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- 2 The impact factor fallacy
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Abstract

23 The use of the journal impact factor (JIF) as a measure for the quality of individual
24 manuscripts and the merits of scientists has faced significant criticism in recent years. We add to
25 the current criticism in arguing that such an application of the JIF in policy and decision making
26 in academia is based on false beliefs and unwarranted inferences. To approach the problem, we
27 use principles of deductive and inductive reasoning to illustrate the fallacies that are inherent to
28 using journal based metrics for evaluating the work of scientists. In doing so, we elaborate that if
29 we judge scientific quality based on the JIF or other journal based metrics we are either guided by
30 invalid or weak arguments or in fact consider our uncertainty about the quality of the work and
31 not the quality itself.

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Introduction

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The journal impact factor (JIF) was initially used to help librarians make decisions about journals (Garfield, 2006). However, during the last decades the usage of the JIF has significantly changed. In deviating from its original purpose it is now widely used to evaluate the quality of individual publications and the work of scientists (Amin & Mabe, 2003; Arnold & Fowler, 2010). Since then, the measure itself has been criticized for various reasons. For example, it is well known that the JIF is an inaccurate estimate for the expected number of citations of an article within a specific journal (Callaway, 2016; Larivière et al., 2016) and that it is relatively easy to manipulate (McVeigh & Mann, 2009; Tort, Targino, & Amaral, 2012). Nonetheless, the JIF has deeply affected the work of scientists and decision making in academia. Scientists get jobs, tenure, grants, and bonuses based on the impact of the journals they are publishing their manuscripts in, outgrowths' which were critically discussed in many previous reviews, comments and editorials (Brembs, Button, & Munafò, 2013; Casadevall & Fang, 2014; Della Sala & Crawford, 2007; DePellegrin & Johnston, 2015; Lehmann, Jackson, & Lautrup, 2006; Reich, 2013; Seglen, 1997; Simons, 2008; Werner, 2015). Notably, the JIF has also been explicitly referred to as a tool to decide how to distribute funds across institutions, for example in Germany (DFG, 2004), and thereby affects policy making on a much larger scale.

"For the calculation of the performance-based bonus of the unit providing the service (department or clinic) the original publications may be used with the unweighted impact factor of the publication organ, in the sense of a step-wise introduction of quality criteria.

52 Thereby, a first- and last authorship may be considered with one third each and the
53 remaining third can be distributed across all remaining authors [...]."¹
54 Besides such explicit usage of the JIF for evaluating scientific excellence, the JIF also
55 implicitly affects other measures which have been suggested to better approximate the quality of
56 a scientist's work or of a specific study (e.g. the h-index, Hirsch, 2005 and the Relative Citation
57 Ratio (RCR), Hutchins, Yuan, Anderson, & Santangelo, 2015). For example, there is some
58 evidence that the number of citations of an article is influenced by the JIF of the journal where
59 the article was published, regardless of the quality of the article itself (Callaham, Wears, &
60 Weber, 2002; Cantrill, 2016). This implies that measures that are based on the citations of the
61 individual articles are still influenced by the JIF of the publication organ. With the many different
62 ways of how the JIF can influence decision making in academia, it is not surprising that empirical
63 data now demonstrate the JIF to be one of the most powerful predictors for academic success
64 (Van Dijk, Manor, & Carey, 2014). We could recently show that some scientists may have
65 adapted to these reward principles in their environment by showing a greater reward signal in the
66 brain's reward structures in the prospect of an own high impact publication (Paulus, Rademacher,
67 Schäfer, Müller-Pinzler, & Krach, 2015).

68 In line with the rising initiatives to prevent the use of the JIF for evaluating the quality of
69 science (see e.g. the DORA initiative, Alberts, 2013, Cagan, 2013 or see the report of the German
70 Science Council, 2015), we have considerable doubts that the arguments in support of using the

¹"Für die Berechnung der LOM [leistungsorientierte Mittel; remark of authors] der jeweiligen leistungserbringenden Einheit (Abteilung bzw. Klinik) kann im Sinne einer stufenweisen Einführung von Qualitätskriterien die Bewertung erfolgter Original-Publikationen unter Verwendung des ungewichteten Impact Faktor der jeweiligen Publikationsorgane (JIF) erfolgen. Dabei können Erst- und Letztautorschaft mit je einem Drittel berücksichtigt werden; das verbleibende Drittel kann auf alle übrigen Autoren verteilt werden [...]" (German Research Foundation, 2004, p. 15).

71 JIF for measuring scientific excellence are justified. In this comment we want to look at the
72 problem of using the JIF from a different perspective and carefully (re)evaluate the arguments for
73 its use as an estimate of scientific quality. Thereby, we hope to better understand the beliefs about
74 the JIF that influence decisions in academia and the implications of policies that use the JIF to
75 assess and remunerate scientific quality. Beyond the specific case of the JIF, this exercise might
76 also help to specify more general misconceptions when using journal based properties to evaluate
77 science, in order to overcome incentive structures based on journal based metrics altogether.

78 **Deductive fallacy when using the JIF**

79 A basic belief when using the JIF for evaluating the quality of a specific manuscript
80 seems to be that (1) if a paper is published in a high impact factor journal (p) then the paper is of
81 high quality (q)². Why would scientists believe this? A straightforward reason is the idea that it is
82 more difficult to publish in a high impact factor journal because higher standards of research
83 quality and novelty have to be passed in order to be accepted. The average number of citations of
84 a journal's articles within in a specific time period signals the average breadth of interest in these
85 articles during that time period, which can of course be affected by many factors other than
86 research quality. But as a first approximation, let us suppose that belief (1) is the case. What can
87 we conclude from it?

88 If we see a paper published in a high impact factor journal, we could then draw the
89 deductively valid inference of modus ponens (MP: *if p then q , p , therefore q*)³ and conclude that

² When we speak of "high" and "low" impact in this paper, the arguments we make are independent of whether "high" and "low" refer to the absolute JIF of a journal, or to the JIF relative to a specific research domain.

³ Here p and q stand for arbitrary propositions. For example, p might stand for "This paper is published in a high impact factor journal" and q for "This paper is of high quality".

90 the paper is of high quality. But what if we see a paper published in a low impact factor journal?
91 Can we draw any conclusions in this case?

92 One aspect of the impact factor fallacy could be operationalized as the tendency to draw
93 the deductively invalid inference of *denial of the antecedent* (DA: *if p then q, not-p, therefore*
94 *not-q*). This inference is deductively invalid because it is logically consistent for the premises *if p*
95 *then q* and *not-p* to be true and yet the conclusion *not-q* to be false. When the premises of an
96 inference can be true and at the same time the conclusion false, the inference does not preserve
97 truth when going from premises to conclusion. In order to argue that the conclusion is not false in
98 a particular case, we would therefore have to go beyond this argument and provide further
99 information that might increase support for the conclusion.

100 For the more realistic case that the premises and conclusion are uncertain, such that they
101 can not only be either true or false, but can be held with varying degrees of belief, the inference
102 of DA is probabilistically invalid (p-invalid) because there are coherent⁴ probability assignments
103 to premises and conclusion for which the probability of the conclusion is lower than the sum of
104 the probabilities of the premises (Adams, 1998; Over, 2016). Therefore, just like in the binary
105 case DA does not preserve truth from premises to conclusion, in the probabilistic case DA does
106 not preserve probability from premises to conclusion, so that it would be warranted to have a high
107 degree of belief in the premises and yet a very low degree of belief in the conclusion. In order to
108 justify the conclusion in a particular instantiation of the argument, we would have to bring further
109 information into the discussion beyond that contained in the premises. Applied to the JIF
110 example, suppose we assume that if a paper is published in a high impact factor journal, it is of

⁴ Two statements are *coherent* if and only if they respect the axioms of probability theory. For example, these axioms state that if we believe it is 80% likely to rain, then in order for our beliefs to be coherent we should also be willing to believe that it is 20% likely not to rain, otherwise the probabilities involved would not sum up to 1.

111 high quality, and then encounter a paper that is published in a low impact factor journal. From
112 this alone it is not justified to conclude that the paper we encountered is not of high quality. In
113 order to draw such a conclusion we would require more information.

114 Denial of the antecedent (DA) is of course not the only inference one can draw on the
115 basis of the conditional belief that if a paper is published in a high impact factor journal, then it is
116 of high quality. A similar, deductively valid inference results if we add a further premise to DA:
117 "If a paper is not published in a high impact factor journal, then it is not of high quality". One can
118 combine this new conditional premise with the conditional premise that we already had: "If a
119 paper is published in a high impact factor journal, then it is of high quality", to obtain the
120 following biconditional premise: "A paper is published in a high impact factor journal if and only
121 if it is of high quality". From this biconditional premise (or equivalently from the two conditional
122 premises) together with the premise that a specific paper was not published in a high impact
123 factor journal, one can indeed validly conclude that the paper is not of high quality. However, this
124 inference will only be useful if one believes the biconditional premise to a non-negligible degree
125 in the first place. If the biconditional premise is implausible, then any deductively valid
126 conclusion based on it will also tend to be implausible, precisely because it follows logically
127 from an implausible starting assumption. Considering that most scientists are likely to agree that
128 it is not only implausible but false that a paper is of high quality if and only if it is published in a
129 high impact factor journal, the fact that the inference from this biconditional is valid has no use
130 for practical purposes.

131 **Inductive fallacies when using the JIF**

132 One could argue that deduction, and with it logical validity, has little impact on actual
133 reasoning and decision making outside of the mathematics classroom, and that therefore the
134 inferences we should be looking at when analysing the use of the JIF in the practice of science

135 should rather be inductive (Baratgin & Politzer, 2016; Chater, Oaksford, Hahn, & Heit, 2011;
136 Evans, 2002; Oaksford & Hahn, 2007).

137 An inductive inference that might describe well the use of the impact factor is the
138 informal fallacy of the *argument from ignorance* (or its Latin equivalent "ad ignorantiam"). This
139 argument tries to justify a conclusion by pointing out that there is no evidence against it. Typical
140 examples could be "No side effects were found for this treatment in clinical trials. Therefore this
141 treatment is safe" or "No one has proven that ghosts do not exist. Therefore ghosts exist" (Hahn
142 & Oaksford, 2007; Oaksford & Hahn, 2004, 2007). In the case of the JIF, if a paper comes from a
143 high impact journal this can be seen as a sign suggesting it is an excellent piece of work. But as
144 we saw above in the discussion of DA, this does not imply that if the paper was published in a
145 low impact factor journal this is a sign suggesting that the quality of the paper is low. A more
146 precise description of the situation would be that a low impact factor journal lacks the sign of
147 high quality that a high JIF provides. If a paper is published in a low impact journal then we have
148 less information about its quality, rather than having information suggesting that its quality is
149 low. It is an argument from ignorance to use the absence of impact factor based evidence for high
150 quality to conclude that a paper is of low quality.

151 However, the argument from ignorance is not always a bad argument (Hahn & Oaksford,
152 2007, 2012). Its strength depends on how informative the lack of information about something
153 being the case is in the situation at hand. Suppose we search a book in a library catalogue and do
154 not find it. In this case it is reasonable to use the lack of information about the book in the
155 catalogue to conclude that the book is not in the library. Similarly, if we look at a train timetable
156 and do not see a particular town listed, it is reasonable to conclude that the train does not stop in
157 that town. However, suppose we are planning a party and have invited the whole department, in
158 the hope that a particular person we are attracted to will attend. In this case a lack of information

159 indicating that the person will come does not warrant the conclusion that the person will not
160 come. Catalogues and timetables are fairly closed environments in which we can expect all
161 relevant information to be stated explicitly. But environments like those of social interactions or
162 research endeavours are typically more open, so that the absence of information about something
163 being the case simply does not warrant us to conclude that it is not the case. A consequence for
164 the JIF would be that low impact publications do not signal low research quality, but rather
165 uncertainty about the quality and the need to gather more information in order to be able to
166 determine research quality.

167 Two further inductive inferences that might be relevant in accounting for the use of the
168 JIF are the informal fallacies of the *argument from authority* (also called by the Latin name "*ad*
169 *verecundiam*"), and of the *ad hominem argument* (Bhatia & Oaksford, 2015; Hahn & Hornikx,
170 2016). The argument from authority tries to justify a conclusion by pointing out that some expert
171 or authority endorses the conclusion. Typical examples could be "Scientist x says that the
172 treatment is safe. Therefore the treatment is safe", "My parents say that Santa Claus exists.
173 Therefore Santa Claus exists" or "My peers say that clothing item x is great. Therefore clothing
174 item x is great". In the case of the JIF, a high impact factor of a journal would play the role of an
175 authority for the quality of the papers within it.

176 In contrast, the *ad hominem argument* tries to justify the rejection of a conclusion by
177 pointing to personal attributes of a person that endorses it. Typical examples could be "The new
178 treatment was developed by a person with no formal degree in the subject. Therefore the
179 treatment is not safe", or "A person without a driver's license says "don't drink alcohol while
180 driving". Therefore, it is false that you should not drink alcohol while driving". In the case of the
181 JIF, a low impact factor would be used to give a journal a reputation of low quality, and this low
182 quality reputation would then be transferred to the papers within it.

183 Like the argument from ignorance, the argument from expert opinion and the ad hominem
184 argument are not always bad arguments. Their quality varies as a function of how informative the
185 authority status, or the personal attributes of the instance endorsing them, is for the problem at
186 hand. Policy decisions are routinely based on the advice of experts, and there seems to be
187 agreement that this is a good thing to do, as long as the experts are really considered experts in
188 their field and their advice is not biased (Harris, Hahn, Madsen, & Hsu, 2015; c. f. Sloman &
189 Fernbach, in press). Dismissing an argument because of personal attributes of a person endorsing
190 it is often more difficult, because it has to be made plausible that those attributes are relevant to
191 the quality of the argument. For example, that one does not need to be a mother to be qualified
192 for being prime minister seems obvious, whereas a case of a person applying to a position against
193 gender discrimination, who in his private life beats his wife, is likely to be more controversial. In
194 the case of the JIF, we would have to justify why we think that a low impact factor indicates that
195 a particular journal is of low quality, and why this low quality can be transferred to a particular
196 paper within it. Such a judgment requires further information about the journal and about the
197 paper at hand to be justified, which is usually not provided. Thus, whereas a high impact factor
198 may add to the reputation of a journal, a low impact factor does not warrant a bad reputation, but
199 rather provides insufficient information about reputation (see Table 1 for examples of the
200 inductive and deductive fallacies as discussed here).

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202 Insert Table 1 about here

203 -----

204 Until now we have discussed inferences on the basis of the belief that if a paper is
205 published in a high impact factor journal, then it is of high quality. But although this belief can
206 sometimes be useful as a quick approximation or rule of thumb, it is often itself not warranted.

207 Not only because the mean number of citations of the papers in a journal is an indicator of the
208 average breadth of interest in these papers during the first years after publication, which is not the
209 same as research quality (e. g. a high quality paper may have low citation rates because it is
210 addressed to a small, highly specialised audience, or because its significance is only realised five
211 years after publication; and a paper may have high citation rates because of highly consequential
212 flaws within it). But more specifically, it is often not warranted because the inference from a
213 metric defined at the journal level to the features of an individual paper within that journal
214 involves an ecological fallacy.

215 **Ecological fallacy when using the JIP**

216 Finally, the evaluation of manuscripts based on the JIF bears an ecological fallacy. When
217 comparing group level data, such as the average citations of journals, it is difficult up to
218 impossible to infer the likelihood of the outcome for comparisons on the individual level, such as
219 citations of manuscripts. In fact, it is relatively easy to think of examples where the likelihood to
220 find a manuscript with more than twelve citations per year in a lower impact journal exceeds the
221 likelihood of finding such manuscript in a higher impact journal. This type of ecological fallacy
222 occurs when the distribution of citations is heavily and differentially skewed within each higher
223 level unit, i.e. the journals. This is typically the case when it comes to citation rates of journals
224 [see e.g. Lariviere et al., 2016]. Accordingly, a journal with a JIF of twelve might contain few
225 manuscripts that were cited several hundred times in the previous two years, but many others that
226 were not cited at all during the same period. Such a citation pattern would result in a heavily
227 skewed distribution of citations per article, while another journal with a JIF of ten might have a
228 normally distributed citation rate of articles for the same time period. Without further knowledge
229 of the distribution of citations within the journals in a given year (i.e. information at the
230 individual level) concluding that a manuscript in the journal with a higher JIF is of better quality

231 (or of broader interest) involves an ecological fallacy, because it is possible that the likelihood of
232 finding a manuscript with more citations in the lower impact journal is in fact similar or even
233 higher.

234 **Concluding remarks**

235 With this comment, we hope to have highlighted some misconceptions in the beliefs and
236 arguments involved in using journal based metrics, and specifically the JIF, for evaluating the
237 work of scientists. While some of the thoughts described here are introduced to illustrate the most
238 controversial arguments, others better approximate the reality of decision making in academia. In
239 this exercise, it is surprising to see many political and academic institutions as well as scientists
240 having believed for so long that they are evaluating the "quality of science" while they are keen
241 to provide weak arguments, draw invalid conclusions, or weigh their lack of information and
242 uncertainty about the subject when using the JIF.

243 From an economic perspective, however, it might in fact be a successful strategy to
244 minimize the uncertainty about the quality of the evaluated work, person, or institution by relying
245 on the JIF, and it might also be better to have a weak argument than to have no argument.
246 Evaluating the quality of a scientist's work surely is a time consuming process and it takes much
247 more effort than simply comparing impact factors. Accordingly, deans, commissions, or
248 institutions which might not have the resources for an actual assessment of "scientific excellence"
249 have reasons to rely on the JIF. However, it should be clear that those decisions are not based on
250 the *quality* of the scientific contribution per se but, optimistically, somehow integrate the
251 *availability of information* about the quality. This distinction makes an important difference for
252 communicating and justifying decisions in academia. As an illustrative example, one can
253 compare the situation of deciding that a candidate does not deserve tenure because one thinks that
254 the quality of the work was not good enough, to deciding that a candidate does not deserve tenure

255 because one lacks information and is uncertain whether the quality of the work was good enough.
256 While persons and institutions usually *communicate* as if they were following the first argument,
257 their *justification* most often implies the latter if they base their decisions on journal based
258 metrics.

259 The JIF is arguably the most popular journal based metric of our times, but it has already
260 been subject to severe criticism in the past (Della Sala & Crawford, 2007; DePellegrin &
261 Johnston, 2015; Lehmann et al., 2006; Reich, 2013; Seglen, 1997; Simons, 2008; Werner, 2015).
262 As a result, it seems that individuals and institutions within the scientific community are ready to
263 shake off the JIF at some point in the nearer future (Alberts, 2013; Cagan, 2013; Callaway,
264 2016). Notably, the problems described here apply in one way or another to any journal based
265 assessment. If journals would drop out of the ‘impact factor game’ (PLoS Medicine Editorial,
266 2006) publications in some journals might still be regarded as more valuable than in others. It is
267 difficult to quantify those influences, but having a publication in one of the ‘golden club’ journals
268 (Reich, 2013) could simply replace the metric of the JIF with another, more implicit qualitative
269 measure for distinguishing prestigious from less prestigious journals. Thereby, the fallacies and
270 problems described above would continue to govern decision making in academia as long as we
271 base them on any kind of journal based assessment.

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Tables

Table 1. The deductive and inductive fallacies discussed in this paper.

Name	Form	Plausible Example	Implausible Example	Journal Impact Factor Example
Deductive fallacy				
Denial of the antecedent	<i>If p then q. Not-p. Therefore not-q.</i>	If the glass falls down then it breaks. The glass does not fall down. Therefore, the glass does not break.	If you carry an umbrella then you stay dry. You do not carry an umbrella. Therefore, you do not stay dry.	If a paper is published in a high impact factor journal, then it is of high quality. This paper is not published in a high impact factor journal. Therefore, this paper is not of high quality.
Inductive fallacies				
Argument from ignorance	<i>It is not known that p is true (false). Therefore p is false (true).</i>	The book is not listed in the library catalogue. Therefore, the book is not in the library.	No one has proven that ghosts do not exist. Therefore, ghosts exist.	This paper does not have the quality sign of having been published in a high impact factor journal. Therefore, this paper is not of high quality.
Argument from authority	<i>This expert says that p is true. Therefore p is true.</i>	Medical experts say that this treatment is safe. Therefore, this treatment is safe.	My parents say that Santa Claus exists. Therefore, Santa Claus exists.	This paper does not have the authority backing of having been published in a high impact factor journal. Therefore, this paper is not of high quality.
Ad hominem argument	<i>This untrustworthy person says that p is true. Therefore p is false.</i>	A person without training says that this treatment is safe. Therefore, this treatment is not safe.	A person without a driver's license says "don't drink alcohol while driving". Therefore, it is false that you should not drink alcohol while driving.	This paper was published in a journal with low quality reputation due to a low impact factor. Therefore, this paper is not of high quality.