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University Rankings

Assessing countries' Higher Education systems: creation and analysis of a new index

Author: **Sacha Dehoorne**
Supervisors: **Vincent Blondel, Julien Hendrickx**
Readers: **Vincent Blondel, Jean-Charles Delvenne, Julien Hendrickx**
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Abstract

In the constantly evolving landscape of higher education, university rankings have quickly become integral to academia, catering to demands for quality assurance, resource optimization, and global visibility. These rankings, such as the Times Higher Education's World University Rankings, Quacquarelli Symonds World University Rankings, and ShanghaiRanking's Academic Ranking of World Universities, aim to motivate improvement and stimulate competition. Yet, their legitimacy and reliability have sparked scholarly debate and criticism.

This thesis systematically explores the methodologies, significance, and shortcomings of these rankings. By dissecting their methodologies, the study gains a profound understanding of how they assess institutions. A comprehensive literature review highlights existing research areas, setting the stage for original contributions.

An innovative direction taken in this work involves national-level rankings, introducing the National Education Performance Index (NEPI) to assess overall educational quality at a country level. This index, developed and analyzed in-depth, offers fresh insights into the quality of higher education systems. Case studies, such as Belgium and the European Union, reveal distinct performance variations within diverse contexts.

Identifying key determinants of educational quality, the research underscores the critical roles of research and development expenditure and per-student funding. By elucidating the factors influencing quality, a predictive model emerges, contributing to the broader understanding of education systems.

This thesis aims to broaden the discourse on rankings by examining positions on a country basis. It confirms biases, explores novel indices, and identifies core determinants.

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Chapter 1

Introduction

In today's academic landscape, characterized by the pursuit of quality assurance and resource optimization by decision-makers, better value for money by students, and global visibility and advertisement by universities, rankings have, within only a few years, become an unavoidable part of academic life. By addressing those demands, rankings have established themselves as indispensable players in the educational landscape. Their impact is wide-ranging, extending across various dimensions of higher education, from government policies to institutional reputation.

Theoretically, by highlighting the best practices and strengths of each institution, rankings strive to foster competition, stimulate continuous improvement, and motivate universities to exceed their own achievements. Nonetheless, despite what appears to be a noble objective, the legitimacy and reliability of rankings have come under scrutiny from numerous scholars, bringing the subject to the center of academic debates and generating a great deal of academic work. Critics argue that rankings oversimplify the intricate nature of higher education and use methodologies that seemingly lack a well-defined rationale.

In this thesis, we will first review the methodology of each of the 3 main rankings: the Times Higher Education's World University Rankings, the Quacquarelli Symonds World University Rankings and the ShanghaiRanking's Academic Ranking of World Universities. This step is crucial because, before starting the in-depth analysis, we need to have an overall understanding of how the rankings assess the quality of universities and the particularities of each of them.

Next, we'll conduct a literature review to examine the various aspects of university rankings that have already been studied by others, from their impact and reasons for popularity to their analysis and criticism. This will enable us to take a thorough look at the aspects that are already covered by existing literature, and thus lay the foundations for our work.

Finally, in contrast to rankings that assess universities one by one, we will explore rankings on a national level. This will enable us to assess the overall quality of a country's higher education. To achieve this, we will propose a new index, the National Education Performance Index (NEPI). We will detail the development of this index, analyze the results and investigate the determinants of countries' educational quality.

The aim of this work is to broaden the horizons of university rankings by having a global view of the research already carried out, and bringing in a component relatively absent, up until now, from the discussion, i.e. the study of position by country rather than by university.

Chapter 2

Rankings Methodology

As stated before, the analysis developed in this thesis will focus on the three most popular university rankings: the Times Higher Education World University Rankings, the Quacquarelli Symonds World University Rankings, and the ShanghaiRanking's Academic Ranking of World Universities.

Each of these rankings uses a different methodology to assess the quality of a Higher Education Institution (HEI), using multiple indicators weighted differently depending on what is prioritized by the ranking. However, they all use the weight-and-sum approach, where they decide on measures of academic quality and their importance (weights), collect data based on these decisions, and arrange it into an easy to understand "sports league table"-like format [1].

Examining those methodologies will give us insights into how they assess universities and what criteria they consider to be most important for evaluating performance. Depending on their interpretation of what makes a high-quality HEI, some rankings prioritize research excellence, while others emphasize the quality of teaching. This will also help us understand why certain universities may be ranked higher or lower on different rankings, and what factors contribute to their overall performance.

Overall, understanding the methodology of the three main university rankings is critical for interpreting their results. In the following sections of this chapter, we will provide a detailed description of the methodology used by each ranking, including the specific indicators, the weighting, etc.

2.1 Times Higher Education's World University Rankings (THE)

The THE Ranking is based on five main categories as summarized in Table 2.1 [2].

2.1.1 Reputation Surveys

The THE Ranking uses reputation surveys as a way to measure the quality of teaching and research conducted in a said HEI.
To establish the score, a survey is sent to a sample of academics selected by THE based on their record of research publication. They then nominate a maximum of 15 institutions that they consider as the best in their fields (educational-wise for the Teaching Survey and research-wise for the Research Survey) [3].

The sample is said to be selected to be balanced in terms of respondent's countries (according to the distribution of scholars across the world) and fields. THE's data team then weights under- or over-represented countries and discipline to have fairly represented results in terms of those two criteria. The exact weighting process and its results are not disclosed by THE.

A score on a scale of 100 is then derived using a logarithmic-based standardization [4].

2.1.2 Ranking's Metrics

2.1.2.1 Teaching - 30%

The teaching quality in an institution is measured through 5 indicators :

The **Teaching Reputation Survey (15%)** represents the prestige of the education offered in the institution. It is based on the Academic Reputation Survey (see 2.1.1).

The **Staff-to-Student Ratio (4.5%)** acts as a proxy to the quality of education and student experience [5] as one can suppose that having smaller classes leads to a better education. It is computed by dividing the total number of full-time equivalent (FTE) employees working in academic positions by the total number of FTE students enrolled [4].

Category	Indicator	Weight
Teaching	Reputation survey	15%
	Staff-to-student ratio	4.5%
	Doctorate-to-bachelor's ratio	2.25%
	Doctorates-awarded-to-academic-staff ratio	6%
	Institutional income	2.25%
Research	Reputation survey	18%
	Research income	6%
	Research productivity	6%
Citations		30%
International outlook	Proportion of international students	2.5%
	Proportion of international staff	2.5%
	International collaboration	2.5%
Industry income		2.5%

Table 2.1: Times Higher Education's World University Rankings methodology

The **Doctorate-to-bachelor's ratio (2.25%)** is computed as the ratio between the total number of doctorates awarded and the total number of undergraduate degrees awarded, a high ratio indicating that students tend to pursue their academic path until completion [4].

The **Doctorates-awarded-to-academic-staff ratio (6%)** is computed by dividing the total subject weighted doctorates by the total subject weighted number of academic staff, a high ratio demonstrates commitment to create the next generation of academics and the attractiveness and effectiveness of the postgraduate program [4].
The subject weights reflect the fact that the volume of doctorates awarded varies by discipline and the detail is not disclosed by THE [4].

Institutional income (2.25%) is computed by dividing the institutional income (adjusted to purchasing power parity (PPP)) by the total number of FTE academic staff [2].
This metric indicates the institution's general status and gives an overview of the infrastructure and facilities offered to students and staff.

2.1.2.2 Research - 30%

The research quality in an institution is measured through 3 indicators :

The **Reputation Survey (18%)** represents the prestige of the research carried out in the institution. It is based on the Research Reputation Survey (see 2.1.1).

Research income (6%) is computed by dividing the total subject-weighted research income (adjusted for PPP), by the total subject-weighted number of FTE academic staff [2].

The weights reflect the fact that research grants differ depending on the subject (i.e. science subjects ones are often bigger than those awarded for social science, arts and humanities research) but the details are not disclosed by THE.

THE discloses itself that this indicator is controversial as it is greatly influenced by national policies and economic conditions but argues that "income is crucial to the development of world-class research, and because much of it is subject to competition and judged by peer review, [their] experts suggested that it was a valid measure" [4].

The **Research productivity (6%)** is obtained by dividing the total subject-weighted number of papers published in academic journals indexed by Elsevier's Scopus database, by the sum of the total subject-weighted number of FTE research staff and FTE academic staff [2]. This indicator shows how capable the organization is to publish articles in quality peer-reviewed journals.

Again, these weights are here to take into account the fact that different subjects have very different traditions of publication and without these adjustments, institutions specialized in medicine and science would be favoured [6].

Authors with multiple affiliations When an author has multiple affiliations, the paper will be counted one time for every institution to which they are affiliated [7]. This is controversial as it is subject to manipulation. This will be discussed in Section 3.3.1.1

2.1.2.3 Citations - 30%

This metric is computed as the average number of times a university's published work from the last 5 years is cited by scholars globally. This is done via Elsevier's Field-Weighted Citation Impact (FWCI) score [4].
The FCWI score is the ratio between the citations actually received, and the average number of citations received by all other similar publications (publications sharing year of publication, Subject field and Output type) [8].
This metric reflects how much each university is contributing to global research.

Indeed, a paper cited by lots of others proves it has been useful to the field and others build new knowledge around it. It is thus rewarded by THE.

Papers with more than 1000 authors According to THE, these types of papers had a huge impact on the citation scores of the small number of universities, they are now accounted for using a fractional counting approach. All universities participating in these papers receive at least 5 per cent of the value of the paper [4]. However, using fractional counting only on a small number of papers is source of controversies as it can distort benchmarking [9].

2.1.2.4 International outlook - 7.5%

The International outlook category is made of 3 indicators.

The **Proportion of international students (2.5%)** is computed as the ratio between the number of international students (FTE) divided by the total number of students (FTE) [4].

The **Proportion of international staff (2.5%)** is computed as the ratio between the number of international academic staff (FTE) divided by the total number of academic staff (FTE) [4].

The **International collaboration (2.5%)** is computed as the ratio between the number of published papers having an international co-author and the total number of papers published. This metric is subject weighted [4].

2.1.2.5 Industry Income - 2.5%

This is the ratio between the industry-provided research income (PPP-adjusted) and the total number of FTE academic staff.
This metric is said to be taken into account to reflect one of the core missions of modern universities: to assist industries, whether it be through innovations, inventions or consultancy [4].

2.1.3 Data Sources

2.1.3.1 Self-Reported Data

Institutional data is self-submitted by a representative for each HEI. Institutional data contains, among other things, information on students and staff, international faculty and student ratios, income, etc. [4]

Criteria	Weight
Academic Reputation	40%
Employer Reputation	10%
Faculty Student Ratio	20%
Citations per Faculty	20%
International Faculty Ratio	5%
International Student Ratio	5%

Table 2.2: Methodology of Quacquarelli Symonds World University Rankings

2.1.3.2 Elsevier

All bibliometric and publication data are provided by Elsevier.

2.1.3.3 Surveys

Academic surveys are conducted by THE themselves as explained in 2.1.1.

2.1.4 Standardization

All metrics are standardized by computing the cumulative probability function of a given indicator and evaluate the position of institutions within that function. To evaluate this position, z-scoring is used for all indicators apart from Teaching and Research Reputation Survey, for which, due to the distribution of data, an exponential approach is more adapted [6].

2.2 Quacquarelli Symonds (QS) World University Rankings

The QS Ranking is based on 4 main categories composed by 6 indicators as summarized in Table 2.2 [10].

2.2.1 Ranking's Metrics

2.2.1.1 Academic Reputation - 40%

Every year, QS conduct a survey among numerous academics. In the survey, participants indicate their area of expertise, as well as the country and regions they are most knowledgeable about. They are then asked to nominate up to 10 institutions (excluding their own) from their chosen country, and up to 30 institutions from the selected regions (but not in their chosen country) that they believe are leading in research within their field of study [11].

Then, after applying weights to balance the representation of countries, regions and fields of study, they obtain a weighted count of international nominations (aggregated over the 5 last years with a declining weight) and a domestic weighted count that is adjusted for competition among institutions in larger countries. The two score are then normalized to achieve individual scores out of 100, combined (15% domestic, 85% international) and scaled again to have a score out of 100 [11].

2.2.1.2 Employer Reputation - 10%

The methodology is the same as Academic Reputation Survey (see 2.2.1.1) except that respondents are global employers and that the domestic-international weight distribution is 50% – 50% [12].

2.2.1.3 Faculty Student Ratio - 20%

This metric acts as a proxy for the quality of the educational setting of the university. It is computed by dividing the number of faculty staff by the number of students [13].

2.2.1.4 Citations per Faculty - 20%

This metric is supposed to measure the research quality, as a higher citation per faculty value suggests that the produced research has a great impact and is widely recognized and referenced by the academic community.

This is computed by dividing the total number of citations received by faculty members by the total number of faculty members. To take into account different faculty sizes and academic fields, the citation count is normalized [14].

2.2.1.5 International Faculty Ratio - 5%

This metric is supposed to measure the attractiveness of the HEI for foreign staff and also supposes that diversity in staff benefits research and teaching.

It is computed as the proportion of the overall staff that is of foreign nationality given that they work at the HEI for at least three months [15].

2.2.1.6 International Student Ratio - 5%

This metric is supposed to measure the attractiveness of the HEI for foreign students and also supposes that diversity in students offers perks related to networking, cultural exchanges, and alumni diversity.

It is computed as the proportion of students (under- and postgraduate) that is of foreign nationality given that they study at the HEI for at least three months [16].

2.2.2 Data sources

Reputation indicators' data is obtained through the annually run survey by QS. The last 5 surveys are taken into account [11], [12].

For citation data, data comes from Scopus (published by Elsevier). They consider papers published in a five-year window and citations received in a six-year window, thus ignoring papers published the year before the ranking computation. The time is longer for citations than for papers as it takes time for a paper to be cited. Citations are considered if they are received up until the end of the calendar year prior to publication [17].

Most of the hard data are collected directly from universities. These data are cross-checked with government data statistics and data accessible on university websites. Inconsistencies are then followed up with each university to be resolved [10].

2.2.3 Standardization

QS do not share the exact methodology used to arrive at a score out of 100. They just mention that they transform the data in various ways, try to minimize outliers impact, and then scale the indicator to present a score out of 100.

2.3 ShanghaiRanking's Academic Ranking of World Universities (ARWU)

The ARWU is based on four main categories composed by six indicators as summarized in Table 2.3 [18].

Criteria	Indicator	Code	Weight
Quality of Education	Alumni of an institution winning Nobel Prizes and Fields Medals	Alumni	10%
Quality of Faculty	Staff of an institution winning Nobel Prizes and Fields Medals	Award	20%
	Highly Cited Researchers	HiCi	20%
Research Output	Papers published in Nature and Science	N&S	20%
	Papers indexed in Science Citation Index-Expanded and Social Science Citation Index	PUB	20%
Per Capita Performance	Per capita academic performance of an institution	PCP	10%

Table 2.3: Methodology of ShanghaiRanking's Academic Ranking of World Universities

2.3.1 Ranking's Metrics

2.3.1.1 Alumni of an institution winning Nobel Prizes and Fields Medals - 10%

This indicator is based on the total number of Nobel and Fields laureate's Alumni. Alumni being defined as anyone who obtained bachelor's, master's or doctoral degrees from the HEI. A Nobel laureates that would've obtained multiple degrees from the same institution is only counted once.
According to the period in which the laureate obtained their degree, the award won't count for the same. Degrees awarded after 2011 count for 100%, those awarded between 2001 and 2011 count for 90%. This weight decrease of 10% for each decade until the ones awarded between 1921 and 1930, counting for 10%.
The data used for this comes directly from the official sites of the distinctions [18].

2.3.1.2 Staff of an institution winning Nobel Prizes and Fields Medals - 20%

This indicator is based on the total number of Nobel (in Physics, Chemistry, Medicine and Economics) and Fields laureates Staff. Staff being defined as those who won the prize while working at the HEI. For laureates with n affiliations, each HEI receives $\frac{1}{n}$ of the award.
If a Nobel prize has multiple recipients, weights are set to reflect their proportion of the prize.
The data used for this comes directly from the official sites of the distinctions [18].

2.3.1.3 Highly Cited Researchers - 20%

This indicator is based on the number of Highly Cited Researchers selected by Clarivate, which is an annual list of researchers who are leaders in their research

field [18].
This distinction award those who have published several highly cited papers, defined as papers that are in the top 1% of the most cited in their disciplines and years of publication. For researchers with multiple affiliation, only their primary one is considered.
The 2021 version of this list contains 6,602 researchers [19].

2.3.1.4 Papers published in Nature and Science (20%)

This indicator is based on the number of articles published in Nature and Science between 2017 and 2021.
For HEIs specialized in humanities and social sciences, this indicator is not considered. Depending on the order of authors, decreasing weights are given, with a minimum of 10%.
The used data comes from Web of Science [18].

2.3.1.5 Papers indexed in Science Citation Index-Expanded and Social Science Citation Index (20%)

This indicator is based on the total number of articles indexed in Science Citation Index-Expanded (SCIE) and Social Science Citation Index (SSCI) in the year preceding the ranking. Papers indexed in SSCI have a weight of two. SSCI and SCIE are citation indexes published by Clarivate.
The used data comes from Web of Science [18].

2.3.1.6 Per capita academic performance of an institution (10%)

This indicator is computed as the ratio between the weighted scores of the other five indicators and the number of FTE academic staff. When the staff data isn't available, this indicator is not considered.
Staff data is obtained through national agencies [18].

2.3.2 Standardization

For a given indicator, the score of an HEI is computed as the percentage of the score obtained by the top-scoring HEI. If the data distribution is affected by a significant distorting effect; standard statistical techniques are used to adjust the indicator.

The global score of an HEI is computed as the percentage of the score obtained by the best HEI. [18]

Chapter 3

State Of The Art

In recent years, university rankings have become an essential element to influence the perception of higher education establishments worldwide. In particular, in the field of university research, these rankings have been the subject of much attention, study and discussion, highlighting their importance. Three predominant rankings, THE, QS, and ARWU, have, in particular, gained significant attention from various stakeholders, reflecting their growing influence in both the academic world and the society in general. This "State of the Art" section will dive into the popularity and relevance of university rankings, examining why they have such impact. We will then explore the exact impacts these ranking have on governments, employers, students, and HEIs. Despite their importance, these rankings are not without controversy. Debates surrounding their methodology, inherent functioning, and potential biases have sparked discussions in the academic community. In response to these criticisms, initiatives such as the IREG and the Berlin Principles have been introduced, though they too have their set of challenges. Conclusively, this section will show what was undertaken to analyse the rankings, focusing on prediction, correlation and comparisons, and potential solutions for HEIs to improve their rank.

3.1 A brief History

The concept of ranking global universities initially emerged as an academic exercise aimed at identifying the factors underpinning institutional excellence and comparing Asian universities to their well-established Western counterparts [20]. While national rankings have been in existence for a long time, the era of international rankings began in 2003 with the introduction of the Academic Ranking of World Universities (ARWU) by Shanghai Jiao Tong University. Subsequently, the Quacquarelli Symonds – Times Higher Education World University Ranking

(QS – THEWUR) emerged as a collaborative initiative between an English consultancy firm (QS) and the Times Higher Education Supplement. Following this phase of collaboration, both entities published independent rankings known as the Quacquarelli Symonds World University Ranking and the Times Higher Education World University Rankings. Over time, these three ranking systems have been those gaining the most attention [1].

3.2 Popularity and relevance

The growing interest, popularity, and relevance of university rankings can be attributed to the combination of several factors. Those are linked with a general shift in the perception of and expectations from HEIs. One of the key reasons is the increased concern for quality assurance from both states and HEIs. This created demand for reliable and standardized accreditation practices [21]. This demand has resulted in interest in rankings as a measure of academic quality and reliability.

In parallel, a new vision of HEIs has emerged. Politicians and the public are increasingly viewing these institutions as 'knowledge-producing' entities that are expected to produce economic benefits. This perception enhanced demand for accountability in the use of public resources [21]. Rankings, by encouraging the academic community to strive for improved quality and productivity, serve as a competitive stimulus [22]. In this context, rankings are seen as providing some sort of rationale for the allocation of funds to HEIs [20]. As such, rankings serve as a critical tool for demonstrating resource efficiency.

As our society becomes increasingly globalized, education is now viewed as an international market. HEIs are thus confronted with the challenge of establishing their presence in that global market, which is another crucial motivating factor behind the popularity of rankings [21]. Rankings indeed provide good, worldwide and free advertisement [20] by offering a platform for HEIs to assert their global standing, differentiating themselves from local but also global HEIs. This advertisement is mainly used by those aspiring to become world-class universities (i.e. top 100 HEI), but neither by the top HEI (like Harvard or Cambridge), nor the low ranking ones [1].

From a consumer perspective, parents and future students require easily interpretable information on the standing of HEIs to guide their decisions. Providing discernible and comparative information is the main purpose advertised by rankings publishers [20]. This holds even greater truth as, with the university fees increases, students are now on a quest for the best 'value for money' [23].

In conclusion, these varied yet interconnected motivations explain the development and prominence of rankings. By offering a universally recognized system for comparing and ensuring quality; stimulating competition; ensuring accountability; and aiding students in their decision-making process, rankings have had a profound impact on the contemporary educational landscape [21].

3.3 Impact of Ranking

As we have seen, rankings are not only growing in popularity but are also increasingly considered relevant. The motivations behind their rise, as previously explored, indicate potential large-scale effects of this trend. Rankings have influence over various stakeholders such as HEIs, students, employers and policymakers.

3.3.1 Impact on HEI

The rise in popularity of rankings has had a numerous consequences on HEI. It has reshaped how they approach institutional strategies and the choice of partnerships but also how students choose their future Alma mater.

First, it has been observed that rankings act like self-fulfilling prophecies. Indeed, by putting an incentive for HEI to conform to what rankings measure, as it is the only way to rank better, their adherence to these quality standards confirms and validates them [24].
This feedback loop together with the HEIs' involvement to improve their rank has led to HEI drifting towards homogeneity by losing their unique character and independence in their pursuit of improved ranking [20]. This involvement is proven, as some HEI include rankings results in their Key Performance Indicators (KPI) [23].
Another self-fulfilling prophecy is that brilliant students and faculty will go to well-ranked HEI which will, in turn, boost the HEI status [24], [25].

Rank variations also impacts those already in the institutions such as current students, faculty members, and members of the administration. Effects on these people manifest in shifts in morale, transfers, and in fluctuations in job security for administrators [24].

Moreover, students and parents, as rankings' main target audience [20], are also greatly impacted. Certain families now prioritize that their children attend a top ranked HEI [26]. However this trend is not universal and seems to be particularly true for high-achieving middle-class students, while more mature students, first-generation university goers, and those pursuing vocational subjects, are less influenced by these rankings [20], [23]. It was found that 11% of undergraduates view rankings as a determinant factor in their choice [20].

Rankings also have a significant influence on international collaborations and funding, as highly ranked universities find it easier to attract foreign students, partners, and funders [26]. An illustration of this can be seen in India's University Grants Commission's directive, which states that foreign universities engaging in bilateral agreements must hold a position within the global top 500 according to either THE or ARWU rankings [26]. The Brazilian government also prioritized high-ranking institutions for its "Science Without Borders" scholarship program [26].

Since the apparition of rankings, a wave of HEI mergers worldwide has been observed. For all these mergers, one of the key arguments was to improve international visibility. Examples of such mergers can be found in France, with the "Initiative d'Excellence" (Excellence Initiatives); in Finland, with the UEF and the Aalto University; in Iran, with the merger of TUMS and IUMS; and in UK with the new University of Manchester. This tactic has proven itself to be efficient, particularly for the ARWU, as 90% of the grade is not weighted by the HEI size (see Section 2) [27]–[31].

Finally, "ranking fetishism" [32] and the rankings' simplistic approach to what makes the quality of HEIs has led to the introduction of perverse incentives. Ranking-focused executives concentrate on short-term gains and fail to address long-term scientific, social, or economic priorities while neglecting the welfare of their internal and external communities [32]. HEIs have tried to artificially inflate their ranking position without having to improve what the criteria are meant to measure. This cynical effort to manipulate appearances while not changing internal practices is named gamification [33].

3.3.1.1 Gamification

This phenomenon has been more and more frequently observed in some HEIs, notably the East Asian ones [32].

The rankings' emphasis on research has led HEIs to heavily encourage the publishing of articles in journals indexed by the Web of Science database [32]. Indeed, only these articles are taken into account for the ARWU (see Section 2.3.1).

Academics are under pressure to be productive, simultaneously due to the long existing "publish or perish" pressure, new pressure coming from HEIs to obtain better results in rankings, and financial incentives [34]. This has led some of them to resort to gaming tactics to boost their publication numbers [32], this includes, for example, the multiplication of authors on a single paper with researchers being "hyperprolific" [34].

While this can seem harmless, other practices, far more unethical and corrupt, appeared. These include plagiarism, research data falsification, students' authorship exploitation, and payment for publication [35]. These practices are not anecdotal as, in China, a third of surveyed academics from leading institutions admitted they had plagiarized, falsified or fabricated results [35].

The HEIs also play with the system by reporting different numbers depending on the ranking and playing with words for definitions [33] as transforming these data can considerably favour the university [5]. One way it could be utilized is to play with the definition of student and staff when reporting their data to optimize QS and THE position. Indeed, these quantities play a weighting role and the ratio of those is a criterion (see Section 2). HEIs think that other HEIs tend to stretch the realities of the data in their submissions, which, in turn, convince them to do the same [23].

Another tactic employed by HEIs to manipulate the system is to offer well-paying adjunct professor positions to highly cited academics with minimal responsibilities. In exchange, the HEI gains the advantage of their citations, as they establish a secondary affiliation with the institution, which boosts the HEI position in rankings. Saudi Arabia appears to be the country that uses this technique the most, as 82% of highly cited researchers affiliated to a Saudi Arabia HEI list these institutions as secondary affiliations [36].

On the other side, gaming can be seen as some sort of symbolic response to rankings by giving a chance for HEIs to protect themselves from the negative consequences of a poor ranking [33].

The effect of gamification is double-edged : on the one hand, it calls into question the legitimacy of rankings as it proves the system can be played, but on the other, reinforces their legitimacy by reinforcing academics' commitment to them [33].

However, ranking publishers are not oblivious about those practices and they try to change the methodology and reporting process, by clarifying the rules and monitoring data [33].

3.3.2 Impact on governments

Rankings have evolved into a geopolitical tool shaping national policies and decisions, especially funding allocation and immigration policies [5]. For instance, the UK, China and New Zealand all have implemented some sort of performance-based funding. Although the performance measure is not directly linked with any international ranking, it is claimed that there are connections and confluence between such fundings and rankings. However, that link seems to be weaker than some would like to assume [20], [37].

Furthermore, rankings have influenced immigration policies as well. The Netherlands and Denmark both have a system where a degree from a top university can categorize immigration applicants as "highly skilled migrants". This is only part of a broader process but can contribute significantly to one's application (up 15% in Denmark) [26].

Lastly, rankings also impact degree recognition: Since 2012, Russia automatically recognizes any degree delivered by a top 300 HEI. Otherwise, the process is long and difficult. This decision was a source of criticism as rankings focus on research rather than teaching and are global, which means that the degree could come from a less competitive department but still be awarded by a leading HEI [26].

3.3.3 Impact on employers

There is evidence suggesting that employers use rankings as a component of their selection process for hiring graduate recruits. In the UK, recruiters hire based on an implicit hierarchy of HEI (linked to international rankings). Similarly in the US, a survey from 2008 indicated that employers hiring graduates consider the HEI from which they graduated as the fourth most important criterion [20].

3.4 Debate Around Rankings

3.4.1 Intrinsic functioning

Most of the academic criticism towards rankings stems from the dissonance between the intrinsic values of HEIs and the values propagated by ranking systems. Diversity is central to academia's culture, as its concept of excellence considers diverse value systems depending on the values and practices of each discipline. Conversely, the methodology behind rankings erases this diversity, promoting a unique concept of what a quality HEI is [5].

The ranking systems tend to treat HEIs with diverse missions as equal, ignoring their unique characteristics. When comparing public and private HEIs, or HEIs from different countries, it is crucial to accept the complexity of the matter and to take into account their political, social, and cultural contexts. Criticism is aimed at rankings for insufficiently considering these factors [20].

These conflicts of value partially come from the multidimensionality of academic excellence and the rankings' self-imposed constraint to output a unique score.

3.4.1.1 Single score and Rank preponderance

The single score approach to evaluating the institutions has been widely criticized for its oversimplification. People focus solely on the score or rank, dismissing any other information and accepting it as an absolute truth, even more when it aligns with their existing preconceptions [5].

Rankings also assume that the indicators are mutually compensatory, which oversimplifies the comparison between diverse HEIs by giving them equivalent overall scores. This method neglects the intrinsic differences between institutions, such as one being research-oriented and another being instruction-oriented. This reduces a complex comparison to "apples-to-oranges" simplicity [1], [5], [38].
This is even more problematic as people often focus more on the rank rather than the actual score, overlooking the fact that minor score differences can lead to significant ranking differences due to heavy clustering around the mean. For instance, in the QS 2009, the spread of score between two top-100 HEI that are 10 places away can be fewer than 2 points on 100 [38], [39].

Also, judging if a HEI improve year-to-year based on the rank is tricky as sometimes the rank worsens even if the score improved [1].

3.4.2 Methodology Issues

Indicators and weightings Harvey [20] suggests that, when choosing indicators, rankings prioritize what is convenient, based on easily accessible data, and what can be quantified over what is relevant or important. The rationale behind the choice of indicators often lacks clarity and does not capture the relation between input and output, raising questions about the decision-making process [5], [20]. University rankings often use five to six interrelated indicators, leading to redundancy and presenting an illusion of comprehensive assessment to enhance marketability [1], [39]. Similarly, weightings were found to be arbitrary [20]. Some are even arguing that indicator and weights are derived from the expected ranking rather than opposite [20], [38].

Weights inconsistencies The application of the methodology has also drawn criticism due to inconsistencies in assigned weights across all major rankings published in 2012, meaning that actual weights and theoretical weights assigned to each indicator were different, causing important shifts in university positions (up to 20 places difference for some top 100 HEIs) [40]. However, it seems that the situation has improved as the THE's actual weights since 2013 are consistent with the given weights [41]. Beyond the error on the ranking itself, it is problematic as it can mislead HEI that then could react in the wrong direction [1].

Surveys Both the THE and the QS heavily depend on surveys. Those surveys are critiqued for their large scale, leading to a large 'cognitive distance' between the evaluator and the entity being evaluated, and questioning the relevance of their judgments. In such cases, evaluators tend to lean more on an institution's established reputation rather than on a comprehensive understanding of its current achievements, leading to a potential disconnect between contemporary performance and perceived reputation [42]. This has been proven as past rankings have been found to significantly influence an institution's current reputation score and as reputation scores and overall rank converge [24].

Teaching indicators To measure the quality of education, the THE and the QS use the student-staff ratios, which, even if there is a correlation between small classes and educational quality, only provides a limited view of quality of teaching and do not guarantee it. Surveys are also used to proxy teaching but with the same shortcomings as described earlier [43]. In addition to the poor quality of the teaching indicators, an imbalance between research and teaching is measured, suggesting a misalignment between their focus and their claimed primary audience: prospective students and parents [43], [44].

3.4.3 Bias

Reputational Bias Research performance indicators were proven to be subject to a reputational bias. The reputation has different consequences for rankings.
First, due to the anchoring effect, which states that judgment is made by adjusting, often insufficiently, a given starting value (that could be random), it has been demonstrated that every new opinion-based ranking is influenced by previous ones. Reputation then becomes dependent from rankings and vice versa due

to reputational surveys in the indicators. This creates a "reputation-ranking-reputation" vicious circle, particularly influencing opinion based rankings such as the THE or the QS [45], [46].
Second, the article's university of origin was found to heavily influence the paper acceptance process and subsequent citations. This is due to the halo effect, meaning that the evaluation of one characteristic impact the assessment of others. The phenomenon suggests that certain universities unfairly gain an advantage due to an elevated past reputation, while others face disadvantages due to a lower perceived stature. The use of Nobels, that also add to that past prestige bias, reinforce this effect [46]–[48].
Third, the Matthew effect can significantly impact rankings based on research performance. It is defined as the cumulative effect that prestigious universities receive by gaining disproportionate recognition and attracting top doctoral students and researchers as well as funds [47], [48].
The sum of the weights of indicators likely to be influenced by reputation bias amounts to 60% for ARWU, 69% for THE and 70% for QS.[1] [46].

English-Language Bias Citations, which are an indicator in each ranking, favour English-speaking academics, as papers published in another language have less reach and are less likely to be cited, and as international journals may not be listed in indexing services [20], [43]. Non-English papers can be seen as diluting the measured impact of a university [42]. This has resulted in a dilemma for scholars in East Asia, forcing them to publish globally in English and locally in their native languages [35].

Disciplinary Bias Another potential bias arises from the disproportionate focus on certain fields, such as those that confer Nobel prizes [20]. Smaller universities and those with a social sciences and humanities focus perform better in rankings with peer review elements like the THE or the QS, than those who do not (like the ARWU) [42]. For the QS and the THE, as they implement subject-weighting methods, the effect of this bias is reduced.

Country-Specific Bias HEIs from the US often secure the top positions. While their high standing is indisputable, this also reflects the US dominance in publication and citation traffic [42]. The use of Nobel Prizes as a proxy for excellence also creates additional disadvantages for developing countries and smaller universities [22].

[1]The cited article only computed that percentage for the THE and the ARWU, we computed the percentage for the QS, based on what was made in the article

Conflict of Interest Bias Rankings may be influenced by commercial interests. For instance, HEIs advertising in the Times Higher Education magazine have seen, on average, an improvement in ranking position of about 15 places. It is, however, impossible to know if it is linked to a media bias or to the applications of reporting advice given by THE [49]. There is also evidence that universities that used services provided by QS companies improved their ranking position, regardless of actual changes in institutional characteristics. The observed improvement was particularly made in the "faculty-student" indicator, which is the easiest to improve by adjusting the way data is reported. As rankers are the ones deciding whether or not to accept or reject data self-submitted by HEIs (this decision being made using subjective judgment and not fixed criteria), a possible explanation, proposed by Chirikov [50], would be that rankers may be more likely to accept inflated scores from their "frequent clients" than from others [50].

Size bias As we have seen in Section 2, the ARWU only take into account the size of institutions in one indicator, accounting for only 10% of the total score. This means that large HEIs gain an unfair advantage over smaller HEIs. It has been demonstrated that around one third of the ARWU's variance was explainable by the size of HEIs alone [51].

Conclusion As university rankings become more and more important in the HE landscape, biases, by skewing results, can have important consequences. From reputational biases that create a self-reinforcing cycle to linguistic and disciplinary biases, it is evident that rankings are influenced by lots of factors beyond pure academic performance. Recognizing and addressing this is crucial for ensuring that rankings offer more equitable representation of institutional excellence.

3.5 Response to the Criticism

3.5.1 The IREG and the Berlin Principles

Despite the numerous flaws and controversies associated with university rankings, efforts have been made bring awareness on these issues and to establish a more transparent and fair approach to evaluating HEI. In this regard, the International Ranking Expert Group (IREG) Observatory on Academic Ranking and Excellence was created [52].

The IREG Observatory is a non-profit association that was created in 2009 under the joint initiative of international ranking experts and the UNESCO European Centre for Higher Education. Its executive committee is composed of staff from various European universities and ranking firms' employees (ARWU and

U-Multirank among others). It is the continuation of the IREG initiative that emerged in 2002 [52].

The IREG Observatory aims to promote good practices in rankings and enhance their credibility. For this matter, it is behind a number of initiatives among which we find inventories of rankings, which includes all HEI rankings [53]; a list of academic awards, which includes and weights international academic awards [54]; guidelines for Stakeholders, which provides recommendations for appropriate interpretations and applications of rankings and is aimed toward everyone using rankings, such as students, policymakers, HEIs or media [55]; and the IREG Ranking Seal of Approval [56].

The IREG Ranking Seal of Approval is a voluntary, fee-based certification awarded following an audit by the IREG. It serves as an endorsement and quality assurance measure for ranking organizations that adhere to established standards and good practices. The only major international ranking having this certification is the QS World University Rankings. Criteria to be met by the rankings are based on the Berlin principles [56].

The Berlin Principles on Ranking of Higher Education Institutions, formulated by the IREG during the International Conference on "Rankings and Quality Assurance in Higher Education" in 2006 [52], provide guidelines for rankings that prioritize methodological rigour, transparency and data source accuracy while taking into account the diversity of HEI missions and profiles.
There are 16 guidelines as described in the Appendix A

3.5.1.1 Critic

The Berlin Principles serve as a symbolic response to criticism and an attempt to establish scientific standards [5]. They were received with enthusiasm and praised as a great advancement in the development and evaluation of rankings. It was hoped that they would permit the construction of appropriate measures of academic performance [57].

However some are critical about them, stating that they fall short of delivering on the practices they promise, ultimately giving legitimacy to rankings without effectively addressing the underlying concerns [5]. Concerns were raised about their practical implementation and their alignment with the principles they prescribe. These critiques shed light on the potential shortcomings and contradictions within the BP framework, considering it problematic in both form and content [21].

One of the main criticisms is related to the third and fifth principle, which emphasizes the recognition of diversity among HEIs, both in mission (research, teaching or inclusivity) and context (linguistic, cultural and economic). While this principle aims to remove any bias and to promote the different missions of the HEIs, its application leads to issues [21].
The first issue arises when trying to deal with the context diversity. The IREG states that nations hold diverse perspectives and values regarding the definition of "quality" in higher education. They thus state that ranking systems should not be designed with the intention of imposing standardized comparisons that disregard these variations. A solution would be to have different weights and quality metrics depending on the region. However, that would make international rankings meaningless by preventing any relevant comparison [57].
Another solution would be to make rankings centred around a mission, like "Best research HEI" or "Best teaching HEI", or around context, like regional rankings. This, however, raises a second issue : by multiplying the number of rankings, new hierarchies and sub-hierarchies emerge within the existing ranking system, confusing the reader by having many hierarchically organized hierarchies. HEI could also specialize in a niche (e.g. educational or inclusivity niche) with the perverse effect that a specialized HEI, that would have cultivated its niche, could encounter difficulties if they want to escape it in the future [5].
Cheng and Liu [57] suggests that there exists no solutions taking into account the diversity (BP5) accurately.

Other principles also face wariness for their application in practice, as implementing some of the principles would require making rankings more complex and nuanced, which goes against the very purpose of rankings as simple, intuitive, and efficient visualization tools. For instance, the U-MultiRank, a customizable multidimensional ranking system, is cited as an example where the ranking system becomes a whole learning task rather than a straightforward assessment, rendering it costly, time intensive and inefficient [5].

Furthermore, conflicts of interest are identified between the authors of the BP and the rankings themselves, as a lot of BP executive committee members are affiliated with rankings. It raises concerns about the objectivity and independence of the principles, especially since all IREG initiatives seems to have in common the goal to legitimize ranking practices and rankers themselves [21]. This conflict is highlighted by the emphasis on conducting audits, questioning the existence of cynical motivations behind the BP [5].

It was also noted that the continuous amelioration promoted by the IREG and BP13 clashes with the desire for stability and comparability over time promoted by BP9. This contradiction is another challenge encountered when implementing the BP [21].

The assumptions underlying the BP are also scrutinized. The choice of indicator weights are left to the choice of the ranker as no theoretical foundation is required. That seems to assume that rankers can successfully assess the usefulness of criteria on behalf of the rankings users. Also, the assumption that rankings can provide meaningful comparisons and establish a fair and true methodology is deemed problematic by some [21].

Overall, the critics argue that the BP face significant challenges in terms of their applicability and effectiveness. The involvement of ranking organizations and their representatives in the development of the principles raises concerns about their authority and legitimacy [21]. The BP's value in assessing, comparing, and improving ranking practices is questioned, as they appear to fall short of addressing fundamental issues and fail to provide practical solutions that account for the complexities of the higher education landscape [57].

3.5.2 Conclusion

The establishment of the IREG and the formulation of the Berlin Principles represent concerted efforts to address the concerns surrounding rankings. While they offer a framework for more transparent and equitable rankings and are a good first step towards better ethics in rankings, their effectiveness and implementation remain a subject of debate, showing the need for continuous refinement in the ranking process.

3.6 Analysis of Rankings

3.6.1 Prediction

Due to all rankings implications and impact, several efforts were made to try and predict rankings [58]. For instance, the THE top 200 for 2019 was predicted with a good accuracy using a classifier [41].

To demonstrate the presence of a Matthew effect induced bias (see Section 3.4.3), some tried to predict the effects of past variations (declining, improving or maintaining the same position) on current ones. It was found that two effects were in opposition: compensatory and Matthew effects, mainly affecting middle and lower-ranking universities.

Firstly, an intra-ranking compensatory effect, that partially neutralizes the changes from the previous ranking, was discovered, as, both for the ARWU and the THE, changes for the current year were negatively correlated to the previous year's changes. This effect is stronger in the THE, possibly due to their methodology.
Secondly, the Matthew or reputational effect was confirmed, as a positive and significant effect can be observed for one- and two-year lags inter-ranking changes. Moreover, in the ARWU, an intra-ranking reputational effect was also observed after a one-year lag, although its effect is quite small, probably due to the simultaneous compensatory effect (which would also explain the absence of an observable Matthew effect in the THE) [46].

3.6.2 Comparison of rankings

Analysis of the top 100 rankings showed a significant correlation between them. THE and ARWU's top 100 have the highest correlation (0.75), while ARWU and QS have the lowest (0.62) [59]. There is also considerable overlap between rankings, with between 60 and 75 universities in common in 2017 [60]. Moed [60] uses this fact to argue that there is no such set as 'the' top 100 universities in terms of excellence. Especially as the methodology sometimes produces "anomalies", such as University College London, top 5 in one ranking but 26 in another, a difference that, at this point in the ranking, is far from negligible [61].

Geographical differences have also been observed, with ARWU including many universities from North America and Western countries, while THE and QS prefer Anglo-Saxon countries [60].

Comparing similar indicators showed that Alumni (ARWU) and Teaching (THE), both measuring educational excellence, were strongly correlated. It is also the case for Academic Reputation (QS) and Research (THE) [62].
In contrast, the comparison of faculty-student ratio from QS and THE shows large differences, even if they still are strongly correlated. As they measure the same thing, the most likely cause of this difference is the gaming of the system (as explained in Section) [62].
Even more disturbing, Citations (THE) and Citations per faculty (QS) are not strongly correlated (0.43). This is strange as there are only minor differences between them like self-citation policy and the field-weighting process that can be assumed to be different. However, these variations don't explain a correlation that low, and no hypothesis was found to justify it. On an individual scale, this low correlation can be observed for HEIs such as the NYU, scoring 23.4 in the QS and 96.5 in the THE [62].

3.6.3 Intra-ranking correlation and redundancy

Both for the QS and the THE, it was found that indicators based on surveys are strongly correlated, raising the question of co-influence and redundancy. Indeed, the Teaching and Research score of the THE, in which surveys weigh respectively 50% and 60%, have a correlation of 0.92. As for QS, the correlation between Academic and Employer Reputation is 0.83 [62].
Other indicators relations are linked. For instance, it was noted that highly cited institutions often have high scientific output, while the converse isn't always true. Also, a good international outlook is tied to a higher research score but a worse teaching score [41].
The correlation of these indicators suggests that an unknown factor underlies them. [63] have theorized that it could be reputation or income. This factor therefore induces redundancy. Indeed, for ARWU, the Nature and Science indicator alone explain 70% of the variance in the ranking. Such results can also be observed in the other rankings, with Teaching and Research each being able to explain 80% of THE's variance and Academic Reputation 55% of QS' variance [64].

3.6.4 Sensitivity

To test the sensitivity and robustness of the ranking frameworks, various alternatives to the basic methodology were implemented: removing one indicator at a time; changing the way weights are calculated; and modifying the method of indicator combination (additive, multiplicative, etc.). The combination of alternatives gave several ranks for each of the 88 studied HEIs and an analysis was based on the distribution of ranks [65].

Sensitivity is then defined as the span of the 90% confidence interval of ranks. An HEI whose sensitivity is higher than 22 (representing $\frac{1}{4}$ of the studied HEIs) is classified as highly sensitive. 67% of the studied HEIs are highly sensitivity for the THE and 59% for the ARWU. What those HEIs have in common is that they have neither excellent nor poor performances in most indicators but fall somewhere in between. The top-ranked HEIs are consistent as the top 5 stays in the top 10 in 90% of the cases [65].

The ranking of an HEI is classified as unreliable if its median ranking, according to different methodologies, significantly deviates from the ranking given by the base ranking. This applies to 10 HEIs for the THE and 6 for the ARWU. It can be concluded that the "reliable" HEIs, even if highly sensitive, are roughly placed, on average, in the correct position, making their ranks quite representative [65].

3.6.5 Improving rankings

An increase of popularity has been linked to rankings improvement on the long term. To improve popularity, several development strategies can be efficient: Improving humanities reputation, as it may bring even higher popularity gains than similar investment in engineering or technology; improving the HEI's web presence, as it can give the HEI prominence within the international community; or investing in world-class research capacity, as it seems to lead to a higher quality student intake [66], [67]. All these strategies are however long term and no other technique than gamification can result in short-term gains [67].

3.7 Conclusion

The landscape of higher education rankings has undeniably transformed the way institutions, policymakers, and students perceive and engage with the academic world. These rankings, while offering a semblance of clarity, are riddled with complexities, biases, and methodological challenges. The Berlin Principles, despite their noble intent, have been met with acclaim from some but lots of scepticism from others, highlighting the unstable balance between standardization and the diverse nature of higher education institutions.

In conclusion, while rankings have their share of controversies and limitations, their enduring influence in the academic world is undeniable. They are here to stay, and rather than dismissing them, it is imperative to work with them. Moving on to the next phase of this thesis, we will be looking at the creation and analysis of a national index based on these rankings.

Chapter 4

National Education Performance Index

Several initiatives were taken to assess a country's quality of education using rankings. However, they all primarily focused on the number of HEIs included in the rankings, sometimes weighting it by the position or by the number of HEI belonging to the country. Therefore, they all fail to capture the country's actual educational capacity as they do not consider the size of each HEI [68]–[70].

Our new approach aims to measure the accessibility of high-quality education for students within a country. Even if, as we have seen in Section 3.4, rankings are highly contestable, we made the choice to accept them as a form of quality assessment and will base the index out of them.

First, we will present the motivation and design process of the new index. We will then present the resulting scores and assess whether they remain consistent depending on the used ranking (THE, QS or ARWU). If the index proves itself to be robust, it would be a hint towards the index's relevance. Finally, we will analyse the results and try to find possible determinants to countries' performance.

4.1 Motivations

There are numerous motivations behind the creation of this index. We wanted a tool that enables countries to benchmark each other in terms of the overall quality of their higher education institutions. Indeed, some countries could shine in the rankings by holding the top positions of rankings but have only few students able to access these schools due to factors such as cost or rigorous admission processes. For instance, HEIs in the top 5 have an average acceptance rate of 10% [71]. This tool is thus a measure of the average educational quality received by a student in higher education. Behind this index, there is a strong commitment to measure accessibility and global quality, rather than elite HEIs. This is very different from what rankings initially measure, since the focus is on an entire country rather than a single institution. We aim to judge the education systems as a whole, as we want to promote another vision of HE than the one initially promoted by rankings.

Furthermore, a recurring critic made to rankings is that they do not capture the added value for students or transformation part of education [20], as they focus on outputs without weighing them with the inputs. They are thus subject to selection bias as one could hypothesize that top students go to well ranked schools. With this indicator, as we consider all HE students, we can state that the selection bias is negligible, thus, our index include this "added value" aspect.

Finally, we hope that this index could be of interest for policy-makers and HEIs in an effort to promote accessible, equitable and high quality higher education systems. By adopting this index and its mission, we strive to promote educational environments that enable all individuals to realize their full potential and contribute to a better future for society as a whole.

We decided to name this index **National Education Performance Index (NEPI)**.

4.2 Elaboration

Note on the used ranking For the elaboration of the index, we used the THE 2022 as a base, since this was the first ranking whose methodology we studied. We will then confirm the final index with other rankings (QS 2022 and ARWU 2021). We have chosen the latest edition for which we had complete results at the beginning of the thesis.

As stated before, the NEPI measures the global educational quality in a given country. Starting from this, we decided to first compute the ranking's score expectancy for an 18-25 year old from the country, an estimation of the age at which people are in the HE system, we name it the NEPI on young population ($NEPI_{YP}$). This would thus reflect the higher education enrolment rates as well as the quality of education obtained. This measure is the following :

$$NEPI_{YP,p} = \frac{\sum_{i \in I_p} N_i S_i}{Y_p}, \tag{4.1}$$

for a country p, with I_p the set of HEIs from a country p, N_i the number of students in a HEI i, S_i the score obtained by the HEI i in the chosen ranking, and Y_p the 18-25 population of country p[1].

The top 15 for this version of the index is shown on Table 4.1. The complete table is shown in Appendix B.1. [2]

Pos.	**Country**	**Score**
1	Australia	19.69
2	Iceland	13.37
3	Ireland	12.98
4	Denmark	12.31
5	New Zealand	12.19
6	United Kingdom	12.16
7	Canada	11.84
8	Netherlands	10.76
9	Belgium	10.68
10	Switzerland	10.66
11	Greece	10.26
12	Finland	10.07
13	Sweden	9.88
14	Italy	9.83
15	Spain	9.40

Table 4.1: Top 15 Countries in the $NEPI_{YP}$

To have a point of comparison and to detect possible problems, we made a second version of the index defined as the ranking's score expectancy for a higher education student in the country. We named it the NEPI on all students ($NEPI_{AS}$). This index is computed as follows :

[1]Note that for all this thesis, population will be defined as the citizens residing within or temporarily absent from a country, and the non-citizens who have established permanent residence in that country

[2]The countries for which the index is computed are limited to those whose data is accessible on the OECD data platform ([72]). Indeed, it was the best trusted platform containing all the needed data. However it is not a problem as we will not pursue with this version of the indicator.

$$NEPI_{AS,p} = \frac{\sum_{i \in I_p} N_i S_i}{N_p}, \tag{4.2}$$

for a country p, with I_p the set of HEIs from a country p, N_i the number of students in an HEI, N_p the total number of students in a country (whether they study in a ranked HEI or not), and S_i the score obtained by a HEI i in the chosen ranking.

The top 15 for this version of the index is shown on Table 4.2. The complete table is shown in Appendix B.1.

Pos.	**Country**	**Score**
1	Australia	42.63
2	Luxembourg	36.51
3	United Kingdom	36.38
4	New Zealand	33.62
5	Iceland	31.75
6	Sweden	30.47
7	Switzerland	29.87
8	Canada	28.59
9	Ireland	27.38
10	Slovenia	26.97
11	Belgium	25.74
12	Italy	24.18
13	Denmark	23.73
14	Finland	23.03
15	Portugal	21.45

Table 4.2: Top 15 Countries in the $NEPI_{AS}$

After analysis of both resulting tables, we found some surprising results. In particular, there are major disparities between certain countries. For example, Luxembourg goes from top 2 to top 30. This can be explained by student mobility. Indeed, 48.4% of those studying in Luxembourg come from abroad and the outbound mobility ratio (number of students studying abroad, expressed as a percentage of total HE enrolment) is of 170.7% [73].

When student mobility is high, several distorting phenomena occur. As the population is defined as "all nationals present in, or temporarily absent from a country, and aliens permanently settled in a country" [74], in- students are not taken into account in population statistics, whereas out- students are. This means that, for a country with a high level of outbound mobility, the young population parameter is inflated compared to the student one. This causes a problem as nationals who study abroad are counted as non-students, which distorts the ‘accessible education’ part of the indicator, giving the illusion that these young people do not attend any HEIs. In- students are not counted as population but are counted in the ’number of students’ statistic for the ranked HEI, giving the illusion of a higher education enrollment rate and also distorting the index.

We could cancel this effect in the $NEPI_{YP}$ by adjusting Y_p to take into account in- and out- mobility. The index could be named NEPI on young population (mobility-adjusted) ($NEPI_{YP(mob),p}$) and be computed as follows :

$$NEPI_{YP(mob),p} = \frac{\sum_{i \in I_p} N_i S_i (1 - In_i)}{Y_p(1 - Out_p)}, \tag{4.3}$$

with N_i, Y_p and S_i as defined before, In_i the percentage of inbound mobility student in an HEI i, and Out_p the percentage of the considered young population in a country p studying abroad.

This index would therefore be the average score of a student from a country p studying in their country of origin. It would thus represent the ability for a country to educate students originating from its own country but this would penalize the internationalization of HE, which is not something we want to do. We thus decided to not retain $NEPI_{YP}$ nor $NEPI_{YP(mob)}$, even if it means leaving out the enrolment rate aspect. Another solution would have been to accept countries like Luxembourg as outliers and proceed with this version. However, this index is also greatly impacted by system differences, such as the proportion of non-university HEIs (that do not produce research and, thus, cannot be ranked). This problem is common with the second version of the index as we will discuss now.

The second index also suffers from a number of shortcomings. In particular, it is highly dependent on what is considered higher education. This problem is linked to the ratio between the *total number of students attending a university included in THE* and the *total number of students reported by the OECD* (which is used for this index). In Slovenia, for example, this ratio is 97%, with only 3 universities included in the ranking and a low ratio of international students. However, it turns out that the country also has HEIs providing higher vocational education [75]. Given this, the ratio seems odd. One explanation might lie in what each country considers to be an HEI. This makes the index unfair between countries by being dependent on their definitions and reported numbers. A second problem is that this index does not take into account different HE systems. For instance, in Belgium, there are different types of HEI, which do not all do academic research [76], [77]. This also distorts the index, as non-research HEIs are excluded from the 3 studied rankings and as this index is system-blind, and could favour some countries regardless of their HE quality.

We thus develop a third index, designed to only use rankings data. This third ranking is defined as the ranking's score expectancy for a student attending a ranked HEI in the country. We named it the NEPI on ranked students ($NEPI_{RS}$). This index is computed as the weighted average of ranks :

$$NEPI_{RS,p} = \frac{\sum_{i \in I_p} N_i S_i}{\sum_{i \in I_p} N_i}, \tag{4.4}$$

for a country p, with I_p the set of HEIs from a country p, N_i the number of students in a HEI i, and S_i the score obtained by a HEI i in the chosen ranking.

The top 15 for this version of the index is shown on Table 4.3. The complete table is shown in Appendix B.1.

Limitations This index does not represent the enrolment rate and does not count the unranked HEIs. It is thus a bit less precise and less representative of what we aim to measure but has the advantage of being based solely on data provided in rankings. Moreover, a perverse effect of this index is that it prefers a non-ranked university to a university ranked at the bottom of the table. This is a real problem considering what we want to reward. However, this is only a proposal that should be refined to obtain a more representative final measure.

We choose to pursue the validation and analysis with this version of the index, which from now on we will simply call $NEPI$, sometimes denoting $NEPI(ranking)$ to specify the ranking from which the index is derived. Moreover, as this version does not depend on OECD data, we can establish the ranking for any country present in the rankings.

4.2.1 Average Score vs Rank

During the elaboration process, we also considered using the average rank instead of score, giving us the Rank NEPI on ranked students ($RNEPI_{RS}$):

$$RNEPI_{RS,p} = \frac{\sum_{i \in I_p} N_i R_i}{\sum_{i \in I_p} N_i}, \tag{4.5}$$

Pos.	Country	Score
1	Netherlands	63.84787
2	Switzerland	62.46886
3	Belgium	58.49811
4	Denmark	55.01065
5	Australia	54.9374
6	Germany	53.73558
7	Sweden	53.24286
8	Canada	52.15873
9	United States	51.03773
10	Luxembourg	50.015
11	Finland	49.32773
12	United Kingdom	48.57351
13	Norway	47.24723
14	New Zealand	46.94142
15	Austria	46.43255

Table 4.3: Top 15 Countries in the $NEPI_{RS}$

for a country p, with I_p the set of HEIs from a country p, N the number of students in an HEI (N_i), and R_i the rank of a HEI i in the chosen ranking.

The two version's top 15 are shown in Table 4.4. By comparing them, we notice that they are extremely similar. The rank correlation confirms this as its value is 0.9975 on all the ranking.[3].

The choice has thus to be made on small differences. On one side, the $RNEPI$ has a simpler interpretation. Indeed, the understanding of what an average score represents, when not familiar with ranking's methodology, can be less obvious compared to the average rank.
However, as we have seen in the state of the art, for HEIs in the middle of rankings, small difference in score has huge consequences in rank and that was identified as a problem with rankings. To avoid doing the same mistake, we will only keep the $NEPI$. Yet, we keep the clarity issue in mind so, in published list, we could translate the $NEPI$ to the rank a HEI with the same score would obtain.

[3]Note that the correlation is between the ranking position and not between the average score and the average rank, the correlation between those two is -0.969

Country	NEPI Rank	RNEPI Rank
Singapore	1	1
Hong Kong	2	3
Netherlands	3	2
Switzerland	4	4
Belgium	5	5
Denmark	6	6
Australia	7	8
Germany	8	9
Sweden	9	7
Canada	10	14

Table 4.4: Comparison between NEPI and RNEPI

4.3 Validation with other Rankings

4.3.1 Data sourcing

The data of the 3 major rankings was kindly provided by Mrs Linda Tempels of the SAMP department of UCLouvain. The raw data was composed of Excel sheets with each year's detailed results and other information (country, continent, . . .). This data was however not standardized in form, so we had to create new columns (e.g. "Overall Score", "Rank", . . .) and rename some columns to achieve similar table formats for all three rankings.

Additionally, to produce this index, we needed the student count for each HEI. This data was available for HEIs in the THE but not for other rankings. Initially, we retrieved the student count by matching HEIs between the rankings. This was done by standardizing the name of HEIs by removing capitalization, removing common particles (e.g. "the", "of", "de", "and", and words beginning with "uni", . . .), etc..

The problem with this method was that not all HEIs in the QS and the ARWU are in the THE. This meant that we had to add the student count for these universities manually, which was a long task as there were more than 400 unmatched HEIs. Moreover, doing this led to another problem as it is known that HEIs adapt the given student count according to the ranking, giving different counts to try and play with the indicators (see Section 3.3.1.1).

To rectify this, we finally decided to work differently and to only use data provided by a ranking when establishing the corresponding NEPI version. To this end, we developed a web scraping tool retrieving student count on both the QS and the ARWU websites.

We had to proceed differently for QS and ARWU. For QS, we used a CURL request to retrieve a JSON file containing the name and URL of all the HEIs. Then, for each HEI, we went to the corresponding web page and retrieved the data on the number of students in the page's source code.
For ARWU, we created a bot that automatically opened the web page containing HEIs' details to store their URLs and names. We then proceeded as we did for QS to retrieve the counts.
The resulting data was stored in a text file, which was then used in the Python code used to create the tables.

We then linked the HEIs between the scraped data and the rankings data to obtain one single table by ranking. However, the ARWU website did not provide data on student counts for 131 of the 1000 HEIs on their site. To fill these missing data, we used several techniques: retrieving data from the other rankings, a second web scraping tool that used the Google Featured Snippet result, and manual searches when the other techniques did not work. Some errors, mainly due to time-outs, also occurred during the scrape. We resolved those by manually searching the data on the rankings' websites.

4.3.2 Results

The top 10 of the NEPI on the three major rankings is shown on Table 4.5. The *Rank Eq.* column is the rank a HEI with the same score as the country would get. The complete results with the exact score for each country are shown in Appendix B.1.

As we can see by comparing the top 10 rankings, the NEPI appears to be quite consistent between the different base rankings, especially among the top positions. This consistency is further supported by examining the rank correlations, as shown in Table 4.6.

	THE	QS	ARWU
THE	1	0.9429	0.8857
QS		1	0.9429
ARWU			1

Table 4.6: Rank correlations of the NEPI derived from the 3 major rankings

	THE	
Position	**Country**	**Rank Eq.**
1	Singapore	29
2	Hong Kong	74
3	Netherlands	85
4	Switzerland	98
5	Belgium	137
6	Denmark	183
7	Australia	184
8	Germany	206
9	Sweden	213
10	Canada	222

	QS	
Position	**Country**	**Rank Eq.**
1	Singapore	30
2	Hong Kong	59
3	Switzerland	98
4	Netherlands	137
5	Sweden	148
6	Denmark	157
7	Belgium	174
8	Australia	178
9	New Zealand	207
10	Canada	221

	ARWU	
Position	**Country**	**Rank Eq.**
1	Switzerland	82
2	Singapore	82
3	Netherlands	116
4	Denmark	121
5	Belgium	148
6	United States	167
7	Norway	177
8	Canada	190
9	Australia	196
10	United Kingdom	203

Table 4.5: Top 10 NEPI for each ranking with Rank equivalent

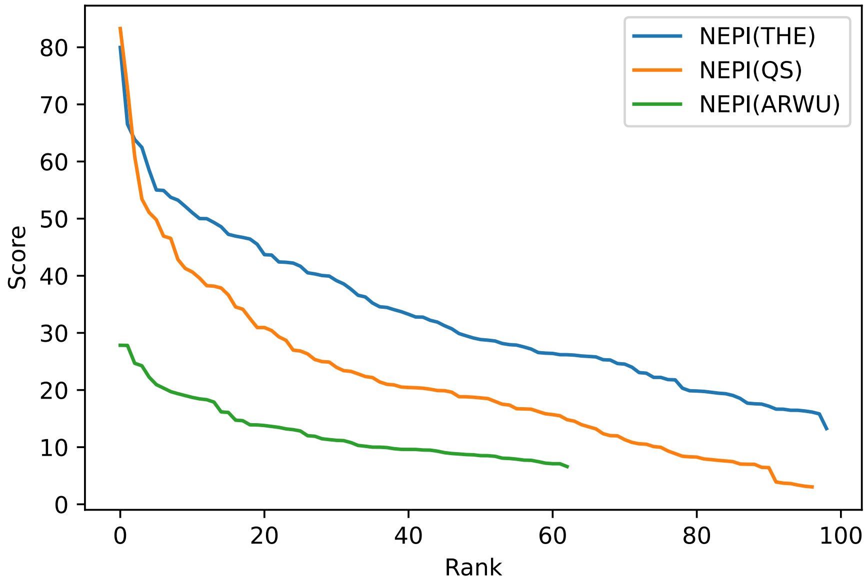


Figure 4.1: Score distribution among NEPI versions before any standardization

The strong positive correlations indicate that institutions performing well according to one ranking system tend to achieve similar results in the NEPI derived from other systems. This tends to prove the robustness and validity of our index as an effective measure of countrywide academic excellence, making it a valuable resource for evaluating and bench-marking performance in the global academic landscape.

However, due to the fact each ranking standardize their data differently, even if very correlated in rank, the resulting tables are different in score. The respective distributions of the NEPI scores are represented on Figure 4.1. This makes comparison between rankings difficult without a standardization step. Despite this, we do not standardize the NEPI here as it would limit the analysis, make the results less representative of each ranking, and prevent us of giving the Rank Equivalent intuition.

4.4 Analysis

4.4.1 Regional analysis

To see how some countries can be favoured by one ranking or another, we applied the following methodology:

First, we only consider countries that are represented in all 3 rankings:
Let $R := \{THE, QS, ARWU\}$ the set of all rankings, C the set of countries common to all three NEPI rankings, and $NEPI_{r,c}$ with $r \in R$ and $c \in C$ the score of country c in $NEPI(r)$.

Then, we define the normalized NEPI ($NNEPI$) to obtain comparable data as the NEPI, as seen previously, has different distribution depending on the base ranking :

$$NNEPI_{r,c} := \frac{NEPI_{r,c} - \sum_{c' \in C} NEPI_{r,c'}}{S_r}, \tag{4.6}$$

with S_r the sample standard deviation in $NEPI(r)$.
Finally, we derive, for each country, a deviation measure of the NNEPI ($\delta_y NNEPI_i$) based on a ranking r compared to the mean of the NNEPI of all rankings:

$$\delta_r NNEPI_c = NNEPI_{r,c} - \sum_{r' \in R} NNEPI_{r',c} \tag{4.7}$$

$\delta_r NNEPI_c$ can be interpreted as the divergence of a country's performance in a particular ranking from its overall performance in all rankings. This measure summarises this degree of divergence while simultaneously taking into account the distribution of several ranking systems. Positive values indicate that the country is favored in the specific ranking, while negative values suggest the opposite. The absolute value of this measure expresses the extent to which this advantage is marked. Although this measure is theoretically not bounded, we observe that, in practice, it is comprised between -1 and 1.

We then plotted the results on a map. The colour of each country represents which ranking favours it the most. The intensity of the colour represents at which point it is favoured.

The resulting plot is shown on Figure 4.2. Regarding the first step, we thought about not removing such countries as to show when regions are ignored but as the size of the rankings is not be the same, it would affect the normalization step. On Figure 4.3 is a side-by-side comparison of the data distribution after normalization when removing countries or not. We see that the ARWU distribution declines faster than the other two as it comprises far fewer countries.

However, as NEPI(ARWU) contains nearly two times fewer countries as THE and QS, we plotted a second graph (Figure 4.4) that compares only THE and QS (by ignoring ARWU in computations) and, as they are similar in size, we do not need to drop countries non-ranked in one of the rankings to obtain similar distributions.

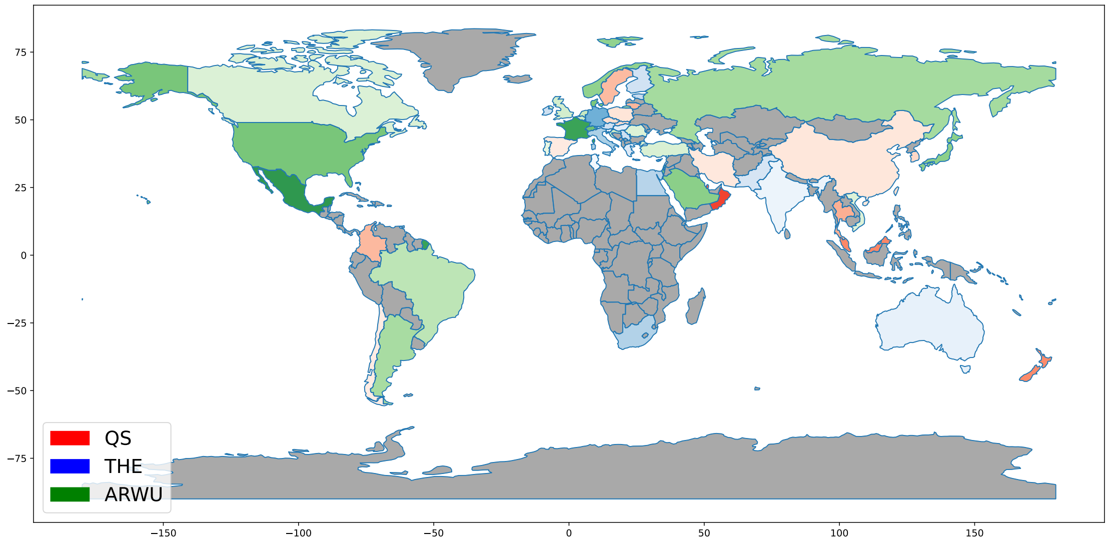


Figure 4.2: Ranking advantage per country. Each country's color represent by which ranking it is favoured, the intensity of the color shows the strength of that advantage

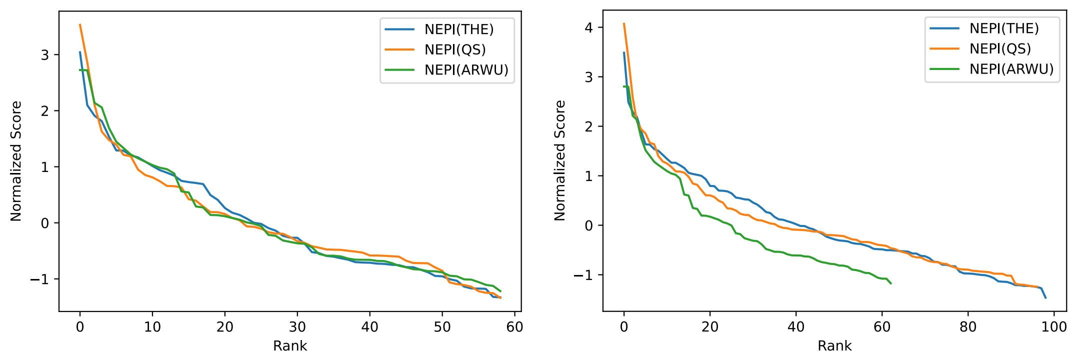


Figure 4.3: Comparison of the distribution of the normalized NEPI scores when non-common countries are removed (left) and when they are not (right).

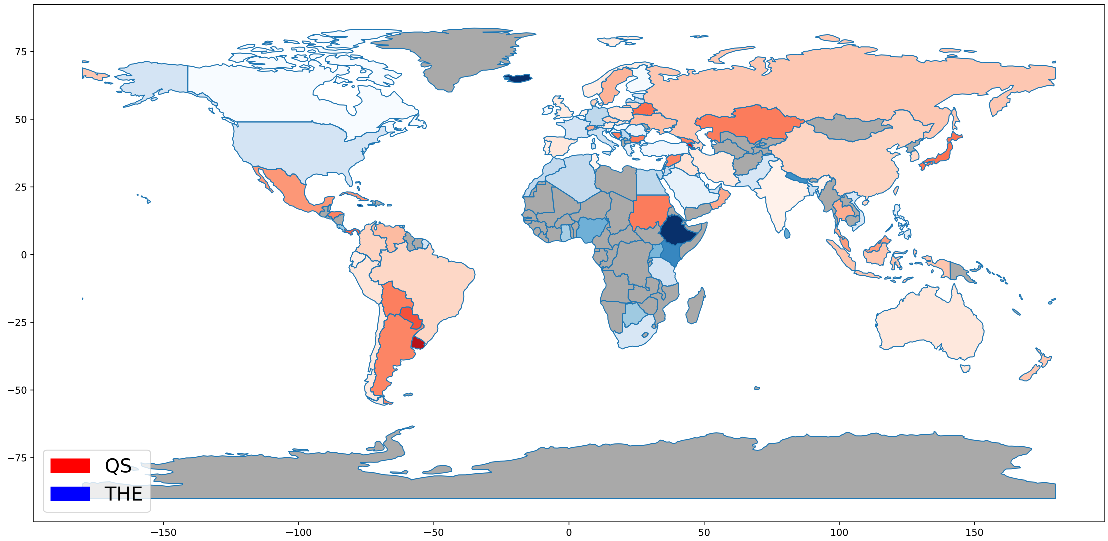


Figure 4.4: Ranking advantage per country (ignoring ARWU in the computation). Each country's color represent by which ranking it is favoured, the intensity of the color shows the strength of that advantage

We thus consider null values as a zero score.

Focusing first on regions, we notice regional similarities. First, the majority of countries from North and South America are favoured by ARWU. Furthermore, this favouritism is substantial for Mexico and the USA that are respectively first and fourth most favoured countries by ARWU. When not taking into account ARWU, we notice that the English-speaking countries of America (i.e. Canada and the USA) are favoured by the THE while South American countries and Mexico tend to be neutral or QS-favoured.

Second, we notice on both graphs that Africa is largely favoured by THE or at least neutral.

Concerning Europe, we notice that France is extremely favoured by the ARWU. This could be explained by France's major merger campaigns, particularly effective on size-insensitive rankings such as ARWU. We also notice Germany, which is the second most THE-favoured country. For the rest of Europe, while no pattern can be found when taking ARWU into account, we find that western Europe seems THE-favoured while eastern Europe and the Iberian Peninsula are more QS-favoured.

Asia and Oceania do not seem exhibit particular patterns. However, when excluding ARWU, it becomes clear that it is QS favoured. We could conclude that Asia is disadvantaged in the THE.

This visualization allows us to analyze the possible existence of certain bias mentioned in Section 3.4.3. It was mentioned that countries with old-established academia could rely on their Nobel prizes to secure better rank in the ARWU. It is verified as 7 of the top 10 countries in terms of Nobel laureates are advantaged by ARWU [78]. This shows that there is a certain bias linked to the Nobel indicator of ARWU.

We also observe that emerging countries, in Asia, Africa, and Eastern Europe, are rarely ARWU-favoured. We can thus emit the hypothesis that the past reputation bias particularly affects the ARWU.

Another mentioned bias was that English-speaking countries were favoured. Thanks to our visualization, we can assess whether one ranking seems more sensitive to this bias. There are six English-speaking countries common to all 3 rankings (Australia, Canada, Ireland, New Zealand, United Kingdom, and USA) and one only common to QS and THE (Malta). Out of these, three are ARWU-favoured, three THE-favoured and one QS-favoured. These observations are a bit too slim to show that one of the rankings is more prone to that bias. We could, with lots of caution, emit the hypothesis that QS is less sensitive to that bias but proving it would require further research. Another conclusion we could make is that either this bias affects THE or ARWU equivalently, either it is not strong enough to determine alone by which ranking the country is favoured.

4.4.2 Belgium's case

Let us now focus on Belgium. The rankings suggest a certain level of academic excellence, as reflected by its NEPI score across all three leading ranking systems. Belgium is positioned fifth in the THE rankings, seventh in the QS, and once again, fifth in the ARWU. For illustrative purposes, if an HEI scored the same as Belgium, its global rank would fluctuate between 174 and 137. These results seem to position Belgium as a top nation with respect to global higher education quality.

Upon examination, there are three countries that consistently outperform Belgium across all rankings: Singapore, Switzerland, and the Netherlands. Conversely, there are other nations, namely Hong Kong, Denmark, and Sweden, that oscillate in position, sometimes appearing above Belgium and at other times below.

Community	THE	QS	ARWU
Flemish	64	54.1	24.2
French	50.3	36.7	19.3

Table 4.7: French and Flemish Community NEPI

Community	THE	QS	ARWU
Flemish	3^{rd}	4^{th}	5^{th}
French	16^{th}	16^{th}	10^{th}

Table 4.8: Potential position of French and Flemish Community in the NEPI tables

From a continental perspective, within Europe, Belgium is prominently placed. It secures a position within the top three nations when evaluated on the basis of THE and QS metrics (and within the top five when assessed via the ARWU-based NEPI).

4.4.2.1 Differences between linguistic communities

In Belgium, universities' funding is primarily given by two entities : the Flemish Community and the French Community. They finance respectively Flemish- and French-speaking HEIs.
Those two entities do not operate the same way. To compare the two systems and assess the consequences of their differences, we assess the NEPI computed on the HEIs of each Community. The results are shown on Table 4.7.

The position they would be in the global NEPI if we considered them as separate countries and excluded Belgium are shown on Table 4.8.
We note that the score for the Flemish Community is significantly better than that of the French Community, pulling the Belgian score upwards. This is made possible by the fact that 60% of students attending a HEI included in the rankings are at a Flemish university. Remarkably, the Flemish community would be the first European 'country' in the NEPI(THE).

One possible explanation for these differences may be disparities in expenditures: the Flemish Community expenses per HE student are 22% higher than those of the French Community [79] and, as we will see in Section 4.5.3.1, expenditures per student plays a key role in the quality of the offered higher education. Nevertheless, expenses are only one possible explanation, and other explanations could perhaps be found in the operating modes, the socio-economic difference between the two Communities or the academic culture. Those are only hypotheses and additional research should be made to identify the causes of this difference in quality.

4.4.3 European Union ranking

The state of HE quality in European Union varies greatly. Indeed, the spread between the top EU country and the worst is huge for NEPI whatever the base ranking. The worst ranked EU country in the NEPI(THE) (resp. NEPI(QS) and NEPI(ARWU)) is Bulgaria (resp. Romania and Slovakia), which is ranked 95th out of 99 (resp. 89th out of 97 and 60th out of 63). On the other hand, the Netherlands consistently emerges as the top-performing EU country in all three ranking systems, securing third place in both NEPI(THE) and NEPI(ARWU), and fourth in NEPI(QS).
If we considered the European Union (EU) as a country, we would obtain the following results :

Ranking	Score	Rank
THE	38.7	32
QS	27.9	25
ARWU	15.1	17

With the large range of ranks of EU countries, we could expect an average score for the EU as a whole, but surprisingly, the EU consistently places in the top third of each ranking. This score underscores the collective strength and quality of higher education within the European Union, despite the disparities among individual member states. It suggests that while there may be variations in individual country performances, the overall standard of higher education in the EU is quite good.

4.4.4 Elitism vs global quality

An interesting feat to note is the the dichotomy between top-ranked universities and top-ranked countries. In fact, only 16 universities in THE's top 50 and 14 in QS's top 50 come from an NEPI top 10 country.[4].

This dichotomy may have its origins in the way each country operates its higher education system and what its priorities are. Some countries could, for instance, choose a strategy of concentrating the highest talents in a limited number of large, strong institutions. Based on these results, it seems possible to hypothesize that this concentration could lead to a lower overall level. However, as our study is limited to exploring the different aspects and not going into detail, further research

[4]The NEPI taken into account being the ranking-corresponding version

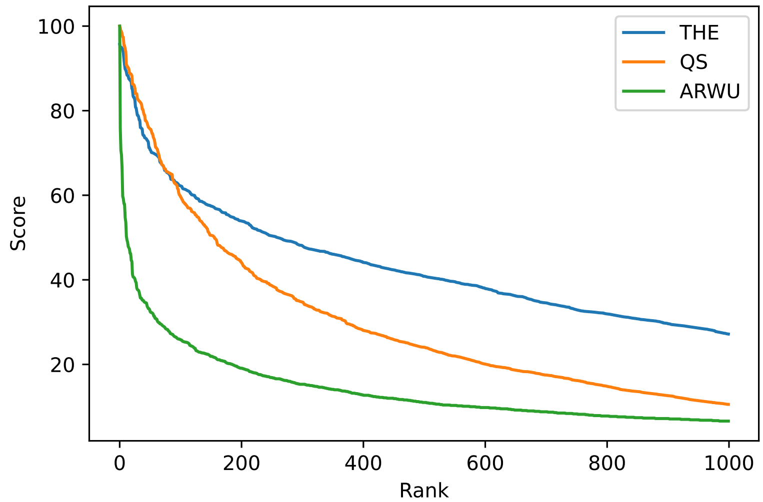


Figure 4.5: Comparison of the Top 1000 score distribution in each ranking

would be needed to prove this.

In the ARWU, the number of top 50 HEI that comes from a top 10 country is much higher, largely due to the presence of the USA and UK in the NEPI(ARWU) top 10. This difference can be explained by the fact that it uses indicators, such as Nobels or Highly Cited Researchers, favouring elite universities, and that its normalization system express the score of an HEI as a percentage of the score of the best university, which creates a big difference in score between the top universities and the rest (see Figure 4.5). So, when the weighted average of scores is used to calculate the NEPI score, the elite universities have much more weight in ARWU than in the other rankings, which have a smoother distribution.

4.5 Multiregression with countries indicators

Having all these data on national educational quality, it would be interesting to search correlations and causes with the countries' attributes. In this section, we will thus select relevant indicators, hypothesize their impacts, and explore relations through Ordinary Least Square (OLS) Regression, aiming to identify key factors contributing to educational outcomes across countries.

4.5.1 Feature selection

We selected various indicators to be our independent variables, based on some hypothesis about their possible impact on the NEPI. All the data comes from the World Bank open databases [80] :

1. **Graduation rate**, the "number of graduates from first degree tertiary programmes expressed as a percentage of the population of the theoretical graduation age of the most common first degree programme" [81]. Indeed, it reflects the country's HEIs efficiency to educate and retain their students, which could indicate better academic support and educational quality.

2. **Enroll[ment] rate**, the "total enrolment in tertiary education regardless of age expressed as a percentage of the population in the 5-year age group immediately following upper secondary education" [82]. A higher enrolment rate indicates better access to higher education, which can lead to a larger pool of talented students and researchers.

3. **Funding per student**, the total initial funding from government for tertiary education per student, expressed in PPP [83]. Funding allows universities to invest to improve teaching and research quality.

4. **Edu[cational] Exp[enditures]**, the Government expenditure on tertiary education per resident. It can be a proof of the government's commitment to the higher education sector.

5. **HCI**, a score taking into account the expected education and health of children born today [84]. It reflects countries' ability to develop human capital, leading to a well-educated and skilled citizens.

6. **Private**, the total number of tertiary students enrolled in private institutions, expressed as a percentage of total number of tertiary students [85]. We selected this indicator to see how the strong presence of private HEIs, that can have more resources, impacts the HE sector.

7. **Inbound**, the "number of students from abroad studying in a given country, expressed as a percentage of total tertiary enrolment in that country" [86]. A country's capacity to attract international students could be proof of a quality HE sector. Furthermore, it is part of THE's and QS's methodology.

8. **Outbound**, the "number of students from a given country studying abroad, expressed as a percentage of total tertiary enrolment in that country" [87]. A high outbound mobility, ceteris paribus, could be a sign of student exodus due to poor quality of education.

9. **PISA mean**, the mean of the PISA scores (an index evaluating the knowledge of 15-year-old students) in reading, science and maths [88]. We selected this indicator to see if a good lower secondary education is linked with quality HE.

10. **Gini**, an index measuring income inequality on a scale from 0 (perfect inequality) to 100 (perfect equality). There may exist a relation between less income inequality and better access to education and overall educational quality.

11. **LPop**, the logarithm of the population. We noticed that some of the top-ranked countries had relatively small population. Thus we wanted to explore this relation.

12. **R&D Exp[enditures] (per capita)**, the Government expenditure on tertiary education per resident. It can be a proof of the government's commitment to the research sector.

13. **Patents per capita**, the number of patent applications filed by the country's residents divided by the population [89]. This indicates the average productivity of researchers in the country.

14. **# R&D Researchers**, the "number of researchers engaged in Research and Development, expressed as per million" [90]. More researchers can lead to increased research output.

15. **GDP (per capita, ppp)**, the Gross Domestic Product per capita and adjusted to purchasing power parity (ppp). One could hypothesize that rich countries tend to perform better. This seems to be corroborated by the top 10 which is only composed of 'rich' countries.

16. **GDP (per capita)**, the Gross Domestic Product per capita.

We selected indicators with potential correlations, such as GDP (PPP) and GDP, to determine which of these factors best explain the variance and has the most significant influence on educational quality. However, this led to multicollinearity problems, making it challenging to isolate their individual effects on educational quality.

To address multicollinearity, it was first tried to resort to the use of techniques such as Ridge Regression, which can help stabilize coefficient estimates but makes it difficult to interpret each coefficient, which is precisely what we aimed to do.

We instead decided to perform feature selection. The goal is to keep the variables in which we were particularly interested, all while assuring ourselves to keep a reasonable quantity of collinearity. To quantify this, we used the Variance Inflation Factor (VIF), a statistical measure that quantifies the existing correlation between a predictor variable and the other predictor variables in the regression model.

The VIF for a particular predictor variable X_j is calculated as follows:

$$VIF(X_j) = \frac{1}{1 - R^2(X_j|X_{-j})} \tag{4.8}$$

with $R^2(X_j|X_{-j})$ the coefficient of determination when X_j is regressed on all other predictor variables X_{-j}.

The VIF is the proportion of variance in X_j that can be explained by the other predictor variables. We thus want to have variables with the lowest VIF possible. In general, VIF under 10 are acceptable [91].

We noticed that NEPI(ARWU) was the most difficult to choose low-VIF features for, which can be explained by the lower number of countries ranked in this version of the index. We managed to keep 7 variables out of 16 while having a maximum VIF of 9.9, associated with the Funding per student. The complete set of retained variables and their associated VIF (for ARWU) is shown on Table 4.9

Feature	**VIF**
Funding per student	9.9
Private	1.7
Inbound	3.4
Outbound	1.9
R&D Exp (per capita)	4.3
Patents per capita	1
GDP (per capita, ppp)	8.2

Table 4.9: Features kept for the regression and their VIF

4.5.2 Results

The features that we previously selected using VIF were employed to conduct an Ordinary Least Squares (OLS) regression for each of the different versions of the

NEPI[5]. The OLS regression aims to identify the significant predictors contributing to the variations in these indices. The complete results of these regression analyses are presented in Appendix C.1.

4.5.3 Analysis

Let us now analyse those results. First, we will dwell into each independent variable to see if they are significant and how we can interpret the coefficient. Then, we will analyse the quality of the regression as a whole.

4.5.3.1 Indicators analysis

A summary of each significant variable is shown on Table 4.10. We observe that on the 7 variables, 2 are not significant regardless of the base ranking : the *private* and *patents per capita* variables.

Feature	THE	QS	ARWU
Funding per student	$8e{-}4^{\ddagger}$	$1e{-}3^{\ddagger}$	$3e{-}4^{\ddagger}$
Private	–	–	–
Inbound	$3.7e{-}1^{\ddagger}$	–	–
Outbound	$-1.9e{-}1^{\ddagger}$	–	$-9.6e{-}2^{\dagger}$
R&D Exp (per capita)	$6e{-}3^{\ddagger}$	$4.3e{-}3^{\dagger}$	$3.2e{-}3^{\ddagger}$
Patents per res	–	–	–
GDP (per capita, ppp)	–	$1e{-}4^{\dagger}$	–

$^{\ddagger}p < 0.01$, $^{\dagger}p < 0.1$

Table 4.10: Summary of variables coefficient and significance

This means that the proportion of private HEIs does not have any effects on any version of the NEPI, which would suggest that public and private HEIs are of equal quality, or, at least, that having more private institutions does not improve the country's score. To investigate this lack of significance, we look at the regression of *Private* on *NEPI (THE)* (Figure 4.6c) and observe absolutely no relation. Transforming the *Private* variable (e.g. using a log-transform) would, in principle, not change anything as the values are already well distributed.

[5]As the values of some indicators were not available for some country, we imputed values by setting it on the median, explaining the vertical alignment of points on some of the following graphs

To try explaining the *patents per researcher* non significance, we look at the regression of this variable alone (Figure 4.6a). We observe, despite the significant regression line, a concentration of the values between 0 and 0.1×10^{-3}, which could worsen the results. This could make us think to use the logarithm function on the indicator. When doing this, we get a regression that is more significant (Figure 4.6b), but, once controlled by the other variables, becomes non-significant, exactly as the non-logarithm version. This means that the relation between the NEPI and the *Patents per capita* is solely due to the existing correlation between these variables and significant variables.

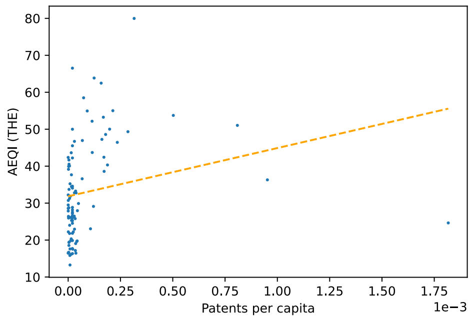
We have 2 independent variables that are significant regardless of the base ranking: the *Funding per student* and the *R&D Expenditures per capita*. We can interpret their coefficient as follows :

- to gain 1 point on the NEPI (THE) (resp. QS and ARWU), one should increase their funding by students by about 1,250$ (resp. 1,000$ and 3,333$) while keeping all other independent variables the same. The standard deviation of *Funding per students* being of 7102 in the sample, this means that being one standard deviation above the mean adds about 5.7 (resp. 7.1 and 2.1) points for an HEI with all other indicators at the mean, which is quite significant.
- to gain 1 point on the NEPI (THE) (resp. QS and ARWU), one should increase their R&D Expenditures per capita by about 167$ (resp. 233$ and 312$) while keeping all other independent variables the same. For a country like Belgium, gaining 1 point would necessitate an increase of between 10 and 20%, which is consequent for a change that would not be sufficient to positively affect its placement. The standard deviation of *R&D Expenditures per capita* being of 698.4 in the sample, meaning that being one standard deviation above the mean adds about 4.17 (resp. 3 and 2.2) points for an HEI with all other indicators at the mean.

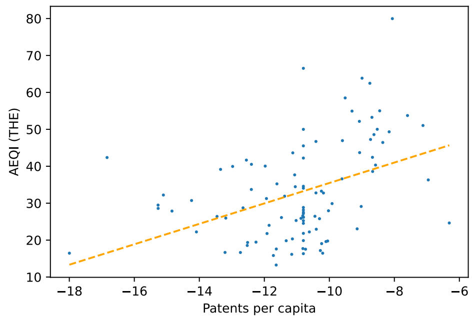
For both these variables, the profile of the data (see Figure 4.6d and 4.6e) could make us think of using a logarithm function. However doing this makes the coefficient less significant so we decided to keep values the way they were.

Both of these significant results' interpretation demonstrate the same intuitive fact: putting more money in research and teaching improves the HEIs quality.

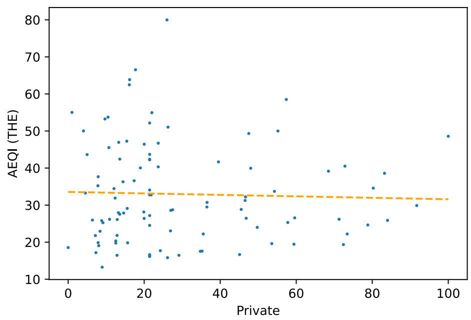
We also notice that, even if these variables are significant, the policies that could be implemented (i.e. increasing the funding and R&D expenses) are expensive. For instance, based on this model, Belgium should increase their Funding by 30.7% or



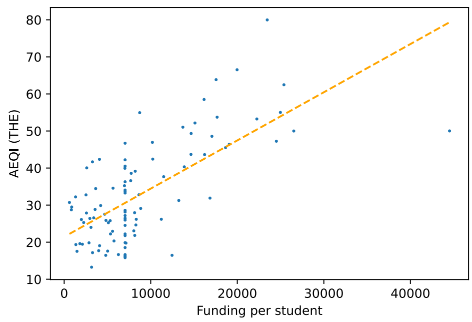
(a) Regression of Patents per capita on NEPI (THE)



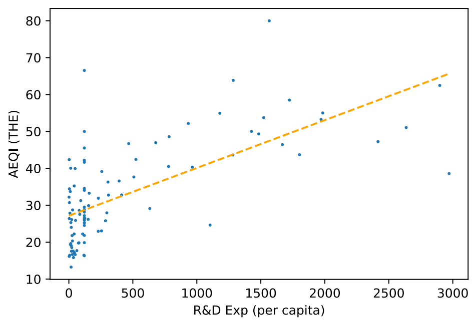
(b) Regression of NEPI (THE) on log(Patents per capita)



(c) Regression of NEPI (THE) on Private



(d) Regression of NEPI (THE) on Funding per students



(e) Regression of NEPI (THE) on R&D Expenditures per capita

Figure 4.6: Regression of NEPI (THE) on various indicators

their R&D expenses by 38.5% to overtake Switzerland in the *NEPI (THE)*.

Finally, we have 3 independent variables that are sometimes significant depending of the base ranking : *Inbound*, *Outbound*, and the *GDP (per capita, ppp)*.

When regressing only the *Inbound* or the *GDP (per capita, ppp)* parameters on NEPI, the obtained coefficients are always significant regardless of the ranking. The fact that they are significant alone but not with the other variables can be explained by the influence of other variables in the OLS that may have overlapping stronger associations with the NEPI than the inbound mobility and the GDP (per capita, ppp). For the GDP, we can interpret this by the fact that what matters the most is not the GDP itself but how the state's money is distributed (cf Funding and R&D).

On the contrary, we observe the opposite for *Outbound*. Indeed, when regressing it alone, we get no significant coefficients. This suggests that the variable's impact on the dependent variable is conditional and influenced by the effect of the other variables in the model. For instance, *Outbound* is positively correlated to *GDP* (meaning that countries were people go to study abroad are often rich countries), which, in turn, is positively correlated with NEPI. As we have seen in the OLS, *Outbound* has a negative coefficient but, when doing a simple regression, this negative effect is compensated by the positive effect associated with *GDP*, making the coefficient non significant. Once purged of the GDP effect, the negative significant coefficient appears.

Concerning the coefficients of these parameters, the following table shows the effects of being one deviation ahead of the mean :

Feature	THE	QS	ARWU
Inbound	3.42	–	–
Outbound	-3.27	–	-1.657
GDP (per capita, ppp)	–	2.65	–

Regression on the population The addition of the population variable to the previous regression was impossible, as it resulted in too high a VIF value. However, it was of great interest to us, since it seems that the best-ranked countries are small Western European countries (Switzerland, Netherlands, Denmark and Belgium). We therefore ran a second regression, regressing *LPop* on our index while controlling for the variables that were most significant previously, i.e. *Funding* *per student* and *R&D Exp (per capita)*. The results (shown in Appendix C.2) are surprising: *LPop* is significant only for ARWU, with a positive coefficient of 0.6. This seems to be in line with the size bias discussed in Section 3.4.3, a bigger country possibly having larger HEIs. This coefficient can be interpreted as follows: ceteris paribus, increasing the population by one percent lead to a gain of 0.6 points in NEPI(ARWU). However, since we find no significant relation for the other two rankings, it doesn't seem that a small size is advantageous for the whole ranking. However, it is possible that this relation exists but is non-linear depending on the NEPI, or that the hypothesized link between small size and score is captured by one of the other two variables.

Limitations and Conclusion However, due to the presence of multicollinearity, even if the variables were deemed acceptable based on VIF analysis, the significance results in the multiple regression should be interpreted with caution as they serve as indicative rather than perfect answers. The VIF analysis helped us select relevant features and address multicollinearity concerns to some extent. Moreover, regressions are very sensitive, meaning that the results can drastically change depending of the addition or removal of a variable. In addition, the complexity of real-world data and interactions among predictors can introduce uncertainties in the significance of individual coefficients. Despite these limitations, we now have a good vision of potential influence of the selected indicators on the NEPI and a better understanding of the complex relations between various factors affecting educational quality across countries.

4.5.3.2 Quality of the regression

After having assessed the individual contributions and significance of each regressor, we will now evaluate the overall quality of the regression. To achieve this, we will examine several key statistics: the coefficient of determination (R-squared), adjusted R-squared, and the F-statistic, which can help us gauge the model's goodness of fit and its ability to explain the variance in the NEPI.

R-squared and Adjusted R-squared The adjusted R-squared gives a sense of the proportion of the variance for NEPI that is explained by the chosen independent variables, like the R-squared, but also taking into account the number of predictors in the model. This measure thus prevents us from wrongfully analysing the R-squared of an overfitted model. It is computed as follows :

$$\bar{R}^2 = 1 - \frac{(1 - R^2)(n-1)}{n-p-1}, \tag{4.9}$$

with $R^2 = 1 - \frac{SS_{res}}{SS_{tot}}$ the classical R-squared, p the number of independent variables, and n the number of observations.

The model explained between 62.5 and 71.8% of the variation in NEPI, depending on the base ranking, as indicated by the R-squared value. However, after adjusting for the number of predictors, the adjusted R-squared value was between 0.592 and 0.679. The decrease between R^2 and $\bar{R}^2$ suggests that some of the predictors might not be relevant. This is consistent with what was discussed previously about the significance of each variable.

These values are remarkably high given the complex and varied nature of HE quality. They indicate that the selected predictor variables capture a considerable portion of the variation in the respective NEPI scores, implying that, although not exhaustive, the significant selected features play a key role in explaining differences in HE quality as measured by the different ranking systems.

F-statistic The F-statistic tests the null hypothesis that all the regression coefficients are equal to zero, suggesting that the model has no explanatory power. A low probability value for the F-statistic indicates that the regression model as a whole is statistically significant and provides a meaningful fit to the data.

In our case, the F-statistic probability takes values between 5.23×10^{-12} and 3.7×10^{-17}, which is essentially zero. This small p-value indicates strong evidence against the null hypothesis, affirming that the NEPI regression models are highly significant and provides a better fit to the data than a constant model.
This suggests that the selected predictor variables collectively contribute significantly to explaining the variations in the respective NEPI scores and validates the use of the selected features as good predictors to assess the HE quality.

Chapter 5

Conclusion

In conclusion, this thesis has thoroughly looked at university rankings to understand their methodologies, significance, and possible effects. These rankings, while being useful tools for various stakeholders in the higher education sector, have faced scrutiny from academics for their legitimacy and methodologies. We have embarked on a journey to dissect and understand the methodologies behind three major university rankings, and we've reviewed existing literature, highlighting the aspects that have been extensively studied.

We first had to obtain was a deep understanding of the methodologies employed by major university rankings. We then investigated why rankings are so important, by studying the causes of their popularity and their impact. Despite this popularity, we identified numerous shortcomings in rankings, like relying on a single score and not fitting well with the different types of universities they try to assess.

Certain problems stood out from literature. These included various biases, overlapping indicators that lead to a reduction in the measure's complexity and dimensionality compared to what is claimed, and contradictions among similar indicators across different rankings, particularly in citation metrics.

The creation, testing, and analysis of the NEPI, our new proposed index for measuring national-level higher education quality, formed the cornerstone of this thesis. Our index's robustness, validated across various rankings, allowed us to interpret the results. We analyzed Belgium's performance, finding that it did particularly well overall and noticing some important differences between the language communities, which we tried to explain. Additionally, we looked at higher education in the European Union and found that the quality varies a lot among member countries, even though the overall standing reflects a good overall quality, as the EU would in the top 35% if considered as a country.

When we looked at the factors determining a country's educational quality, we found out that the expenditures on research and development, as well as the funding per student, played the most significant roles. This finding showed the crucial role of financial investment in establishing a high quality education system, and, even if this result is intuitive and quite trivial, this information can help to show countries the way to improve their higher education system. This also allowed us to come up with a model explaining around seventy percent of the quality of a country's higher education

Looking at rankings on a country level also helped us confirm some regional, reputational, or language-based biases that are mentioned in existing literature. For instance, it was measured that the ARWU seemed to favor North American countries.

While acknowledging the limitations of our index and the need for further research, we firmly believe that our novel approach has significant potential, offering a valuable contribution worthy of consideration in future studies.

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Appendix A

Berlin Principles on Ranking of Higher Education Institutions

Purposes and Goals of Rankings The complete list of Berlin principle is as follow [52]:

1. Be one of a number of diverse approaches to the assessment of higher education inputs, processes, and outputs.

2. Be clear about their purpose and their target groups

3. Recognize the diversity of institutions and take the different missions and goals of institutions into account.

4. Provide clarity about the range of information sources for rankings and the messages each source generates.

5. Specify the linguistic, cultural, economic, and historical contexts of the educational systems being ranked.

Design and Weighting of Indicators

6. Be transparent regarding the methodology used for creating the rankings.

7. Choose indicators according to their relevance and validity.

8. Measure outcomes in preference to inputs whenever possible.

9. Make the weights assigned to different indicators (if used) prominent and limit changes to them.

Collection and Processing of Data

10. Pay due attention to ethical standards and the good practice recommendations articulated in these Principles.

11. Use audited and verifiable data whenever possible.

12. Include data that are collected with proper procedures for scientific data collection.

13. Apply measures of quality assurance to ranking processes themselves.

14. Apply organizational measures that enhance the credibility of rankings.

Presentation of Ranking Results

15. Provide consumers with a clear understanding of all of the factors used to develop a ranking, and offer them a choice in how rankings are displayed.

16. Be compiled in a way that eliminates or reduces errors in original data, and be organized and published in a way that errors and faults can be corrected.

Appendix B

Tables

B.1 NEPI Elaboration

See Table B.1

Table B.1: Complete table for all versions of $NEPI$

	Score			Position		
Country	$NEPI_{YP}$	$NEPI_{AS}$	$NEPI_{RS}$	$NEPI_{YP}$	$NEPI_{AS}$	$NEPI_{RS}$
Australia	19.70	42.63	54.94	1	1	5
Austria	6.04	12.09	46.43	22	28	15
Belgium	10.68	25.74	58.50	9	11	3
Brazil	1.36	3.87	22.21	35	36	34
Canada	11.84	28.59	52.16	7	8	8
Chile	4.31	8.30	25.88	29	31	30
Colombia	0.78	2.23	24.00	37	37	32
Czech Republic	6.14	20.61	26.18	21	18	29
Denmark	12.31	23.73	55.01	4	13	4
Estonia	5.93	21.11	37.66	24	17	21
Finland	10.07	23.04	49.33	12	14	11
France	7.43	17.28	40.32	20	23	19
Germany	7.69	19.50	53.74	19	22	6
Greece	10.27	12.13	32.76	11	27	25
Hungary	4.85	20.06	27.95	26	20	28
Iceland	13.37	31.75	43.69	2	5	16
Ireland	12.98	27.38	43.63	3	9	17
Israel	5.04	13.20	38.59	25	26	20
Continued on next page						

Table B.1 Continued from previous page

	Score			Position		
Country	$NEPI_{YP}$	$NEPI_{AS}$	$NEPI_{RS}$	$NEPI_{YP}$	$NEPI_{AS}$	$NEPI_{RS}$
Italy	9.83	24.18	42.42	14	12	18
Japan	3.01	8.18	24.64	32	32	31
Latvia	4.45	15.42	29.89	28	24	26
Luxembourg	4.73	36.51	50.02	27	2	10
Mexico	1.19	3.98	17.59	36	35	37
Netherlands	10.76	21.12	63.85	8	16	1
New Zealand	12.19	33.62	46.94	5	4	14
Norway	9.30	20.04	47.25	16	21	13
Poland	2.35	8.38	23.05	34	30	33
Portugal	8.56	21.45	36.58	17	15	22
Slovakia	2.36	10.66	21.83	33	29	35
Slovenia	8.35	26.97	29.11	18	10	27
South Korea	3.51	6.32	34.57	30	33	23
Spain	9.40	20.12	32.78	15	19	24
Sweden	9.88	30.47	53.24	13	6	7
Switzerland	10.66	29.87	62.47	10	7	2
Turkey	3.20	4.00	19.87	31	34	36
United Kingdom	12.16	36.38	48.57	6	3	12
United States	5.99	15.17	51.04	23	25	9

B.2 Full NEPI Tables for all the rankings

For THE, see Table B.2; for QS Table B.3; and for ARWU B.4

Table B.2: Full results of NEPI (THE)

Pos.	**Country**	**NEPI**	**Rank Eq.**
1	Singapore	79.97	29
2	Hong Kong	66.52	74
3	Netherlands	63.85	85
4	Switzerland	62.47	98
5	Belgium	58.50	137
6	Denmark	55.01	183
7	Australia	54.94	184
8	Germany	53.74	206

Continued on next page

Table B.2 Continued from previous page

Pos.	Country	NEPI	Rank Eq.
9	Sweden	53.24	213
10	Canada	52.16	222
11	United States	51.04	241
12	Luxembourg	50.02	262
13	Macau	49.99	262
14	Finland	49.33	272
15	United Kingdom	48.57	292
16	Norway	47.25	316
17	New Zealand	46.94	324
18	Qatar	46.71	336
19	Austria	46.43	343
20	Brunei	45.52	367
21	Iceland	43.69	412
22	Ireland	43.63	412
23	Italy	42.42	449
24	Ethiopia	42.36	451
25	Palestine	42.22	454
26	Jamaica	41.67	471
27	United Arab Emirates	40.52	511
28	France	40.32	519
29	Kenya	40.04	534
30	Costa Rica	39.95	535
31	Cyprus	39.15	561
32	Israel	38.59	588
33	Estonia	37.66	611
34	Portugal	36.58	640
35	China	36.29	649
36	South Africa	35.23	680
37	South Korea	34.57	700
38	Sri Lanka	34.46	704
39	Northern Cyprus	34.06	718
40	Philippines	33.71	731
41	Saudi Arabia	33.26	743
42	Spain	32.78	755
43	Greece	32.76	755
44	Uganda	32.21	789
45	Malta	31.89	806

Continued on next page

Table B.2 Continued from previous page

Pos.	Country	NEPI	Rank Eq.
46	Oman	31.25	829
47	Nepal	30.72	856
48	Latvia	29.89	894
49	Bangladesh	29.48	907
50	Slovenia	29.11	928
51	Iran	28.84	941
52	Jordan	28.73	946
53	Kuwait	28.59	954
54	Egypt	28.15	973
55	Hungary	27.95	979
56	Ghana	27.87	981
57	Serbia	27.54	990
58	Taiwan	27.18	1002
59	Lebanon	26.56	1021
60	Malaysia	26.46	1030
61	Pakistan	26.41	1032
62	Puerto Rico	26.19	1045
63	Czech Republic	26.18	1045
64	Vietnam	26.11	1049
65	Nigeria	25.96	1054
66	Chile	25.88	1055
67	Lithuania	25.80	1058
68	India	25.30	1076
69	Russia	25.25	1078
70	Japan	24.64	1101
71	Fiji	24.54	1103
72	Colombia	24.00	1124
73	Poland	23.05	1169
74	Croatia	22.95	1174
75	Botswana	22.22	1209
76	Brazil	22.21	1210
77	Slovakia	21.83	1224
78	Morocco	21.78	1224
79	Tunisia	20.33	1289
80	Turkey	19.87	1305
81	Thailand	19.83	1308
82	Romania	19.76	1312

Continued on next page

Table B.2 Continued from previous page

Pos.	Country	NEPI	Rank Eq.
83	Kazakhstan	19.61	1323
84	Indonesia	19.45	1332
85	Peru	19.35	1334
86	Ukraine	19.05	1351
87	Algeria	18.54	1381
88	Argentina	17.71	1428
89	Mexico	17.59	1435
90	Georgia	17.54	1436
91	Belarus	17.17	1461
92	Ecuador	16.66	1488
93	Cuba	16.64	1490
94	Tanzania	16.46	1497
95	Bulgaria	16.45	1497
96	Venezuela	16.33	1501
97	Iraq	16.14	1513
98	Montenegro	15.83	1528
99	Azerbaijan	13.25	1618

Table B.3: Full results of NEPI (QS)

Pos.	Country	NEPI	Rank Eq.
1	Singapore	83.27	30
2	Hong Kong	72.79	59
3	Switzerland	60.93	98
4	Netherlands	53.43	137
5	Sweden	51.08	148
6	Denmark	49.80	157
7	Belgium	46.94	174
8	Australia	46.55	178
9	New Zealand	42.85	207
10	Canada	41.30	221
11	Qatar	40.66	226
12	United Kingdom	39.59	239
13	Norway	38.27	256
14	Finland	38.18	256
15	Austria	37.86	259
16	Brunei	36.64	275

Continued on next page

Table B.3 Continued from previous page

Pos.	Country	NEPI	Rank Eq.
17	United States	34.54	303
18	Germany	34.15	306
19	Ireland	32.51	330
20	China	30.94	360
21	Israel	30.94	360
22	Oman	30.41	370
23	Japan	29.32	382
24	South Korea	28.70	391
25	Portugal	26.98	429
26	Malaysia	26.83	432
27	Cyprus	26.32	441
28	Macau	25.34	466
29	Italy	24.98	476
30	Spain	24.89	477
31	France	23.97	503
32	United Arab Emirates	23.39	515
33	Kazakhstan	23.27	518
34	Taiwan	22.83	529
35	Estonia	22.37	540
36	Belarus	22.18	542
37	Russia	21.42	569
38	Czech Republic	21.00	578
39	Georgia	20.89	581
40	Argentina	20.52	592
41	Iran	20.44	592
42	Lithuania	20.40	593
43	Bulgaria	20.32	595
44	Saudi Arabia	20.15	599
45	Lebanon	19.91	605
46	Philippines	19.88	608
47	South Africa	19.63	615
48	Colombia	18.83	645
49	Greece	18.81	645
50	Thailand	18.74	647
51	Mexico	18.62	653
52	Slovenia	18.50	657
53	Cuba	18.01	683

Continued on next page

Table B.3 Continued from previous page

Pos.	Country	NEPI	Rank Eq.
54	Costa Rica	17.52	698
55	Chile	17.38	706
56	Brazil	16.72	734
57	Hungary	16.69	737
58	Poland	16.65	738
59	Ukraine	16.24	749
60	Indonesia	15.84	765
61	Uruguay	15.69	767
62	India	15.50	776
63	Bahrain	14.81	801
64	Slovakia	14.56	810
65	Venezuela	13.94	830
66	Armenia	13.56	854
67	Malta	13.20	866
68	Latvia	12.36	912
69	Bangladesh	12.01	926
70	Peru	11.98	928
71	Croatia	11.31	958
72	Pakistan	10.83	982
73	Vietnam	10.58	998
74	Kuwait	10.51	1002
75	Tunisia	10.10	1024
76	Jordan	9.98	1030
77	Iraq	9.34	1063
78	Egypt	8.87	1083
79	Serbia	8.41	1100
80	Turkey	8.31	1103
81	Kenya	8.26	1105
82	Azerbaijan	7.93	1121
83	Paraguay	7.82	1124
84	Ecuador	7.69	1127
85	Sri Lanka	7.58	1129
86	Puerto Rico	7.47	1141
87	Uganda	7.05	1162
88	Panama	7.01	1164
89	Romania	7.00	1166
90	Ghana	6.47	1197

Continued on next page

Table B.3 Continued from previous page

Pos.	Country	NEPI	Rank Eq.
91	Palestine	6.42	1199
92	Sudan	3.90	1278
93	Bosnia And Herzegovina	3.70	1282
94	Bolivia	3.63	1285
95	Honduras	3.37	1293
96	Syrian Arab Republic	3.16	1297
97	Morocco	3.04	1300

Table B.4: Full results of NEPI (ARWU)

Pos.	Country	NEPI	Rank Eq.
1	Switzerland	27.83	82
2	Singapore	27.81	82
3	Netherlands	24.68	116
4	Denmark	24.25	121
5	Belgium	22.26	148
6	United States	20.95	167
7	Norway	20.34	177
8	Canada	19.72	190
9	Australia	19.36	196
10	United Kingdom	19.03	203
11	Sweden	18.71	209
12	France	18.45	214
13	Hong Kong	18.31	214
14	Israel	17.89	227
15	Finland	16.17	276
16	Germany	16.07	278
17	Saudi Arabia	14.73	326
18	Japan	14.63	328
19	Portugal	13.91	361
20	China	13.89	364
21	Austria	13.79	366
22	Mexico	13.62	372
23	Ireland	13.46	378
24	Italy	13.20	388
25	New Zealand	13.06	392
26	Russia	12.83	398

Continued on next page

Table B.4 Continued from previous page

Pos.	Country	NEPI	Rank Eq.
27	Estonia	12.00	441
28	South Korea	11.91	451
29	Spain	11.47	479
30	Greece	11.32	483
31	Argentina	11.19	493
32	Taiwan	11.15	493
33	Brazil	10.81	509
34	Iceland	10.30	545
35	Czech Republic	10.16	564
36	Slovenia	10.00	577
37	Macau	10.00	586
38	South Africa	9.93	586
39	Serbia	9.73	608
40	Malaysia	9.62	619
41	Iran	9.61	619
42	Cyprus	9.60	620
43	Croatia	9.50	627
44	Vietnam	9.48	639
45	Qatar	9.30	645
46	Chile	9.03	670
47	Poland	8.88	691
48	Luxembourg	8.80	692
49	Hungary	8.70	704
50	Pakistan	8.66	714
51	Egypt	8.52	719
52	Thailand	8.50	719
53	Lebanon	8.40	734
54	Turkey	8.08	771
55	India	8.02	771
56	Ethiopia	7.90	791
57	Lithuania	7.73	805
58	Romania	7.70	805
59	Colombia	7.47	846
60	Slovakia	7.20	881
61	Oman	7.10	904
61	Nigeria	7.10	904
63	Tunisia	6.60	986

Appendix C

Figures

C.1 NEPI Regressions

Hereunder are the results of the regressions on all selected variables. Figure C.1 for THE, Figure C.2 for QS, and Figure C.3 for ARWU.

C.2 NEPI Regressions on Population

Hereunder are the results of the regressions on the logarithm of population, R&D expenses and Funding per student. Figure C.4 for THE, Figure C.5 for QS, and Figure C.6 for ARWU.

```
                            OLS Regression Results
==============================================================================
Dep. Variable:               THE AEQI   R-squared:                       0.629
Model:                            OLS   Adj. R-squared:                  0.601
Method:                 Least Squares   F-statistic:                     22.06
Date:                Mon, 07 Aug 2023   Prob (F-statistic):           3.74e-17
Time:                        16:43:49   Log-Likelihood:                -348.41
No. Observations:                  99   AIC:                             712.8
Df Residuals:                      91   BIC:                             733.6
Df Model:                           7
Covariance Type:            nonrobust
=========================================================================================
                            coef    std err          t      P>|t|      [0.025      0.975]
-----------------------------------------------------------------------------------------
const                    20.6519      2.170      9.516      0.000      16.341      24.963
Funding per student       0.0008      0.000      3.550      0.001       0.000       0.001
Private                   0.0028      0.040      0.071      0.943      -0.076       0.082
Inbound                   0.3636      0.125      2.920      0.004       0.116       0.611
Outbound                 -0.1892      0.062     -3.054      0.003      -0.312      -0.066
R&D Exp (per capita)      0.0060      0.002      2.780      0.007       0.002       0.010
Patents per capita    -1939.5015   4264.292     -0.455      0.650   -1.04e+04    6530.990
GDP (per capita, ppp)  4.274e-05   5.47e-05      0.781      0.437    -6.6e-05       0.000
==============================================================================
Omnibus:                        7.972   Durbin-Watson:                   2.132
Prob(Omnibus):                  0.019   Jarque-Bera (JB):                7.928
Skew:                           0.689   Prob(JB):                       0.0190
Kurtosis:                       3.154   Cond. No.                     2.43e+08
==============================================================================
```

Figure C.1: OLS results on NEPI THE

OLS Regression Results

Dep. Variable:	QS AEQI	R-squared:	0.625
Model:	OLS	Adj. R-squared:	0.592
Method:	Least Squares	F-statistic:	18.84
Date:	Mon, 07 Aug 2023	Prob (F-statistic):	1.51e-14
Time:	16:43:49	Log-Likelihood:	-316.02
No. Observations:	87	AIC:	648.0
Df Residuals:	79	BIC:	667.8
Df Model:	7		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	5.9162	2.760	2.144	0.035	0.422	11.410
Funding per student	0.0010	0.000	3.870	0.000	0.000	0.002
Private	0.0256	0.046	0.559	0.578	-0.065	0.117
Inbound	0.1248	0.142	0.878	0.383	-0.158	0.408
Outbound	0.0378	0.147	0.257	0.798	-0.255	0.330
R&D Exp (per capita)	0.0043	0.002	1.731	0.087	-0.001	0.009
Patents per capita	3924.7184	4847.931	0.810	0.421	-5724.847	1.36e+04
GDP (per capita, ppp)	0.0001	6.56e-05	1.680	0.097	-2.04e-05	0.000

Omnibus:	22.692	Durbin-Watson:	2.286
Prob(Omnibus):	0.000	Jarque-Bera (JB):	51.144
Skew:	0.893	Prob(JB):	7.84e-12
Kurtosis:	6.304	Cond. No.	2.33e+08

Figure C.2: OLS results on NEPI QS

```
                            OLS Regression Results
==============================================================================
Dep. Variable:              ARWU AEQI   R-squared:                       0.718
Model:                            OLS   Adj. R-squared:                  0.679
Method:                 Least Squares   F-statistic:                     18.52
Date:                Mon, 07 Aug 2023   Prob (F-statistic):           5.23e-12
Time:                        16:43:49   Log-Likelihood:                -145.26
No. Observations:                  59   AIC:                             306.5
Df Residuals:                      51   BIC:                             323.1
Df Model:                           7
Covariance Type:            nonrobust
=========================================================================================
                            coef    std err          t      P>|t|      [0.025      0.975]
-----------------------------------------------------------------------------------------
const                     7.1577      1.157      6.188      0.000       4.835       9.480
Funding per student       0.0003      0.000      2.737      0.009    7.86e-05       0.001
Private                   0.0071      0.018      0.394      0.695      -0.029       0.043
Inbound                  -0.0078      0.060     -0.130      0.897      -0.128       0.113
Outbound                 -0.0959      0.057     -1.685      0.098      -0.210       0.018
R&D Exp (per capita)      0.0032      0.001      3.579      0.001       0.001       0.005
Patents per capita      730.2790   1560.226      0.468      0.642   -2402.006    3862.564
GDP (per capita, ppp)  2.111e-05   2.45e-05      0.862      0.393   -2.81e-05    7.03e-05
==============================================================================
Omnibus:                        0.672   Durbin-Watson:                   2.040
Prob(Omnibus):                  0.715   Jarque-Bera (JB):                0.709
Skew:                           0.239   Prob(JB):                        0.701
Kurtosis:                       2.753   Cond. No.                     2.22e+08
==============================================================================
```

Figure C.3: OLS results on NEPI ARWU

```
                            OLS Regression Results
==============================================================================
Dep. Variable:               THE AEQI   R-squared:                       0.561
Model:                            OLS   Adj. R-squared:                  0.547
Method:                 Least Squares   F-statistic:                     40.50
Date:                Fri, 11 Aug 2023   Prob (F-statistic):           6.03e-17
Time:                        09:31:03   Log-Likelihood:                -356.75
No. Observations:                  99   AIC:                             721.5
Df Residuals:                      95   BIC:                             731.9
Df Model:                           3
Covariance Type:            nonrobust
========================================================================================
                           coef    std err          t      P>|t|      [0.025      0.975]
----------------------------------------------------------------------------------------
const                   12.3916     10.577      1.172      0.244      -8.607      33.390
Funding per student      0.0009      0.000      4.886      0.000       0.001       0.001
LPop                     0.5768      0.607      0.950      0.344      -0.628       1.782
R&D Exp (per capita)     0.0075      0.002      4.310      0.000       0.004       0.011
==============================================================================
Omnibus:                        6.258   Durbin-Watson:                   2.230
Prob(Omnibus):                  0.044   Jarque-Bera (JB):                5.723
Skew:                           0.566   Prob(JB):                       0.0572
Kurtosis:                       3.324   Cond. No.                     1.32e+05
==============================================================================
```

Figure C.4: OLS (on population) results on NEPI(THE)

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                QS AEQI   R-squared:                       0.594
Model:                            OLS   Adj. R-squared:                  0.580
Method:                 Least Squares   F-statistic:                     40.54
Date:                Fri, 11 Aug 2023   Prob (F-statistic):           3.11e-16
Time:                        09:31:03   Log-Likelihood:                -319.48
No. Observations:                  87   AIC:                             647.0
Df Residuals:                      83   BIC:                             656.8
Df Model:                           3
Covariance Type:            nonrobust
========================================================================================
                           coef    std err          t      P>|t|      [0.025      0.975]
----------------------------------------------------------------------------------------
const                    1.0196     13.150      0.078      0.938     -25.135      27.174
Funding per student      0.0013      0.000      5.533      0.000       0.001       0.002
LPop                     0.4916      0.753      0.653      0.516      -1.007       1.990
R&D Exp (per capita)     0.0063      0.002      3.117      0.003       0.002       0.010
==============================================================================
Omnibus:                       25.568   Durbin-Watson:                   2.386
Prob(Omnibus):                  0.000   Jarque-Bera (JB):               50.897
Skew:                           1.084   Prob(JB):                     8.87e-12
Kurtosis:                       6.055   Cond. No.                     1.36e+05
==============================================================================
```

Figure C.5: OLS (on population) results on NEPI(QS)

OLS Regression Results

Dep. Variable:	ARWU AEQI	R-squared:	0.721
Model:	OLS	Adj. R-squared:	0.706
Method:	Least Squares	F-statistic:	47.45
Date:	Fri, 11 Aug 2023	Prob (F-statistic):	2.82e-15
Time:	09:31:03	Log-Likelihood:	-144.87
No. Observations:	59	AIC:	297.7
Df Residuals:	55	BIC:	306.0
Df Model:	3		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	-2.9603	4.697	-0.630	0.531	-12.373	6.453
Funding per student	0.0003	8.21e-05	3.952	0.000	0.000	0.000
LPop	0.5988	0.266	2.248	0.029	0.065	1.133
R&D Exp (per capita)	0.0038	0.001	5.545	0.000	0.002	0.005

Omnibus:	2.142	Durbin-Watson:	2.075
Prob(Omnibus):	0.343	Jarque-Bera (JB):	1.343
Skew:	0.304	Prob(JB):	0.511
Kurtosis:	3.419	Cond. No.	1.51e+05

Figure C.6: OLS (on population) results on NEPI(ARWU)

Appendix D

Code

All the used code is available on Github

UNIVERSITÉ CATHOLIQUE DE LOUVAIN
École polytechnique de Louvain
Rue Archimède, 1 bte L6.11.01, 1348 Louvain-la-Neuve, Belgique | **www.uclouvain.be/epl**