The Use and Misuse of Statistics in Research: Theory and Practice

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ABSTRACT

Purpose: *The article discusses whether the use of statistical approaches is a real necessity or a publication bias, resulting from the adoption of the structure of experimental and basic research articles by most journals under the positivist influence.* Methodology: *The analysis differentiates, based on the depth of research, between studies (mostly published by 2nd tier journals) and research (usually published by the 1st tier journals) using different examples from the scientific literature of several fields.* Main findings: *The analysis shows that the use of statistics is embedded in the positivist approach governing basic and experimental research. For the other areas, the use of statistics is determined merely by the depth of research rather than being a publication bias.* Value: *This research can serve as a basis for researchers willing to better off their activity and publish in 1st tier journals, understanding the need for quantitative research. Recommendations: Modern research should use a methodology including the statistical analysis of data in order to support the strength of findings.*

Key words*: positivism, hypothesis, measurement of science, publication bias, evidence*

JEL classification*: C, Y*

1. INTRODUCTION

1.1. General context

This article is triggered by the "conversation" with a reviewer, related to a certain submission. "[Reviewer] Despite the reported aims of the paper, no statistical analysis is applied or models are implemented to the data to reveal the links..." "None of the declared goals [...] refers to applying a statistical approach or model. To clarify, [...] was inserted to show that the aim is not to produce a statistical or mathematical approach." "I suggested how to improve the work, abandoning the old-fashioned analysis of underlying causes [...] without statistical evidence." "A statistical approach was developed [...]. It is discussed in lines [...]." The approach consisted of a t-test that did not yield any significant results, but the paper was accepted. Obviously, the story raises

the question whether the 'modern' use of statistics is really a necessity or a publication bias.

The debate is not new and relates to the positivist approach (Keat, 1979), consisting of a certain structure of the research process and even of scientific reasoning: based on empirical observations and a review of the literature, the author develops one or more hypotheses; they are tested by experiments, resulting into data, which are analyzed using statistical methods (Petrişor, 2010; Petrişor and Mitrea, 2018). The validity of results is determined by the results of analysis of statistical data resulting from the experiments (Petrişor, 2010). As a consequence, the research articles start with an introduction introducing the context defined by the existing literature, moving gradually to a statement of the hypotheses; the methodological section describes the methods used to test them and the final section presents the experimental results discussed against the original hypotheses (Meheus, 1999; Petrişor and Mitrea, 2018).

The positivist approach has been successfully applied to experimental sciences in particular and basic research in all fields in general, and most publications adopted the structure of articles determined by the model, including the use of statistical analyses as part of the 'core' methodology, and then moved gradually to the social sciences and other fields. In this process, the use of experiments and statistical analyses was used as a criterion from discerning 'science' from 'non-science' (Keat, 1979).

1.2. Positivism

1.2.1. Positivism and the positivist method

Positivist appeared in the illuminist period of the Renaissance (Ryan, 2006; Farr, 2012); the scientific progress during this period is often explained by the positivist approach of causal analysis (Farr, 2012). This is attributed to Comte, the founder of sociology, who starts to apply the methods of experimental biology to human populations (Ryan, 2006; Farr, 2012) in order to obtain scientific information in an objective manner (Farr, 2012). The causal analysis makes a difference between the teleological question – 'Why?' and the mechanicist one – 'How?' (Louca *et al*., 2004). 'Why?' is answered by a condition hypotheses phrased as "A involves B" (Caldwell, 1980), tested using a hypothetical-deductive model where new scientific statements are validated by deriving verifiable knowledge and comparing it with the observations (Meheus, 1999). As a consequence, positivists consider that the complete understanding of phenomena must rely only on observations and experiments (Ryan, 2006).

In the positivist philosophy, science starts with the development of hypotheses (Meheus, 1999) based on prior observations and an exhaustive

study of the literature. To test the validity of hypotheses, positivist design experiments using objective, empirical, scientific and reproducible methods, usually quantitative (Meheus, 1999; Ryan, 2006), resulting into data analyzed using statistical methods. The statistical tests can sustain the hypothesis, but can never prove it to be true. Nevertheless, hypotheses can be proven to be false (Dragomirescu, 1998; Petrişor, 2010). The results are supported by inner validation against the hypothesis, and by outer validation, against the results of similar studies (Petrişor, 2014; Petrişor and Mitrea, 2018). This flow results in the structure of articles (Petrişor and Mitrea, 2018).

Some of the important features of positivism are the premises that only the problems of the public realm are worthy of being investigated, and knowledge is discovered, but not produced by the researchers (Ryan, 2006). Others include the premises that new statements cannot be derived directly from the observations, the procedures used to develop knowledge do not provide arguments for accepting or rejecting hypotheses, and some methods are more efficient than the others (Meheus, 1999). With respect to applying the methods, the researcher must not involve his ego in research; for this reason, mathematics, sciences and technology have a special status, as they are objective and separated by personal and private interpretations (Ryan, 2006).

1.2.2. Studies versus research

Although the dictionaries do not make a clear difference, research and studies are different. In fact, the difference is the one between research and non-research. Two definitions were chosen as the difference is usually suggested, although it is not obvious. Research is the "*investigation or experimentation aimed at the discovery and interpretation of facts, revision of accepted theories or laws in the light of new facts, or practical application of such new or revised theories or laws*" (Merriam-Webster, 2004, p. 1059), and studies consist of the "*application of the mental faculties to the acquisition of knowledge*" (Merriam-Webster, 2004, p. 1239). In more details, studies use existing methods to check an existing theory in a new area or using a new sample. Their scientific impact is limited, funding less likely to obtain, and results hard to publish (Petrişor, 2014; Petrişor and Mitrea, 2018). The research embeds innovation (Meheus, 1999), methodological or theoretical, has a higher impact, can obtain funding and results are easier to publish (Petrişor, 2014; Petrişor and Mitrea, 2018). Studies can be part of a research aimed to check a theory when the research process is organized on more directions, each of which is a study. The common perception of research is described by words including: data, figures, statistics, publications, evaluation, objectiveness, science and logic (Ryan, 2006).

In the European Union, the legal classification distinguishes between fundamental research – "*experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any direct commercial application or use in view*", industrial research and technological development (European Union Commission, 2014). The classification suggests that what is commonly understood by research corresponds to the fundamental research; it can be inferred that industrial research and technological development can lead at most to studies. In a broader context, a 2011 article states that "*in developing countries, research is often concerned with investigating or addressing local or national issues and problems*" (Al-Suqri and Lillard, 2011). Speculating further, such concerns lead to studies and not to research.

1.2.3. Criticisms of the positivism

The privileged status of some fields, mentioned above, started vivid criticisms, especially after 1950, when the positivist approach started its domination of natural and social sciences (Caldwell, 1980), and, consequently, the acceptance (and publication) of results was conditioned by using the hypothesis – experiment – (quantitative) analyses. The first were related to the very genesis of the positivist method. Social scientists argued that the uniqueness of individuals questions the results obtained from a sample to the entire population because it assumes that the sample is uniform (Farr, 2012). Moreover, the method can be hardly applied to non-scientific areas; for example, science and theology are two fundamental elements of the knowledge effort, yet different in terms of language and methods (Boldur-Lăţescu, 2012).

Other criticisms come from logic and philosophy. For example, sometimes the hypothesis is sometimes simple, but in other cases it is a whole theory. What does its partial confirmation mean in the last case? Furthermore, there are no one-to-one correspondence of theoretical and non-observable or non-theoretical and observable terms, no clear distinction between observable and non-observable, and the observation itself requires a selection and interpretation of the researcher, meaning that the ego is involved. Last but not least, the legitimacy of explanations phrased by the researcher is questionable (Caldwell, 1980).

1.3. Statistics

1.3.1. The multiple statistics

A good way to introduce several meanings of statistics is the perhaps overused quote attributed usually to Mark Twain, "There are three kinds of lies: lies, damned lies, and statistics." Most people would take the statement

as a lack of consideration for statistics, but in fact the statement relates to two sides of statistics – data and their analysis, with the second being twisted to sustain certain arguments (Huff, 1993).

The commonly acknowledge sides of statistics are:

1. Statistics as a science. This side corresponds to mathematical statistics, a mathematical branch related to theory of probabilities, responsible for the substantiation of the statistical tools (tests) used in data analysis, but also for the 'set of rules' for their proper and honest application.

2. Applied statistics. This side of statistics is mostly known as "data analysis". The most used side is the inferential statistics, including the estimation theory, hypothesis testing, and experimental design (including the sampling theory).

3. Statistics as mathematical instruments (most usually tests). A statistic is a formula used, again, in the data analysis.

4. Data or results. This version is mostly used in the Balkan and former Soviet countries (Akhabbar and Allisson, 2014), with the common image of the 'zemstvo' statistician – portrayed by Anton Chekhov's Ivan Alexeevich Ognev (Bartlett, 2014). The image ties also to the common understanding of statistics as results of the data analysis (values, numbers, figures) or simple presentation of data (including charts and tables), such as the census data.

1.3.2. The misuse of statistics

In the view of the positivist approach, the "appropriate" use of statistics requires the dialogue with the statistician before and after the experiments. In the first place, the researcher should already know what is expected from the data analysis, and in the second place the dialogue translates the statistical jargon into the language of his fields (Petrişor, 2014). In other words, in the first case the researcher should know, for example, which sample should yield higher values after the comparison, and after the analysis of data he should be able to explain the theoretical meaning of the fact that the results proved, upon the statistical analysis, that the second sample yielded the larger values.

Unfortunately, in many of these cases, the chain is broken. In the 'happier' case, researchers come to the statistician presenting him a bunch of data, which most needs to be arranged in order to be used by the statistical program, without knowing what they want to get out of it. If they know, the statistician is usually approached with "make this data show that [...]." Again, this is the happier situation, but unfortunately with the extensive use of the Internet, there are researchers who do no longer need a statistician. By reading other papers they know what software and methods were used; they

can use the software to get some results, and read some papers who interpreted more or less similar results and 'copy the idea', disregarding completely the mathematical conditions required by each test.

The situation described above applies to researchers who are willing to publish their research in a higher-level journal, which requires to some extent the analysis of data. However, there are numerous second-tier journals, which do not require more than a pseudo-scientific appearance, e.g. the 'statistics' seen through tables, charts etc.

1.4. Research objectives

This article is exploring the use and misuse of statistics in the research carried out by different fields, trying to explore whether the mimicked used of pseudo-statistical approaches is a consequence of the publication bias imposing the use of statistics under the positivist influence.

2. METHODOLOGY

The analysis of the theoretical context showed that the essential difference between research and studies are that the first answers to the "why" question, and the later to "how". In order to answer "why", the positivist method phrases hypotheses tested by experiments and data analysis. This is also the structure of articles. The mainstream publishers prefer research to studies due to its impact.

For each point – titles, results and discussion, and references – the case studies oppose "studies" to research. Instead of taking and analyzing an entire article, the presentation is based on illustrative samples, taken from second-tier Romanian journals and the equivalent international correspondent. In this choice, the first tier is represented by journals listed with Thomson-Reuters having an impact factor or with Scopus, considered 'mainstream', and the second tier by journals that do not meet this criterion.

3. RESULTS

3.1. Titles

The difference between study and research is the one between "how" and "why"; this is visible in the titles and introduction. Table 1 presents several representative titles of articles published in journals from the same field, and Table 2 compares the very beginning of introduction.

Comparison of representative 1st and 2nd tier titles from the same field

Table 1

Field	2nd tier	1st tier
Sociology	*The economic activity rate of the Romanian population. Level and aims* [in Romanian] (Simion, 2012)	*Financial consequences of relationship dissolution: A longitudinal comparison of formerly married and unmarried cohabiting men and women* (de Regt *et al*., 2013)
Geography	*Characteristics of the wind in the Bârsa Depression* (Sandor, 2012)	*The demographic drivers of future ethnic group populations for UK local areas 2001-2051* (Rees *et al*., 2013)
Architecture and civil engineering	*Tudor Office Center, Iaşi* (Florea, 2012)	*Dynamic characteristics of a damaged nine-story building during the 2011 off the Pacific coast Tohoku earthquake* (Tsamba *et al*., 2012)
Zoology	*The parasitoid complex of Eupoecilia ambiguella (Lepidoptera: Tortricidae) in a vineyard of southern Romania* (Bărbuceanu and Andriescu, 2012)	*Patterns of parasitism in insular lizards: effects of body size, condition and resource availability* (Garrido and Pérez-Mellado, 2013)

To illustrate the difference, two titles, "*The parasitoid complex of Eupoecilia ambiguella (Lepidoptera: Tortricidae) in a vineyard of southern Romania*" (Bărbuceanu and Andriescu, 2012) and "*Patterns of parasitism in insular lizards: effects of body size, condition and resource availability*" (Garrido and Pérez-Mellado, 2013) are discussed. Both articles deal with the same biological issue, parasitism, both differ substantially. The Romanian title clearly states where the research was performed (south of Romania), while the foreign title has a vague reference to location, but very generalizing: insular areas. Second – and most important – the Romanian title does not state the biological issue investigated, while the foreign title is focused on it – analysis of the effects of size, environmental conditions and availability of resources aimed at classifying the different forms of parasitism. This last difference distinguishes between a study (the Romanian title, focused on the site where the study was carried out) and research (the foreign title focused on the research issue investigated). Most likely, if the Romanian author had sent the article to the foreign journal, the article would have been rejected, with the suggestion to submit it to a local or regional journal. The research reasoning beyond this rejection is the question: why would some researcher argue that the parasitoid complex *Eupoecilia ambiguella* in a vineyard from southern Romania would differ from the same complex from a French vineyard so much that the location needs to be stated instead of *what* was the object of investigations performed using that complex?

The zoological example was chosen as the most striking. According to the criticisms of positivism, biology is a field where the application of the positivist approach is very appropriate because geographical differences do not influence the validity of results. Nevertheless, the pattern repeats for all the other fields. The title of the Romanian sociology article does not state an issue (*what* was studied with respect to the rate of economic activity), but specifies the place where the study was carried out. The geography article (please note that geography is a science of the place) specifies the object, but also in the terms of a study: characteristics of the wind, but not in a causal relationship with the factors influencing them, as the foreign title. At the same time, the foreign title attempts to generalize (local areas situated in the United Kingdom). In architecture (and civil engineering), the Romanian title suggests the name of a project, while the foreign one specifies *what* is studied.

Furthermore, this issue is fundamental for further statistical analyses. An article focused on *why* needs a statistical methodology for future generalizations of the case studies analyzed within; an article presenting a study ("*what*") does not need any statistical tools for this purpose.

Comparison of representative 1st and 2nd tier introduction from articles on the medicinal plants

Table 2

2nd tier	1st tier
Oltenia is a region situated in the South-West of Romania, between $22^0 1'$ and $24^0 51' E$ longitude, and $43^0 42'$ and $45^0 38' N$ latitude, occupies the area of approximately 30 000 km^2, with elevations ranging from 0 (Danube River) to 2518 m (Parang Mountains), and has corresponding moderate or excessive continental and Mediterranean climates. About 50% of population is engaged with farming... (Tiţă *et al*., 2009)	*Humans have used plants as therapeutic agents from pre-historic times (Solecki and Shanidar, 1975). Since then, out of estimated 250,000 flowering plant species in the world (Cronquist, 1981), 15% have been evaluated phytochemically and only 6% have been screened for biological activity (Verpoorte, 2000)...* (Budovsky and Fraifeld, 2012)

In the introduction, most studies start abruptly by presenting the (methodological) steps, results and conclusions. A research starts with the theoretical background, using the previous literature to build up a research question or hypothesis. The next chapters present the methods (of testing the hypothesis), results (including discussions on their theoretical value, *i.e.*, the internal and external validation), and conclusions.

The *first* sentences of the 2nd tier article describe the study area in a geographical manner, perhaps appropriate for the era of discovering new continents. In contrast, the foreign journal presents the importance of

medicinal plants creating a context meant to emphasize the importance of the research described. Again, huge differences are visible among the two.

3.2. Presentation and discussion of the results

A research article must not only present, but also discuss the results. The discussion is first aimed at validating the results. The inner validation means whether the results confirm the research hypothesis or not (in the last case, possible explanations are also required). The external validation consists of comparisons with the results of similar studies (Petrişor, 2014). In addition, the researchers must also state the limits of their study, suggesting future directions (although some researchers believe that the exposure of limits decreases the value of their study).

2nd tier articles are different in this case too. Table 3 compares two similar articles, discussing the effects of the activity of earthworms on plants. The 2nd tier article *presents* the articles without discussing them or showing their epistemological value. The foreign article includes a presentation of results (the increase of biomass +11% where earthworms had a higher density), but also an explanation (correlation with the +35% increase of the shoot biomass) and their epistemological value (direct correlation of biomass and productivity) underlined by other similar studies (e.g., "Tilman *et al*., 1997" etc.)

Comparison of representative 1st and 2nd tier presentations of results from articles on the effects of the activity of earthworms on plants

Table 3

2nd tier	1st tier
Biological productivity of the soil layers in 2007 was high at the level 0–10 cm, with a maximum value of (4.03 mg.d.s./m^2) for Octolasion lacteum species, followed by Eisenia lucens (0.9 mg.d.s./m^2) and Aporrectodea rosea rosea (0.641 mg.d.s./m^2). A high biological productivity was recorded at levels 10-20 cm and 30-40 cm in Octolasion lacteum species. The lowest biological productivity was recorded in the litter, where the biomass was also low... (Brînzea, 2012)	*The results of the present study underline the positive diversity–productivity relationship (e.g. Tilman et al. 1997; Hector et al. 1999; Hooper et al. 2005) by showing increasing shoot biomass of the plant community with increasing plant species and functional group richness. A previous study using all experimental plots of the Jena Experiment reported transgressive overyielding due to both complementarity and selection effects (Roscher et al. 2005). However, total shoot biomass of the plant community was increased in subplots with higher earthworm density (+11%) which was primarily due to an increased shoot biomass of legumes (+35%)...* (Eisenhauer *et al*., 2012)

The question of using statistical methods is obviously exemplified by the comparison. The 2nd tier article presents some figures, without comparing

them to similar studies. It seems to be focused on offering a snapshot of *what* was found on the study site. The 1st tier article answers the question "*Why* are earthworms beneficial to the plants", and relies on a comparison of samples taken in the presence and absence of earthworms.

3.3. Consequences over the reference list

Although the extensive use of citation metrics has some shortcomings, including the unethical behaviors mentioned in a 2007 article [15], unless their number is increased artificially (auto-citation, citation stacking etc.), citations can prove the value of an article. Perhaps surprising for Romanian researchers, when new and original results are presented, a rich list of relevant citations increase the value of a paper by showing that authors know the research in their field and emphasize the value of their own contribution in the context of what has been done. For this reason, most citations are found in the introductory literature review and in the discussions aimed at the external validation of the results.

However, Romanian articles are poor in citations. Apart from misconceptions ("many citations mask the author's original contribution", "my research on this particular topic has not been done by others who can be cited"), this is a simple consequence of the previous issues. As long as the introduction focuses on presenting the study area and the article describes mechanically the research flow and results, answering to "how" instead of "why", the articles cannot be related to the broader mainstream literature. Similarly, as long as the results are presented without being analyzed and validated, especially by comparisons with other studies, the article will lack the appropriate references to similar studies.

4. CONCLUSIONS

The article was aimed at examining whether the use of statistical methods is a real necessity or publication bias by performing a qualitative analysis of the scientific literature, including a comparison of 2nd and 1st tier publications. While it is clear that statistical tools *must* be used in basic and experimental research, the question addresses more the *studies* published in 2nd tier journals, especially from areas where qualitative research co-exists with the quantitative tools.

The analysis revealed that the publication in 1st tier journals is conditioned by the application of statistical tools in the analysis of data, 2nd tier journals still publish 'statistics' including simple presentations of data or descriptive statistics of these. However, the need for quantitative approaches is not necessarily a publication bias, but is actually connected to the depth of

research. Therefore, if a researcher has pertinent research and wants to present them in a 1st tier journal, she or he must prove the validity of results by the means of statistical analyses.

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