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The Antarctica Treaty System and the promotion of international scientific cooperation: an evaluation of the regime

El Sistema del Tratado Antártico (STA) y la promoción de la cooperación científica internacional: una evaluación del régimen

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ABSTRACT

The Antarctic Treaty System (ATS) came into force intending to end litigation and promote scientific cooperation. The regime was originally criticized but managed to gain international recognition. There remains, however, a doubt about its effectiveness in advancing international cooperation. This paper aims to evaluate, through bibliometric analysis and counterfactual tecnique, the effectiveness of the ATS in promoting international scientific cooperation. Using international co-authorship rates of scientific articles as an indicator, a case study was conducted in a scientific journal. The results show that international co-authorship in the journal was superior to the one of science and technology. Despite the inherent limitations of a case study, we concluded that ATS was effective in fulfilling the purpose of promoting international scientific cooperation.

Keywords: Antarctic Treaty System – Regime evaluation – International scientific cooperation – Bibliometric Analysis – Antarctic productivity.

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RESUMEN

El Sistema del Tratado Antártico (STA) entró en vigor para encerrar litigios y promover la cooperación científica. Criticado originalmente, el régimen ganó reconocimiento internacional pero siguen habiendo dudas sobre su capacidad de avanzar en la cooperación internacional. Este artículo evalúa, mediante análisis bibliométrico y técnica contrafática, si el STA ha logrado promover la cooperación científica internacional. Utilizando como indicador las tasas internacionales de coautoría de artículos científicos, se realizó un estudio de caso. Los resultados muestran que la coautoría internacional en la revista estudiada fue superior a la encontrada en ciencia y tecnología. A pesar de las limitaciones inherentes a un estudio de caso, llegamos a la conclusión de que el STA fue eficaz en promover la cooperación científica internacional.

Palabras clave: Sistema del Tratado Antártico – Evaluación de Régimen – Cooperación Científica Internacional – Análisis Bibliométrico – Productividad Antártica.

Introduction

The Antarctic Treaty System (ATS) came into force in 1961 to constitute Antarctica as an international condominium, managed by 12 original members.[1] While the ATS represents the political dimension of Antarctic governance, the Scientific Committee on Antarctic Research (SCAR-1958) coordinates scientific activity on the continent. The regime established science and international cooperation as groundwork, but raised controversy by accepting sovereignty[2] claims over the Antarctic territory and instituting a restrictive policy, based on scientific performance, to attain access to decision-making processes. Over the years, the regime gained more legitimacy, by accepting new members and loosening the demands for the acquisition of consultative *status*. Over the last fifty years, the ATS has incorporated 41 new members, of which 29 are consultative. The regime was certainly effective in increasing the number of State actors, but it is, nevertheless, necessary to assess whether it was able to achieve one of its main purposes: the promotion of international cooperation in the field of science. As the governance of Antarctica depends on both science and politics, we consider that ATS and

1 Argentina, Australia, USA, USSR, United Kingdom, France, Norway, New Zealand, Chile, Japan, Belgium, South Africa.

2 Seven countries with territorial claims: Argentina, Chile, United Kingdom, Australia, New Zealand, France, Norway.

scar are inseparable parts of the same regime. When referring to ats, scar is comprised.

Bibliometric studies carried out by Dastidar and Ramachandran (2008) and Ji, Pang and Zhao (2014) verified an increase of international co-authorship inpublished papers covering Antarctic science, which indicate the advance of international cooperation in this field. However, international co-authorship is a rising phenomenon in science and these authors did not compare their data with some other international benchmark that would allow them to evaluate if there was really a breakthrough.

Under these circumstances, this paper aims to assess whether the ats regime was effective in promoting international scientific cooperation in Antarctica (isca).Instead of focusing on State actors we will investigate whether the international cooperation sought by the ats has reached the level of the regime's users, namely the scientists and institutions that develop research activity on the sixth continent. If the ats had not been signed in 1959, how would international scientific cooperation in Antarctica have evolved? Would it have achieved different levels of performance? Based on the literature that proposes the counterfactual technique to perform regime assessment (Underdal, 1992; Young, 2011), the paper proposes a case study to verify the effectiveness of ats in promoting isca.

The first part of the article introduces the regime assessment methodology and discusses the implications of using international co-authorship indicators. The second part presents the research results together with a geopolitical approach of the priority given to Antarctica by countries. Moreover, the research verified that isca performed better than international cooperation in the field of science and technology (S&T). We also noted that some countries show strong interest in producing Antarctic science, despite not so favorable conditions.

1.1 Reasons to investigate

An expanding line of research in the area of International Relations is the one that seeks to evaluate regimes in order to establish which conditions pave the way for success or failure. This initiative stems from a two-fold concern, the realization that weak regimes might achieve some degree of success and that strong regimes might not always complete their course. In order to carry out this assessment, it is necessary to determine the meaning of regime effectiveness.

Young (2011) suggests that due to the great causal complexity of the subject, the assessment of regime effectiveness must be approached through a methodology that combines quantitative and qualitative method. Since the former hardly identifies the causal mechanisms and the latter uncovers them yet has difficulties to generalize them, the joining of both methods would solve mutual deficiencies. Underdal (1992) recommends setting the regime against some achievement or success standard by means of a counterfactual method. There are two possible ways to proceed. The first one is to choose as a reference point the situation that would prevail if the regime had not been established. The relative improvement achieved by it could then be verified (or not). The second is to compare what was actually accomplished by the current regime with what the author calls a collective optimum, a projection of the ideal to be reached by it. Young (2011) summarizes this approach in the following equation:

$$\text{Effectiveness of a regime} = \frac{\text{Actual performance} - \text{no regime counterfactual}}{\text{Collective optimum} - \text{no regime counterfactual}}$$

Source: Young (2011: 19854)

Although the equation above is conceptually attractive and allows the creation of a common scale for comparing different regimes, Young recognizes its operational difficulty. In this research, only Underdal and Young's first suggestion will be implemented: to oppose actual performance against the no regime counterfactual. Despite omitting the comparison with the collective optimum, we propose for future researches, two examples of successful facilities as a counterpoint: the European Southern Observatory (ESO) and the European Synchrotron Radiation Facility (ESFR) both operated by several countries (Elzinga, 2013).

Some of the objections addressed to the ATS refute the existence of international cooperation and base their arguments on the absence of shared polar stations. In 2013, in an opening speech for the 36th Antarctic Treaty Consultative Meeting, Prince Albert of Monaco stated that the continent "does not benefit enough from coordinated international scientific programs" (Grimaldi, 2013: 4) and that "from the 80 installed research stations in Antarctica, only two can be qualified as international. Even though, they only bring together two countries" (Grimaldi, 2013: 5). The claim, while pertinent, is controversial because it limits the concept of international cooperation to a single variable: the sharing of stations.

The controversy surrounding the ATS regime effectiveness relies on the different metrics used to evaluate it. If the regime effectiveness is evaluated only on the basis of the cooperation between State actors, carried out through diplomatic channels, the longevity and breadth of the ATS attest to its value. If what is being evaluated is the ability of the ATS to operationalise the cooperation by removing it from the formal political plane to the practical exercise of its users (scientists and research institutions), it is necessary to reconsider the regime effectiveness through another methodological approach.

Young (1995) considers that a regime consists of rules formulated in two different levels. First, the members of the regime (the States) —through diplomatic and political channels— outline the nature and normative structure of the regime. Under this structure, there is a second level responsible for implementing the agreed principles. Subsequent actors, private or corporations, convert what has been agreed into practical arrangements. In the case of ATS, scientists, polar stations and research institutions are responsible for implementing the rules that lead to ISCA.

The counterfactual technique should not be confused with an assessment of before and after the regime. Within ATS, it is not possible to analyze the evolution of ISCA before and after the Treaty signature (1959), since the internationalization of science is a recent phenomenon, having developed mostly since the end of the Cold War (Vanz and Stumpf, 2010). In Antarctica, as well as in all other fields of scientific knowledge, it would have been observed an increase in ISCA, owing not necessarily to the signature of the Treaty.

Since it was impossible to make projections about a phenomenon that was poorly documented before 1989, the alternative was to assume that ISCA, without the regime, would have evolved at the same rate of international cooperation in global science and technology. One of the indicators used to evaluate International Scientific Cooperation (ICC) is the international co-authorship index, a resource widely used by specialized literature (Dastidar and Ramachandran, 2008; Ji, Pang and Zhao, 2014; Katz, 1994; Vanz and Stumpf, 2010).

The paper, trough a statistical research, compares the rates between international co-authorship found in a specialized journal in Antarctic science with those in the field of Science and Technology. When performing the counterfactual technique, the purpose is to estimate the causal effect of ATS (explanatory variable) on ISCA (dependent variable). The research aimed to verify if the amount of international co-authorship found in the journal exceeded or not the indexes in the area of Science and Technology (S&T). It is not a question of affirming that ATS is the only mechanism acting behind ISCA, but of assessing its contribution, as a regime, to the existence of such phenomenon. The advantage of a case study is that, even if the scope of its conclusions are limited, it allows verification tests for the proposed hypotheses.

For the case study, we sought a scientific publication with international prestige exclusively dedicated to Antarctic matters. The choice fell on the British *Antarctic Science* (AS) (ISSN: 0954-1020), a journal published by the renowned University of Cambridge and linked to the *British Antarctic Survey*, a world reference institution. The case study also used as reference and basis of comparison the data of two papers published in *Scientometrics*. The first, "*Intellectual structure of Antarctic Science: a 25 year analysis*" (2008) was written by the Indian researchers Dastidar and Ramachandran. The second, published by the Chinese team Ji, Pang and Zhao, is entitled "*A bibliometric analysis of research on Antarctica during 1993–2012*" (2014). Both teams used a statistical-mathematical method in order to measure Antarctic science publications and endorse the notion that Antarctic science is global and cooperative and, that there has been an increase in collaborative[3] publications.

Although both researches provide abundant data on science in Antarctica, their purely quantitative approach does not examine the political dimension of cooperation within the ATS. For this reason, the present research aims at examining ISCA not only through quantitative observations, but also with a qualitative bias, in order to fill some of the existing gaps in the mentioned researches (Ollaik and Ziller, 2012). Using the data provided by Dastidar and Ramachandran (2008) and Ji, Pang and Zhao (2014) gives more sustainability to the investigation and corrects eventual distortions of the case study through triangulation of data.

1.2 Methodology

Balancieri *et al.* (2005) report that the use of co-authored papers as an indicator to measure collaboration between scientists first appeared in 1958. On this occasion, Michael Smith noticed that it was possible to observe the collaborative process of science through the publication of investigations and their authors. Subsequently, Derek Price verified the expansion of scientific collaboration through the growth of co-authored papers.

The decision to publish jointly results from several factors: more access to financing, rationalization of work, sharing of facilities, demand for scientific productivity, need for specialization of science, or diversification of expertise (Katz and Martin, 1997). Scientific collaboration may arise spontaneously or formally. In the first case, it originates within an academic institution or in contact made at congresses. In the second case, it occurs through international agreements signed between Ministries of Science and Technology that promote cooperation projects.

In this research, we classified the *Antarctic Science* articles as single author, domestic co-authorship (when authors belong to one or several institutions of the same country) and international co-authorship (when authors belong to institutions from different countries). Only the nationality of the institution was evaluated, not the scientist. Each paper written in international co-authorship

3 They call it collaborative, we prefer the term cooperation.

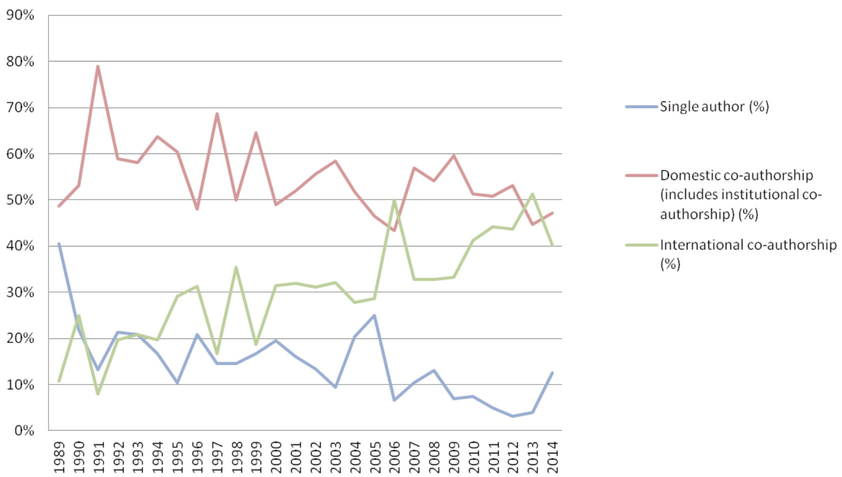
was assigned as a unit to the countries involved in its production. The result of this procedure called "whole count" is an increase in the participation of each country, exceeding the original number of published papers in the journal. A paper with two authors — one belonging to a Brazilian institution and another belonging to an Argentinian institution— was counted as one international co-authorship for Brazil and one for Argentina. If the Argentinian author belongs simultaneously to an institution in Germany, the paper will be counted as an international co-authorship among these three countries.

Some bibliometric analysis perform a "fractional count" of international co-authorship, considering how many countries are included in a paper and assigning to each one a proportion in the participation. In this case, the cited paper, would be accounted a 0.5 of authorship for Brazil and 0.5 for Argentina. Or in the case of a German institution membership, it would be 0.3 for each country. The advantage of this method is that the sum of international co-authorship papers does not exceed the sum of published papers; its drawback is to devalue the weight of international co-authorship compared to domestic co-authorship.

We found the whole count more appropriate because it is standardly used by the Organization for Economic Cooperation and Development (OECD) and other research institutions. We opted for the use of the term "international co-authorship"[4] for the same reason. The survey examined a 26-year period of *Antarctic Science* journal, from 1989 to 2014. Papers written by institutions in England, Scotland, Northern Ireland and Wales were attributed to the United Kingdom. Papers that until 1991 were from the former USSR were grouped as Russia and those from Hong Kong (from July 1997) were attributed to China.

4 Dastidar and Ramachandran (2008) use the fractional count methodology and the terms 'multinational collaboration' and 'multinational papers.' Ji, Pang and Zhao (2014) use the whole count methodology and the expression 'international collaboration.' It is important to take into consideration that a database constructed from a whole count is different from one constructed from a fractional count, which leads to some slight differences in the percentages obtained.

Fig. 1 – Evolution in paper distribution of Antarctic Science (1989–2014).



Source: The author. Data extracted from Antarctic Science.

1.3 Research results

Between 1989 and 2014, 1,410 papers, short notes and scientific opinions were published in Antarctic Science.[5]

We observe that the publication of scientific papers in the journal *Antarctic Science* matches the co-authoring pattern in the Experimental Sciences field with a downward trend for single author papers and an upward one for co-authorship whether domestic or international. The production of expertise in this sphere of science tends to be carried out in a collaborative way, since the complexity of tests and observations and the cost of laboratory equipment require researchers with varied expertise sharing skills and expenses. In recent years, one variable that contributed to the expansion of international co-authorship was the advance of information and communication technologies.

In the early years of the journal, the international co-authorship —compared with data presented by Stenberg (2013)— was higher than the world average.[6] In a three-year period 1993–1995,

5 44 countries contributed: South Africa, Argentine, Australia, Austria, Belgium, Brazil, Brunei, Bulgaria, Canada, Chile, China, Cyprus, Colombia, Denmark, Estonia, Finland, France, Hungary, India, Ireland, Iceland, Israel, Italy, Japan, Malaysia, Norway, New Zealand, Netherlands, Poland, Portugal, United Kingdom, Czech Republic, Romania, Russia, Sweden, Switzerland, Thailand, Taiwan, Ukraine and Venezuela.

6 Stenberg works with data from the *Web of Science of Thomson Reuters* that refers to all fields of science.

international co-authorship in *Antarctic Science* was 23%, nearly the double of international co-authorship, which was 12%. Nonetheless, the growth rate of international co-authorship in the journal was more moderate. In the three-year period 2008–2010, international co-authorship in the journal was 36% (56% increase), while worldwide international co-authorship increased to 20% (67% increase) (Stenberg, 2013: 18).

The same comparison exercise was carried out in the more specific field of science and technology, with data produced by the OECD. The OECD data also reveal a decline in single authorship and increase in international co-authorship from 6,6% (1982–87) to 13,7% (1992–97) and again to 20,7% (2002–2007). On the other hand, domestic co-authorship remained relatively stable 72% (1982–87); 72.4% (1992–97); 70.6% (2002–2007) (OECD, 2009).

Table 1 lists, in descending order, the main countries to participate in *Antarctic Science*. Between 1989 and 2014, 44 different countries published articles in the journal, but we worked only with those who had at least 26 participations in that period, resulting in an average of one per year. Nineteen countries fulfilled this requirement.

Table 1 – Distribution in *Antarctic Science* of authorship/co-authorship per country (1989–2014)

	Total participations	Single Author	Domestic Co-authorship	International Co-authorship
1. United Kingdom (5)	320	61	130	129
2. U.S.A. (1)	301	31	118	152
3. Australia (12)	226	19	97	110
4. Germany (4)	158	20	49	89
5. Italy (8)	157	8	74	75
6. New Zeland (34)	148	13	46	89
7. Argentina (33)	76	0	48	28
8. France (6)	73	3	23	47
9. Spain (10)	71	5	23	43

10. South Africa (36)	61	3	33	25
11. Poland (21)	34	5	13	16
11. Sweden (18)	34	5	7	22
12. Brazil (15)	31	1	18	12
13. Chile (40)	30	0	13	17
13. Belgium (22)	30	0	10	20
13. Russia (14)	30	6	7	17
14. China (2)	28	1	10	17
14. Netherlands (13)	28	5	7	16
15. Japan (3)	26	2	9	15
Total	1.862	188	735	939

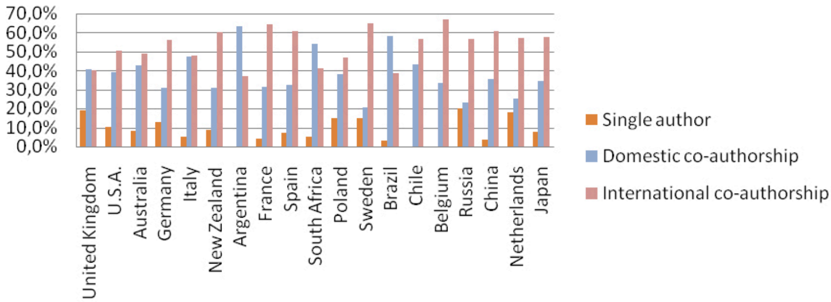
Source: The author. Data extracted from Antarctic Science.

Obs. 1: In brackets, the international output score in Science and Technology by the World Bank, data from 2011.
Obs.2: The total of column 2 (1,862) and that of column 5 (939) do not refer to the total of articles produced, but to participations of each country, since the methodology used was whole count, which leads to overlapping results.
Obs.3: In the case of individual articles and domestic co-authorship, the figures correspond to the number of articles.

Among the 19 listed producers, 11 of the 12 original signatories of the Antarctic Treaty are included, except for Norway, who with only 14 participations ranked 17th in the journal. Due to its *status* as an original member of the ATS, Norway was included in some subsequent analysis, although it did not fulfill the condition of 26 participations. The international co-authorship of these 19 countries corresponds to 50.4%, which confirms Antarctic science as being cooperative, since the OECD average of international co-authorship is 21.9% (OECD, 2009).

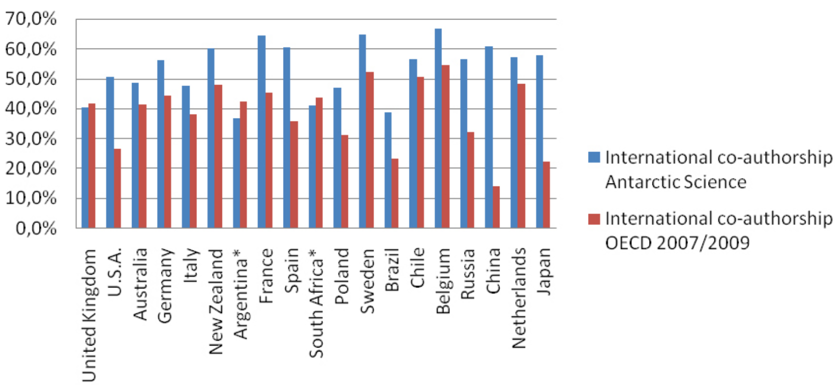
Figure 2 shows that fifteen countries have a higher international co-authorship than domestic co-authorship, demonstrating the importance of ISCA in the output/production of Antarctic science. The exceptions are: United Kingdom, Argentina, South Africa and Brazil, three of which are emerging economies, which may interfere with their ability to establish cooperative relationships.

Fig. 2 – Percentage share of co-authorship by countries in *Antarctic Science* (1989–2014).



Source: The author. Data extracted from Antarctic Science.

Fig. 3 – Comparison of international co-authorship in *Antarctic Science* (1989–2014) and OECD (2007–2009).



Source: The author. Data extracted from Antarctic Science and OECD.

Obs.1: The international co-authoring numbers for Argentina and South Africa are relative only to the year 2007. Possibly, this figure would be a little higher with the inclusion of later years.

Obs.2: Data from Argentina and South Africa are not from the OECD, but from: http://www.researchtrends.com/issue14-december-2009/country/. Access on: 9/14/2015.

Figure 3 confronts the international co-authorship in the *AS* journal with the one of science and technology.[7] This control procedure was neither performed by Dastidar and Ramachandran (2008) nor by Ji, Pang and Zhao (2014).

The chart suggests a successful ISCA with 16 countries developing more international co-authorship than the one measured by the OECD. The exceptions were United Kindgom, Argentina and South Africa, original members of the ATS, with the first two having territorialist interests on the continent.

Table 2 shows that the average international co-authorship in the *AS* journal for the 20 countries is 54.5%, 38.6% higher than the international co-authorship average of the OECD for the S&T field. Looking at the first column, the countries that are above or below the international co-authorship average are identified. But since it is difficult to exceed the average limit of 54.5% for a country with small co-authorship tradition, the criterion of proportional co-authorship was also used. As a result, the United States, Poland and Brazil showed good growth capacity, while the United Kingdom, Australia, Italy, Argentina and South Africa were below average and grew less than 38.6%.

Using the same analysis procedure with the values of Ji, Pang and Zhao (2014): the United States, Spain, Brazil, Russia, China and Japan also showed a capacity for international co-authorship growth above 43.7%, although they did not reach the expected average of 56.5%. Australia, Italy, Argentina, South Africa and Poland were below average and grew less than 43.7%. The analysis suggests that the highest standard of international co-authorship in Antarctic science is not uniformly pursued by all concerned and that some countries are consistently at the rear.

In order to verify the existence of other motivations behind the output

7 Data collected in Antarctic Science relate to the period 1989 to 2014 and OECD data for the period 2007-2009. We chose not to work with the same time frame because the universe of articles collected in those three years in the journal would be reduced to 252 articles distributed among 27 contributing countries, creating distortions. Since year-to-year output is not linear, in countries with significant production, the variation is small and the sample remains representative, but in countries with smaller output, the sample is deformed and would not reveal the true profile of international co-authorship. Working with more extensive output over time gives a more accurate picture of international co-authorship in *Antarctic Science*, even though we are aware that in recent years the trend towards international co-authorship has had a positive impact on the journal's sample. Nonetheless, we believe that this positive impact is partially offset by the initial years, in which international co-authorship advanced less.

Table 2 – Percentage comparison of international co-authorship between the journal *AS* and OECD and Ji, Pang and Zhao's research.

Countries	Internacional Co-authorship *Antarctic Science* 1989–2014	International Co-authorship OECD 2007/2009	International Co-authorship Ji, Pang, Zhao 1993–2012
United Kingdom	40,3% (17)	41,8% (11)	56,9% (9)
U.S.A.	50,5% (12)	26,7% (17)	47,5% (15)
Australia	48,7% (13)	41,3% (12)	54,9% (10)
Germany	56,3% (11)	44,5% (8)	64,2% (8)
Italy	47,8% (14)	38,0% (13)	46,8% (16)
NewZealand	60,1% (7)	48,0% (6)	67,2% (5)
Argentina*	36,8% (19)	42,4% (10)	46,6% (17)
France	64,4% (4)	45,2% (7)	68,9%(4)
Spain	60,6% (6)	35,9% (14)	52,4% (12)
South Africa *	41,0% (16)	43,6% (9)	51,3% (13)
Poland	47,1% (15)	31,2% (16)	43,5% (18)
Sweden	64,7% (3)	52,3% (2)	66,4%(6)
Brazil	38,7% (18)	23,4% (18)	48,9% (14)
Chile	56,7% (10)	50,6% (3)	65,0%(7)
Belgium	66,7% (2)	54,6% (1)	77,2%(1)
Russia	56,7% (10)	32,2% (15)	52,4% (11)
China	60,7% (5)	14,2% (20)	37,6% (20)
Netherlands	57,1% (9)	48,2% (5)	69,0%(3)
Japan	57,7% (18)	22,2% (19)	43,8% (19)
Norway	78,5% (1)	50,2% (4)	70,6% (2)
Mean	54,5 %	39,3%	56,5%

Source: The author. Data extracted from Antarctic Science, OECD and Ji, Pang and Zhao (2014).

Obs.1: Norway, despite its low participation in AS journal, was added to this table because it is a consultative and original member of the ATS.

Obs.2: In brackets, the position occupied by the countries in descending order of co-authorship.

of Antarctic science, we compared the position held by countries in terms of output of *AS*, science and technology and whole science to assess if they were equivalent.[8]

The analysis of columns 3 and 4, in relation to 2, substantiates four different situations. A first case is that of countries with parity across the three scientific spheres, showing that equal importance is given to all of them. It will be said of these countries that they feature regular Antarctic investment (Table 1).

Another category concerns countries that are more willing to produce Antarctic science and hold a position in the journal above that found in S&T and science as a whole. One can attribute this greater interest to the fact that they are original members of the ATS, which seems to show that previous background plays a significant role in the production of Antarctic science, although it is not a unique factor (Table 1). These countries display significant Antarctic investment.

A third category is that of countries who stand out for the importance of their Antarctic output compared to their standing in S&T and science as a whole. Both in *AS* and in the survey of Dastidar and Ramachandran (2008) and Ji, Pang and Zhao (2014), this group of four countries is constituted by original members of the ATS (three territorialists) and manifests deep Antarctic investment. The last category is the inverse of the previous one and consists of those countries whose Antarctic science output is inferior to the one found in S&T and science as a whole. The most striking case is China, which has shown great prominence in the universe of science, but whose Antarctic output does not reflect the new pattern.[9]

8 SCIMAGO is a portal specialized in Science indicators. Whole science includes natural sciences, exact sciences and social sciences. S&T includes the areas of Physics, Biology, Chemistry, Mathematics, Clinical Medicine, Biomedical Research, Engineering and Technology, Earth and Space Sciences.

9 Japan does not fare well in the journal, although it has output in antarctic research. The language may be a barrier and might encourage scientists to publish in local journals. This phenomenon might also explain its reduced international co-authorship in S&T of 22.2% (OECD). Nonetheless, in the AS journal Japan displays fairly high international co-authorship (57.7%) .

Table 3 – Comparison of scientific output of countries in *AS*, World Bank and SCIMAGO

Countries	Antarctic Science (*AS*)	S&T (WorldBank)	Whole Science (SCIMAGO)
United Kingdom	1° (2°) (2°)	5°	3°
U.S.A.	2° (1°) (1°)	1°	1°
Australia	3° (3°) (4°)	12°	11°
Germany	4° (4°) (3°)	4°	4°
Italy	5° (5°) (6°)	8°	9°
New Zealand	6° (8°) (8°)	34°	37°
Argentina	7° (12°) (11°)	33°	39°
France	8° (6°) (5°)	6°	6°
Spain	9° (10°) (9°)	10°	10°
South Africa	10° (11°) (16°)	36°	35°
Poland	11° (16°) (20°)	21°	20°
Sweden	11° (15°) (14°)	18°	21°
Brazil	12° (20°) (18°)	15°	13°
Chile	13° (19°) (19°)	40°	46°
Belgium	13° (14°) (15°)	22°	22°
Russia	13° (9°) (12°)	14°	16°
China	14° (17°) (10°)	2°	2°
Netherlands	14° (13°) (13°)	13°	14°
Japan	15° (7°) (7°)	3°	5°
Norway	17°(18°) (17°)	27°	31°

Source: The author. Data extracted from Antarctic Science, World Bank (WB) and SCIMAGO[1].

1 In column 2, the first brackets correspond to the score attributed by Dastidar to antarctic scientific ouput in the period 1980–2004 (fractional count methodology). Dastidar and Ramachandran (2008) examined 82 countries, but we standardized this rating considering only the 19 countries cited + Norway (because it is an original member country). In the second brackets, the score of antarctic scientific output measured by Ji, Pang and Zhao (2014) between 1993 and 2012 (whole count methodology). Ji, Pang and Zhao (2014) measured 25 countries, but to uniformize this ranking, only 19 countries + Norway were considered. The divergences between Dastidar and Ramachandran (2008) and Ji, Pang and Zhao (2014) can be explained by the different counting methodology and different timeline, especially because China has experienced in recent years a geometric growth of its scientific output. Some countries, such as India, Canada, Denmark and South Korea, which appear in the surveys of Dastidar and Ramachandran and Ji, Pang and Zhao, were excluded from our research because they had less than 26 participations in the journal.

Chart 1 – Classification of countries according to their degree of investment in Antarctic science

Limited	Regular	Significant	Deep
China.	U.SA, France, Germany, Spain, Netherlands, Brazil, Poland, Russia, Japan, Sweden.	United Kingdom, Belgium, Italy, Norway, Australia.	New Zealand, Argentina, Chile, South Africa.

Source: The author. Data obtained from AS, WB and SCIMAGO.

This discrete performance can be explained by the still recent history in Antarctica, associated with a low degree of international co-authorship, which compromises its ability to respond to the logistical challenges of research on the continent. It will be said that China has limited Antarctic investment.[10]

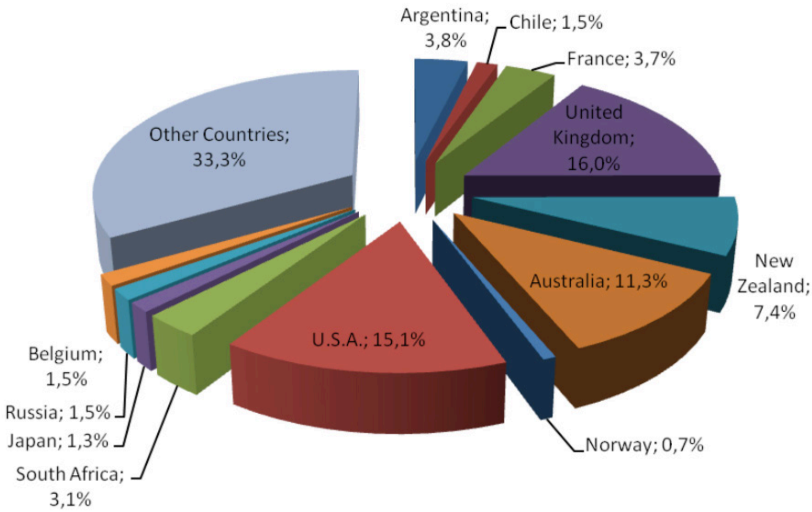
We realize that there is not necessarily a correlation between the output of Antarctic science, science and technology and science as a whole, leading to the need of researching why some countries are more dedicated to Antarctic science than others.

Among the top 10 in the journal, there are seven original ATS members of whom five are territorialists. This finding raises the need to investigate how much the original adherence to the STA as well as the sovereign interests within the continent can influence the production of Antarctic science.

From the 44 countries (+ one institution, SCAR) that published in the journal, the original 12 members accounted for 66.7% of the 1,410 published articles.

10 In AS magazine, Chinese international co-authorship is relatively high (60.7%), possibly due to the sample size. In Ji, Pang and Zhao (2008), it is 37.63%. Although China is not fully engaged in antarctic science, there are indications that this will change in a short period of time. China has currently four Antarctic stations (two permanent ones) and is in the process of building the fifth. On the other hand, the increasing pace of its financial expenditures in recent years leads us to believe in a future increase of Antarctic science output.

Fig. 4 - Participation of the original member countries in the ouput of *AS* Journal.

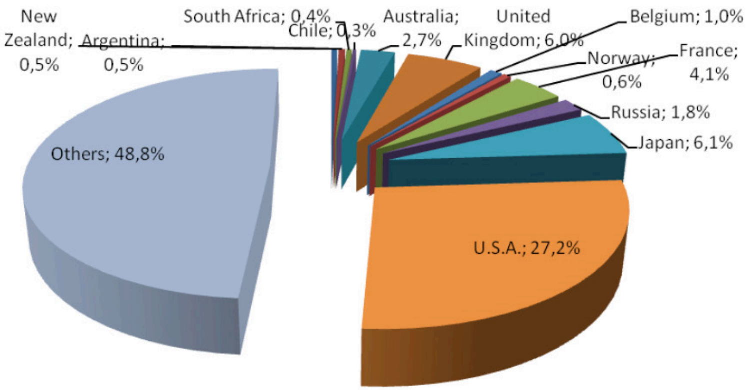


Source: The author. Data collected in AS.

N: 2,000 participations from 44 countries. Whole counting methodology.

The seniority of the original and consultative member countries in the ATS has produced concrete results in terms of scientific output, distancing them from the other contributors. It may be objected that the consultative countries are among the great leaders of world scientific production, which explains the magnitude of their contribution. In order to verify the this argument, the S&T output data of the 44 countries cited in the *AS* were considered in order to assess the ratio of the 12 member countries. In a total of 768,048 scientific articles (fractional count) produced by the 44 countries, the participation of the original member countries is much lower than that found in the *AS* journal.

FIG 5 – Participation of the original 12 members in the total output of articles in S&T (World Bank-2011).



Source: The author. Data extracted from WB.

N: 768 048 articles produced by 44 countries. Methodology: fractional count.

The performance of the original 12 members is barely over half the output (51.2%), a significant drop from the previous 66.7%. We observe that being an original member of the ATS is relevant for the production of Antarctic science, although it does not explain the full extent of this phenomenon. One must also try to avoid a truism and not confuse cause and effect. The larger scientific output in Antarctica may have as an explanatory variable the original adherence to the Treaty but the reverse, joining the regime because of a previous political/scientific investment in the continent, is also valid.

Figures 4 and 5 confirm the higher productivity in Antarctic science of Argentina, Chile, the United Kingdom, New Zealand, Australia and South Africa in proportion to their S&T performance. In this group, all have claims of sovereignty, with the exception of South Africa. We also observed that France and Norway maintain consistent performances on both figures, as well as Russia and Belgium, that do not hold sovereignty claims. The United States and Japan occupy a more prominent position in S&T than in antarctic science within the journal. It should be remembered that Japan, in *AS*, displays discreet participation, which interferes in this comparison. Nevertheless, as Dastidar and Ramachandran (2008) and Ji, Pang and Zhao (2014) positioned Japanese output of antarctic science in the 7th place of the international score, the result converges with the conclusions of Figures 4 and 5.

While investigating this first hypothesis, we verified that the original 12 members of the ATS did not behave similarly: although all performed consistently, some countries produced proportionately more than others. It is worth investigating a second hypothesis, to what extent territorialist interests play an important role in the decision to produce antarctic science. If we consider the seven territorialist countries, the sum of their contributions is equivalent to almost half of the published material (44.3%). Among these seven, only two exhibit a renowned history of S&T output and science as a whole: the United Kingdom and France. Argentina, Chile, New Zealand, Australia and Norway have no tradition in this respect and can be considered beginners in the field of science. It is also clear that France and Norway seem proportionately less concerned with producing antarctic science than the other territorialist countries and if their shares were excluded, the result of the other five would correspond to 40% of the journal. In S&T, the publications of these five states amount to 14.6%. The specificities of a case study as well as methodological differences between whole count (in AS) and fractional count (in WB) may result in some distortions in the percentages obtained, yet we found that countries with territorial claims publish three times more Antarctic science than S&T. However, this behavior is not uniform and some countries pursue this output more than others.

Our view is that science can be understood as an instrument of power and that for some States there is a political rationale behind the ouptput of antarctic science. Interest in Antarctica seems to grow in proportion to the proximity to the continent, seen as a potential "backyard" by surrounding countries. Argentina, Australia, Chile and New Zealand fit this profile, as well as South Africa (although not territorialist). The United Kingdom can be considered geographically close thanks to sovereignty on its overseas territories in the South Atlantic: the Falkland Islands, South Georgia and South Sandwich Islands.

The initial part of this analysis investigated to what extent being an original member of the ATS and having sovereign interests could affect the output of Antarctic science. We found out that, in general, the original member countries as well as territorialists have a higher output of antarctic science than S&T.

However, some countries that joined the ATS later also performed expressively in AS journal.

To produce new observations on the output of antarctic science, we created an indicator called "antarctic productivity". The indicator consists of the quotient obtained by dividing a country's participations in AS journal by its total S&T output (World Bank figures).[11] The antarctic productivity indicator becomes relevant if it is set against countries with equivalent S&T output. The criterion for the arrangement of table 4 was to bring together countries with similar S&T output and then compare their antarctic productivity. In this way, not only the 19 most productive countries appear, but also others listed in the journal. For such exercise to be beneficial it must take into account the risks inherent to a case study: the excess or lack of representativeness of certain countries in the AS journal.

The first category shows deep divergences between antarctic productivity in six countries with equivalent S&T output. All, except Ireland, are signatories to the ATS, but the Czech Republic is not an original member. Territorial claims alone do not seem to be a decisive factor for antarctic productivity, since South Africa —which has no sovereignty claim over the continent— has a performance superior to Norway (although Norway probably has an antarctic productivity somewhat higher than what is shown in this case study). New Zealand's strong performance coincides with a high percentage of international co-authorship in the journal corroborating literature that shows that this is an important mechanism for multiplying scientific ouput.

Chile has 10 times more Antarctic productivity than the other countries in its category. As already noted, most of the ATS original members usually have expertise in Antarctic science, especially if they are territorialists. Ukraine, despite having belonged to the former USSR, performs poorly, as does Romania. Malaysia, although it leads the S&T output among the four countries mentioned, has fewer weight in antarctic science, possibly due to its late adhesion to the ATS.

Australia has a three times higher antarctic productivity than the second country in its category —Spain— proving indeed the importance of original adherence and sovereign interests in the output of Antarctic science. In the case of South Korea and India, AS journal is not representative of their antarctic production, since in both Dastidar and Ramachandran (2008) and Ji, Pang and Zhao (2014), Indian output exceeds South Korea, the opposite of what happens in the journal.[12]

11 Plus, it is multiplied by 1,000 to facilitate the observation of numbers.

12 India in 15° and Korea in 24° (Ji, Pang and Zhao, 2014). India in 14° and Korea in 25° (Dastidar and Ramanchandran, 2008).

Table 4 – Antarctic productivity comparison

Countries	Number of Participations in AS	S&T Output (WB) (2011)	Antarctic Productivity Col.2/ col.3 (X 1000)
N. Zealand (1961)	148	3472	42,63
Argentina (1961)	76	3863	19,67
S. Africa (1961)	61	3125	19,52
Norway (1961)	14	4777	2,93
Tchech R. (1962)	7	4127	1,70
Ireland	4	3186	1,26
Chile (1961)	30	1979	15,16
Ukraine (1992)	3	1727	1,74
Romenia (1971)	1	1626	0,62
Malaysia (2011)	1	2092	0,48
Australia (1961)	226	20603	10,97
Spain (1982)	71	22910	3,10
S. Korea (1986)	23	25593	0,90
India (1983)	7	22481	0,31
U.K. (1961)	320	46035	6,95
Germany (1979)	158	46259	3,42
Japan (1961)	26	47106	0,55
Italy (1981)	157	26503	5,92
France (1961)	73	31686	2,30
Canada (1988)	23	29017	0,79
Brazil(1975)	31	13148	2,36
Russia(1961)	30	14151	2,12
Netherlands(1967)	28	15508	1,81
Poland(1961)	34	7564	4,49
Belgium (1961)	30	7484	4,01
Sweden (1984)	34	9473	3,59
Israel	3	6096	0,49
USA (1961)	301	208601	1,44
China (1983)	28	89894	0,31

Source: The author. Data collected from Antarctic Science and World Bank.[13]

13 Table 4, the figures of *Antarctic Science* are whole count. Figures from the World Bank are fractional count and the author has excluded the numbers after the comma without rounding them. In bold, countries with consultative *status*. In brackets, date of accession. In italics, non-signatory countries.

Japan, despite being an original signatory of ATS (third in the world S&T score), differs from the Antarctic productivity of Germany and above all of the United Kingdom. Even if we are aware that AS journal is not a very popular medium for publication among Japanese scientists, we found that the country produces relatively little antarctic science in proportion to its S&T output and, that its antarctic productivity is the lowest among the 12 original members. One possible explanation for this phenomenon, apart from geographic distance, is Japan's low degree of international co-authorship in the S&T area (22.2%). In a remote continent such as Antarctica, international cooperation helps support an abundant scientific ouput.

Italian productivity is also surprising, although the country only joined the ATS during the 1980s. This performance, also noticed by Dastidar and Ramachandran (2008) and Ji, Pang and Zhao (2014), deserves to be addressed, but not in this paper. France, despite its history on the sixth continent, does not show great antarctic productivity. The limited extent of French territorial claims may help explain this as well as that of Canada, which does not even have consultative *status*.

Poland has relatively high antarctic productivity and it is worth recalling that it was the first country to join and obtain consultative *status* in the ATS, fulfilling the requirement of continued antarctic science capability. The effort is evident in its antarctic productivity, which competes with that of Belgium, an original member. Israel is included in the table to show how a country, with relatively compatible S&T performance, is not interested in producing antarctic science or joining the ATS. The United States and China are the two largest producers of S&T in the world so this affects the significance of their antarctic productivity in relation to the other countries. The antarctic productivity, when cross referencing with the research and development expenditure of each country and its number of researchers shows how invested certain countries are in producing antarctic science.[14]

14 R&D refer to activities that are undertaken to increase expertise and include humanity, culture and Society and the use of expertise for new applications. R&D covers basic research, applied research and experimental development. Available at: http://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS. The option of remaining in the World Bank database and not working directly with Antarctic programs budgets is due to the difficulty of obtaining accessible and updated information on these funds. Another reason is the fact that this funding does not necessarily reflect the output of scientific articles.

Table 5 – Comparison of countries' expenditure and research capacity

Countries	Antarctic productivity	Expenditure for research & development (in US$ billions)	N° of researchers per million people (2005–2012)
6. New Zealand (7)	42,63	2,4	3693
7. Argentina (19)	19,67	3,5	1236
10. South Africa (16)	19,52	2,7	364
13. Chile (10)	15,16	1,0	317
3. Australia (13)	10,97	34,6	4280
1. U. Kingdom (17)	6,95	50,5	4024
5. Italy (14)	5,92	27,1	1820
11. Poland (15)	4,49	4,9	1753
13. Belgium (2)	4,01	11,9	3983
11. Sweden (3)	3,59	19,4	5181
4. Germany (11)	3,42	112,4	4139
9. Spain (6)	3,10	18,2	2719
17. Norway (1)	2,93	8,2	5588
12. Brasil (18)	2,36	28,3	710
8. France (4)	2,30	63,7	3918
13. Russia (10)	2,12	20,8	3096
14. Netherlands (9)	1,81	18,7	3506
2. U.S.A. (12)	1,44	486,0	3979
15. Japan (8)	0,55	155,9	5185
14. China (5)	0,31	205,1	1020

Source: The author. Data from the World Bank.[15]

15 The number that precedes the country corresponds to its position in terms of participations in the AS (Table 1). As many countries have had the same number of participations, they are tied. This is the case of Poland and Sweden, in 11th; Chile, Belgium and Russia in 13th; China and the Netherlands in 14th. Norway ranks 17th in AS, with Canada and South Korea rating 16th in AS journal, but were excluded from the survey because they had fewer than 26 participations. Norway was included in the analysis because in spite of having only 14 participations, it is an original signatory of the ATS. In brackets, the international co-authorship rank held by the 20 countries in AS journal. Russia and Chile are tied in 10th. To obtain the values in column 3, the 2014 GDP of each country was divided by the percentage destined to R&D in the period 2005–2012.

Although New Zealand, Argentina, South Africa and Chile have fewer resources, it seems a significant part of the funds destined for research and development in these countries are turned to the production of science in the white continent.

A simple comparison shows that the USA invests in research and development more than 100 times the Argentinean expenditure, an amount worth 90 % of its GDP.[16] Argentina has a third of researchers for every million people compared to the United States. Even if the Argentinean Antarctic science output is much lower than the United States, it does not reflect the immense financial and team disparity between the two countries. In AS journal, Argentina's participation is four times lower than the USA, while for Ji, Pang and Zhao (2014), it is nine times lower and for Dastidar and Ramachandran (2008), 15 times lower.

Similarly, China invested in research and development the equivalent of 80 % of Chile's GDP. Although the Chilean R&D expenditure is 200 times lower than the Chinese and the country has a third of researchers (for every million people), in AS the Antarctic output of both is equivalent.[17] For Dastidar and Ramachandran (2008), Chilean output is 30 % lower than the Chinese one and for Ji, Pang and Zhao (2014), 60 % lower. Although the United States are the undisputed leader in Antarctic scientific output, New Zealand, Argentina, South Africa and Chile, with much lower funds, and —in the case of the last three— reduced scientific staff, occupy positions of reasonable prominence.

New Zealand, although it has a slightly lower R&D budget than Argentina and South Africa, compensates for this shortage through an expressive team of researchers. It is the country with the highest antarctic productivity, which may also be related to its international co-authorship index.

We consequently infer that Antarctic productivity is motivated by political and scientific interests and if Antarctic science is a priority, limited material resources (whether capital or technical personnel) do not hinder its quantitative ouput. The production of antarctic science requires material resources (financing, skilled labor, etc.), cognitive tradition in the area, and political interest in the continent. It is often irregular because few international actors meet these three requirements.

Literature states that productivity in science is also the result of international cooperation established among scientists. According to Dastidar and Ramachandran (2008) and Ji, Pang and Zhao (2014), antarctic science is no exception and they provide broad evidence of this reality. Our survey found that 16 of the most productive

16 GDP figures for 2014. Percentage of research and development for 2005–11 obtained from the World Bank.

17 China has about 90 researchers living in Antarctic stations during the summer while Chile has 359 (CIA, 2016).

countries in AS journal established an international co-authorship superior to that existing in S&T, proving ATS's success in promoting ISCA.

Table 6 - Distribution of international co-authorship in AS journal (N: 1038 participations)

Countries	U.S.A.	U.Kingdom	Australia	NewZealand	Germany	Italy	France	Spain	Argentina	South Africa
U.S.A	152	32	31	34	12	25	9	10	4	4
U.Kingdom	32	128	22	12	20	18	6	11	4	6
Australia	31	22	110	23	17	14	7	4	1	4
New Zealand	34	12	23	89	13	13	3	8	1	2
Germany	12	20	17	13	89	7	8	8	7	3
Italy	25	18	14	13	7	75	9	4	-	1
France	9	6	7	3	8	9	47	4	2	3
Spain	10	11	4	8	8	4	4	43	5	1
Argentina	4	4	1	1	7	-	2	5	28	1
South Africa	4	6	4	2	3	1	3	1	1	25

Source: The author. Data from AS.[18]

N: 1.038 (wholecount).

International co-authorship in antarctic science is due to several factors: similar language, political identity between States, material capacity to produce science and tradition in the field. The English-speaking countries belonging to the *Commonwealth* work mostly among themselves. In the case of European countries, the last two factors have more weight, as well as geographical contiguity in the choice of partners. Ji, Pang and Zhao (2014) suggest that co-authorship —in the specific case of Antarctica— may correspond to the proximity of research stations on the continent. It was not possible to verify this hypothesis in our research, but there seems to be no grounds for it. The *Antarctic Treaty Inspections* report (2005) claims to have found little scientific cooperation

18 *Antarctic Science* displays 448 articles written in international co-authorship that correspond to 1,038 participations of the 44 countries that published in the journal. The crossing of a country with itself reveals the total number of its international co-authorship in the journal (whole count). The figures correspond to the number of participations.

between adjacent stations. Although there may be logistic or social interaction, there is no evidence of scientific dialogue between Antarctic bases. In general, the great producers of Antarctic science boost their scientific output thanks to a closed loop co-authorship.

Among antarctic productivity leaders, we noticed that Argentina and South Africa cooperate internationally less than expected. It is possible that limited resources have restricted the internationalization of their science, which is mostly made up of national content. Literature suggests that greater openness to international co-authorship promotes the increase of scientific output, but this practice has yet to be incorporated by the two countries (Nassi-Caló, 2014).

1.3.1 The case of South America

The contribution of South America to the AS journal is negligible. Of the eight countries that belong to the ATS, only five published in the journal and their total participation corresponds to 7% of the publications.

Table 7 - Participation of South American countries in *Antarctic Science* (1989–2014)

Countries	Participations
Argentina	76
Brazil	31
Chile	30
Colombia	1
Equador	-
Peru	-
Uruguay	-
Venezuela	1
Total participations	139

Source: The author. Data collected in Antarctic Science[19].

N: 2,000 (whole count).

19 The AS has a total of 1,410 articles that correspond to 2,000 participations by the 44 contributing countries. In bold, countries with consultative *status*.

Table 8 – International co-authorships established by South American countries in *Antarctic Science*

Countries	Argentina	Chile	Brazil	Colombia	Venezuela
Argentina	28	1	1	1	-
Chile	1	17	-	-	-
Brazil	1	-	12	-	-
U.S.A.	4	4	3	-	-
United Kingdom	4	6	3	-	-
Australia	1	3	-	-	-
New Zealand	1	-	-	-	-
Germany	7	5	1	-	-
Italy	-	1	1	-	-
France	-	3	3	-	-
Spain	5	1	-	-	1
South Africa	1	1	-	-	-
Colombia	1	-	-	1	-
Venezuela	-	-	-	-	1
Poland	2	-	1	-	-
Israel	1	-	-	-	-
China	1	-	-	-	-
Canada	2	-	-	-	-
S. Korea	-	1	-	-	-
Ukraine	-	1	-	-	-
Sweden	1	-	-	-	-
Belgium	-	-	1	-	-

Source: The author. Data collected in AS.[20]

N: 1.038 (whole count).

Chile is an example of how international co-authoring can boost antarctic productivity despite limited budgetary and personnel resources. However, table 8 shows how scarce is the co-authorship among countries in the region. In 26 years of AS, only three articles in co-authorship were published between the ever present Argentina and Brazil, Chile and Colombia. Brazil, Argentina and Chile are not newcomers to AS journal. They began contributing respectively in March 1989, June 1990 and March 1993 yet it took them 20 years to publish together.

In the competitive universe of scientific articles, the partnership with economically strong countries and/or science experts facilitates the publication process. In South America, the logic that seems to guide the choice of international co-authors is the

20 Same information as in footnote 20.

financing and visibility/recognition of the institution (Katz, 1994). Not only do countries tend to privilege partners outside the Southern Cone, as two of the three South American co-authored articles include a European partner. It is reasonable to assume that budgetary and cognitive difficulties will limit the chances of south American countries engaging in regional partnerships and conversely encourage them to associate with stronger financial and technical-scientific partners (Lima, Velho, Faria, 2007). Nevertheless, there may be other reasons than the lack of funds.

A research in the field of S&T and bioprospecting in Latin America identified this same deficiency and pinpointed as hindering the development of an international cooperative culture, the absence or obsolescence of incentive programmes by South American governments (Domingues, Costa, 2014; Lima, Velho, Faria, 2007). Another possible explanation might be mutual circumspection caused by divergent geopolitical interests on the sixth continent. To back this claim we would have to collect additional data from other sources and redirect the research line, which is beyond the scope of this paper. Notwithstanding, the picture in South America seems to contradict one of the principles of international co-authoring which asserts that geographical proximity between countries (or Antarctic stations) is a key element to bring it about (Ji; Pang and Zhao, 2014; Katz, 1994).

Conclusion

The purpose of this investigation was to examine whether the ATS was effective in promoting international cooperation by regime users: scientists, stations, and research institutions. We verified that:

i. The regime established by ATS and SCAR was effective in promoting a higher level of international co-authorship, thus cooperation, than the one found in S&T.

ii. Scientific output obeys the international distribution of power with a few *players* dominating the global scene but some countries overcome their budget constraints by actively engaging in Antarctic research.

iii. Latin American countries do not favour international co-authorship in their region.

Although international co-authorship rates reveal that ISCA went further than the pattern of S&T (non-regime *status*), the decision to allocate ISCA's development to the implementation of the ATS disregards effects that might have been caused by other factors. On the other hand, the ambiguous nature of the ATS, admitting territorial claims, may also prevent ISCA from realizing its full potential. The lack of shared stations can be explained by the need for countries, once settled in Antarctica, to stand out internationally. This is what some scholars call the ATS's post-colonialist perspective (Elzinga, 2013, 213).[21]

In general, antarctic science, scientists and research institutions reproduce the political distribution of power of the Westphalian system with major powers dominating the international scene and accounting for a significant part of the scientific output. Still, the research found that some countries specialized heavily in Antarctic science despite unfavorable conditions. Their proficiency is a result of what AS publisher David Walton (2012) openly recognizes as a combination of political commitment and scientific interest. When signing the ATS, the so-called "Antarctic powers" had access to the best research locations and, as the key to lead the continent's management is to conduce antarctic research, they all intend to retain this prerogative (Brady, 2013; Elzinga, 2013). The difficulties of researching in Antartica harm mainly the late-comers and the developing or middle-income countries.

The paper did not discuss the issue of the quality of antarctic scientific output. We would, however, like to point out that since the criterion for becoming a consultative member does not specify the amount or worth of science output, the tendency is to favor the quantitative aspect rather than the qualitative one. According to experts, the way to assess the deficiencies of antarctic research is trough bibliometric evaluation of the citation and impact factor of published articles.[22]

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21 Post-colonial studies seek to understand the political and cultural effects of colonial experience in developing countries.

22 Such a procedure could be carried out by the Scientific Committee on Antarctic Research (SCAR).

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