\succ$ DE–AOK;
- SE–AOK $\succ$ SE–FOK;
- PTE–AOK $\succ$ DE–AOK;
- PTE–AOK $\succ$ SE–FOK; and
- DE–AOK $\succ$ SE–FOK.

Thus the applicant has provided six preferences.

If the state-financed and student-financed forms are treated separately, then there are only two preferences revealed

- SE–AOK $\succ$ PTE–AOK; and $(A)$
- DE–AOK $\succ$ SE–FOK. $(K)$

The objects are $X_1 = \text{SE–AOK}$, $X_2 = \text{SE–AOK}$, $X_3 = \text{DE–AOK}$, and $X_4 = \text{SE–FOK}$. The corresponding unweighted ($A^{UW}$), weighted ($A^W$), and moderately weighted ($A^{MW}$), as well as, adjusted unweighted ($\hat{A}^{UW}$), weighted ($\hat{A}^W$), and moderately weighted ($\hat{A}^{MW}$) preference matrices are

\[
A^{UW} = \begin{bmatrix}
0 & 1 & 1 & 1 \\
0 & 0 & 1 & 1 \\
0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0
\end{bmatrix}, \quad A^W = \begin{bmatrix}
0 & 1/6 & 1/6 & 1/6 \\
0 & 0 & 1/6 & 1/6 \\
0 & 0 & 0 & 1/6 \\
0 & 0 & 0 & 0
\end{bmatrix},
\]

\[
A^{MW} = \begin{bmatrix}
0 & 1/4 & 1/4 & 1/4 \\
0 & 0 & 1/4 & 1/4 \\
0 & 0 & 0 & 1/4 \\
0 & 0 & 0 & 0
\end{bmatrix}, \quad \hat{A}^{UW} = \begin{bmatrix}
0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0
\end{bmatrix},
\]

with $\hat{A}^{UW} = \hat{A}^W = \hat{A}^{MW}$, respectively.
Figure 2 presents some descriptive statistics of the dataset in the period analysed. It can be realised that the Hungarian higher education admission is a huge system with more than 150 thousand revealed preferences in each year. It is under constant reform, even the set of the faculties, the basic units of higher education, changes in almost every year. Therefore, in the first step, we restrict our attention to the seven Dentistry and Medicine faculties and to the last recorded year of 2016. The calculations are summarised in Table 3: Table 3.a shows the main characteristics of these faculties, Table 3.b presents the unweighted preference matrix derived with the methodology described in Section 3, and Table 3.c provides the scores and rankings. Since the unweighted matrix does not take the length of preference lists into account, it is known that 138 students have preferred DE–AOK to DE–FOK, while 146 applicants have made the opposite choice. Furthermore, 2939 applicants have revealed a preference concerning DE–AOK, as the last column of Table 3.c shows.

The ranking obtained from the row sum and normalised row sum methods coincide, while the least squares method changes the position of two pairs of faculties. Since these scores sum up to 0, one can say that all rural faculties are below the average (in this

3 Probably these faculties have the most international students in Hungary. For example, their ratio is close to 50% at the faculties SE–AOK, and SE–FOK (altogether more than 2,500 foreigners with Germany, Iran, Italy, Norway, and Israel being the top five countries of origin). See at http://semmelweis.hu/english/the-university/facts-and-figures/.
Table 3: Comparison of the Hungarian Dentistry and Medicine faculties, 2016

(a) List of Dentistry and Medicine faculties

| Faculty   | City      | Type                  |
|-----------|-----------|-----------------------|
| DE–AOK    | Debrecen  | Medicine              |
| DE–FOK    | Debrecen  | Dentistry             |
| PTE–AOK   | Pécs      | Dentistry and Medicine|
| SE–AOK    | Budapest  | Medicine              |
| SE–FOK    | Budapest  | Dentistry             |
| SZTE–AOK  | Szeged    | Medicine              |
| SZTE–FOK  | Szeged    | Dentistry             |

(b) The unweighted preference matrix $A^{UW}$ of Dentistry and Medicine faculties

| Faculty          | F1  | F2  | F3  | F4  | F5  | F6  | F7  |
|------------------|-----|-----|-----|-----|-----|-----|-----|
| DE–AOK (F1)      | 0   | 138 | 506 | 127 | 53  | 308 | 43  |
| DE–FOK (F2)      | 146 | 0   | 144 | 21  | 37  | 52  | 76  |
| PTE–AOK (F3)     | 270 | 87  | 0   | 140 | 84  | 273 | 83  |
| SE–AOK (F4)      | 634 | 72  | 778 | 0   | 244 | 874 | 68  |
| SE–FOK (F5)      | 109 | 178 | 258 | 101 | 0   | 129 | 204 |
| SZTE–AOK (F6)    | 560 | 58  | 835 | 132 | 49  | 0   | 72  |
| SZTE–FOK (F7)    | 45  | 137 | 200 | 17  | 32  | 122 | 0   |

(c) Scores of Dentistry and Medicine faculties, unweighted preference matrix $A^{UW}$

Numbers in parentheses indicate the score, bold numbers sign the rank of the faculty

| Faculty   | Row sum | Norm. row sum | Least squares | Preferences |
|-----------|---------|---------------|---------------|-------------|
| DE–AOK    | (-589) 6 | (-0.200) 6    | (-0.176) 5    | (2939) 4    |
| DE–FOK    | (-194) 5 | (-0.169) 5    | (-0.202) 6    | (1146) 6    |
| PTE–AOK   | (-1784) 7 | (-0.488) 7    | (-0.387) 7    | (3658) 1    |
| SE–AOK    | (2132) 1 | (0.665) 1     | (0.531) 1     | (3208) 3    |
| SE–FOK    | (480) 2  | (0.325) 2     | (0.301) 2     | (1478) 5    |
| SZTE–AOK  | (-52) 4  | (-0.015) 4    | (-0.022) 3    | (3464) 2    |
| SZTE–FOK  | (7) 3    | (0.006) 3     | (-0.045) 4    | (1099) 7    |

particular set) with the exception of the two at Budapest, the capital of Hungary.

Rankings can be validated not only through their axiomatic properties but by measuring
how they “represent” the preference matrix. One way is to count the number of preferences
which contradict to the ranking:

$$\sum_{X_i \neq X_j \in N} a_{ij} : j \succ i.$$ (8)

Their number is 2195 for the row sum and normalised row sum, which increases to 2253
in the case of the least squares ranking. Nonetheless, this is only a small sample of the entire dataset, so it is premature to state that the least squares method does not work appropriately.

Table 4: Kendall rank correlation coefficients, 2016

|                | $A_{UW}$ | Row sum | $A_{UW}$ | Norm. row sum | $A_{UW}$ | Least squares | $A_{UW}$ | $A_{UW}$ | $A_{UW}$ |
|----------------|----------|---------|----------|---------------|----------|---------------|----------|----------|----------|
| $s(A_{UW})$   | —        | 0.909   | 0.953    | 0.783         | 0.759    | 0.771         | 0.719    | 0.709    | 0.705    |
| $s(A_{W})$    | —        | 0.888   | 0.779    | 0.797         | 0.766    | 0.724         | 0.730    | 0.712    |
| $s(\hat{A}_{UW})$ | —       | 0.764   | 0.741    | 0.775         | 0.705    | 0.694         | 0.702    |
| $p(A_{UW})$   | —        | 0.902   | 0.944    | 0.831         | 0.826    | 0.820         |
| $p(A_{W})$    | —        | 0.882   |          | 0.808         | 0.836    | 0.798         |
| $p(\hat{A}_{UW})$ | —       | 0.815   | 0.815    | 0.830         |
| $q(A_{UW})$   | —        | 0.932   | 0.960    |
| $q(A_{W})$    | —        | 0.927   |

Table 4 shows the (symmetric) Kendall rank correlation coefficients (Kendall, 1938) between the nine rankings obtained from the unweighted $A_{UW}$, the weighted $A_{UW}$, and the adjusted unweighted $\hat{A}_{UW}$ preference matrices with the three methods presented in Section 3. This measure is based on the number of concordant and discordant pairs between the two rankings, its value is between $-1$ and $+1$ such that $-1$ indicates complete disagreement, while $+1$ indicates perfect agreement. In order to avoid the adjustment for ties, the number of preferences has been used as a tie-breaking rule to get strict rankings.

It can be seen that the effect of the ranking method is significantly larger than the effect of the preference matrix (compare the italic numbers with the other ones). Rankings from the unweighted $A_{UW}$ and adjusted unweighted $\hat{A}_{UW}$ preference matrices are more similar than rankings from the weighted version $A_{W}$. Furthermore, the least squares method is more robust to the choice of the preference matrix than the other two procedures. Therefore, in the following analysis we will mainly focus on this procedure and the unweighted preference matrix $A_{UW}$.

Figure 3 illustrates the performance of the three methods “in practice”, by calculating the ratio of preferences which contradict to the appropriate ranking as given in formula (8). It turns out that the normalised row sum procedure is better than the simple row sum, but the least squares method continuously beats both of them. Thus, the message of Table 2 in favour of the least squares method, which was based on purely theoretical considerations, is reinforced by its superior performance on a large-scale dataset across more than a decade.

It can also be seen that the ratio of preferences that contradict to the rankings has increased robustly between 2001 and 2016. While it is difficult to disentangle the effect of the constantly changing set of objects, this tendency shows that the judgements of the applicants have probably become more diverse in the period considered.

In order to investigate the sensitivity of the results, eight faculties have been chosen for an in-depth analysis:

$$4$$ It can be seen from the preference matrix in Table 3.b: DE–FOK is preferred by more applicants to DE–AOK than vice versa, and the same holds in the relation of SZTE–FOK and SZTE–AOK.
Figure 3: The ratio of preferences opposite to the ranking, 2001-2016

(a) Unweighted preference matrix $A^{UW}$

(b) Weighted preference matrix $A^W$

- BME–GEK: Faculty of Mechanical Engineering, Budapest University of Technology and Economics (with more than 2000 revealed preferences in each year);
- BME–GTK: Faculty of Economic and Social Sciences, Budapest University of Technology and Economics (with more than 4500 revealed preferences in each year);
- PTE–AOK: Medical School, University of Pécs (with more than 2000 revealed preferences in each year);
- SE–AOK: Faculty of Medicine, Semmelweis University (with more than 1500 revealed preferences in each year);
- ELTE–AJK: Faculty of Law, Eötvös Lóránd University (with more than 4000 revealed preferences in each year);
- ELTE–TTK: Faculty of Science, Eötvös Lóránd University (with more than 5500 revealed preferences in each year);
- SZTE–BTK: Faculty of Humanities and Social Sciences, University of Szeged (with more than 3500 revealed preferences in each year); and
- ZSKF: King Sigismund University (with more than 2000 revealed preferences in each year).

Figure 4 shows the least squares scores (Figure 4.a) and ranks (Figure 4.b) of these faculties. SE–AOK has achieved at least the second position in each year between 2001 and 2016. PTE–AOK has been close to the bottom of top 10 consistently. On the other hand, BME–GTK, as well as ELTE–AJK (and, to some extent, SZTE-BTK) have displayed a declining performance, especially law studies have become less popular among the applicants in this one and a half decade. The gradual improvement of BME–GEK...
Figure 4: Least squares scores and ranks of selected Hungarian faculties, 2001-2016

(a) Scores, unweighted preference matrix $A^{UW}$

(b) Ranks (logarithmic scale), unweighted preference matrix $A^{UW}$

 demonstrates that an appropriate long-term strategy can yield significant gains. ELTE–TTK has remained a strong middle-rank faculty with some fluctuations, while ZSKF has not managed to increase its low prestige.

Tables A.1, A.2, and A.3 in the Appendix present the scores and ranks of the faculties that existed in 2016, as obtained from the unweighted $A^{UW}$, the weighted $A^{UW}$, and the adjusted unweighted $\hat{A}^{UW}$ preference matrices, respectively. It is not surprising that some small faculties have a good position according to the normalised row sum and least squares methods. Turning to the more popular institutions and concentrating on the suggested least squares method, all of the seven Dentistry and Medicine faculties are among the top faculties in Hungary. While the worse faculties of this set (such as DE–AOK, DE–FOK, or PTE–AOK, see Table 3) do not seem excellent by the two local measures of row sum

\footnote{The number of faculties was originally 191 in the database. After eliminating the ones without a preference from any applicant, only 179 remained.}
and normalised row sum, their performance significantly improves after taking the whole structure of the network into account: despite they are not favoured by the applicants over the leading Dentistry and Medicine faculties, they are still preferred to faculties in other subject areas. Similar causes are behind the relatively better positions of the four Pharmacy faculties (DE–GYTK in Debrecen, PTE–GYTK in Pécs, SE–GYTK in Budapest, SZTE–GYTK in Szeged).

On the other hand, the most prestigious economics faculty (BCE–GTK) is outside the top 20 according to the least squares ranking. The unique Veterinary Medicine faculty (SZIE–AOTK) and the leading Faculty of Architecture (BME–ESZK) are also in the top 10, but their good position is still revealed by the normalised row sum method. Some other faculties gain (e.g. PPKE–ITK, Faculty of Information Technology and Bionics at Pázmány Péter Catholic University), or lose (e.g. ELTE–GYFK, Bárczi Gusztáv Faculty of Special Needs Educations at Eötvös Loránd University; NKE–RTK, Faculty of Law Enforcement at National University of Public Service; TE, University of Physical Education) from the use of the least squares method.

Table 5: Ranks of some Hungarian faculties, 2016

| Faculty     | Row sum $A_{UW}$ | $A_W$ | $\hat{A}_{UW}$ | Norm. row sum $A_{UW}$ | $A_W$ | $\hat{A}_{UW}$ | Least squares $A_{UW}$ | $A_W$ | $\hat{A}_{UW}$ |
|-------------|------------------|-------|----------------|------------------------|-------|----------------|----------------------------|-------|----------------|
| BCE–GTK     | 2                | 1     | 2             | 12                     | 12    | 12            | 21                       | 21    | 22            |
| BME–ESZK    | 22               | 23    | 22            | 6                      | 6     | 7             | 10                       | 7     | 9             |
| BME–TTK     | 48               | 115   | 53            | 52                     | 112   | 53            | 38                       | 51    | 39            |
| DE–AOK      | 19               | 27    | 19            | 38                     | 35    | 39            | 9                        | 13    | 8             |
| DE–FOK      | 40               | 49    | 39            | 42                     | 47    | 42            | 8                        | 8     | 7             |
| DE–GYTK     | 149              | 110   | 153           | 162                    | 143   | 165           | 50                       | 50    | 51            |
| ELTE–GYFK   | 13               | 8     | 10            | 15                     | 13    | 15            | 31                       | 27    | 30            |
| NKE–RTK     | 20               | 12    | 21            | 24                     | 18    | 24            | 39                       | 28    | 41            |
| PPKE–ITK    | 51               | 40    | 50            | 53                     | 46    | 52            | 33                       | 29    | 32            |
| PTE–AOK     | 169              | 144   | 173           | 99                     | 109   | 105           | 12                       | 14    | 12            |
| PTE–GYTK    | 144              | 128   | 148           | 175                    | 173   | 174           | 62                       | 94    | 64            |
| SE–AOK      | 1                | 3     | 1             | 2                      | 1     | 2             | 1                        | 1     | 1             |
| SE–FOK      | 10               | 24    | 8             | 8                      | 7     | 6             | 2                        | 2     | 2             |
| SE–GYTK     | 122              | 48    | 135           | 87                     | 53    | 91            | 16                       | 15    | 18            |
| SZIE–AOTK   | 16               | 19    | 15            | 3                      | 4     | 3             | 4                        | 4     | 5             |
| SZTE–AOK    | 7                | 26    | 7             | 22                     | 29    | 21            | 3                        | 6     | 4             |
| SZTE–FOK    | 32               | 39    | 31            | 32                     | 28    | 32            | 5                        | 3     | 6             |
| SZTE–GYTK   | 126              | 94    | 130           | 133                    | 113   | 134           | 36                       | 37    | 35            |
| TE          | 11               | 5     | 9             | 17                     | 16    | 16            | 37                       | 36    | 38            |

Table 5 summarises the ranks of the faculties mentioned above, classified by the three methods and the three variants of preference matrices. It also reveals that the unweighted $A_{UW}$ and adjusted unweighted $\hat{A}_{UW}$ preference matrices lead to almost the same ranking, that is, separation of preferences with respect to the financing of the tuition has marginal effects. On the other hand, there are some differences between the rankings obtained from the unweighted $A_{UW}$ and weighted $A_W$ preference matrices, especially for the row sum and normalized row sum methods. The case of GYTKs is probably explained by the fact that Pharmacy faculties are “substitutes” of Medicine faculties for several applicants (but
not vice versa), so the revealed preference lists of these students with an unfavourable view on pharmacy are inherently longer. However, the issue of BME–TTK (Faculty of Natural Sciences, Budapest University of Technology and Economics) remains to be explored.

Thus the least squares ranking of the faculties has an obvious, intuitive explanation. Concisely, the dataset reveals that the number of applicants who want to be a doctor but choose another field if this dream is not achievable is significantly greater than the number of applicants employing an opposite strategy. Naturally, one can eliminate this effect by composing separate lists on different subject areas, for example, by considering only an appropriate submatrix of the whole preference matrix as in Table 3. However, sometimes there is a demand for a universal ranking. This is what we have provided in this paper.

5 Conclusions

In this paper, a novel methodology has been offered to rank universities on the basis of applicants’ preferences, which can be implemented in any country using a centralised admission system. Our approach essentially eliminates all strategies for colleges to improve their positions by only manipulating certain indicators as it does not require any preliminary selection of criteria, and weights university characteristics implicitly according to the aggregated opinion of all students.

We have presented an application by ranking all faculties in the Hungarian higher education between 2001 and 2016. Three different methods and three variants of preference matrices have been considered for this purpose. Our results reinforce that the suggested ranking possesses favourable theoretical properties and it performs well in practice, too: the least squares method is hardly sensitive to the aggregation of individual preferences, and it reflects the revealed preferences better than the other procedures discussed.

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## Appendix

Table A.1: Rankings of Hungarian faculties, unweighted preference matrix $A^{UW}$, 2016

Numbers in parentheses indicate the score, bold numbers sign the rank of the faculty

| Faculty       | Row sum | Norm. row sum | Least squares | Preferences |
|---------------|---------|---------------|---------------|-------------|
| ANNYE         | (21) 43 | (0.6) 20      | (0.372) 19    | (105) 157   |
| AVKF          | (−383) 159 | (0.366) 166 | (−0.313) 154 | (1431) 93   |
| BCE–ETK       | (−22) 78 | (0.359) 171   | (−0.216) 137 | (78) 161    |
| BCE–GTK       | (2913) 2 | (0.638) 12     | (0.37) 21     | (10547) 1    |
| BCE–KERTK     | (12) 45 | (0.579) 26     | (0.068) 61    | (76) 162    |
| BCE–KTK       | (207) 30 | (0.578) 28     | (0.364) 22    | (1327) 96   |
| BCE–TAJK      | (1) 51  | (0.516) 47     | (0.131) 53    | (31) 165    |
| BCE–TK        | (821) 12 | (0.583) 25     | (0.32) 25     | (4951) 17   |
| BCE–ETK       | (−79) 93 | (0.432) 124    | (−0.204) 134 | (577) 140   |
| BCE–KKK       | (−130) 108 | (0.492) 60   | (0.025) 68    | (8034) 6    |
| BCE–KVIK      | (202) 31 | (0.514) 48     | (0.04) 67     | (7348) 8    |
| BCE–PSZK      | (−179) 121 | (0.491) 62    | (0.024) 69    | (9465) 3    |
| BCE–KKFK      | (1) 51  | (0.533) 40     | (−0.145) 114  | (15) 173    |
| BCE–KVIFK     | (−6) 64 | (0.393) 154    | (−0.192) 130  | (28) 166    |
| BCE–PSZFGBK    | (−8) 69 | (0.468) 81     | (−0.042) 83   | (124) 156   |
| BCE–KKFK      | (174) 36 | (0.557) 35     | (0.269) 32    | (1526) 88   |
| BCE–ESZK      | (342) 22 | (0.717) 6      | (0.592) 10    | (788) 126   |
| BCE–GEK       | (1366) 4 | (0.694) 9      | (0.543) 14    | (3528) 40   |
| BCE–GTK       | (187) 33 | (0.513) 49     | (0.163) 51    | (7449) 7    |
| BCE–KSK       | (127) 38 | (0.524) 44     | (0.21) 42     | (2599) 51   |
| BCE–TTK       | (3) 48  | (0.501) 52     | (0.237) 38    | (1041) 117  |
| BCE–VBK       | (304) 26 | (0.552) 36     | (0.302) 28    | (2918) 45   |
| BCE–VIK       | (1444) 3 | (0.642) 11     | (0.481) 15    | (5080) 15   |
| BCE–BGK       | (−452) 163 | (0.444) 107  | (−0.024) 76   | (4024) 29   |
| BCE–KKFK      | (−470) 167 | (0.44) 116    | (−0.117) 103  | (3890) 32   |
| BCE–KVK       | (176) 35 | (0.533) 39     | (0.173) 48    | (2628) 50   |
| BCE–KKFK      | (235) 29 | (0.551) 41     | (0.216) 40    | (3751) 36   |
| BCE–BGK       | (−163) 112 | (0.429) 128  | (−0.065) 88   | (1143) 110  |
| BCE–AJK       | (−38) 84 | (0.488) 65     | (−0.038) 81   | (1598) 84   |
| BCE–AOX       | (464) 19 | (0.548) 38     | (0.643) 9     | (4866) 20   |
| BCE–BTC       | (−452) 163 | (0.449) 102  | (−0.104) 100  | (4390) 26   |
| BCE–EK        | (−493) 168 | (0.364) 168  | (−0.317) 157  | (1815) 76   |
| BCE–FKO       | (97) 40  | (0.531) 42     | (0.684) 8     | (1557) 86   |
| BCE–GTK       | (−408) 160 | (0.446) 104  | (−0.214) 136  | (3772) 34   |
| BCE–GYTK      | (−295) 149 | (0.378) 162  | (0.167) 50    | (1209) 103  |
| BCE–HPFK      | (−99) 102 | (0.469) 77     | (−0.258) 145  | (1603) 83   |
| BCE–IK        | (−173) 120 | (0.45) 101    | (−0.137) 109  | (1713) 78   |
| BCE–MK        | (−165) 115 | (0.459) 90    | (−0.138) 110  | (2013) 67   |
| BCE–MTK       | (−334) 154 | (0.414) 143  | (−0.278) 149  | (1944) 69   |
| BCE–NK        | (11) 46  | (0.504) 51     | (0.003) 72    | (1517) 89   |
| BCE–TTK       | (−768) 177 | (0.391) 155  | (−0.134) 106  | (3532) 39   |

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Table A.1 – continued from the previous page

| Faculty       | Row sum | Norm. row sum | Least squares | Preferences |
|---------------|---------|---------------|---------------|-------------|
| DE–ZK         | (−18) 75 | (0.477) 74    | (0.178) 45    | (386) 151   |
| DF            | (−7) 67  | (0.348) 174   | (−0.451) 175  | (23) 169    |
| DRHE          | (−15) 74 | (0.484) 68    | (−0.219) 139  | (467) 147   |
| DUE           | (−466) 166 | (0.373) 164  | (−0.319) 160  | (1838) 72   |
| EGHF          | (−7) 67  | (0.231) 177   | (−0.526) 176  | (13) 175    |
| EHE           | (14) 44  | (0.85) 1      | (0.763) 6     | (20) 171    |
| EJF           | (−121) 107 | (0.42) 137   | (−0.315) 155  | (761) 127   |
| EJFM          | (−2) 55  | (0.438) 118   | (−0.451) 174  | (16) 172    |
| EJFP          | (−2) 55  | (0.429) 129   | (−0.36) 167   | (14) 174    |
| EKF–BTK       | (−235) 138 | (0.43) 125   | (−0.159) 118  | (1681) 81   |
| EKF–CK        | (−115) 104 | (0.411) 147  | (−0.38) 172   | (643) 135   |
| EKF–GTK       | (−332) 153 | (0.396) 152  | (−0.338) 163  | (1598) 84   |
| EKF–TKTK      | (−249) 142 | (0.451) 98   | (−0.216) 138  | (2521) 52   |
| EKF–TTK       | (−334) 154 | (0.442) 114  | (−0.169) 125  | (2862) 46   |
| ELTE–AJK      | (915) 9   | (0.601) 19    | (0.371) 20    | (4525) 24   |
| ELTE–BTK      | (297) 27  | (0.518) 46    | (0.173) 49    | (8073) 5    |
| ELTE–GYFK     | (799) 13  | (0.63) 15     | (0.288) 31    | (3071) 43   |
| ELTE–IK       | (478) 18  | (0.564) 33    | (0.289) 30    | (3762) 35   |
| ELTE–PPK      | (1150) 5  | (0.578) 27    | (0.267) 35    | (7332) 9    |
| ELTE–TATK     | (−295) 149 | (0.464) 85   | (0.105) 56    | (4143) 28   |
| ELTE–TTK      | (433) 21  | (0.571) 29    | (0.268) 34    | (3037) 44   |
| ELTE–TOFK     | (647) 15  | (0.567) 31    | (0.074) 59    | (4813) 21   |
| ELTE–TOK      | (−247) 140 | (0.48) 69    | (0.177) 46    | (6031) 10   |
| GDF           | (−293) 146 | (0.362) 170  | (−0.339) 165  | (1065) 113  |
| GFF–PK        | (−21) 76  | (0.49) 64     | (−0.171) 127  | (1023) 118  |
| GFF–TK        | (−4) 60   | (0) 179       | (−0.985) 179  | (4) 179     |
| GFF–TSZK      | (−3) 58   | (0.2) 178     | (−0.577) 178  | (5) 178     |
| GYHF          | (0) 54    | (0.5) 54      | (−0.032) 79   | (22) 170    |
| IBS           | (−115) 104 | (0.39) 157   | (−0.16) 119   | (523) 144   |
| KE–ATK        | (−45) 87  | (0.47) 75     | (−0.203) 133  | (747) 128   |
| KE–CSPFK      | (−338) 156 | (0.399) 151  | (−0.279) 150  | (1670) 82   |
| KEE           | (45) 42   | (0.742) 4     | (0.69) 7      | (93) 159    |
| KE–GTK        | (−41) 85  | (0.457) 94    | (−0.221) 141  | (481) 146   |
| KE–MFK        | (−194) 129 | (0.391) 156  | (−0.004) 73   | (890) 122   |
| KE–GAMFK      | (−166) 116 | (0.467) 83    | (−0.136) 108  | (2484) 53   |
| KE–KKF        | (−88) 97   | (0.421) 136   | (−0.31) 153   | (554) 142   |
| KE–TFK        | (−248) 141 | (0.382) 159   | (−0.354) 166  | (1054) 115  |
| KJF           | (−574) 171 | (0.381) 161   | (−0.318) 159  | (2412) 54   |
| KRE–AJK       | (−436) 161 | (0.448) 103   | (−0.006) 74   | (4198) 27   |
| KRE–BTK       | (1070) 6   | (0.559) 34    | (0.212) 41    | (9090) 4    |
| KRE–TFK       | (−71) 92   | (0.487) 66    | (−0.083) 92   | (2833) 47   |
| KRF           | (−360) 158 | (0.395) 153   | (−0.363) 169  | (1708) 79   |
| LFZE          | (309) 25   | (0.715) 7     | (0.55) 13     | (719) 130   |
| ME–AJK        | (−79) 93   | (0.467) 82    | (−0.092) 96   | (1211) 102  |
| ME–BBZI       | (−37) 82   | (0.428) 130   | (0.061) 63    | (257) 155   |
| ME–BTK        | (−172) 119 | (0.426) 132   | (−0.237) 144  | (1164) 107  |
| ME–EKF        | (−294) 147 | (0.367) 165   | (−0.315) 156  | (1104) 112  |

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| Faculty    | Row sum | Norm. row sum | Least squares | Preferences |
|------------|---------|---------------|---------------|-------------|
| ME–GEK     | (−259)  | (0.444)       | (0.145)       | (2315) 58  |
| ME–GTK     | (−241)  | (0.413)       | (0.29)        | (1379) 95  |
| ME–MAK     | (−41)   | (0.458)       | (0.168)       | (493) 145  |
| ME–MFK     | (−4)    | (0.497)       | (0.078)       | (608) 138  |
| ME–THFTGK  | (−610)  | (0.419)       | (0.204)       | (3786) 33  |
| ME–TKMK    | (−183)  | (0.461)       | (0.005)       | (2323) 56  |
| MKE        | (183)   | (0.6)         | (0.373)       | (915) 121  |
| MOME       | (576)   | (0.649)       | (0.423)       | (1930) 70  |
| MTF        | (71)    | (0.635)       | (0.319)       | (263) 154  |
| MUTF       | (−314)  | (0.366)       | (0.363)       | (1168) 106 |
| NKE–HHK    | (169)   | (0.423)       | (0.355)       | (703) 131  |
| NKE–KTK    | (327)   | (0.551)       | (0.205)       | (3175) 41  |
| NKE–NETK   | (319)   | (0.569)       | (0.293)       | (2325) 55  |
| NKE–RTK    | (456)   | (0.583)       | (0.221)       | (2732) 48  |
| NYE        | (−886)  | (0.39)        | (0.338)       | (4024) 29  |
| NYME–AK    | (−4)    | (0.423)       | (0.326)       | (26) 167   |
| NYME–BDPK  | (−231)  | (0.437)       | (0.167)       | (1835) 73  |
| NYME–BPK   | (−29)   | (0.486)       | (0.124)       | (1043) 116 |
| NYME–EMK   | (−24)   | (0.469)       | (0.149)       | (386) 151  |
| NYME–FMK   | (−92)   | (0.428)       | (0.088)       | (638) 136  |
| NYME–KTK   | (−117)  | (0.442)       | (0.231)       | (1003) 120 |
| NYME–MEK   | (−2)    | (0.477)       | (0.161)       | (44) 163   |
| NYME–TTMK  | (−80)   | (0.439)       | (0.193)       | (652) 133  |
| OE–AMK     | (−187)  | (0.429)       | (0.14)        | (1235) 97  |
| PAF        | (123)   | (0.611)       | (0.313)       | (555) 141  |
| PE–GK      | (−184)  | (0.42)        | (0.292)       | (1150) 109 |
| PE–GTK     | (−208)  | (0.45)        | (0.192)       | (2096) 63  |
| PE–MFTK    | (−167)  | (0.417)       | (0.177)       | (1009) 119 |
| PE–MIK     | (−153)  | (0.436)       | (0.087)       | (1193) 104 |
| PE–MK      | (−164)  | (0.444)       | (0.076)       | (1456) 92  |
| PHF        | (−3)    | (0.364)       | (0.264)       | (11) 176   |
| PPKE–BTK   | (−747)  | (0.463)       | (0.053)       | (10187) 2  |
| PPKE–ITK   | (1)     | (0.5)         | (0.268)       | (1949) 68  |
| PPKE–JAK   | (922)   | (0.594)       | (0.321)       | (4898) 18  |
| PTE–AJK    | (−98)   | (0.46)        | (0.007)       | (1230) 101 |
| PTE–AOK    | (−542)  | (0.45)        | (0.553)       | (5044) 11  |
| PTE–BTK    | (−823)  | (0.411)       | (0.143)       | (4635) 23  |
| PTE–ETK    | (−660)  | (0.41)        | (0.146)       | (3678) 37  |
| PTE–GYTK   | (−270)  | (0.347)       | (0.064)       | (880) 125  |
| PTE–KPVK   | (−215)  | (0.43)        | (0.27)        | (1531) 87  |
| PTE–KTK    | (−193)  | (0.443)       | (0.173)       | (1687) 80  |
| PTE–MIK    | (−306)  | (0.433)       | (0.108)       | (2290) 59  |
| PTE–MK     | (−10)   | (0.493)       | (0.173)       | (742) 129  |
| PTE–TTK    | (−564)  | (0.411)       | (0.166)       | (3158) 42  |
| SE–AOK     | (3162)  | (0.832)       | (1.232)       | (4762) 22  |
| SE–EKK     | (−69)   | (0.445)       | (0.029)       | (631) 137  |
| SE–ETK     | (273)   | (0.527)       | (0.178)       | (5019) 16  |

Continued on the next page
| Faculty    | Row sum | Norm. row sum | Least squares | Preferences |
|------------|---------|---------------|---------------|-------------|
| SE–FOK     | 859     | 0.711         | 1.083         | 2 (2035) 65 |
| SE–GYTK    | -181    | 0.461         | 0.427         | 16 (2319) 57 |
| SZAGKHF    | 3       | 0.636         | 0.054         | 64 (11) 176 |
| SZE–AJK    | -95     | 0.455         | -0.047        | 85 (1059) 114 |
| SZE–AK     | -228    | 0.457         | -0.121        | 104 (2682) 49 |
| SZE–GK     | -294    | 0.423         | -0.221        | 140 (1904) 71 |
| SZE–MÉK    | -193    | 0.351         | -0.375        | 170 (647) 134 |
| SZE–MTK    | -459    | 0.455         | -0.066        | 89 (5137) 14 |
| SZE–PLI    | -80     | 0.441         | -0.17         | 126 (670) 132 |
| SZE–ZMI    | -68     | 0.414         | 0.079         | 58 (396) 149 |
| SZF        | -225    | 0.403         | -0.334        | 162 (1161) 108 |
| SZFE       | 663     | 0.721         | 0.553         | 11 (1497) 90 |
| SZIE–ABPK  | -164    | 0.434         | -0.235        | 143 (1246) 100 |
| SZIE–AOTK  | (641)   | 0.743         | 0.807         | 4 (1317) 98 |
| SZIE–ETK   | -37     | 0.49          | 0.105         | 55 (1833) 74 |
| SZIE–GEK   | -229    | 0.444         | -0.103        | 99 (2033) 66 |
| SZIE–GK    | -171    | 0.403         | -0.318        | 158 (881) 124 |
| SZIE–GTK   | -359    | 0.466         | -0.098        | 98 (5349) 13 |
| SZIE–KETK  | -50     | 0.479         | -0.055        | 87 (1184) 105 |
| SIE–MKK    | -132    | 0.469         | -0.104        | 101 (2116) 62 |
| SIE–TÁJK   | -10     | 0.492         | 0.074         | 60 (600) 139 |
| SIE–YMEK   | -9      | 0.496         | 0.102         | 57 (1123) 111 |
| SSZHF      | (2)     | 0.524         | 0.127         | 54 (42) 164 |
| SZTE–AJK   | -92     | 0.478         | 0.019         | 70 (2080) 64 |
| SZTE–AOK   | 925     | 0.595         | 0.823         | 22 (4875) 19 |
| SZTE–BTK   | -282    | 0.468         | -0.032        | 78 (4422) 25 |
| SZTE–ETSZK | -111    | 0.47          | -0.035        | 80 (1831) 75 |
| SZTE–FOK   | 189     | 0.567         | 0.8            | 32 (1407) 94 |
| SZTE–GTK   | -21     | 0.494         | -0.045        | 84 (1751) 77 |
| SZTE–GYTK  | -190    | 0.426         | 0.266         | 36 (1276) 99 |
| SZTE–GYYPK | -447    | 0.444         | -0.147        | 116 (3963) 31 |
| SZTE–MÉGK  | -61     | 0.442         | -0.263        | 146 (525) 143 |
| SZTE–MK    | -195    | 0.456         | -0.135        | 107 (2203) 60 |
| SZTE–TTK   | -6      | 0.498         | 0.042         | 66 (1490) 91 |
| SZTE–TTIK  | -726    | 0.433         | -0.049        | 86 (5454) 12 |
| SZTE–ZMEK  | -33     | 0.458         | 0.138         | 52 (395) 150 |
| TE         | 844     | 0.618         | 0.242         | 37 (3576) 38 |
| TPF        | -153    | 0.323         | -0.542        | 177 (431) 148 |
| VHF        | -4      | 0.479         | -0.161        | 120 (94) 158 |
| WJLF       | 4       | 0.507         | -0.039        | 82 (284) 153 |
| WSUF       | -208    | 0.382         | -0.384        | 173 (884) 123 |
| ZSKF       | -624    | 0.355         | -0.375        | 171 (2154) 61 |
Table A.2: Rankings of Hungarian faculties, weighted preference matrix $A^W$, 2016

Numbers in parentheses indicate the score, bold numbers sign the rank of the faculty.

| Faculty     | Row sum | Norm. row sum | Least squares | Preferences |
|-------------|---------|---------------|---------------|-------------|
| ANNYE       | (12.6)  | (0.624) 17    | (0.38) 18     | (50.8) 157  |
| AVKF        | (−135.27) | 157 (0.384) 162 | (−0.258) 154 | (584.8) 88  |
| BCE–ETK     | (−13)   | 87 (0.368) 166 | (−0.184) 136 | (49.4) 158  |
| BCE–GTK     | (1274.77) | 1 (0.644) 12  | (0.357) 21    | (4414.5) 1  |
| BCE–KERTK   | (3.27)  | 54 (0.534) 41 | (0.002) 73    | (47.4) 160  |
| BCE–TK      | (66.63) | 34 (0.559) 30 | (0.324) 25    | (562.63) 91 |
| BCE–TAJK    | (0.63)  | 59 (0.517) 48 | (0.176) 43    | (18.23) 164 |
| BGE–GBK     | (−28.07) | 104 (0.444) 121 | (−0.177) 134 | (251.33) 134 |
| BGE–KKK     | (−152.13) | 162 (0.476) 85  | (−0.024) 81  | (3122.27) 6  |
| BGE–KVIK    | (84.23)  | 29 (0.514) 51  | (0.015) 66    | (2938.97) 8  |
| BGE–PSZK    | (93.67)  | 147 (0.488) 72 | (0.004) 71    | (3921.13) 2  |
| BGF–GBK     | (0.83)  | 57 (0.549) 36  | (−0.036) 86   | (8.5) 171   |
| BGF–KKFK    | (−9)    | 83 (0.407) 154 | (−0.105) 107  | (48.33) 159  |
| BGF–KVIFK   | (−8.17) | 81 (0.247) 177 | (−0.46) 173   | (16.17) 166  |
| BGF–PSZFKBP  | (−5.33) | 76 (0.469) 92  | (−0.023) 79   | (86) 156    |
| BKTF        | (−8.17) | 81 (0.198) 178 | (−0.379) 170  | (13.5) 169  |
| BME–EOK     | (67.4)  | 33 (0.558) 32  | (0.271) 31    | (581.2) 89  |
| BME–ESZK    | (134.87) | 23 (0.703) 6   | (0.568) 7     | (332.4) 122  |
| BME–GEK     | (514.47) | 2 (0.681) 9    | (0.529) 10    | (1422.6) 33  |
| BME–GTK     | (−18.1) | 91 (0.497) 63  | (0.131) 52    | (2943.43) 7  |
| BME–KSK     | (44.23)  | 37 (0.523) 44  | (0.213) 39    | (945.97) 59  |
| BME–TTK     | (−40.73) | 115 (0.454) 112 | (0.131) 51   | (438.53) 110  |
| BME–VBK     | (204.87) | 16 (0.593) 20  | (0.335) 23    | (1095.8) 44  |
| BME–VIK     | (424.97) | 4 (0.609) 19   | (0.435) 16    | (1953.1) 16  |
| BMF–BGK     | (−157.03) | 164 (0.451) 117 | (0.002) 72   | (1601.57) 27  |
| BMF–KGK     | (−200.53) | 171 (0.431) 135 | (−0.139) 122 | (1459.6) 31  |
| BMF–KVK     | (113.23) | 25 (0.552) 33  | (0.216) 38    | (1087.57) 45  |
| BMF–NIK     | (39.1)   | 38 (0.514) 50  | (0.183) 41    | (1354.1) 36  |
| BMF–RKK     | (−29.5)  | 106 (0.465) 98 | (0.015) 65    | (424.7) 113  |
| DE–AJK      | (6.4)    | 50 (0.505) 59  | (−0.035) 85   | (648.73) 84  |
| DE–AOK      | (101.83) | 27 (0.551) 35  | (0.493) 13    | (1002.9) 52  |
| DE–BTK      | (−124.2) | 156 (0.462) 101 | (−0.117) 114 | (1649.53) 25  |
| DE–EK       | (−145.13) | 159 (0.408) 152 | (−0.232) 148 | (788.73) 72  |
| DE–FOK      | (9.4)    | 49 (0.518) 47  | (0.566) 8     | (255.2) 132  |
| DE–GTK      | (−117.2) | 155 (0.468) 93 | (−0.173) 130  | (1853.27) 18  |
| DE–GYTK     | (−33.43) | 110 (0.424) 143 | (0.145) 50    | (219.77) 141  |
| DE–HPFK     | (−28)    | 103 (0.482) 77  | (−0.214) 141  | (798) 71    |
| DE–IK       | (−22.23) | 98 (0.486) 74  | (−0.07) 96    | (785.1) 74   |
| DE–MK       | (−26.27) | 102 (0.486) 73  | (−0.076) 98   | (938.4) 60   |
| DE–MTK      | (−144.6) | 158 (0.422) 146 | (−0.271) 158  | (923.27) 62  |
| DE–NK       | (13.67)  | 46 (0.512) 54  | (0.005) 70    | (565.47) 90  |
| DE–TTK      | (−227.63) | 172 (0.418) 150 | (−0.108) 108  | (1383.83) 34  |
| DE–ZK       | (−7.77)  | 80 (0.475) 86  | (0.179) 42    | (157.83) 150  |
| DF          | (−5.67)  | 78 (0.311) 172 | (−0.488) 175  | (15) 168    |

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Table A.2 – continued from the previous page

| Faculty       | Row sum | Norm. row sum | Least squares | Preferences |
|---------------|---------|---------------|---------------|-------------|
| DRHE          | (−19.7) | (0.452) 115   | (−0.261) 156  | (206.23) 143|
| DUE           | (−147.9)| (0.406) 155   | (−0.236) 149  | (785.43) 73 |
| EGHF          | (−3)    | (0.263) 176   | (−0.464) 174  | (6.33) 175  |
| EHE           | (2.8)   | (0.688) 8     | (0.494) 12    | (7.47) 174  |
| EJF           | (−42.4) | (0.443) 126   | (−0.239) 152  | (369.87) 120|
| EJFM          | (−2)    | (0.375) 164   | (−0.552) 178  | (8) 172     |
| EJFP          | (0.67)  | (0.538) 38    | (−0.129) 117  | (8.67) 170  |
| EKF–BTK       | (−114.1)| (0.417) 151   | (−0.195) 139  | (687.57) 82 |
| EKF–CK        | (−28.87)| (0.456) 106   | (−0.261) 155  | (328.07) 123|
| EKF–GTK       | (−149.1)| (0.392) 159   | (−0.335) 166  | (688.87) 81 |
| EKF–TKTK      | (−90.87)| (0.459) 103   | (−0.189) 137  | (1114.53) 43|
| EKF–TTK       | (−103.67)| (0.457) 105  | (−0.123) 116  | (1232.47) 38|
| ELTE–AJK      | (226.83)| (0.573) 26    | (0.291) 26    | (1559.03) 28|
| ELTE–BTK      | (182.17)| (0.528) 43    | (0.153) 47    | (3198.03) 5 |
| ELTE–GYFK     | (314.1) | (0.635) 13    | (0.281) 27    | (1159.1) 41 |
| ELTE–IK       | (145.47)| (0.551) 34    | (0.258) 34    | (1425.2) 32 |
| ELTE–PPK      | (182.03)| (0.535) 40    | (0.153) 48    | (2602.83) 9 |
| ELTE–TATK     | (−169.7)| (0.438) 132   | (0.023) 62    | (1360.5) 35 |
| ELTE–TKKK     | (151.87)| (0.581) 22    | (0.261) 33    | (938.27) 61 |
| ELTE–TOFK     | (321.17)| (0.581) 23    | (0.105) 55    | (1990.17) 15|
| ELTE–TTK      | (−21.77)| (0.495) 66    | (0.17) 45     | (2191.9) 13 |
| GDF           | (−116.73)| (0.363) 168   | (−0.334) 164  | (426.4) 111 |
| GFF–PK        | (15.1)  | (0.516) 49    | (−0.085) 102  | (473.3) 104 |
| GFF–TK        | (−1.33) | (0) 179       | (−0.963) 179  | (1.33) 179  |
| GFF–TSZK      | (−1.67) | (0.273) 175   | (−0.504) 176  | (3.67) 178  |
| GYHF          | (−0.93) | (0.442) 129   | (−0.177) 132  | (8) 172     |
| IBS           | (−32.87)| (0.404) 156   | (−0.14) 123   | (170.47) 147|
| KE–ATK        | (−7.37) | (0.49) 70     | (−0.168) 129  | (371.23) 119|
| KE–CSPFK      | (−117.1)| (0.419) 148   | (−0.231) 147  | (723.1) 79  |
| KEE           | (24.33) | (0.766) 2     | (0.714) 5     | (45.67) 161 |
| KE–GTK        | (−11.43)| (0.478) 83    | (−0.177) 133  | (254.23) 133|
| KE–MFK        | (−174.53)| (0.303) 174   | (−0.122) 115  | (441.93) 107|
| KF–GAMFK      | (−24.67)| (0.489) 71    | (−0.082) 99   | (1084.73) 46|
| KF–KKK        | (−36.57)| (0.425) 142   | (−0.286) 160  | (244.23) 136|
| KF–TFK        | (−100.97)| (0.393) 158   | (−0.308) 163  | (472.57) 105|
| KJF           | (−234.93)| (0.378) 163   | (−0.34) 165   | (961.6) 58  |
| KRE–AJK       | (−182.6)| (0.44) 130    | (−0.044) 89   | (1531.87) 29|
| KRE–BTK       | (307.47)| (0.548) 37    | (0.151) 49    | (3199.87) 4 |
| KRE–TFK       | (−38.33)| (0.484) 76    | (−0.07) 95    | (1196.93) 40|
| KRF           | (−167.67)| (0.39) 160    | (−0.377) 168  | (765.6) 75  |
| LFZE          | (141.3) | (0.716) 5     | (0.353) 9     | (326.97) 124|
| ME–AJK        | (−4.6)  | (0.496) 65    | (−0.07) 97    | (511.2) 96  |
| ME–BBZI       | (−12.07)| (0.443) 125   | (0.1) 56      | (105.4) 155|
| ME–BTK        | (−42.37)| (0.456) 107   | (−0.191) 138  | (479.9) 103|
| ME–EFK        | (−64.13)| (0.423) 144   | (−0.213) 140  | (416.87) 114|
| ME–GEK        | (−41.63)| (0.48) 80     | (−0.062) 92   | (1057.37) 48|
| ME–GTK        | (−77.97)| (0.444) 124   | (−0.223) 145  | (690.17) 80 |

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Table A.2 – continued from the previous page

| Faculty     | Row sum | Norm. row sum | Least squares | Preferences |
|-------------|---------|---------------|---------------|-------------|
| ME–MAK      | (−22) 97 | (0.454) 111   | (−0.15) 127   | (237.4) 137 |
| ME–MPK      | (1.77) 56 | (0.504) 60    | (−0.041) 88   | (250.97) 135 |
| ME–THFTGK   | (−241.2) 176 | (0.418) 149   | (−0.221) 144  | (1474.8) 30 |
| ME–TKMK     | (−71.9) 131 | (0.465) 99    | (0.008) 69    | (1031.77) 49 |
| MKE         | (71.27) 32  | (0.578) 25    | (0.331) 24    | (455.93) 106 |
| MOME        | (247.43) 14 | (0.627) 14    | (0.369) 20    | (977.03) 56  |
| MTF         | (46) 36    | (0.661) 10    | (0.342) 22    | (142.53) 153 |
| MUTF        | (−91.2) 143 | (0.396) 157   | (−0.308) 162  | (440.47) 109 |
| NKE–HHK     | (75.97) 31  | (0.626) 15    | (0.402) 17    | (302.63) 126 |
| NKE–KTK     | (80.8) 30   | (0.558) 39    | (0.174) 44    | (1066.6) 47  |
| NKE–NETK    | (90.3) 28   | (0.559) 31    | (0.257) 35    | (762.63) 76  |
| NKE–RTK     | (271.1) 12  | (0.612) 18    | (0.28) 28     | (1216.23) 39 |
| NYE         | (−328.57) 178 | (0.419) 147   | (−0.269) 157  | (2036.77) 14 |
| NYME–AK     | (−3.5) 74   | (0.387) 161   | (−0.378) 169  | (15.5) 167  |
| NYME–BDPK   | (−92.63) 145 | (0.444) 123   | (−0.138) 121  | (820.17) 69  |
| NYME–BPK    | (−1.03) 65  | (0.499) 62    | (−0.084) 101  | (501.23) 98  |
| NYME–EMK    | (3.97) 52   | (0.512) 55    | (−0.058) 91   | (169.3) 148  |
| NYME–FMK    | (−19.53) 92 | (0.465) 97    | (−0.011) 75   | (282) 130   |
| NYME–KTK    | (−66.1) 127 | (0.433) 134   | (−0.236) 151  | (495.97) 99  |
| NYME–MEK    | (−2.13) 70  | (0.446) 120   | (−0.227) 146  | (19.73) 163  |
| NYME–TTMK   | (−14.03) 88 | (0.474) 89    | (−0.092) 103  | (271.7) 131  |
| OE–AMK      | (−70.73) 129 | (0.426) 140   | (−0.135) 118  | (480.6) 102  |
| PAF         | (46.43) 35  | (0.645) 11    | (0.371) 19    | (160.5) 149  |
| PE–GK       | (−81.37) 138 | (0.427) 139   | (−0.276) 159  | (554.9) 92   |
| PE–GTK      | (−54.67) 121 | (0.472) 90    | (−0.143) 124  | (973.87) 57  |
| PE–MFTK     | (−47.97) 120 | (0.444) 122   | (−0.149) 126  | (425.43) 112 |
| PE–MIK      | (−42.53) 119 | (0.458) 104   | (−0.036) 87   | (507.13) 97  |
| PE–MK       | (−30.77) 107 | (0.475) 87    | (−0.012) 76   | (619.97) 85  |
| PHF         | (0.9) 62    | (0.607) 153   | (−0.175) 131  | (4.5) 177   |
| PPKE–BTK    | (−393.4) 179 | (0.44) 131    | (−0.023) 80   | (3292.4) 3   |
| PPKE–ITK    | (27.7) 40   | (0.523) 46    | (0.278) 29    | (610.77) 86  |
| PPKE–JAK    | (305.83) 11  | (0.586) 21    | (0.275) 30    | (1775.23) 20 |
| PTE–AJK     | (−32.63) 108 | (0.467) 95    | (−0.03) 82    | (488.03) 101 |
| PTE–AOK     | (−92.07) 144 | (0.455) 109   | (0.469) 14    | (1028.87) 50 |
| PTE–BTK     | (−233.83) 173 | (0.43) 136    | (−0.144) 125  | (1671.43) 24 |
| PTE–ETK     | (−237.23) 175 | (0.426) 141   | (−0.115) 112  | (1685.8) 26  |
| PTE–GYTK    | (−67.47) 128 | (0.304) 173   | (−0.064) 94   | (1719.3) 146 |
| PTE–KPVK    | (−87.23) 141 | (0.442) 128   | (−0.236) 150  | (756.63) 77  |
| PTE–KTK     | (−64.23) 126 | (0.46) 102    | (−0.137) 119  | (809.63) 70  |
| PTE–MIK     | (−76.6) 130  | (0.462) 100   | (−0.032) 83   | (1020.8) 51  |
| PTE–MK      | (−9.57) 84   | (0.484) 75    | (0.17) 46     | (303.83) 125 |
| PTE–TTK     | (−174.73) 168 | (0.434) 133   | (−0.116) 113  | (1318.6) 37  |
| SE–AOK      | (504.07) 3   | (0.786) 1     | (1.085) 1     | (882.07) 63  |
| SE–EKK      | (−20.37) 95  | (0.454) 110   | (−0.016) 78   | (223.63) 139 |
| SE–ETK      | (308.83) 9   | (0.579) 24    | (0.204) 40    | (1948.23) 17 |
| SE–FOK      | (134.17) 24  | (0.695) 7     | (0.998) 2     | (344.17) 121 |
| SE–GYTK     | (9.67) 48    | (0.513) 53    | (0.44) 15     | (379.53) 118 |

Continued on the next page
| Faculty   | Row sum | Norm. row sum | Least squares | Preferences |
|-----------|---------|---------------|---------------|-------------|
| SZAGKHF   | (0.33)  | 61            | (0.529) 42    | (−0.138) 120 | (5.67) 176  |
| SZE–AJK   | (5.3)   | 51            | (0.506) 58    | (0.021) 63   | (410.9) 115 |
| SZE–AK    | (−74.67)| 132           | (0.467) 94    | (−0.099) 105 | (1138.53) 42|
| SZE–GK    | (−113.87)| 151           | (0.442) 127   | (−0.179) 135 | (989) 54    |
| SZE–MÉK   | (−81.43)| 139           | (0.356) 169   | (−0.361) 167 | (282.1) 129 |
| SZE–MTK   | (−92.83)| 146           | (0.48) 79     | (−0.003) 74  | (2363.1) 10 |
| SZE–PLI   | (−25.43)| 101           | (0.456) 108   | (−0.113) 111 | (287.37) 128|
| SZE–ZMI   | (−37.93)| 113           | (0.372) 165   | (0.042) 60   | (148.07) 151|
| SZF       | (−79.9) | 137           | (0.422) 145   | (−0.296) 161 | (512.77) 95 |
| SZFE      | (316.17)| 7             | (0.734) 3     | (0.518) 11   | (675.57) 83 |
| SZE–ABPK  | (−75.63)| 133           | (0.43) 137    | (−0.22) 142  | (539.5) 93  |
| SZE–AOTK  | (177.1) | 19            | (0.729) 4     | (0.718) 4    | (386.1) 117 |
| SZE–ETK   | (0.4)   | 60            | (0.5) 61      | (0.082) 58   | (587.8) 87  |
| SZE–GEK   | (−84.03)| 140           | (0.452) 114   | (−0.064) 93  | (880.03) 65 |
| SZE–GK    | (−55.87)| 122           | (0.429) 138   | (−0.254) 153 | (394.67) 116|
| SZE–GTK   | (−155.43)| 163           | (0.466) 96    | (−0.11) 109  | (2271.77) 11|
| SZE–KETK  | (−3.33) | 73            | (0.497) 64    | (−0.051) 90  | (493.6) 100 |
| SZE–MKK   | (−35.33)| 111           | (0.482) 78    | (−0.093) 104 | (995.73) 53 |
| SZE–TÁJK  | (3.87)  | 53            | (0.51) 57     | (0.091) 57   | (188.27) 144|
| SZE–YMEK  | (−5.57) | 77            | (0.494) 67    | (0.117) 54   | (440.9) 108 |
| SSZHF     | (−0.87) | 63            | (0.475) 88    | (0.012) 68   | (17.4) 165  |
| SZTE–AJK  | (−15.23)| 90            | (0.491) 68    | (0.012) 67   | (844.3) 68  |
| SZTE–AOK  | (109.83)| 26            | (0.563) 29    | (0.692) 6    | (874.1) 66  |
| SZTE–BTK  | (−71.2) | 130           | (0.479) 81    | (−0.035) 84  | (1704.93) 22|
| SZTE–ETSZK| (19.97) | 43            | (0.513) 52    | (0.023) 61   | (754.17) 78 |
| SZTE–FOK  | (29.4)  | 39            | (0.566) 28    | (0.732) 3    | (221.4) 140 |
| SZTE–GTK  | (18.67) | 44            | (0.511) 56    | (−0.012) 77  | (880.2) 64  |
| SZTE–GYTK | (−20.13)| 94            | (0.453) 113   | (0.245) 37   | (215.47) 142|
| SZTE–JGYPK| (−181.03)| 169          | (0.45) 118    | (−0.11) 110  | (1812.03) 19|
| SZTE–MGK  | (−24.13)| 99            | (0.448) 119   | (−0.221) 143 | (234.27) 138|
| SZTE–MK   | (−59)   | 123           | (0.47) 91     | (−0.101) 106 | (980.47) 55 |
| SZTE–TKK  | (24.77) | 41            | (0.523) 45    | (0.077) 59   | (539.37) 94 |
| SZTE–TTK  | (−95.97)| 148           | (0.478) 82    | (0.016) 64   | (2206.7) 12 |
| SZTE–ZMK  | (−14.13)| 89            | (0.451) 116   | (0.125) 53   | (144.27) 152|
| TE        | (419.77)| 5             | (0.625) 16    | (0.252) 36   | (1683.1) 23 |
| TPF       | (−60.47)| 124           | (0.337) 171   | (−0.533) 177 | (185.93) 145|
| VHF       | (−1.63) | 67            | (0.476) 84    | (−0.161) 128 | (339.7) 162 |
| WJLF      | (−2.23) | 71            | (0.491) 69    | (−0.083) 100 | (120.5) 154 |
| WSUF      | (−78.53)| 136           | (0.368) 167   | (−0.432) 172 | (298) 127  |
| ZSKF      | (−251.1)| 177           | (0.353) 170   | (−0.405) 171 | (854.37) 67 |
Table A.3:
Rankings of Hungarian faculties, adjusted unweighted preference matrix $\hat{A}^{UW}$, 2016

Numbers in parentheses indicate the score, bold numbers sign the rank of the faculty.

| Faculty     | Row sum | Norm. row sum | Least squares | Preferences |
|-------------|---------|---------------|---------------|-------------|
| ANNYE       | (26) 41 | (0.638) 13   | (0.441) 16   | (94) 157    |
| AVKF        | (−380) 163 | (0.362) 168 | (−0.33) 161 | (1376) 92  |
| BCE–ETK     | (−22) 75 | (0.359) 170 | (−0.219) 138 | (78) 159 |
| BCE–GTK     | (2606) 2 | (0.64) 12     | (0.385) 22   | (9296) 2    |
| BCE–KERTK   | (12) 43 | (0.579) 25     | (0.073) 61   | (76) 161   |
| BCE–KTK     | (198) 30 | (0.589) 22     | (0.4) 19      | (1114) 104 |
| BCE–TAJK    | (4) 46 | (0.571) 29     | (0.278) 31   | (28) 164   |
| BCE–TK      | (688) 13 | (0.577) 27     | (0.315) 25   | (4476) 21  |
| BGE–GKZ     | (−69) 95 | (0.429) 131    | (−0.219) 139 | (485) 143  |
| BGE–KKK     | (−171) 125 | (0.487) 64     | (0.031) 70   | (6721) 7    |
| BGE–KVIK    | (−34) 82 | (0.497) 55     | (0.033) 69   | (6052) 9    |
| BGE–PSZK    | (−296) 154 | (0.482) 70     | (0.022) 72   | (8116) 4    |
| BGF–GKZ     | (1) 50 | (0.533) 41     | (−0.119) 103 | (15) 172   |
| BGF–KKFK    | (−14) 73 | (0.41) 150     | (−0.092) 94  | (78) 159   |
| BGF–KVIFK   | (−7) 66 | (0.37) 166     | (−0.205) 132 | (27) 165   |
| BGF–PSZFKBP | (−6) 63 | (0.475) 75     | (−0.029) 77  | (122) 156  |
| BKTF        | (−4) 60 | (0.167) 178    | (−0.489) 175 | (6) 177    |
| BME–EOK     | (157) 34 | (0.553) 35     | (0.265) 36   | (1491) 83  |
| BME–ESZK    | (326) 22 | (0.713) 7      | (0.59) 9     | (764) 123  |
| BME–GEK     | (1352) 4 | (0.695) 8      | (0.549) 13   | (3464) 34  |
| BME–GTK     | (208) 29 | (0.516) 49     | (0.174) 48   | (6662) 8    |
| BME–KSK     | (111) 38 | (0.522) 47     | (0.212) 43   | (2517) 48  |
| BME–TTK     | (0) 53  | (0.5) 53       | (0.237) 39   | (1016) 113 |
| BME–VHK     | (291) 24 | (0.551) 36     | (0.301) 28   | (2871) 43  |
| BME–VIK     | (1426) 3  | (0.643) 10     | (0.488) 15   | (4978) 13  |
| BMF–BGK     | (−408) 164 | (0.446) 106    | (−0.015) 75  | (3756) 29  |
| BMF–KGK     | (−427) 165 | (0.438) 117    | (−108) 100   | (3431) 36  |
| BMF–KVK     | (133) 36 | (0.526) 43     | (0.164) 52   | (2513) 49  |
| BMF–NIK     | (163) 33 | (0.523) 46     | (0.214) 42   | (3527) 33  |
| BMF–RKK     | (−161) 121 | (0.425) 137    | (−0.065) 85  | (1069) 106 |
| DE–AJK      | (−54) 91 | (0.481) 71     | (−0.054) 83  | (1398) 90  |
| DE–AOK      | (447) 19 | (0.546) 39     | (0.645) 8    | (4821) 16  |
| DE–BTK      | (−373) 162 | (0.453) 94     | (−0.099) 98  | (3971) 25  |
| DE–EK       | (−490) 169 | (0.36) 169     | (−0.328) 160 | (1756) 68  |
| DE–FOK      | (94) 39  | (0.531) 42     | (0.69) 7     | (1540) 79  |
| DE–GTK      | (−316) 156 | (0.453) 95     | (−0.204) 131 | (3364) 38  |
| DE–GYTK     | (−288) 153 | (0.379) 165    | (0.171) 51   | (1194) 99  |
| DE–HPFK     | (−95) 105 | (0.469) 80     | (−0.266) 146 | (1555) 78  |
| DE–IK       | (−152) 115 | (0.453) 92     | (−0.126) 106 | (1624) 74  |
| DE–MK       | (−159) 119 | (0.459) 86     | (−0.137) 109 | (1945) 61  |
| DE–MTK      | (−318) 157 | (0.415) 144    | (−0.277) 150 | (1864) 64  |
| DE–NK       | (12) 43  | (0.504) 50     | (0.002) 73   | (1458) 86  |
| DE–TTK      | (−769) 177 | (0.386) 161    | (−0.141) 111 | (3383) 37  |
| DE–ZK       | (−7) 66  | (0.491) 59     | (0.23) 40    | (369) 150  |
| DF          | (−2) 54  | (0.444) 108    | (−0.227) 141 | (18) 169   |

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Table A.3 – continued from the previous page

| Faculty | Row sum | Norm. row sum | Least squares | Preferences |
|---------|---------|---------------|---------------|-------------|
| DRHE    | (-10) 72 | (0.489) 60   | (-0.216) 136  | (452) 145   |
| DUE     | (-484) 168 | (0.352) 173  | (-0.358) 165  | (1638) 72   |
| EGHF    | (-7) 66   | (0.231) 175  | (-0.527) 176  | (13) 174    |
| EHE     | (15) 42   | (0.895) 1    | (0.87) 3     | (19) 168    |
| EJF     | (-115) 113 | (0.418) 142  | (-0.335) 162  | (705) 127   |
| EJFM    | (-2) 54   | (0.438) 119  | (-0.407) 173  | (16) 171    |
| EJFP    | (-2) 54   | (0.429) 132  | (-0.314) 158  | (14) 173    |
| EKF–BTK | (-231) 138 | (0.428) 133  | (-0.163) 118  | (1595) 76   |
| EKF–CK  | (-103) 110 | (0.416) 143  | (-0.378) 170  | (613) 134   |
| EKF–GTK | (-286) 152 | (0.4) 155    | (-0.339) 163  | (1428) 88   |
| EKF–TKTK| (-243) 145 | (0.449) 99   | (-0.226) 140  | (2397) 51   |
| EKF–TTK | (-334) 159 | (0.439) 114  | (-0.177) 124  | (2754) 44   |
| ELTE–AJK| (900) 6   | (0.618) 17   | (0.4) 20     | (3804) 26   |
| ELTE–BTK| (287) 25  | (0.519) 48   | (0.176) 47   | (7549) 5    |
| ELTE–GYFK| (749) 10 | (0.627) 15   | (0.279) 30   | (2959) 41   |
| ELTE–IK | (464) 17  | (0.565) 31   | (0.3) 29     | (3556) 31   |
| ELTE–PPK| (1066) 5  | (0.577) 26   | (0.264) 37   | (6908) 6    |
| ELTE–TATK| (-254) 147 | (0.466) 82   | (0.112) 56   | (3710) 30   |
| ELTE–TK  | (431) 20  | (0.574) 28   | (0.271) 34   | (2931) 42   |
| ELTE–TOFK| (625) 14  | (0.568) 30   | (0.065) 63   | (4619) 19   |
| ELTE–TTK| (-276) 149 | (0.476) 74   | (0.174) 49   | (5866) 10   |
| GDF     | (-83) 99  | (0.434) 122  | (-0.236) 142  | (627) 133   |
| GFF–PK  | (-32) 80  | (0.484) 67   | (-0.193) 127  | (986) 115   |
| GFF–TK  | (-2) 54   | (0) 179     | (-0.995) 179  | (2) 179     |
| GFF–TSZK| (-3) 58   | (0.2) 177   | (-0.584) 178  | (5) 178     |
| GYHF    | (2) 47    | (0.55) 37   | (0.065) 62   | (20) 167    |
| IBS     | (-39) 87  | (0.438) 115  | (-0.076) 89   | (317) 151   |
| KE–ATK  | (-36) 84  | (0.475) 76   | (-0.201) 130  | (716) 125   |
| KE–CSPFK| (-324) 158 | (0.399) 156  | (-0.287) 153  | (1606) 75   |
| KEE     | (6) 45    | (0.667) 9    | (0.496) 14   | (18) 169    |
| KE–GTK  | (-40) 88  | (0.453) 93   | (-0.238) 143  | (426) 146   |
| KE–MFK  | (-177) 128 | (0.391) 158  | (0.024) 71   | (813) 121   |
| KF–GMFK | (-215) 136 | (0.453) 97   | (-0.163) 119  | (2281) 53   |
| KF–KFK  | (-82) 98  | (0.422) 140  | (-0.319) 159  | (526) 141   |
| KF–TFK  | (-240) 144 | (0.383) 162  | (-0.366) 168  | (1022) 111  |
| KFJ     | (-159) 119 | (0.447) 103  | (-0.2) 128   | (1487) 84   |
| KRE–AJK | (-438) 167 | (0.436) 120  | (-0.027) 76   | (3440) 35   |
| KRE–BTK | (736) 11  | (0.544) 40   | (0.191) 45   | (8284) 3     |
| KRE–TFK | (-97) 107 | (0.482) 69   | (-0.104) 99   | (2695) 46   |
| KRF     | (-369) 161 | (0.382) 164  | (-0.388) 172  | (1559) 77   |
| LFZE    | (303) 23  | (0.722) 5    | (0.585) 10   | (683) 129   |
| ME–AJK  | (-59) 93  | (0.472) 78   | (-0.09) 93   | (1041) 110  |
| ME–BBZI | (-37) 85  | (0.423) 138  | (0.079) 60   | (241) 154   |
| ME–BTK  | (-163) 122 | (0.427) 135  | (-0.238) 144  | (1119) 103  |
| ME–EFK  | (-278) 150 | (0.369) 167  | (-0.313) 157  | (1060) 108  |
| ME–GEK  | (-278) 150 | (0.438) 116  | (-0.153) 114  | (2234) 55   |
| ME–GTK  | (-173) 127 | (0.425) 136  | (-0.271) 148  | (1155) 101  |

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Table A.3 – continued from the previous page

| Faculty | Row sum | Norm. row sum | Least squares | Preferences |
|---------|---------|---------------|---------------|-------------|
| ME–MAK  | (−38) 86 | (0.46) 84     | (−0.166) 122  | (478) 144   |
| ME–MPK  | (−6) 63  | (0.495) 56    | (−0.081) 91   | (584) 137   |
| ME–THFTGK | (−98) 108 | (0.48) 72    | (−0.096) 97   | (2486) 50   |
| ME–TKMK  | (−31) 78  | (0.489) 62    | (0.034) 68    | (1535) 93   |
| MKE     | (169) 32  | (0.602) 20    | (0.397) 21    | (825) 120   |
| MOME    | (463) 18  | (0.642) 11    | (0.435) 17    | (1631) 73   |
| MTF     | (60) 40   | (0.628) 14    | (0.304) 27    | (234) 155   |
| MUTF    | (−132) 114 | (0.413) 146  | (−0.272) 149  | (760) 124   |
| NKE–HHK | (150) 35  | (0.618) 17    | (0.356) 23    | (634) 132   |
| NKE–KTK  | (257) 26  | (0.547) 38    | (0.196) 44    | (2743) 45   |
| NKE–NETK | (224) 28  | (0.555) 34    | (0.271) 33    | (2034) 58   |
| NKE–RTK  | (392) 21  | (0.583) 24    | (0.222) 41    | (2368) 52   |
| NYE     | (−890) 179 | (0.382) 163  | (−0.358) 166  | (3766) 28   |
| NYME–AK | (−5) 61   | (0.4) 154     | (−0.386) 171  | (25) 166    |
| NYME–BDPK | (−236) 141 | (0.432) 125  | (−0.178) 125  | (1744) 70   |
| NYME–BDPK | (−31) 78  | (0.485) 66    | (−0.134) 108  | (1011) 114  |
| NYME–EMK | (−30) 77  | (0.46) 85     | (−0.168) 123  | (376) 149   |
| NYME–FMK | (−86) 102 | (0.429) 128   | (−0.083) 92   | (608) 136   |
| NYME–KTK | (−94) 104 | (0.449) 100   | (−0.217) 137  | (920) 118   |
| NYME–MEK | (−7) 66   | (0.405) 153   | (−0.284) 152  | (37) 163    |
| NYME–TTMK | (−85) 101 | (0.433) 123   | (−0.21) 133   | (635) 131   |
| OÆ–AMK  | (−202) 133 | (0.419) 141  | (−0.156) 116  | (1248) 96   |
| PAF     | (127) 37  | (0.617) 19    | (0.323) 24    | (543) 140   |
| PE–GK   | (−187) 131 | (0.414) 145  | (−0.307) 155  | (1091) 105  |
| PE–GKT  | (−223) 137 | (0.44) 113   | (−0.214) 135  | (1855) 65   |
| PE–MFTK | (−171) 125 | (0.412) 148  | (−0.188) 126  | (969) 116   |
| PE–MIK  | (−156) 118 | (0.433) 124   | (−0.093) 95   | (1158) 100  |
| PE–MK   | (−165) 123 | (0.442) 111   | (−0.081) 90   | (1421) 89   |
| PHF     | (−5) 61   | (0.222) 176   | (−0.534) 177  | (9) 175     |
| PPKE–BTK | (−815) 178 | (0.457) 89    | (0.043) 67    | (9509) 1    |
| PPKE–ITK | (1) 50    | (0.5) 52      | (0.275) 32    | (1909) 62   |
| PPKE–JAK | (698) 12   | (0.587) 23    | (0.305) 26    | (4016) 24   |
| PTE–AJK | (−83) 99  | (0.46) 83     | (−0.009) 74   | (1069) 106  |
| PTE–AOK | (−584) 173 | (0.446) 105   | (0.551) 12    | (5406) 11   |
| PTE–BTK  | (−730) 176 | (0.413) 147   | (−0.147) 112  | (4188) 22   |
| PTE–ETK  | (−657) 174 | (0.408) 152   | (−0.153) 115  | (3555) 32   |
| PTE–GYTK | (−273) 148 | (0.342) 174   | (0.057) 64    | (863) 119   |
| PTE–KPVK | (−206) 134 | (0.429) 127   | (−0.277) 151  | (1460) 85   |
| PTE–KTK  | (−155) 116 | (0.448) 101   | (−0.162) 117  | (1493) 82   |
| PTE–MIK  | (−312) 155 | (0.429) 130   | (−0.116) 102  | (2196) 56   |
| PTE–MK   | (−17) 74   | (0.488) 63    | (0.186) 46    | (711) 126   |
| PTE–TTK  | (−537) 172 | (0.41) 149    | (−0.165) 121  | (2993) 40   |
| SE–AOK   | (3128) 1   | (0.832) 2     | (1.238) 1     | (4704) 18   |
| SE–EKK   | (−66) 94   | (0.441) 112   | (−0.034) 79   | (564) 139   |
| SE–ETK   | (227) 27   | (0.524) 45    | (0.172) 50    | (4817) 17   |
| SE–FOK   | (860) 8    | (0.715) 6     | (1.099) 2     | (1998) 59   |
| SE–GYTK  | (−207) 135 | (0.455) 91    | (0.419) 18    | (2281) 53   |

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| Faculty       | Row sum | Norm. row sum | Least squares | Preferences |
|--------------|---------|---------------|---------------|-------------|
| SZAGKHF      | (1) 50  | (0.556) 33    | (-0.123) 104  | (9) 175     |
| SZE–AJK      | (-95) 105 | (0.449) 98   | (-0.067) 86   | (939) 117   |
| SZE–AK       | (-237) 143 | (0.453) 95   | (-0.131) 107  | (2523) 47   |
| SZE–NK       | (-236) 141 | (0.429) 129  | (-0.211) 134  | (1662) 71   |
| SZE–MÉK      | (-180) 129 | (0.353) 172  | (-0.375) 169  | (612) 135   |
| SZE–MTK      | (-505) 171 | (0.448) 102  | (-0.075) 88   | (4841) 14   |
| SZE–PLI      | (-70) 96   | (0.446) 104  | (-0.165) 120  | (652) 130   |
| SZE–ZMI      | (-70) 96   | (0.41) 150   | (-0.098) 58   | (390) 147   |
| SZF          | (-234) 139 | (0.389) 159  | (-0.364) 167  | (1052) 109  |
| SZFE         | (602) 16   | (0.729) 4    | (0.585) 11    | (1316) 94   |
| SZIE–ABPK    | (-155) 116 | (0.436) 121  | (-0.244) 145  | (1203) 98   |
| SZIE–AOTK    | (623) 15   | (0.742) 3    | (0.81) 5      | (1287) 95   |
| SZIE–ETK     | (-45) 89   | (0.487) 65   | (0.102) 57    | (1767) 67   |
| SZIE–GEK     | (-235) 140 | (0.438) 118  | (-0.11) 101   | (1885) 63   |
| SZIE–GK      | (-169) 124 | (0.395) 157  | (-0.341) 164  | (805) 122   |
| SZIE–GTK     | (-501) 170 | (0.445) 107  | (-0.126) 105  | (4593) 20   |
| SZIE–KETK    | (-51) 90   | (0.477) 73   | (-0.057) 84   | (1125) 102  |
| SZIE–MK      | (-100) 109 | (0.475) 77   | (-0.094) 96   | (1972) 60   |
| SZIE–TÁJK    | (-6) 63    | (0.495) 57   | (0.084) 59    | (568) 138   |
| SZIE–YMEK    | (-3) 58    | (0.499) 54   | (0.12) 55     | (1019) 112  |
| SSZHFK       | (2) 47     | (0.524) 44   | (0.12) 54     | (42) 162    |
| SZTE–AJK     | (-25) 76   | (0.493) 58   | (0.044) 66    | (1749) 69   |
| SZTE–AOK     | (893) 7    | (0.592) 21   | (0.824) 4     | (4831) 15   |
| SZTE–GTK     | (-247) 146 | (0.469) 81   | (-0.034) 78   | (4025) 23   |
| SZTE–ETSZK   | (-104) 111 | (0.471) 79   | (-0.035) 80   | (1786) 66   |
| SZTE–FOK     | (176) 31   | (0.563) 32   | (0.803) 6     | (1390) 91   |
| SZTE–GTK     | (-34) 82   | (0.489) 61   | (-0.05) 81    | (1510) 81   |
| SZTE–GYTK    | (-181) 130 | (0.427) 134  | (0.269) 35    | (1243) 97   |
| SZTE–JGYPK   | (-435) 166 | (0.443) 110  | (-0.152) 113  | (3791) 27   |
| SZTE–MGK     | (-57) 92   | (0.443) 109  | (-0.267) 147  | (501) 142   |
| SZTE–MK      | (-190) 132 | (0.455) 90   | (-0.14) 110   | (2120) 57   |
| SZTE–TKK     | (2) 47     | (0.501) 51   | (0.049) 65    | (1446) 87   |
| SZTE–TTIK    | (-725) 175 | (0.432) 126  | (-0.052) 82   | (5307) 12   |
| SZTE–ZMK     | (-33) 81   | (0.458) 88   | (0.158) 53    | (389) 148   |
| TE           | (789) 9    | (0.621) 16   | (0.25) 38     | (3259) 39   |
| TPF          | (-87) 103  | (0.358) 171  | (-0.472) 174  | (307) 152   |
| VHF          | (-7) 66    | (0.459) 87   | (-0.2) 129    | (85) 158    |
| WJLF         | (-8) 71    | (0.484) 68   | (-0.068) 87   | (246) 153   |
| WSUF         | (-107) 112 | (0.423) 139  | (-0.294) 154  | (691) 128   |
| ZSKF         | (-338) 160 | (0.389) 160  | (-0.313) 156  | (1518) 80   |