“Space of physics journals”: in search of journals of quality

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Abstract

This paper analyses the problem of scientific quality of physics journals. The main assumption is that the quality of a physics journal exists only in reference to other journals. Instead of constructing new indicators of scientific quality, we identify a physical journal with corresponding empirical distribution function of citations. From our relational point of view, the space of physics journals is only a system of differences between empirical distribution functions of citations. Using data from Web of Science Core Collection we consider the space of physics journals and the space of scientific publishers. The first provides an objective basis for the grouping of physics journals on the basis of a whole range of indicators (citation statistics, country, publisher, etc.). The second reveals the “competitors’ triangle” of regional publishers, transnational publishers and professional physical societies. These findings have prompted us to advance the hypothesis that the structure of the space of physics journals is determined by a system of relations between publishers.

Keywords: Citation analysis, Scientometric indicators, Scientific quality of a journal, Space of journals, Scientific publishers,

2010 MSC: 91D30, 91D99

1. Introduction

In its present form, scientometrics cannot take the place of in-depth science of science\textsuperscript{ Adler et al. (2009); Glänzel & Moed (2013); Leydesdorff & Milojević (2015).} Scientometrics does not offer a “clear window” into science, but rather something more akin to a stained-glass window, which allows one to gain some impressions of the world, but at the same time imposes its own patterns

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Preprint submitted to Journal of Informetrics

December 1, 2016
and colours on that world. In this regard, the scare quotes around the term “space of physics journals” in the title of this paper are intentional — they draw attention to the fact that we must explicitly define what we mean by the term. Having refined our empirical insights into the nature of this space, the formal determination may then be used for further scientometric exploration.

The history of scientometrics is very interesting in itself (Godin 2006; Archambault & Larivière 2009; Smith 2012; De Bellis 2014; Kinouchi 2014; Wyatt et al. 2015), and demonstrates that, in many cases, scientometric understanding of a journal consists in deconstructing the quality of a journal to its bare bones. This suggests that a hard indicator of scientific quality is citation statistics (we do not go into details, and refer the reader to Garfield (1979); Moed (2005); Aksnes (2006); Leydesdorff (2008); Abramo & D’Angelo (2011); Mazloumian et al. (2011); Cronin & Sugimoto (2014); Radicchi & Castellano (2015); Leydesdorff et al. (2016); Tahamtan et al. (2016); van Wesel (2016); Frittelli et al. (2016)). Perhaps the most widely-known and analysed scientometric indicator based on citation statistics is the Journal Impact Factor (Garfield 2006; JIF for short). JIF is provided by the Journal Citations Reports (Thomson Reuters), and is a quantitative measure for ranking and evaluating scientific journals. It consists of “the average number of citations received per paper published in that journal during the specific period of two preceding years” Thomson Reuters. JIF is “a ratio between citations and recent citable items published” Thomson Reuters. The JIF calculation is well presented in the scientometric literature, therefore we shall not detail it here. JIF has become practically the standard measure for evaluating and ranking scientific journals. The receipt of a high JIF is an object of fierce competition between scientific publishers; this indicator is actively used in scientific policy and management. Unsurprisingly, JIF has been subject to close scrutiny from professional and citizen bibliometricians, as well as scholars, publishers, policymakers and research managers. For example, in 2012 the leading journal Scientometrics published a special edition dedicated to JIF, and the journal Nature regularly publishes articles on this subject (for instance, see Hicks et al. (2015)). Since an analysis of the literature on JIF is not one of the aims of our work, we refer the reader to several excellent reviews which consider this subject in depth (Glänzel & Moed 2002; Bar-Ilan (2008); Mingers & Leydesdorff 2015; Vanclay (2012); Liu et al. (2016); Ferrer-Sapena et al. (2016); Mingers & Yang (2017); Todeschini & Baccini (2016); Waltman (2016).

Despite being the subject of ongoing criticism, JIF continues to be widely used. It follows that there must be good reasons for this. It should be recognised that scientometrics has not yet arrived
at reflexive analysis over the concept of “scientific quality of a journal” (cf. Moed (2016)). On the one hand, scientometrics cannot regard it as a primitive concept, because it does not belong to the category of observable quantities, and must therefore be a definable concept. But on the other hand, it is impossible to give a precise and explicit definition of the quality of a journal without a more or less comprehensive theory of scientometrics. Hence, a satisfactory definition of “quality of a journal” cannot be anything other than an integral part of the theory of scientometrics.

It is difficult to conceive of an operationalisation of the scientific quality of a journal free of scientometric critic. It is clear that this concept expresses a complex social phenomenon. However, whilst setting aside this complexity, in scientometrics it is possible to work with an individual aspect of the concept. In practice, scientometricians adopt implicit definitions of the scientific quality of a journal when they develop ways to measure scientific recognition, popularity, impact, and so on. The multifaceted nature of the scientific quality of a journal indicates the relatively complex structure of the concept. The differences between the elements of this structure can be so great that this in itself can justify the study of the individual aspects as isolated scientometric constructs.

In light of scientometric practice, it would seem reasonable to consider a scientific journal as a representative of the totality of journals, all coexisting interdependently in the scientific field. To establish the quality of a physics journal it is necessary, inter alia, to appeal directly to a given class of experimental data. Without going beyond the well-established scientometric data and abandoning the search for the causa finalis of a journal, we can nevertheless aim to find the causa efficiens of a journal directly, in the space of physics journals (hereafter SPJ) itself. This means that the SPJ as a system of relations offers the possibility to correlate bibliometric data on journals exclusively among themselves. It is impossible to formulate a priori concepts about the relations that constitute the SPJ; on the contrary, these relations are determined only within the framework of research. Thus, the development of theoretical concepts only becomes possible in light of the development of empirical knowledge.

The SPJ, as the product of a distinctive history, generates its own conceptions of the quality of a physics journal. The SPJ can be interpreted as a system of differences, which manifest themselves as elements of its structure. The SPJ enables empirical data on journal citation to be systematised within the physics periodicals’ own inherent system of logic. Hence, in order to evaluate the quality of a journal, it is necessary to construct the SPJ by building on the existing system of differences between journals.
The formulation of the SPJ as a (relatively) autonomous scientometric entity (i.e. based only on itself) provides an imperative to uncover the SPJ through relational concepts. For the present authors, given the available bibliometric data, these concepts are “distance between the journals” and “situs of a journal” (or SJ in abbreviated form). The SJ is defined as the ratio that exists between the properties of a journal, and those of the sample of journals being studied. The SJ characterises the structure of citations of a journal relative to a sample of journals. In this paper, the point is not so much the SJ of any given journal itself, but rather understanding how SJ works.

Conceptually, we make six claims about the SPJ.

1. We propose that it is a scientometric concept that can encompass both social relations and bibliometric networks, social institutions and scientific resources (including popularity, scientific recognition, authority, impact, etc.). We claim that the SPJ can be treated as a relational construct, and that can be explained in terms of regularities observed at the level of its constituent relational “situs” (cf. Leydesdorff (2006)).

2. The concept of the SPJ is a means of creating an object of scientometric study by constructing synthetic relations between empirical data. However, the SPJ is the totality of relations, which is not located in the area of scientometric experience in the form of an “end product”. This set of relationships is constructed by scientometric theory as a means of studying the systematic connections between empirical data on journals — a tool that brings together bibliometric knowledge into a logical whole. Scientometric theory organises not the empirical data themselves, but their statistical representations. By using mathematical concepts, we are able to reduce the gap between scientometric concepts and bibliometric data.

3. We suggest that the SPJ is inherently non-deterministic. We thus arrived at the probabilistic representation of the SPJ.

4. In a scientometric experiment, almost all that is measured is the probability distribution of citations. This in itself appears to be sufficient justification for identification of the physics journal with the empirical distribution function of citations (cf. Larivière et al. (2016)).

5. The SPJ is a bound state of several journals, and therefore consists of a certain number of different stochastic processes. To characterise configurations of such a complex social system is a difficult problem. But it has a simplifying feature: social relations between scientific journals may be approximated by probability distances between the corresponding probability distributions.
6. The SPJ is a practical classification of physics journals, which summarises the initial differences between them.

This paper aims at contributing to a better theoretical and empirical understanding of the scientific quality of physics journals. In this work, we first intend to construct and interpret the SPJ using a bibliometric data set on physics journals extracted from Web of Science Core Collection (WoS CC for short). The second step is to develop a model of SJ. We derive values of SJ for physics journals and compare these results with the JIF.

2. Materials and Methods

The data on journal citations and indicators was extracted from the WoS CC — scientific citation indexing service, and the Journal Citation Reports — an analytical tool providing bibliometric information about academic journals. Both are provided by Thomson Reuters. The first step was to select all journals included in the “physics” category in the Journal Citation Reports, according to the category schema “Essential Science Indicators”, which resulted in 298 items. Journals which had published less than 100 papers in two years were excluded from the selection, resulting in a narrowed sample of 240 journals. It is worth noting that six of the ten journals with the highest JIF were excluded from the sample, since these were review journals publishing a small number of papers per year. Taken together, the excluded journals publish on average 55.8 citable items in two years. The next step was to extract information from the WoS CC on citations made in 2015 for all papers published in the journal sample during 2013 and 2014. Only “article” and “review” data types were included in the sample. We opted for a two year publication window, a one year citation window, and “article” and “review” document types, so that our corpus of would be as close as possible to that which forms the basis for the calculation of JIF in the Journal Citation Reports.

The dataset was downloaded from WoS CC in August 2016. In addition to citation data, we used journal indicators provided by the Journal Citation Reports for the year 2015. Data on journals’ publishers and countries were extracted from the “Scopus title list”.

For statistical data processing, we used the R programming language and IBM SPSS Statistics 22.
3. Model

In this paper, we treat the word “model” approximately as the “formalism”, that is, a collection of abstract analytic tools for working formally with bibliometric quantities, deriving formulas, and interpreting them. Good formalism is almost as useful as exact formulas. However, a clear grasp of the essence of the SJ must be achieved before introducing a formalism itself. There is no reason to justify a formalism which has not been perceived yet.

Note that in the probabilistic approach, numerical characteristics of a journal are random variables $\xi_i$, where the index $i$ will sometimes be left out. For definiteness therefore, let us consider the distribution $P_n^*(\xi \in B)$ constructed from the sample $X_n = (x_1, \ldots, x_n)$, for any Borel set $B$. In a sense, the empirical distribution function (or, in abbreviated form, EDF) $\hat{F}_n(x) := P_n^*(\xi < x)$, corresponding to the sample $X_n$, characterizes the journal $X$. To give a scientometric meaning to the EDF, we assume that $\hat{F}_n(x)$ is a property of the state of $X$. This interpretation will serve as a guideline throughout this paper.

Our key intuition is to think of the SJ of $X$ as a property of the EDF $\hat{F}_n$ and its relations.

We want to evaluate the SJ of a given journal in a natural and intuitive way. To achieve our goal of deriving the SJ of a journal from first principles, we represent $\hat{F}_n$ directly by means of a measurable “utility function”. Let us suppose, for the sake of argument, that the above-mentioned utility function is a functional $U[\hat{F}_n]$ that is continuous in the uniform metric at any point $\hat{F}_n$.

We will concentrate here on the subspace $D_b \equiv (D_b([0, 1]; \mathbb{R}_+), \|\cdot\|_{\infty, D_b})$ of the Skorokhod space, comprising all bounded, nondecreasing functions $\eta : [0, 1] \to \mathbb{R}_+$ that are right-continuous and have left-hand limits, with the norm $(\forall \eta \in D_b) : \|\eta\|_{\infty, D_b} := \sup_{t \in [0, 1]} |\eta(t)| < \infty$ (cf. Jacod & Shiryaev (2003)). To help the intuitive interpretation of what follows, we shall treat the space $D_b$ as a phase space. If one adopts this point of view, the state of a journal on $D_b$ is defined by a point $\hat{F}_X \in D_b$.

Thus, the EDF $\hat{F}_X$ is a point of space $D_b$, and at the same time possesses an inner structure.

Let us now be more technical and turn to the derivation of our SJ. One knows that $D_b$ is a Banach space, and we use $D_b^*$ and $\langle \cdot, \cdot \rangle$ to denote its topological dual and the duality pairing, respectively. This yields that the dual $D_b^*$ of $D_b$ can be considered as the space of utilities $U[\cdot]$ associating with any journal $X$ (i.e., $\hat{F}_X \in D_b$) its value $\langle \hat{F}_X^*, \hat{F}_X \rangle = U[\hat{F}_n]$.

Choose any $\varepsilon > 0$; then, the partial order of Bishop–Phelps on $D_b \times \mathbb{R}_+$ can be defined as
follows (cf. Phelps (1993)):
\[
\left( \forall X, Y \in D_b \right) \left( \hat{F}_X, \hat{F}_Y \in D_b^* \right): \left[ \hat{F}_X, \hat{F}_Y \right] \leq \left[ \hat{F}_Y, \hat{F}_Y \right] \iff \\
\left\langle \hat{F}_X, \hat{F}_Y \right\rangle + \varepsilon \| \hat{F}_X - \hat{F}_Y \|_{\infty, D_b} \leq \left\langle \hat{F}_Y, \hat{F}_Y \right\rangle. 
\]

When we interpret the result which we obtain, by mathematical means, in scientometric terms, we obtain information about scientometric entities. By construction, the expression
\[
\left\langle \hat{F}'_Y, \hat{F}_Y \right\rangle - \left\langle \hat{F}'_X, \hat{F}_X \right\rangle
\]
is a “relative gain”. In the case studied here, from the formula (2) it can be seen that
\[
(\vartheta \in \mathbb{R}_+) \left( \hat{F}_X, \hat{F}_Y \in D_b \right): G(X, Y) = \vartheta \| \hat{F}_X - \hat{F}_Y \|_{\infty, D_b}
\]
is a gain of the journal Y \textit{relative} to the journal X, with a “unitary gain” \( \vartheta \). (Here, we examine two samples \( X_n \) and \( Y_m \) of sizes \( n \) and \( m \), respectively.) More intrinsically, we use in the expression Kolmogorov distance Rachev et al. (2013) of \( \hat{F}_Y \) to \( \hat{F}_X \). It is scientometrically sensible that
\[
G(X, Y) = G(Y, X).
\]
Trivially, the formula (3) cannot, by itself, tell us whether gain of Y is greater than gain of X, and vice versa.

We get the formula (3) out of our general assumptions without any arbitrariness. Actually, the utility function \( U[\hat{F}_n] \) is uniquely determined by the geometry (or a system of open balls) of the space \( D_b \), since for the norm \( \| \cdot \|_{\infty, D_b} \) we can construct the functional \( \left\langle \hat{F}'_X, \hat{F}_X \right\rangle \) with the required properties.

Further, the relation (3) continues to hold if we replace the constant \( \vartheta \) by \( \sqrt{\frac{nm}{n+m}} \). Then to each relative gain \( G(X, Y) \) we can assign a well-known Kolmogorov–Smirnov statistic, thus:
\[
G(X, Y) = \sqrt{\frac{nm}{n+m}} \sup_x \left\{ |\hat{F}_X(x) - \hat{F}_Y(x)| \right\}.
\]

Setting
\[
\left( \forall X, Y \in D_b \right) \left( \hat{F}_X, \hat{F}_Y \in D_b^* \right): d(\hat{F}_X, \hat{F}_Y) := G(X, Y) = \| \hat{F}_X - \hat{F}_Y \|_{KS},
\]
we obviously get new metric \( d(\cdot, \cdot) \) of \( D_b \). Trivially, that norms \( \| \cdot \|_{\infty, D_b} \) and \( \| \cdot \|_{KS} \) are equivalent in \( D_b \). This introduces the next crucial point in our model. Let \( S \subset D_b \) be a sample of physics journals. The formal definition of the remoteness from a journal Y to S is the following:
\[
(S \subset D_b) \left( \hat{F}_X, \hat{F}_Y \in S \right): R(Y) := \inf \left\{ G(X, Y): \hat{F}_X \in S \setminus \hat{F}_Y \right\} = \\
\inf \left\{ d(\hat{F}_X, \hat{F}_Y): \hat{F}_X \in S \setminus \hat{F}_Y \right\},
\]

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where $S \setminus \hat{F}_Y$ denote the difference between $S$ and $\hat{F}_Y$. We can see more clearly the geometrical significance of the above definition. The formula (6) means that $R(Y)$ is the distance from $\hat{F}_Y$ to the (non-empty) set $S \setminus \hat{F}_Y$ corresponding to the sample $S$. Incidentally, we may notice that $|R(X) - R(Y)| \leq G(X,Y)$.

The *diameter* of a journal $Y$ can be defined as the least upper bound of $G(X,Y)$:

$$
(S \subset D_b) \left( \hat{F}_X, \hat{F}_Y \in S \right) : D(Y) := \sup \left\{ G(X,Y) : \hat{F}_X \in S \setminus \hat{F}_Y \right\} = \sup \left\{ d \left( \hat{F}_X, \hat{F}_Y \right) : \hat{F}_X \in S \setminus \hat{F}_Y \right\}.
$$

(7)

For the SJ model, two quantities are needed: the remoteness $R(Y)$ and the diameter $D(Y)$. We can use the concept of ordered pair $(R(Y), D(Y))$ to define a situs $SJ(Y)$ of a journal $Y$.

At the same time, the notion of the SPJ is more abstract than it need be. This leads us to introduce a new term: “map of the SPJ”. It denotes a set, each member of which is an ordered pair $(\forall \hat{F}_Y \in S) : (R(Y), D(Y))$. More precisely, the map of the SPJ is a pair $\left( \left( S, d(\cdot, \cdot) \right), \{ SJ(\cdot) \} \right)$ consisting of a metric subspace $(S, d(\cdot, \cdot)) \subset D_b$ and a set $\{ SJ(\cdot) \}$ of all ordered pairs $(R(\cdot), D(\cdot))$. The SJ characterises the structure of citations of a journal relative to a sample of journals. Thus, it is certainly legitimate to represent the SPJ as the map of the SPJ.

In general, there is no unique way of presenting $SJ(Y)$ in a more practical form. However, to a first approximation, we can obtain an estimate $(R(Y), D(Y)) \mapsto E(Y)$ of $SJ(Y)$ by using of the ratio between $R(Y)$ and $D(Y)$:

$$
(\forall \hat{F}_Y \in S) : E(Y) := \frac{R(Y)}{D(Y)}.
$$

(8)

4. Results and Discussion

We first begin our empirical exploration with a small but significant formal result: Fig. 1 shows that $E(Y)$ is highly correlated with $JIF(Y)$ (Pearson’s $\rho = 0.895, p = 0.000$). Also it is seen that the relationship is linear and positive. Furthermore, $E(Y)$ is highly correlated with the median of $\hat{F}_Y$ (Pearson’s $\rho = 0.904, p = 0.000$) (cf. Garfield & Pudovkin (2015)).

4.1. Common space of physics journals

In this article, the visualisation of the SPJ is based on the use of multidimensional scaling (cf. Zhu et al. (2013); Palla et al. (2015)). To analyse and visualise the pattern of similarity between the physics journals, the multidimensional scaling method was applied to the distance matrix.
Figure 1: Scatterplot of JIF against $E(Y)$. Journals having JIF higher than 3 marked by numbers. List of journals see in Appendix 1.

\[
\left( d\left( \hat{F}_X \hat{F}_Y \right) \right)_{X,Y=240}^{X,Y=1}. \]

Multidimensional scaling enables us to reduce the dimensionality of the initial space of journals. We constructed a two-dimensional common space of physics journals, which satisfactorily describes the initial matrix of distances between journals. This reduces a system of interconnected differences between journals to two generalised “axes”, shown in Fig. 2. The coordinate axes of the common space of physics journals are scientometric invariants of the sample $S$. These axes express the foundations of the classification of physics journals, which is generated by the system of scientometric differences. The axis $x$ of the common space of physics journals correlates with the quantity $R(Y)$ (Pearson’s $\rho = 0.718, p = 0.000$), while the axis $y$ correlates with the quantity $D(Y)$ (Pearson’s $\rho = 0.690, p = 0.000$).

The SPJ is a relational multi-level system. Each level of relations in the SPJ encloses a certain selection of scientometric data into a logical whole. The aim of our analysis of the common space
of physics journals is not to portray the multitude of physics journals as the manifestation of a single principle of structuring scientific communication in physics. Rather, we aim to establish a constructive relationship between the journals, which manifests itself as an opportunity to move from any position in the common space of physics journals to all the others. Journals located in the different quadrants vary by size, citation level, impact factor, and the length of time they have been indexed in the WoS CC. As a result, they enjoy different levels of popularity and prestige. In fact, when moving clockwise from quadrant I to quadrant II the properties of the journals changes monotonically. The average value of JIF for journals of quadrant I is equal to 12.256, for journals of quadrant IV — 2.617; for journals of quadrant III and quadrant II the average value of JIF is 1.471 and 0.840 respectively. The total number of citations received by a journal in the WoS CC
changes analogously. The average value for the indicator total cites for journals of quadrant I is equal to 65,186; for publications of quadrant IV — 29,345. The lowest average value of total cites is observed among the journals of quadrant III and quadrant II, where the value of the indicator is 11,384 and 2,458 respectively.

The highest average value of variance can be observed in quadrant I and quadrant II, where it is 308.3 and 44.4 respectively. The differentiation of articles by level of citation in these two quadrants is very high. In this respect they differ from the journals in quadrant IV and quadrant III, which are more homogenous. For the latter, the average variance in the level of citation is 14.7 and 5.0.

The indicator for the number of citable items in two years behaves somewhat differently. On average, the journals of quadrant I publish 1342 papers, and the journals of quadrant IV — 1443. The figures for journals of quadrant III and quadrant II are significantly less; on average, they publish 921 and 479 citable items in two years.

We can note an important feature of the journals in quadrant I. By comparison with the others these are relatively new journals. The average year of their foundation is 1995. These journals are mainly products of the era of the internet and bibliometric databases. They are more in line with modern tools for the dissemination of scientific information better than other journals. This may be one of the factors that contributes to their high bibliometric indicators. The journals in quadrant I are “journals of quality”, if one goes by their citation statistics.

The structure of the common space of physics journals contains information on certain qualitative characteristics of journals. For example, 18.8% of journals in quadrant II have Open Access status. In all the remaining quadrants their share does not exceed 11%. This state of affairs is consistent with the results of scientometric studies, which have demonstrated that the openness of scientific publications does not automatically lead to a higher level of citation (cf. Craig et al. (2007); Davis & Walters (2011); Tennant et al. (2016)). In the case of physics journals, the majority of Open Access publications have a relatively low level of citation. Even in quadrant II, Open Access journals do not enjoy a higher level of citation than those which maintain a traditional copyright policy. The average citation level for those journals in quadrant II which have Open Access status is 188 total cites, while the remaining journals in this group have on average 427 total cites. It can be suggested that journals consider Open Access status to be a means of increasing their popularity, but the citation rates of these journals suggest that Open Access in itself is no guarantee of increased citation.
The common space of physics journals acts as a kind of meta-language for the description of journals, which enables us to identify regularities through analysis of their properties in a fixed “alphabet” of quadrants. Thus, when it comes to publishers of journals, certain regularities can be observed when moving in a clockwise direction through the common space of physics journals.

Although publishers’ sophisticated strategies are constantly changing the landscape, we attempt to map these regularities. Quadrant I is dominated by journals which belong to academic institutions: American Chemical Society, Institute of Physics, Royal Society of Chemistry, and Tsinghua University. The publisher Springer Nature is the exception to this. As we move from quadrant I to quadrant II, the influence of scientific publishing companies increases. In the quadrant IV, scientific publishing companies begin to predominate. Elsevier, Springer Nature and Wiley – Blackwell have a share of 46.1% of all journals in the quadrant. However, leading physics societies also enjoy a significant position. Journals published by Institute of Physics account for 17.1%, while American Physical Society and American Institute of Physics have shares of 7.8% and 6.6% respectively. Quadrants IV and III can be considered the “world of Elsevier”. The large majority of this publisher’s journals (86.4%) can be found in these quadrants. In quadrant III, the share of journals owned by large multinational publishers increases, while the share of journals belonging to professional societies decreases. The share of journals published by Institute of Physics, American Physical Society and American Institute of Physics is just 9.4% in quadrant III, while the proportion of journals belonging to Elsevier, Springer Nature and Wiley – Blackwell is 52.8%.

Quadrant II differs substantially from the three preceding quadrants. The first striking characteristic is the concentrated presence of the scientific publishing company Maik Nauka, which publishes translations of Russian journals. All of this publisher’s journals can be found in quadrant II, accounting for 15.8% of all journals in this quadrant. All journals published by World Scientific can also be found in this quadrant — 8.9% of the total. The third major publisher in quadrant II is Springer Nature, with a share of 10.9%. Elsevier is weakly represented in this quadrant, with a concentration of just 5.9%.

Due to the strong internationalisation of the publishing process, it is not possible to straightforwardly classify physics journals in terms of national affiliation. However, it is possible to trace the distinction between “global” and “local”, which is formed on the principle of “the West and the rest”. In moving from quadrant I to quadrant II the number of countries to which a journal can be ascribed rises. In quadrant I the only countries represented are the USA, Great Britain,
Germany and China. Quadrant IV contains eight countries, of which the Netherlands (to which Elsevier is affiliated) occupies a prominent place. The most international quadrant in terms of publisher affiliation is II, which contains journals affiliated with 22 countries. Besides the USA and Great Britain, Russia and Singapore play a significant role in this quadrant (home respectively to the publishers Maik Nauka and World Scientific).

Also, the common space of physics journals is not only a geometrical locus of relations between citations, but also between those social forces which aim at transforming these relations. The common space of physics journals can be treated, amongst other things, as a projection of competitive relations within the triad “transnational publishers — professional physics societies — regional publishers” (cf. Larivière et al., 2015):
• In quadrant I professional physics societies are dominant.

• In quadrant IV there is interference of professional societies and transnational publishers.

• quadrant III is dominated by transnational publishers, while professional physics societies have a relatively weak representation.

• In quadrant II the dominant players are regional publishers from Asia, Latin American and the former Soviet Union, while the role of professional physics societies and transnational publishers is insignificant. The journals of the second quadrant are those which stem from “non-Western” science, which are less well adapted than others to the demands of global physics and the WoS CC.

4.2. Map of the space of physics journals

Journals according to values of $SJ(Y)$ are shown in Fig. 3. We include the results of the analysis of the common space of physics journals in the next stage of our research as an empirical knowledge. In this way, we give the relational definition to empirical data and organise them. From Fig. 3 it can be clearly seen that the structure of the common space of physics journals accords with the distribution of $SJ(Y)$. For the sake of continuity, in Fig. 3 the journals are marked using colours, which correspond to the four quadrants in Fig. 2. The journals of quadrant I still significantly differ from the others, having higher values on the $R(Y)$ axis. Nature Photonics (149) and Nature Physics (150) particularly stand out in this respect. The remaining publications form a monotonic sequence in which the journals from quadrant II gradually take the place of the journals from quadrant III, and finally the journals from quadrant IV. Let us describe this sequence, digressing briefly from “journals of quality”.

Around 96% of the total sample of physics journals are located within a diagonal band running from the top-left to the bottom-right. In the upper part of this “main sequence” we find journals with a low JIF (e.g., Journal of Infrared and Millimeter Waves (98), Bulletin of the Lebedev Physics Institute (23), Journal of Applied Mechanics and Technical Physics (92), Moscow University Physics Bulletin (143)), while the bottom-right contains those with a high JIF (e.g., Journal of High Energy Physics (97), Physics Letters B (190), Physical Review E (184), European Physical Journal B (55)). Moving along the “main diagonal” from top to bottom, we move in turn from journals located in quadrant II in Fig. 2 to those located in quadrant III, and finally to those of quadrant IV. This
Figure 4: Map of the space of physics journals, publishers, and countries. The map of the SPJ is shown here as the set of values of $S J(Y)$ in coordinates of $R(Y)$ and $D(Y)$. Journals having the variance of citations higher than 10 marked by numbers. List of journals see in Appendix 1.

means that we are moving to journals with a successively higher JIF. Separately, above and to the right of the “main diagonal” lies a group of journals with “abnormally” high JIFs. All ten journals which form this group belong to quadrant I.

From Fig. 3 it can be seen that the minimum values of $D(Y)$ and the maximum values of $R(Y)$ correspond to journals with a high JIF. The smaller the value of $D(Y)$ and the larger the value of $R(Y)$, the higher its “force of attraction”, and the more journals from $S$ try to resemble it. It is no coincidence that the journals of quadrant IV — i.e. well-established, reputable physics journals — can be found in the rectangle $S J(Y)$, which corresponds to large values of $R(Y)$ and small values of $D(Y)$. At the same time, journals with a low JIF can be found in the rectangle representing high values of $D(Y)$ and low values of $R(Y)$. 

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Figure 5: Common space of 15 scientific publishers. Plot of the first and second coordinates of multidimensional scaling analysis (with the use of the ALSCAL algorithm \cite{Takane1977}) of distances $d_H(A, B)$ ($S = \text{Stress} = 0.229$).

Fig. 4 provides a visualisation of the connections between $SJ(Y)$ and journals’ national affiliation. Journals affiliated to the USA, Great Britain, the Netherlands and Germany are located in the area $SJ(Y)$, which corresponds to high values of $R(Y)$ and low values of $D(Y)$. These are “points of attraction” of the sample, having a large remoteness $R(Y)$ and a small diameter $D(Y)$. In contrast, publications affiliated with China, Singapore, Russia, Egypt and Poland are located in the area $SJ(Y)$, which combines low values of $R(Y)$ with large values of $D(Y)$. It can be noted in particular that certain journals try to gain affiliation with the USA or Great Britain in a bid to increase their status. This fact makes the distinction between global and local (which we pointed to in our analysis of the map of the SPJ) less significant, if the national affiliation of a publisher is determined only by formal factors. The area $SJ(Y)$, which corresponds to small values of $R(Y)$
and large values of $D(Y)$, contains journals which *de jure* are affiliated to the USA, but *de facto* are connected with Russia: see, e.g., *Bulletin of the Lebedev Physics Institute* (23), *Moscow University Physics Bulletin* (143), *Russian Physics Journal* (220), and *Mechanics of Solids* (137). The same can be said about *Chinese Physics C* (33) and *Chinese Physics Letters* (34), published by the Chinese Physical Society, but affiliated to the UK.

Consecutive movement to the right along the $R(Y)$ axis and downwards along the $D(Y)$ axis coincides with an increase in the time span over which a journal has been indexed in the WoS CC. Journals which have a significantly longer time span of indexation in the WoS CC lie in the rectangle which combines large values of $R(Y)$ with small values of $D(Y)$. By contrast, those journals which are located in the rectangle with low values of $R(Y)$ and high values of $D(Y)$ have a shorter time span of indexation in the WoS CC.

Fig. 3 and Fig. 4 allow us to state that the distribution $SJ(Y)$ accords with the distribution of journals’ characteristics. In moving along the main sequence, a shift takes place from high impact factor journals to low impact factor journals; from global to regional; from journals with a longer time span of indexation in the WoS CC to those with a shorter time span of indexation in WoS CC. “Newcomer giants”, to whom these dependencies do not extend, are situated apart from the main sequence.

### 4.3. Scientific publishers

While long-term strategies of merger and acquisition can disrupt patterns of similarity between publishers, the citation rates of journals belonging to one publisher often show statistical similarities. We analysed 15 main publishers from the sample, which accounted for 73.3% of all journals. In order to represent relationships between the scientific publishers, the multidimensional scaling method was applied. Fig. 5 is the plot of the first and second coordinates of multidimensional scaling of the matrix $(d_H(A, B))_{A, B=1}^{A, B=15}$ of Hausdorff distances

\[
(A, B \subset S): d_H(A, B) = \max \left\{ \sup_{\alpha \in A} \inf_{\beta \in B} G(\alpha, \beta), \sup_{\beta \in B} \inf_{\alpha \in A} G(\alpha, \beta) \right\}
\]  

between all pairs of the publishers.

The $x$ axis in Fig. 4 polarises publishers according to $R(Y)$. On the right pole are Springer Nature (transnational), American Chemical Society (US), American Physical Society (US), Wiley-Blackwell (transnational). It is these publishers’ journals which lie in quadrant I in Fig. 2. On the
left pole are publishers which do not have journals with high values of $R(Y)$: the American Institute of Physics (US), Hindawi (Egypt), Science Press (China), EDP Press (France), Maik Nauka (Russia). Only two American scientific societies which are global players in the scientific field fall into the area with negative values of $x$; the remainder are regional players.

The $y$ axis in Fig. 5 provides a visualisation of the differences between scientific societies and commercial publishers. At the top of the $y$ axis are the American Chemical Society (US), the American Physical Society (US), the Institute of Electrical and Electronics Engineers (US), the Optical Society of America (US). At the bottom of the $y$ axis are the largest of the transnational publishers: Springer Nature (transnational), Elsevier (transnational) and Taylor & Francis (transnational), as well as World Scientific (Singapore). Of the scientific societies, only the United Kingdom’s Institute of Physics is located in this area.

It can be suggested from Fig. 5 that the space of physics publishers is structured around two
fundamental oppositions:

1. The first opposition centres around traditional and American publishers on the one hand, which publish “high ranking” journals in the sphere of “mainstream” global research agendas, contrasted with mainly regional publishers on the other hand, which own journals aimed at more “niche” readerships and cover the results of less topical research.

2. The dominant role in the second key opposition is played by the differences separating the professional societies of mainly American origin, and the transnational commercial publishers originating from Europe.

Let us consider the publishers themselves in the map of the SPJ. As can be seen from Fig. 6, publishers are situated relative to each other in an orderly manner. Moving from the lowest average values of $R(Y)$ to the highest, and simultaneously from the highest average values of $D(Y)$ to the lowest, it can be observed that regional publishers give way to traditional ones, which in turn are displaced by publishers belonging to professional societies. Thus, a “competitors’ triangle” (cf. Larivière et al. (2015)) is reproduced in the system of coordinates $R(Y) — D(Y)$ between regional publishers — transnational publishers — professional societies.

5. Conclusions

The suggested approach to scientific quality of a physics journal is more like a mode of reasoning, characterised by free exchanges between empirical and analytical arguments, rather than a “hypothetico-deductive” model. The SPJ should not be taken as the definition of scientific quality of a journal in the sense of basic sciences. In the worst case this scientometric notion represents social stereotypes, everyday knowledge or business demands; in the best case it implies them but is not implied by them. The SPJ is not a guideline for scientometric research programmes, but an attitude towards the field of physics itself. Of course, the use of the SPJ is significant not because the distance matrix $\left(d\left(\hat{F}_X, \hat{F}_Y\right)\right)_{X,Y \in S}$ constitutes a “scientific quality”, but because we believe that by using the SPJ we will learn something about the regularities that govern scientific field.

From our relational point of view, the quality of a physics journal exists only in reference to other journals. Since the issue we are seeking to address is concerned not with individual journals, but rather with the totality of journals and the interrelations between them, it should come as no surprise that the resultant working model is the SPJ. In the given context, the SPJ is a
mathematical construct that relates different elements within the entire data set to each other, and thereby produces a single scientometric entity. The SPJ as metric space *sui generis* is a natural generalisation of the concept of closeness of physics journals. It is a heuristic approach based on an abstract assumption (covering a wide range of concrete phenomena) for which there is no fundamental theoretical justification.

In summary, the totality of physics journals can be represented in the form of the SPJ. In studying physics journals as the SPJ, we are abstracting from that to which physics journals owe their existence, in the form of subjects of scientometric research. Each journal is characterised through negation. Broadly speaking, a physics journal is defined by that which distinguishes it from all other journals. By virtue of this, the system of distances which differentiates EDFs also expresses the system of conditions for the existence of physics journals. This system is inscribed in the totality of social relations which constitutes scientific field.

The SPJ we have constructed describes scientometric data on journals in a compact form. Moreover, the SPJ models certain regularities to which journals conform. Thus, the SPJ provides an objective basis for the grouping of physics journals on the basis of a whole range of indicators. This makes it possible to analyse the structure of the SPJ. In turn, this structure sheds light not only on journals as direct forms of scientific communication, but also reveal the structuring role of publishers, something which is not usually highlighted. Analysis of the SPJ allows us to advance the hypothesis that the structure of its positions is determined by a system of relations between publishers.

Publishers are only able to structure the SPJ because they themselves are structured:

- Agents of the SPJ differ, firstly, by whether their research activity is carried out by self-organised groups of scholars, or as a member of an organisation which seeks to make a profit. It is a matter of distinguishing between collectively-produced collective products, and products produced by a relatively autonomous field of publication production and circulation.

- Secondly, agents differ in terms of volume of economic capital, which in our case manifests itself most clearly in the opposition between global and local players in the SPJ.

We hope that this paper offers a new and easy way of studying scientific journals to anybody who treats it mathematically. The prompted method differs from those usually employed.
Acknowledgment

The article was prepared within the framework of the Basic Research Program at the National Research University Higher School of Economics (HSE) and supported within the framework of a subsidy by the Russian Academic Excellence Project “5-100”.

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Appendix 1. Physics journals in the sample

1. ACOUSTICAL PHYSICS
2. ACS PHOTONICS
3. ACTA ACUSTICA UNITED WITH ACUSTICA
4. ACTA PHYSICA POLONICA A
5. ACTA PHYSICA POLONICA B
6. ACTA PHYSICA SINICA
7. ADVANCES IN CONDENSED MATTER PHYSICS
8. ADVANCES IN HIGH ENERGY PHYSICS
9. ADVANCES IN MATHEMATICAL PHYSICS
10. AMERICAN JOURNAL OF PHYSICS
11. ANNALEN DER PHYSIK
12. ANNALES HENRI POINCARE
13. ANNALS OF PHYSICS
14. APPLIED ACOUSTICS
15. APPLIED OPTICS
16. APPLIED PHYSICS A-MATERIALS SCIENCE & PROCESSING
17. APPLIED PHYSICS B-LASERS AND OPTICS
18. APPLIED PHYSICS EXPRESS
19. APPLIED PHYSICS LETTERS
20. APPLIED RADIATION AND ISOTOPES
21. ARCHIVES OF ACOUSTICS
22. BRAZILIAN JOURNAL OF PHYSICS
23. BULLETIN OF THE LEBEDEV PHYSICS INSTITUTE
24. CANADIAN JOURNAL OF PHYSICS
25. CENTRAL EUROPEAN JOURNAL OF PHYSICS
26. CHALCOGENIDE LETTERS
27. CHAOS
28. CHAOS SOLITONS & FRACTALS
29. CHINESE JOURNAL OF CHEMICAL PHYSICS
30. CHINESE JOURNAL OF PHYSICS
31. CHINESE OPTICS LETTERS
32. CHINESE PHYSICS B
33. CHINESE PHYSICS C
34. CHINESE PHYSICS LETTERS
35. CLASSICAL AND QUANTUM GRAVITY
36. COMMUNICATIONS IN COMPUTATIONAL PHYSICS
37. COMMUNICATIONS IN MATHEMATICAL PHYSICS
38. COMMUNICATIONS IN NONLINEAR SCIENCE AND NUMERICAL SIMULATION
39. COMMUNICATIONS IN THEORETICAL PHYSICS
40. COMPTES RENDUS PHYSIQUE
41. COMPUTER PHYSICS COMMUNICATIONS
42. CONDENSED MATTER PHYSICS
| 86. | INTERNATIONAL JOURNAL OF QUANTUM INFORMATION |
| 87. | INTERNATIONAL JOURNAL OF THEORETICAL PHYSICS |
| 88. | INVERSE PROBLEMS |
| 89. | IONICS |
| 90. | JAPANESE JOURNAL OF APPLIED PHYSICS |
| 91. | JETP LETTERS |
| 92. | JOURNAL OF APPLIED MECHANICS AND TECHNICAL PHYSICS |
| 93. | JOURNAL OF APPLIED PHYSICS |
| 94. | JOURNAL OF CHEMICAL PHYSICS |
| 95. | JOURNAL OF COMPUTATIONAL PHYSICS |
| 96. | JOURNAL OF EXPERIMENTAL AND THEORETICAL PHYSICS |
| 97. | JOURNAL OF HIGH ENERGY PHYSICS |
| 98. | JOURNAL OF INFRARED AND MILLIMETER WAVES |
| 99. | JOURNAL OF LOW TEMPERATURE PHYSICS |
| 100. | JOURNAL OF LUMINESCEENCE |
| 101. | JOURNAL OF MAGNETICS |
| 102. | JOURNAL OF MAGNETISM AND MAGNETIC MATERIALS |
| 103. | JOURNAL OF MATHEMATICAL PHYSICS |
| 104. | JOURNAL OF MODERN OPTICS |
| 105. | JOURNAL OF NANOPHOTONICS |
| 106. | JOURNAL OF NON-CRYSTALLINE SOLIDS |
| 107. | JOURNAL OF OPTICS |
| 108. | JOURNAL OF PHASE EQUILIBRIA AND DIFFUSION |
| 109. | JOURNAL OF PHYSICAL CHEMISTRY C |
| 110. | JOURNAL OF PHYSICS-CONDENSED MATTER |
| 111. | JOURNAL OF PHYSICS A-MATHEMATICAL AND THEORETICAL |
| 112. | JOURNAL OF PHYSICS AND CHEMISTRY OF SOLIDS |
| 113. | JOURNAL OF PHYSICS B-ATOMIC MOLECULAR AND OPTICAL PHYSICS |
| 114. | JOURNAL OF PHYSICS D-APPLIED PHYSICS |
| 115. | JOURNAL OF PHYSICS G-NUCLEAR AND PARTICLE PHYSICS |
| 116. | JOURNAL OF PLASMA PHYSICS |
| 117. | JOURNAL OF RHEOLOGY |
| 118. | JOURNAL OF STATISTICAL MECHANICS-THEORY AND EXPERIMENT |
| 119. | JOURNAL OF STATISTICAL PHYSICS |
| 120. | JOURNAL OF SUPERCONDUCTIVITY AND NOVEL MAGNETISM |
| 121. | JOURNAL OF SYNCHROTRON RADIATION |
| 122. | JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA |
| 123. | JOURNAL OF THE EUROPEAN OPTICAL SOCIETY-RAPID PUBLICATIONS |
| 124. | JOURNAL OF THE KOREAN PHYSICAL SOCIETY |
| 125. | JOURNAL OF THE OPTICAL SOCIETY OF AMERICA A-OPTICS IMAGE SCIENCE AND VISION |
| 126. | JOURNAL OF THE OPTICAL SOCIETY OF AMERICA B-OPTICAL PHYSICS |
| 127. | JOURNAL OF THE OPTICAL SOCIETY OF KOREA |
| 128. | JOURNAL OF THE PHYSICAL SOCIETY OF JAPAN |
| Journal Number | Journal Name |
|----------------|--------------|
| 129            | JOURNAL OF X-RAY SCIENCE AND TECHNOLOGY |
| 130            | LASER & PHOTONICS REVIEWS |
| 131            | LASER AND PARTICLE BEAMS |
| 132            | LASER PHYSICS |
| 133            | LASER PHYSICS LETTERS |
| 134            | LETTERS IN MATHEMATICAL PHYSICS |
| 135            | LOW TEMPERATURE PHYSICS |
| 136            | MAGNETOHYDRODYNAMICS |
| 137            | MECHANICS OF SOLIDS |
| 138            | METROLOGY AND MEASUREMENT SYSTEMS |
| 139            | MICRO & NANO LETTERS |
| 140            | MODERN PHYSICS LETTERS A |
| 141            | MODERN PHYSICS LETTERS B |
| 142            | MOLECULAR PHYSICS |
| 143            | MOSCOW UNIVERSITY PHYSICS BULLETIN |
| 144            | NANO |
| 145            | NANO LETTERS |
| 146            | NANO RESEARCH |
| 147            | NANOSCALE |
| 148            | NANOSCALE RESEARCH LETTERS |
| 149            | NATURE PHOTONICS |
| 150            | NATURE PHYSICS |
| 151            | NEW JOURNAL OF PHYSICS |
| 152            | NUCLEAR DATA SHEETS |
| 153            | NUCLEAR FUSION |
| 154            | NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION A-ACCELERATORS SPECTROMETERS DETECTORS AND ASSOCIATED EQUIPMENT |
| 155            | NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION B-BEAM INTERACTIONS WITH MATERIALS AND ATOMS |
| 156            | NUCLEAR PHYSICS A |
| 157            | NUCLEAR PHYSICS B |
| 158            | NUCLEAR SCIENCE AND TECHNIQUES |
| 159            | NUKLEONIKA |
| 160            | OPTICAL REVIEW |
| 161            | OPTICS COMMUNICATIONS |
| 162            | OPTICS EXPRESS |
| 163            | OPTICS LETTERS |
| 164            | OPTIK |
| 165            | ORGANIC ELECTRONICS |
| 166            | PHASE TRANSITIONS |
| 167            | PHILOSOPHICAL MAGAZINE LETTERS |
| 168            | PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A-MATHEMATICAL PHYSICAL AND ENGINEERING SCIENCES |
212. RENDICONTI LINCEI-SCIENZE FISICHE E NATURALI
213. REPORTS ON MATHEMATICAL PHYSICS
214. REPORTS ON PROGRESS IN PHYSICS
215. REVISTA MEXICANA DE FISICA
216. RHEOLOGICA ACTA
217. ROMANIAN JOURNAL OF PHYSICS
218. ROMANIAN REPORTS IN PHYSICS
219. RUSSIAN JOURNAL OF PHYSICAL CHEMISTRY B
220. RUSSIAN PHYSICS JOURNAL
221. SCIENCE CHINA-PHYSICS MECHANICS & ASTRONOMY
222. SEMICONDUCTOR SCIENCE AND TECHNOLOGY
223. SEMICONDUCTORS
224. SOLID-STATE ELECTRONICS
225. SOLID STATE COMMUNICATIONS
226. SOLID STATE IONICS
227. SOLID STATE SCIENCES
228. STUDIES IN HISTORY AND PHILOSOPHY OF MODERN PHYSICS
229. SUPERCONDUCTOR SCIENCE & TECHNOLOGY
230. SUPERLATTICES AND MICROSTRUCTURES
231. SURFACE AND INTERFACE ANALYSIS
232. SURFACE REVIEW AND LETTERS
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234. SYMMETRY INTEGRABILITY AND GEOMETRY-METHODS AND APPLICATIONS
235. SYNTHETIC METALS
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240. WAVE MOTION