BRAZILIAN HEALTH SCIENCES: PRODUCTION AND IMPACT FROM 1981 TO 1995

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Palabras Clave: Health Science Measurements of production

Resumen Ensuing a previous study of Brazilian sciences production for the period 1981-95, health sciences were taken apart for scrutiny. ISI data was obtained in an aggregate format comprising 40 health research fields recording their yearly number of papers, proportion out of the country, proportion out of the field, and impact relative to field.

Simple linear regression was used to examine time trends in production and impact of research fields. A complementary variable representing growth trend was computed as the regression slope. Data were then analysed by means of Factor and Correspondence Analysis. Results allowed the production of location maps of research fields so that hierarchy and relationships among them could be examined in the form of geometric distances.

It was found that health sciences represent 42% of the Brazilian scientific production and that their trends in both production and impact do not differ from other sciences taken altogether. Measurements of production were found negatively correlated with impact and factor analysis revealed that the major distinction between fields is attributable to production (64% of measurement variations against 19% due to impact). Experimental Biology & Medicine largely exceeds other fields in production, though at ordinary levels of impact. Correspondence analysis refined the study of impact allowing the identification of the best performers as Clinical Immunology & Infectious Diseases, Environmental & Social Medicine, and Radiology & Nuclear Medicine.

The information provided can advise national policy makers on science & technology about priorities concerning the improvement of the country’s competitiveness.

Introduction

The present study ensues a formerly published analysis of Brazilian sciences[1], and focus on health sciences as a corollary of its results. Indeed, health related fields as Biology & Biochemistry, Clinical Medicine, and Molecular Biology & Genetics were among the fields of highest productivity. The level of data aggregation then used, though adequate for a large view of the country's scientific profile, could not unveil the role of health disciplines of lower levels.

The importance of health sciences in a country's structure of science & technology has been concurrently reassured by recent foresight exercises conducted in different countries of the world. Indeed, in 1996, the Organisation for Economic Co-operation and Development[2] reported the experiences of Japan, Germany, France, Australia, the Netherlands, and the United Kingdom, and in all these countries health sciences came out as a priority. It is expected that the Brazilian Government will be conducting its foresight study by next year, and thus information on the state of affairs in health sciences should be opportune and useful.

Sikka[3], studying the development of science and technology in India and Brazil, indicates that both countries have been building up competencies for a competitive integration to global economy. Health sciences have an important participation in Brazilian scientific production and its potential contribution to the economic and social development of the country is unequivocal. Leta and DeMeis[4] have found that Brazilian scientific production is increasing its participation in the global total and estimate that life sciences as a whole represent some 58% of the domestic production. Marton et al.[5], studying European countries, recently concluded that intensity of production is highly correlated with effectiveness, and therefore one could expect that in Brazil quality would be increasing as well. Nevertheless, this might not be true for developing countries and, in Brazil, Meneghini[6] suggests that impact of the scientific production is related with opportunities of collaboration with international partners.

Herein health sciences will be examined in regard to production and impact, with a multivariate approach as to elicit patterns within the country.

Material and methods

Databases were purchased from the Institute for Scientific Information (ISI) by the Brazilian Ministry of Science and Technology and kindly provided to investigators by Mr. Luiz Antonio Barreto de Castro, Attaché for Special Programmes. The ISI 'de luxe' database, covering the period of 1981 to

1995 for Brazil, included 102 research fields, 40 of which belonging to health sciences. The following variables were recorded broken-down by year and research field:

1. Number of publications;
2. Percentage of papers out of the field;
3. Percentage of papers out of the country;
4. Impact relative to field (rate of the mean number of citations per paper in the field out of Brazil and its global equivalent).

Time trends in research fields were examined through simple linear regression for number of publications and impact relative to field. Additional variables to account for trends in the form of regression coefficients were considered from this analysis.

The methodology applied in the preceding study of Brazilian sciences was kept, which is application of Factor Analysis[7] and generation of a location map of research fields. In addition, Correspondence Analysis was used to explore patterns of impact for research fields and to provide a supplementary map of research field performances. Categories of impact performance were drawn from analysis of the data frequency distribution for the whole period, and devised as 'bellow national average', 'above national average', and 'above international average'. While Factor Analysis deals with data as a continuous spectrum of values, Correspondence Analysis[8] take into account the mass of data belonging to critical categories. Thus, the results of each analysis should be complementary to each other and final information should be enhanced.

Results

During the period of 1981 to 1995, 56,128 papers from Brazil were identified, 23,804 (42.4%) belonging to health sciences. Simple linear regression resulted suggestive that the Brazilian production in health sciences is significantly increasing at a rate of 125 paper/ year ($r = .97$, $p = .000$). In contrast, the impact relative to field is fairly stable around a mean of 0.57 (slope = .009, $r = .65$, $p = .008$). Figures 1 and 2 show trends over the period studied.

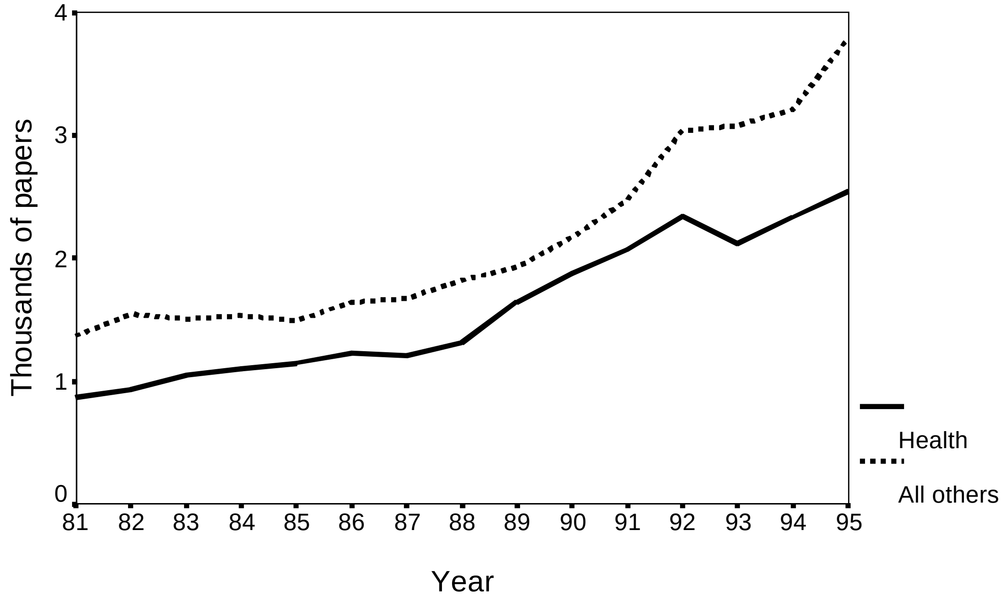

Figure ¡Error!Argumento de modificador desconocido. **- Brazilian scientific production in health and other sciences, 1981 to 1995**

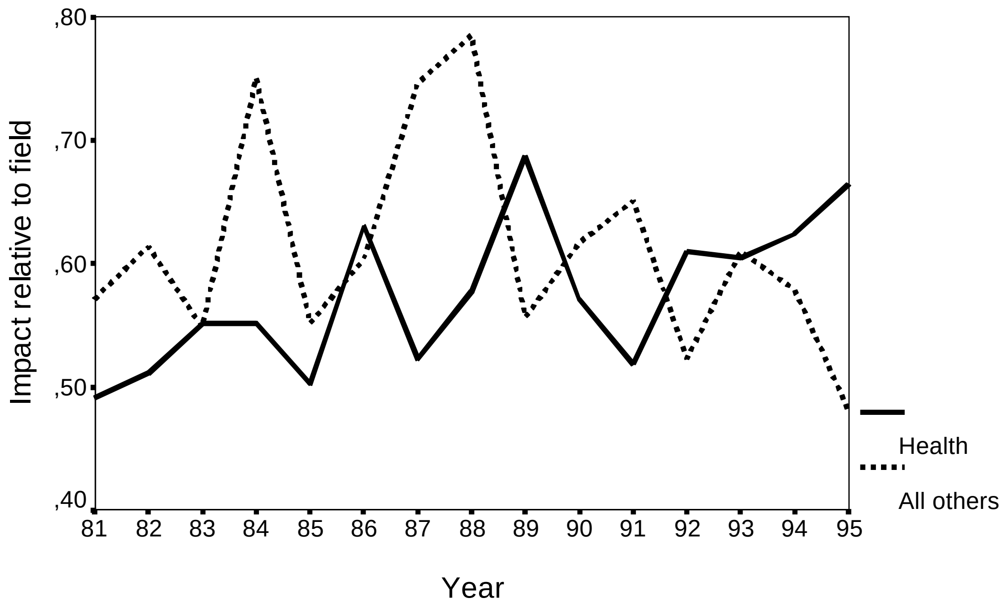

Figure ¡Error!Argumento de modificador desconocido. **- Annual mean impact of Brazilian production in health and other sciences, 1981 to 1995**

Accordingly, impact trend was disregarded as a variable. Table 1 describes the variables considered for multivariate analysis of health research fields.

Table ¡Error!Argumento de modificador desconocido. **- Aggregated information on Brazilian health research fields, 1981 to 1995**

Research Field	Total number over the period	Yearly growth trend (regression slope*)	Mean yearly impact relative to field	Mean yearly proportion out of the country	Mean yearly proportion out of the field
1. Anaesthesia & Intensive Care	41	.26⊗	.36	.08	.09
2. Biochemistry & Biophysics	1688	7.01	.42	3.49	.42
3. Biology	1929	8.35	.17	3.98	2.76
4. Biotech & Appl Microbiology	354	3.30	.60	.65	.86
5. Cardiovasc & Resp Systems	663	4.52	.63	1.29	.42
6. Cell Biology	622	2.85	.26	1.28	.45
7. Clin Immun & Infect Disease	284	2.72	1.17	.52	.52
8. Clinical Medicine	1627	8.88	.62	3.26	.29
9. Clinical Psychol & Psychiat	86	.67	.68	.17	.18
10. Dentistry/Oral Surgery & Med	212	1.90	.64	.39	.51
11. Dermatology	89	.34⊗	.73	.19	.19
12. Endocrinology	268	1.69	.44	.53	.38
13. Environmental & Social Med	406	1.50	.97	.85	1.04
14. Exp Biology & Medicine	4778	31.60	.31	9.30	1.18
15. Gastro and Hepatology	110	.49	.54	.23	.19
16. General Medicine	1030	-3.37⊗	.44	2.47	.38
17. Hematology	74	.79	.26	.13	.18
18. Immunology	785	6.40	.64	1.49	.47
19. Medical Tech & Lab Medicine	201	1.61	.87	.38	.33
20. Microbiology	1350	8.68	.58	2.66	.71
21. Molecular Biology & Genetics	1691	5.74	.15	3.55	1.37
22. Neurology	160	1.02	.55	.31	.20
23. Neurosciences & Behaviour	1037	7.22	.59	2.01	.35
24. Nutrition	133	.42⊗	.61	.28	.38
25. Oncology	91	.89	.76	.17	.11
26. Ophthalmology	90	.79	.82	.17	.21
27. Ortho & Sports Medicine	69	.14⊗	.41	.15	.14
28. Otolaryngology	65	.40	.48	.13	.17
29. Paediatrics	221	1.16	.57	.44	.30
30. Pharmacology	1065	6.46	.60	2.12	.44
31. Pharmacology/Toxicology	95	.41⊗	.48	.20	.21
32. Physiology	398	1.76	.38	.82	.47
33. Psychiatry	103	.26⊗	.74	.22	.19

Research Field	Total number over the period	Yearly growth trend (regression slope*)	Mean yearly impact relative to field	Mean yearly proportion out of the country	Mean yearly proportion out of the field
34. Psychology	195	.39⊗	.40	.43	.11
35. Public Health & Health Care	832	3.32	.33	1.73	1.35
36. Radiology Nucl Med & Imag	109	.00⊗	1.14	.24	.12
37. Reproductive Medicine	210	.85	.55	.44	.32
38. Rheumatology	80	.92	.57	.14	.33
39. Surgery	306	1.33	.62	.63	.39
40. Urology	257	1.35	.89	.52	.43

* $p < .05$, unless otherwise marked
⊗ $p > .05$

The raw data for these variables, recording values for each year and research field, were used in Factor Analysis by the method of principal components. The correlation matrix was submitted to a varimax rotation. Two factors were extracted, representing 83.1% of the measurement variations (Factor 1 = 63.9%, Factor 2 = 19.2%). Table 2 presents the rotated factor matrix.

Table ¡Error!Argumento de modificador desconocido. **- Results of Factor Analysis**

Variables	Factor Loading	
	Factor 1	Factor 2
Proportion out of the country	,96539	-,10139
Number of publications	,95506	-,07953
Growth trend	,90633	,00850
Proportion out of the field	,66293	-,23321
Impact relative to field	-,09517	,98371

Factor 1 was interpreted as *productivity*, as it rises with increases in either absolute number of publications or rates regarding growth trend, participation within the country or participation within the field. Factor 2 straightforwardly refers to impact relative to field. Thus, taking factor scores as co-ordinates, a location map of research fields (Figure 3) could be plotted. In this map, the performance of any given research field in relation with factors is provided by its projection over the factor axes, and the relation between fields is suggested by the geometric distances (Euclidean) between them. From the 40 fields analysed, 17 cluster around the origin of axes as an inconspicuous group of fairly homogeneous performance, and thus they are plotted as a single unit.

Impact relative to field is found negatively correlated with Factor 1. Indeed, despite low values of correlation coefficients suggesting no correlation at all, impact is negatively related to all other variables: number of papers ($r = -.18$, $p = .000$), growth trend ($r = -.13$, $p = .000$), proportion out of the country ($r = -.21$, $p = .000$), proportion out of the field ($r = -.19$, $p = .000$)

Correspondence analysis was conducted as to further understand the performance of research fields with regard to impact. For this, the impact relative to field was categorised and the number of years of each category for each research field was computed, as shown in Table 3. Figure 4 shows results of correspondence analysis, where the spread of fields around categories of impact can be identified. The centroid of research fields lies at the origin of axes (co-ordinates 0,0), close to the location of the impact category ‘< national average’ (co-ordinates -.60, .08). To ease interpretation, lines were drawn (bisectrices of the internal angles of the triangle of impact categories) from the centroid of impact categories (co-ordinates .43, .21) so that influence zones for each category could be delimited. The relationship between fields can be examined as proximities in geometric distances (chi-square) between them, and cluster of similar performances can be recognised.

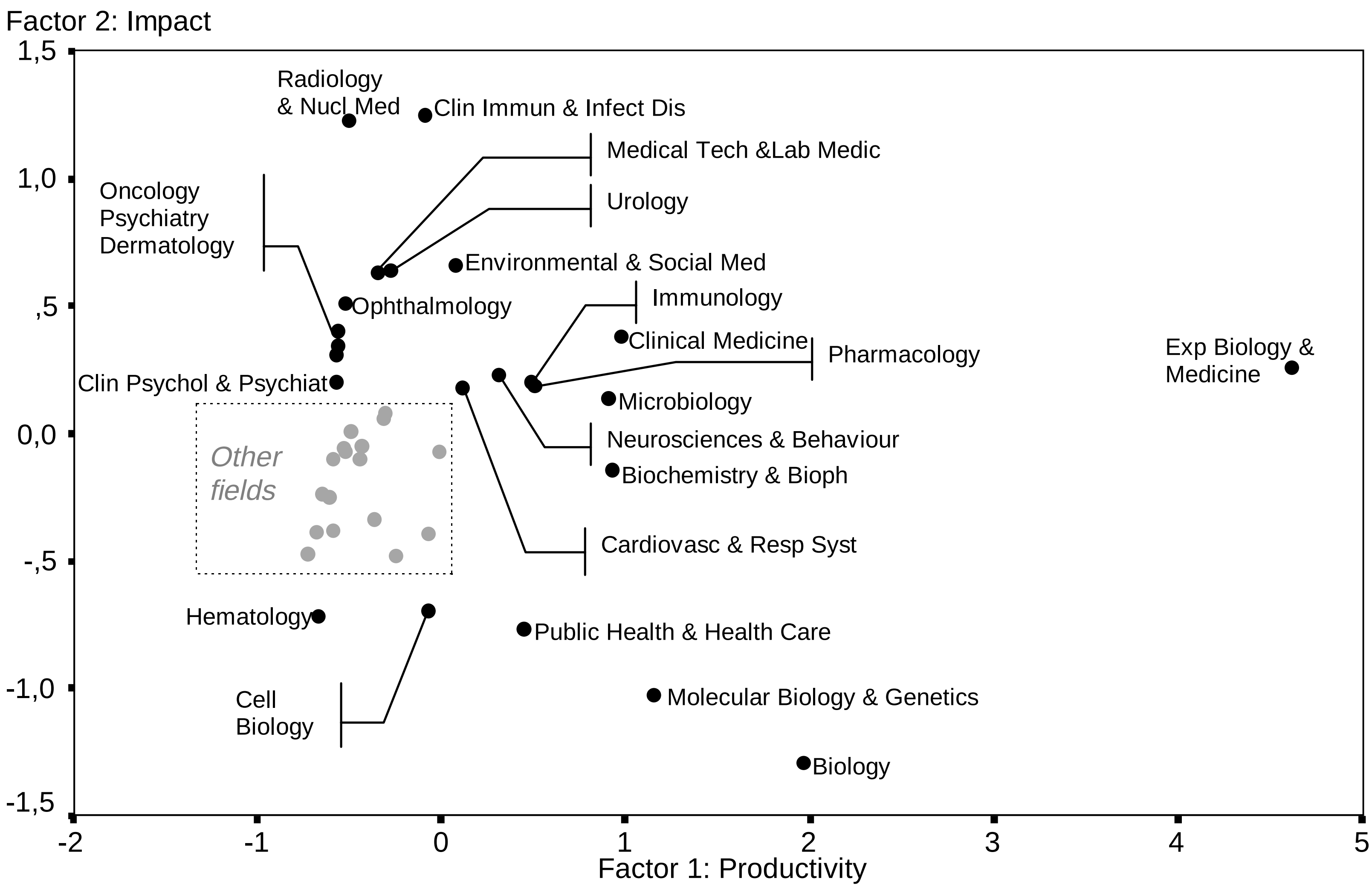

Figure ¡Error!Argumento de modificador desconocido. **- Map of health research fields in Brazil, 1981 to 1995**

OTHER FIELDS: Anaesthesia & Intensive Care, Biotech & Appl Microbiology, Dentistry/Oral Surgery & Med, Nutrition, Endocrinology, Gastro and Hepatology, General Medicine, Neurology, Ortho & Sports Medicine, Otolaryngology, Paediatrics, Pharmacology/Toxicology, Physiology, Psychology, Reproductive Medicine, Rheumatology, Surgery.

Table ¡Error!Argumento de modificador desconocido. **- Number of years in each category of impact for each research field**

Research Field	Impact relative to field			Row total
	Bellow national average	Above national average	Above international average	
1. Anaesthesia & Intensive Care	12	1	2	15
2. Biochemistry & Biophysics	15			15
3. Biology	15			15
4. Biotech & Appl Microbiology	9	4	2	15
5. Cardiovasc & Resp Systems	7	8		15
6. Cell Biology	15			15
7. Clin Immun & Infect Disease	1	5	9	15
8. Clinical Medicine	6	9		15
9. Clinical Psychol & Psychiat	9	1	5	15
10.Dentistry/Oral Surgery & Med	7	7	1	15
11.Dermatology	7	4	4	15
12.Endocrinology	12	2	1	15
13.Environmental & Social Med	2	6	7	15
14.Exp Biology & Medicine	15			15
15.Gastro and Hepatology	8	6	1	15
16.General Medicine	13	1	1	15
17.Hematology	14		1	15
18.Immunology	8	5	2	15
19.Medical Tech & Lab Medicine	1	10	4	15
20.Microbiology	8	7		15
21.Molecular Biology & Genetics	15			15
22.Neurology	10	3	2	15
23.Neurosciences & Behaviour	5	10		15
24.Nutrition	7	6	2	15
25.Oncology	7	5	3	15
26.Ophthalmology	6	4	5	15
27.Ortho & Sports Medicine	9	5	1	15
28.Otolaryngology	10	4	1	15
29.Paediatrics	9	5	1	15
30.Pharmacology	4	11		15
31.Pharmacology/Toxicology	10	4	1	15
32.Physiology	14	1		15
33.Psychiatry	5	6	4	15

Research Field	Impact relative to field			Row total
	Bellow national average	Above national average	Above international average	
34.Psychology	12	3		15
35.Public Health & Health Care	13	2		15
36.Radiology Nucl Med & Imag	3	6	6	15
37.Reproductive Medicine	8	7		15
38.Rheumatology	10	2	3	15
39.Surgery	9	3	3	15
40.Urology	6	6	3	15
Column Total	356	169	75	600

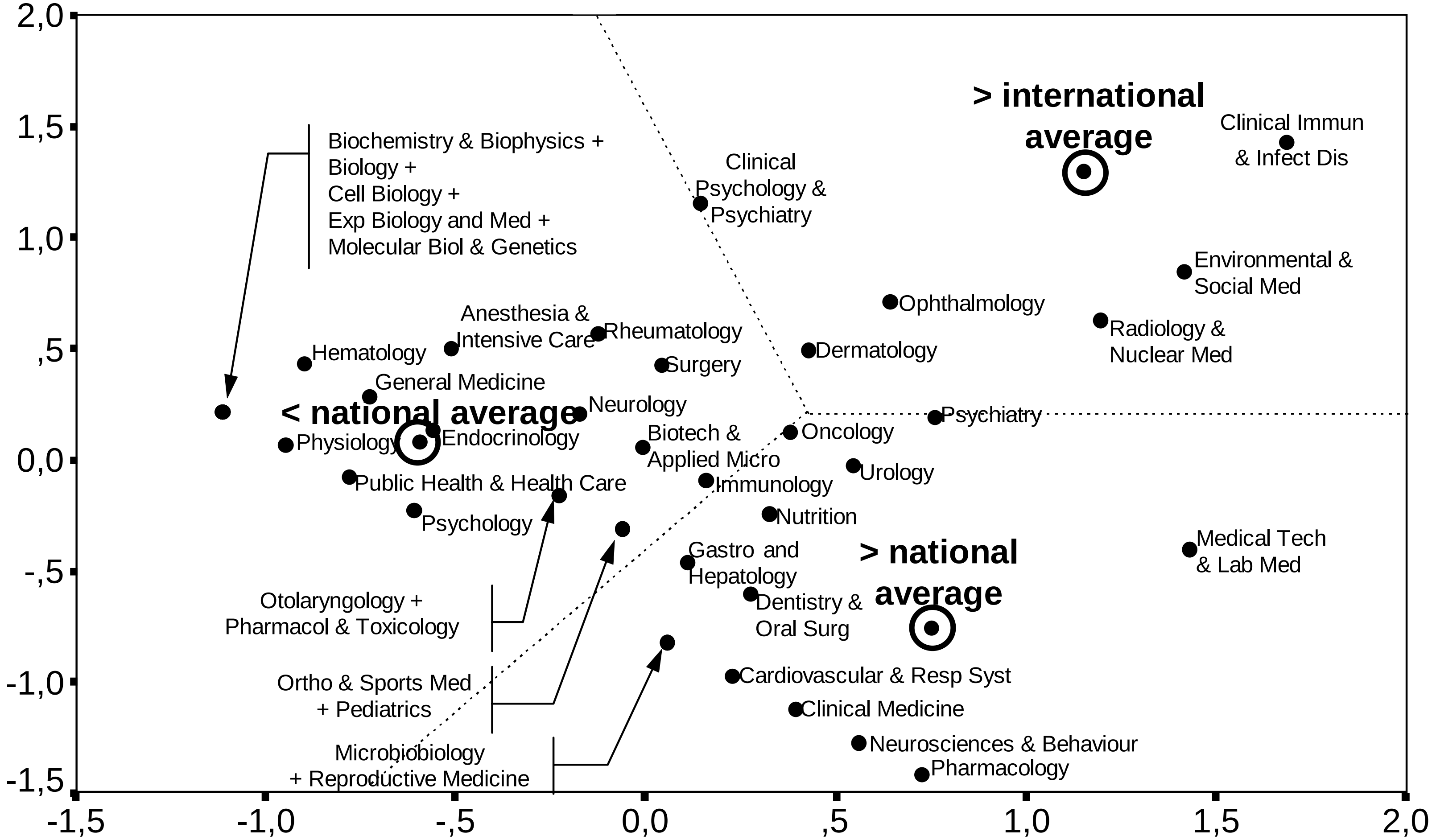

Figure ¡Error!Argumento de modificador desconocido. **- Correspondence analysis: research fields and impact relative to field**

Comments and conclusion

In the present study, quantity, quality, and time trend of scientific production were analysed and the information provided should contribute to the knowledge of the characteristics of health sciences in Brazil. Though they play a major role in the country's scientific production (42%), they do not differ from other sciences in trends of either production or impact (Figures 1 and 2). Moreover, their impact level is the same of, if not inferior to, that of the other sciences (Figure 2). Indeed, not only their higher level of production does not lead to higher levels of impact but also when separate health fields are analysed, impact relative to field is negatively correlated with measurements of production, suggesting that fields achieving higher impact levels have lesser production.

This disagrees with what Marton et al. found in the previously mentioned paper on European countries. One could understand with Sancho[9] that less developed countries are misrepresented in the ISI databases and that, therefore, conclusions could not be accurate. Nevertheless, what this author has found is that, as the ISI records focus on the mainstream of science, a large number of papers domestically published are disregarded. Inasmuch as these papers are not internationally visible, their impact to the field is bound to be modest if not null at all and thus, were they considered and the negative correlation would not abate but increase.

Moreover, one can learn from Czapski[10] that the more prominent part of a scientific production should be the best representative of a given country or discipline success. Indeed, this author suggests that evaluations taking the whole bulk of production unduly enlarge denominators and lead to underestimation of performances, for which he recommends that only the top ten or twenty percent cited papers be considered.

The concern of the present study is not to have a precise measurement of each variable in each research field but to assure that all of them have the same metric basis, so that relationships can be analysed. That is what is achieved by the two multivariate techniques applied, where measurement scales are senseless in themselves but richly meaningful in informing relations and hierarchy among the research fields.

Factor analysis has shown that production is overwhelmingly more important than quality in the discrimination of research fields as Factor 1 corresponds to 63.9% of measurement variations in contrast with Factor 2 that explains only 19.2% of these variations. As a result, the most distinct field, standing alone in the right hand of the map in Figure 3 (Experimental Biology and Medicine), separates from others mainly on the basis of productivity (Factor 1) and scores indistinctly as to Factor 2. In contrast, in the top left corner of the map, two clusters of best quality but low productivity fields can be identified: at an upper position Radiology & Nuclear Medicine and Clinical Immunology & Infectious Diseases, and at a lower position Oncology, Psychiatry, Dermatology, Medical Technology & Laboratory Medicine, Urology, Environmental & Social Medicine, and Ophthalmology.

Further interpreting the Factor Map (Figure 3), the group labelled ‘Other fields’ seems to represent the standard performance of health research fields and provides a contrast for evaluation of other fields and clusters of fields. Thus, Immunology, Clinical Medicine, Pharmacology, Neurosciences and Behaviour, Biochemistry, and Cardiovascular & Respiratory Systems seem fields that exceed the standard performance mainly in terms of production (Factor 1), some of which score slightly better also in quality (Factor 2). Public Health & Health Care, Molecular Biology & Genetics, and Biology are fields with greater levels of production but with lower levels of impact. Finally, Haematology and Cell Biology are fields that diverge from standard performance due to lower levels of impact.

Correspondence Analysis has concluded that the gravitational centre of the research fields is close to the impact level ‘bellow national average’. This suggests that the national average is pulled up by the contribution of a few fields of higher scores in impact, which confirms the Czapski’s theory previously mentioned. The strategy of delimiting influence zones in Figure 4 allows the identification of these fields divided in two groups, one with performances neighbouring the category of impact ‘above international level’ and another close to ‘above national level’. As to the latter, one can identify: Urology, Nutrition, Gastro and Hepatology, Dentistry & Oral Surgery, Microbiology, Reproductive Medicine, Cardiovascular & Resp. Systems, Clinical Medicine, Neurosciences & Behaviour, Pharmacology, and Medical Technology & Laboratory Medicine. Checking with Table 3, one can see that all these fields have 6 or more years with impact relative to field above the national average.

The few fields with at least 4 years registering impact relative to field above the international average, hang around this category: Clinical Psychology & Psychiatry, Dermatology, Ophthalmology, Radiology & Nuclear Medicine, Environmental & Social Medicine, and Clinical Immunology. Psychiatry is in the borderline of the two categories, having both 6 years in the category ‘above national average’ and 4 years in the category ‘above international average’. The remaining 22 research fields, having 9 or more years of impact bellow the national average, belong to the influence zone of this impact category.

These results provide information that can advise Brazilian policy makers on science & technology in their forthcoming foresight exercise. For instance, to achieve short-term results on enhancing the country’s competitiveness in the global scenario, it seems that those fields with impact levels above international average could rapidly respond with increased production if resources were directed to them. Indeed, as they have proven competitive in the international arena, they should only need proper means to boost production. Likewise, those fields of high productivity but low impact could benefit from medium term policies aimed at improving their quality, as they show a promising potential to be worked upon.

Bibliometric analysis is not seldom disputed as a means to assess quality of scientific production by those who favour qualitative approaches[11]. Nevertheless, a high correlation between bibliometric analysis and other strategies has been repeatedly found by scientometric investigators. Oppenheim[12] recently compared the results of the British Research Exercise, a gigantic effort on evaluation of the UK universities, with ISI citation records and found a good agreement between the two assessments in regard to the three subject areas he examined. Quality is not an intangible phenomenon not liable to measurement and if adequate analysis techniques are adopted, a reliable and objective information can be produced more quickly and with lower costs.

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