Scientometrics, Vol. 9. Nos 1–2 (1986) 71–89

THE "MEANING" OF CITATION IN THE CONTEXT OF A SCIENTIFICALLY PERIPHERAL COUNTRY

LÉA VELHO

Conselho Nacional de Desenvolvimento Científico e Tecnológico
Superintendência de Desenvolvimento Científico
Coordenação de Ciências Agrárias
Av. W3 Norte – Q.511 – Bl. A -Ed. Bittar II
70.750 – Brasília – D.F. (Brazil)

(Received December 2, 1984 in revised form April 12, 1985)

This paper reports an investigation into the referencing pattern of Brazilian agricultural scientists. The study was based on the use of both quantitative data – citations appearing in a sizeable sample of articles published by these scientists – and qualitative data – interviews with a large number of scientists who authored the source papers. The aim was to explore the extent to which citation counts may be taken as valid indicators of the quality, influence or impact of published scientific knowledge in the general context of a scientifically peripheral country. The findings presented confirm the view that in this context, citation patterns are significantly influenced by factors "external" to the scientific realm and, thus, reflect neither simply the quality, influence nor even the impact of the research work referred to.

Introduction

Citation counts have tended to be treated as a reliable indicator of the quality[1] of scientific output, to the extent that they could be considered a measure of scientific progress, and not simply of scientific productivity as are paper counts.[2] This stance has been justified by the correlation of citation counts with various other indices of "quality" such as Nobel laureat counts and peer evaluation.[3] The underlying assumption of the use of references as a measure of quality is that "the research a scientist cites in producing his own papers represents a roughly valid indicator of influence on his work".[4] Thus, citations to a document are taken as indicating its influence on the research reported in citing papers.[5] It still remains to be seen whether in fact quality may be conflated with influence in this way.[6] However, most sociologists of science have been concerned to test the assumption that citations reflect the influence of one scientist upon another. The point has been disputed on the basis that "the use of citation patterns as an index of lines of intellectual influence, clearly involves a theory of citing which is far from being satisfactorily

elaborated."[7] Attention has been called to the fact that little is known about how scientists decide to cite papers in their work and why they choose to cite particular papers rather than others.[8] It has also been suggested that the conceptual confusion surrounding the use of citation counts may be avoided by viewing these as a measure of the impact, rather than quality, of scientific publications.[9] This contribution is valuable because it recognises that social factors play a role in shaping citation patterns in science.

These considerations notwithstanding, there remains a consensus that "citations are very often a visible record of genuine influence",[10] although it is now generally accepted that citations reflect actual influence rather than potential influence, and represent an approximate measure at that. Yet it is becoming increasingly clear that citations are not always or solely a reflection of the influence of a particular piece of research on another group of researchers. As *Edge* argues, "the giving of citations is only one aspect of the behaviour of scientists; and if, in any instance, the citation picture is to be accepted as the most accurate available representation of the real events, it can only be because it is well supported by other evidences".[11] Thus, precisely because social factors mediate citation behaviour in science, it is advisable to use data additional to those derived from citation counts when measuring the quality of scientific output. In particular, it is advisable to use qualitative data derived from face-to-face interviews if we are to be sure of exactly what citations measure and what, therefore, we may safely conclude from citation counts. This means that the analyst must have some first hand experience of the scientific endeavour under study. It also means, as *Mulkay* amongst others have argued, that "if we are to study in detail the operation of scientific communities, we must have the active cooperation of participants".[12] Of course, all of this renders the validation of citation counts a potentially laborious process but, I would argue, the effort involved can be easily justified where there is reason to believe that the pattern of formal communication in science – as reflected in the publication and citation of scientific papers – does not fully reveal the network of influence operating, or the quality of cited (and uncited) research work.

To date, analyses of the social factors which shape the citation behaviour of scientists have been based on studies of science in the developed/industrialized countries. In so much as these countries are "advanced" in terms of scientific output (this is not true of all industrialized countries), we may consider them to be at the centre of scientific endeavour globally. By contrast, all of the developing/less developed countries (with the possible exception of India) are on the "periphery" of the international scientific community.[13] Existing studies of science in the latter suggest that the formal communication patterns of scientists working in developing countries is heavily influenced by their being on the periphery.[14] If this is indeed

the case, the need to investigate the citation behaviour of scientists working in the developing countries – using qualitative as well as quantitative measures – would seem particularly urgent.

As it is, a number of additional problems emerge when the use of citations is extended to assess scientific output in scientifically peripheral countries. First, the data base conventionally used in the study of citation patterns – that is the *Science Citation Index (SCI),* which is the only computerised source available – is arguably biased in favour of the scientifically central nations.[15] Thus, when the *SCI* is used to assess the national scientific effort of peripheral countries it is able to grasp only the contributions of these countries to internationally "mainstream" research, which, as we will see, is only a small part of their scientific output. Second, literature-based analyses of developing countries have generally been undertaken on a country comparative basis and the data are frequently aggregated so as to assess gross scientific effort. As a result, the comparison of scientific performance of developing countries with one another or with that of the leading scientific nations may be misleading: it makes no account of the great diversity in environment and social conditions in which scientific activity takes place in different nations.[16] Moreover, it has been shown that the "product mix" in scientific research is not the same the world over,[17] and so if figures aggregated for all research fields are compared they will tend to mask the contribution of developing countries to specific areas of knowledge in which they may be focusing their scientific effort.

There have been very few attempts to investigate in depth a specific scientific field in a particular developing country using citation measures from sources other than the *SCI.*[18] Even less effort has been devoted to trying to find out exactly what citations measure or reflect in the case of these scientifically peripheral nations and what factors influence the decision of scientists in these countries to refer to some papers and not others.

This paper reports an investigation into the referencing pattern of scientists in a single country, Brazil, and a particular field, agricultural science. Brazil is of interest because it ranks as one of the higher scientific producers of the developing world.[19] Agricultural science is of particular interest to developing countries – not least because of the pressing problems of food supply and agricultural productivity – and has for many years received a substantial portion of Brazil's scientific resources.

It could be argued that agricultural science may constitute a poor choice as a subject in studies of this kind. Agricultural science is an applied field, and as such it is frequently suggested that work in it would be of local relevance only. Whereas research in basic disciplines is universalistic in its appeal, the potential audience for agricultural science may be far more restricted.[20] Despite its plausibility, the validity of this hypothesis is yet to be certified. The term applied science is frequently

misunderstood as if it were nothing but the application of a given science. It is necessary to bear in mind that "the production of applicable science will of necessity entail a process of theory-construction evolving independently from the mother disciplines".[21] Thus, agricultural science involves the development of theories which lead to special heuristics, research methods and explanatory models of universal interest.

The study was based on the use of both qualitative and quantitative data. In order to avoid the pitfalls surrounding the use of sources like the *SCI*, citations appearing in a sizeable sample of articles published by Brazilian agricultural scientists were analysed. Interviews were then conducted with a large proportion of the scientists who authored the source papers in an attempt to find out how and why the formal communication patterns described by quantitative measures emerge. The aim here was, therefore, to explore the extent to which citation counts may be taken as valid indicators of quality, influence or impact of published scientific knowledge in the general context of a scientifically peripheral country. In addition, it was hoped that the study would elucidate some of the specific conditions surrounding the performance of agricultural science in Brazil, and so suggest some areas in which citation-based indicators may be of use to science policy makers in developing countries. In the concluding section of this paper, I make a few, simple policy proposals for countering the situation described by the data.

The data base and methodological procedures

Agricultural science in Brazil is firmly established in two quite distinct research settings. On the one hand, the Brazilian Corporation for Agricultural Research (EMBRAPA), created in 1973, operates a network of research centres covering practically the whole nation. On the other hand, scientific activity was considerably strengthened with the establishment of graduate schools in agricultural colleges during the last two decades. Today, there are more than 100 graduate programmes in agriculture in Brazil which over the past twenty years have produced some 3600 Masters and 200 PhDs.[22] Whereas the main concern of EMBRAPA has been with technology-development research, more fundamental research is seen as the province of the universities.[23]

Although EMBRAPA is claimed to be "stealing" the best talent from the universities, a recent survey has shown that the centre of gravity for agricultural research in Brazil is still clearly with the universities.[24] For this reason, my data are drawn from eight graduate programmes offered by four Brazilian universities, namely, the Federal University of Viçosa (henceforth UFV), the agricultural branch of the University of

Table 1
Number of scientists with MSc and PhD degrees engaged to each graduate programme in the four universities studied

Degrees	UFV		ESALQ		UFRGS		UFC		TOTAL	
	SSPN	CP	SSPN	CP	SSPN	CP	SSPN	CP	SSPN	CP
Masters	7	11	0	0	7	13	7	9	21	33
PhDs	20	43	48	17	10	16	14	18	92	94
Total	27	54	48	17	17	29	21	27	113	127

Table 2
Scientific output of each graduate programme at the four institutions studied

Scientific output	UFV		ESALQ		UFRGS		UFC		TOTAL	
	SSPN	CP	SSPN	CP	SSPN	CP	SSPN	CP	SSPN	CP
Art. in-house J.	34	60	71	12	9	12	17	39	131	130
Art. national J.	11	15	30	9	12	36	2	5	55	65
Art. foreign J.	0	2	11	1	4	4	0	2	15	9
National confs.	3	15	31	14	42	83	10	7	86	119
Internat. confs.	0	2	18	3	9	1	0	0	27	6
Research repts.	3	5	2	0	4	0	5	17	14	22
Books (chap. in)	0	0	11	2	1	3	0	0	12	5
Others	0	4	34	5	11	10	10	7	55	26
Total	51	103	208	46	92	156	44	77	395	382

São Paulo (henceforth ESALQ), the Federal University of Rio Grande do Sul (henceforth UFRGS) and the Federal University of Ceará (henceforth UFC). The universities selected are located in different regions of the country and each one of them is clearly the leading agriculture school in its region. Two graduate programmes in each university were selected for closer analysisnamely, Soil Science and Plant Nutrition (henceforth SSPN) and Crop Production (henceforth CP) – on the basis that these were the only two subfields within the general field of agricultural science in which all the four universities offer graduate training. Table 1 shows the number of scientists engaged in each programe. These data were taken from reports submitted annually by the different Brazilian graduate programmes to research funding agencies in order to obtain scholarships for their master students. They document, among other information, the scientific output of the institutions in question. My sample of source paper was drawn from data in the reports submitted for 1980, 1981 and 1982 and relate to the output of a three-year period – from August 1978 to July 1981. The scientific output of each programme under study, broken down according to where the articles appeared, is presented in Table 2.

For sampling purposes I dealt only with papers published in scientific periodicals[25] (and I obtained copies of all of them). These papers were carefully read, their contents closely analysed and the origin of the articles in their reference lists noted and classified. Thus, I distinguished self-citation (S) from in-house citation (H) and from

Table 3
Number of papers and references analysed

Institutions	SSPN		CP		TOTAL	
	Papers	Refs.	Papers	Refs.	Papers	Refs.
UFV	45	683	77	1160	122	1843
ESALQ	112	1621	22	272	134	1893
UFRGS	25	404	59	1016	84	1420
UFC	19	162	46	457	65	619
Total B.	201	2870	204	2905	405	5775
Adv. C. J.	49	898	52	811	101	1709
Total	250	3768	256	3716	506	7484

references to work produced by Brazilian scientists at other domestic institutions (B).[26] Papers not referring to work done by Brazilian scientists were divided into those published in journals produced in Latin American countries (L), in other peripheral nations (P) and those published in advanced country journals (A).[27]

A similar analysis was performed on a selection of papers published in advanced country journals. To make the selection, I first established which scientific periodicals in category (A) were most heavily cited by my Brazilian authors. This produced six periodicals[28] which I scanned from 1975 to 1981 inclusive, searching for papers similar in content to those of my sample.[29] These papers were read and their references were classified as above, except for the category of in-house citation (H) which was not drawn since the work required to accomplish it was incommensurate with the aims and needs of my investigation. Table 3 gives the number of papers and references analysed in each subfield for the four Brazilian institutions and for my sample of articles taken from advanced country periodicals.

Finally, I interviewed scientists from each of the four Brazilian universities in order to find out their reasons and motivations for selecting the literature they had cited in the source papers. I decided to interview only the scientists who had published at least one journal article, either as single author or co-author, during the period studied.[30] In the event, I was able to interview 95 scientists in total: 24 each for UFV and ESALQ, 25 at UFRGS and 22 at UFC.

Results and discussion

Table 4 gives the breakdown by origin of the references in my sample of Brazilian and advanced country papers. In the event, there was no significant difference between the referencing pattern in the two subfields selected, and so citation data for these is aggregated here.

The differences in referencing behaviour of scientists from each of the four universiti will not be discussed here. For the purposes of this paper, I will consider first the

Table 4
Origin of papers referred to by Brazilian agricultural scientists and by a comparable sample of advanced country papers

	UFV	ESALQ	UFRGS	UFC	TOTAL	ADV. C.
S	220(12)	272(14)	138(10)	104(17)	743(13)	232(14)
H	143(8)	191(10)	121(9)	41(7)	496(8)	–
B	423(23)	238(12)	143(10)	132(21)	936(16)	19(1)[3 1]
L	76(4)	41(2)	21(1)	15(2)	153(3)	9(0)
P	26(1)	39(2)	10(1)	7(1)	73(1)	39(2)
A	955(52)	1121(60)	987(69)	320(52)	3383(59)	1410(83)
T	1843	1893	1420	619	5775	1709

Figures in brackets give rounded percentage of total (T).

referencing behaviour of advanced country agricultural scientists, notably to those working in peripheral nations; and second, the referencing pattern of Brazilian agricultural scientists – to their colleagues working outside their own institutions, in other peripheral countries and in advanced countries.

Advanced country citation of peripheral country papers

The data in Table 4 indicate that authors publishing in advanced country journals make negligible use of work emanating from Brazil or from other peripheral nations. Peripheral country publications would appear to have had little impact or influence in the scientific activity of central country researchers. A crude interpretation might conclude, on the basis of these findings, that the quality of the scientific output of peripheral countries is extremely low. However, to conflate impact or influence with quality in this way is to assume perfect communication in the international scientific community; that the contribution to scientific knowledge embodied in a nation's published papers is available to all to see and judge and, therefore, that citations

represent an unambiguous measure of their actual contribution to scientific knowledge. In practice, of course, the world's publications are not equally available and, in the case of peripheral nations especially, social as well as cognitive factors determine the range of publications likely to be referred to.

One of the social factors which greatly influence the likelihood of advanced country scientists referring to Brazilian publications concerns the language barrier between scientists in central and peripheral countries. *Rabkin* and *Inhaber* report that less than 1% of 214 000 American scientists covered in one survey have a knowledge of Portuguese and only 0.22% have a competence equal to, or better than, the ability to translate this language into English.[32] Yet, in a survey conducted by *Wood,* 76% of the 2355 American scientists and technologists sampled had recently come across a paper in a foreign language which they would like to have read but could not because of the language barrier. In the field of biology, medicine and agriculture this figure was as high as 80%.[33] One important reason, therefore, why Brazilian agricultural literature is not cited by central country scientists is that it cannot be understood by the vast majority of them. Another, somewhat associated with this one, is that advanced country scientists have virtually no access to Brazilian publications. Only two of the 149 Brazilian journals listed by UNESCO were used as sources in the 1973 edition of *WIPIS.*[34] Neither of these two journals is available in North American libraries outside the Institute for Scientific Information.[35] Furthermore, neither of these two journals deal with agricultural science. The Science Reference Library in London is the only place in the UK where some Brazilian agricultural journals may be read. Even in this library, the collections are far from complete, lacking many numbers and, not rarely, whole volumes. Clearly, Brazilian agricultural papers are made virtually inaccessible to advanced country scientists by both language and publication location constraints.

It could be argued that these constraints account only in part for the little use that advanced country scientists make of Brazilian scientific literature for, as *Rabkin* and *Inhaber* found "scientists from peripheral nations often publish in journals of the central nations".[36] However, Brazilian agricultural scientists do not publish often in advanced country periodicals. Table 5 gives the location of articles published in scientific periodicals between August 1978 and July 1981 by scientists at the four Brazilian institutions studied. It shows that only 6% of their scientific output appeared in foreign periodicals. Moreover, about 70% of the papers published abroad were co-authored by American and Brazilian researchers. The latter maintained in the interviews that publishing these papers in foreign journals was a requirement of their American graduate supervisors and that they had no intention to continue to do so. Similarly, out of the 101 papers from advanced country periodicals sample, only one was authored by Brazilian agricultural scientists. Because of this feature, the

language barrier and the inaccessibility of Brazilian journals are particularly important factors militating against Brazilian agricultural publication's being known by and, consequently, cited by, advanced country scientists.

However, language and publication location constraints cannot account for the equally low use advanced country scientists make of papers from other peripheral nations – 2% of the total number of references – which are often published in

Table 5
Publication location of articles produced by Brazilian agricultural scientists from August 1978 to July 1981

Journal	UFV	ESALQ	UFRGS	UFC	TOTAL
National Journals					
Ed. by Inst. itself	94(77)	83(62)	28(33)	56(86)	261(64)
Ed. Other Braz. Inst.	26(21)	39(30)	48(57)	7(11)	120(30)
Non-national Journals					
published in USA	1(1)	2(1)	8(10)	2(3)	13(3)
other	1(1)	10(7)	0(0)	0(0)	11(3)
Total	122	134	84	65	405

Figures in brackets give rounded percentage of total.

English and in more readily available periodicals. (The case, for example, of those African and Asian countries once under British rule). It seems, then, that other factors may also shape the referencing pattern of researchers in the advanced countries. This issue was raised in the interviews with Brazilian scientists, some of whom suggested that advanced country scientists do not refer to research work carried out in peripheral nations because they do not esteem it particularly highly. One interviewee illustrated this point by describing an incident he witnessed during his doctoral training in the US: "I was attending a genetics course and was given a handout about breeding maize by the convenor of the course. It contained a statement to the effect that *Webel* and *Lonquist,* in the US, had obtained a 9.44% gain per year with their new maize hybrid and *Parteniani,* in Brazil, got a gain of 13.6% with his. It went on to say that *Paterniani*'s results were remarkable, *if true*". There, for any student to read, was a clear indication of distrust, on the part of an academic researcher, for research findings produced in a peripheral country.[37]

I would argue, then, that factors other than the intrinsic quality of a publication determine in great part whether or not it will be cited. And, as a result, the qualitative contribution of those scientific nations more on the periphery internationally will not be reflected in the number of references they receive by advanced country

scientists. It would be reasonable to assume that if the factors outlined above were removed, citation counts may then more accurately reflect the quality of knowledge generated in peripheral countries. As language and access to Brazilian journals would seem not to place any problem to the communication of scientific findings within the Brazilian agricultural scientific community, it will be worth observing the referencing pattern of this community.

Citation pattern of Brazilian agricultural scientists

The figures presented in Table 4 show that Brazilian agricultural scientists' use of self-citation is comparable to that of their advanced country colleagues. When S is combined with H composite figures are obtained which are similar to those reported by *Irvine* and *Martin* for four radio-astronomy groups. They found that from 16 to 22% of all citations by these groups were self plus in-house citation.[38] My figures for the four institutions range from 19 to 24%. The proportion of references to Brazilian scientists at other domestic institutions (16%), to peripheral countries (4% including Latin America) and to advanced country publications revealed by my findings corroborate earlier studies of the scientific communication in peripheral countries.[39] In other words, there is evidence here that Brazilian agricultural scientists have very weak linkages with Brazilian colleagues working outside their own institutions; that they make almost insignificant use of investigations conducted in other peripheral countries; and, by contrast, rely heavily upon knowledge generated in advanced countries.

On the basis solely of the quantitative data we may reasonably conclude that Brazilian agricultural scientists are highly influenced in their work by their advanced country colleagues, and that the contrary is true as far as their national and peripheral colleagues are concerned. It is this general picture which I hoped to investigate by conducting interviews with the authors of the papers analysed. These interviews revealed a number of factors which influence how Brazilian agricultural scientists use and select the scientific literature and, thus, elucidate the "meaning" of the references they make.

Competition between Brazilian agricultural research centres was an issue raised directly and indirectly during the interviews as one factor which plays a role in shaping the formal communication system of agricultural science in Brazil.[40] To put it other way, because, as I found, there is competition both for financial resources and "priority of discovery", the scientists from different institutions tend not to use the work of their colleagues at both other universities and, with some exceptions, public funded research institutes.[41] However, competition can not be totally and solely blamed for the low level of formal communication between these institutions, nor

can it account on its own for the heavy use the scientists make of advanced country literature. Other factors, I have found, are also at play.

One of such factors is the accessibility of the scientific literature. New information is a vital ingredient for healthy research but its intrinsic value must be set against the price to be paid in gaining access to it. As *Large* puts it: "information will be gathered from the most readily available sources, and more difficult or obscure documents will only be explored when their contents are judged worthy of the effort".[42] It is striking that most of the interviewees maintain they find it easier to scan foreign periodicals than domestic ones. There are various reasons for this. First, the majority of domestic agricultural journals are of a very general nature, so it is very difficult to find in them articles dealing with a specific subject of interest to the scientist. Many of the interviewees complained that when scanning domestic journals, particularly those published by the universities, they have to look throughout a great number of issues to find an article of relevance to their work. By contrast, the advanced country journals which are most usually consulted, deal with more specific research areas.

Second, there is a strong tendency among Brazilian agricultural scientists to use scientific literature promptly available to them. None of the main libraries in the four universities were visited very frequently by the researchers – nominally because of time constraints. Instead, the scientists tend to use sources existing in their offices or departments. Many scientists have personal subscription to the journals they use so as to ensure easy access to them. These include typically foreign journals more related to their work, domestic ones edited by national scientific societies of which they are members and their own university's journals; journals published by other universities are generally only available in the institution's main libraries. Personal subscription to periodicals plays an important role in the scientific activities of the scientists interviewed. This conclusion is upheld by *Abou-id*'s study of UFV's agricultural scientific community. She found a strong positive correlation between the productivity of the scientists – measured by the number of papers they produced divided by the number of years of their professional lives as scientists – and the number of journals to which they individually subscribe.[43]

A third reason why Brazilian agricultural scientists find it easier to scan scientific literature from advanced countries is related to the fact that, nowadays, the individual scientist is being overloaded with scientific information. In trying to keep up with all the information being produced in their primary specialty, the scientists interviewed said they rely very heavily on the various Abstracts. The consequence of this practice is twofold. First, because not all Brazilian agricultural journals are indexed by the Abstracts,[44] using this source for reviewing the literature is unlikely to increase the scientists' awareness of research work conducted in Brazil. This, of course, applies to

scientists working in other countries as well as Brazil. Second, Brazilian agricultural periodicals represent such a small proportion of the journals indexed by the various Abstracts that using this source for obtaining information reveals considerably more papers emanating from central countries than from Brazil.[45]

Moving away from the practical issues of accessibility, the referencing pattern of the scientists interviewed was also clearly influenced by their educational history. *Moura Castro* and *Spagnolo* have pointed out that over 60% of Brazilian PhDs in agriculture obtained their degree abroad and of these, over 80% qualified in the US.[46] This pattern was confirmed by this study, and neatly mirrors the citation data I obtained. Over 70% of references type *A* were to American publications. This suggests that the preference of the scientists for advanced country literature, particularly for work generated in the US results, at least, in part from their having undertaken graduate training in those countries.

There are a number of reasons to believe that graduate training has a bearing on referencing patterns. First, as *Large* puts it, "scientists will tend to use information produced by people and institutions known to hem".[47] Second, and perhaps more important, academic habits acquired during training tend to persist throughout one's professional life. Some of the scientists maintain that they got used to reading certain American journals when they were being trained in the US and continued the practice. This tendency is reinforced by the fact that the consortia with American schools through which many of them were sent abroad, usually granted them the subscription to American journals. Thus, some of the scientists now subscribe to such periodicals at their own expense – inspite of the availability of these journals in their university libraries.

It could be argued that none of the qualitative findings presented above invalidates the general conclusions drawn from quantitative data – that Brazilian agricultural scientists are heavily influenced by the work of their advanced country colleagues; or, as some authors would put it, that knowledge generated in advanced countries has a great impact on agricultural research in Brazil, which in turn has a low impact both within Brazil and in other countries. I am convinced that these conclusions are at least partly applicable to my case. It is impossible to deny, for example, the influence of knowledge generated in advanced countries particularly upon the methodology and theoretical framework used by scientists in their articles and reported in their references lists. However, references of this kind are only a part of the total number of citations made by Brazilian agricultural scientists, and by no means the greatest part. The bulk of references, in fact, cannot categorically be said to reflect visible traces of past communication or the paying of intellectual debts as has been suggested elsewhere.[48]

There are at least two reasons for taking this view, both related to how and why the scientists compile their references list and decide about which papers to cite. First, the interviewees generally carry out their literature search *after* their research work has already been completed, in the case of writing their articles. In these circumstances, the literature review is nothing more than a collegial procedure, part of a ritual based on the norms of scholarship. The research cited cannot, therefore, be said to have actually influenced the investigation. Second, scientists have total freedom to choose which papers they will cite and tend to use this freedom to select articles which justify and corroborate their claims and findings, or those which do not but can be easily refuted or explained within the arguments presented. Thus, rather than being influenced by the papers they refer to, the scientists are selecting the sections of the available literature which most enables them to validate their theories and findings.[49]

Underpinning this selection procedure I found a widespread belief among Brazilian agricultural scientists that citing advanced country publications confers more prestige to their work; that it shows they know the literature and are working in a frontier field.[50] Ironically, of course, this very belief will tend to reinforce the notion that science conducted in the advanced countries is of a higher quality than that conducted in peripheral countries.

Conclusions

A number of factors mediate the decision of individual scientists about which research papers they will refer to in their publications. In the context of science undertaken in developing countries, citation patterns are significantly influenced by factors "external" to the scientific realm, which are, thus, social rather than cognitive in nature. These concern fundamentally the existence of imperfections in scientific communication internationally. There are a number of practical reasons for this imperfect communication, including the language barrier, difference in the accessibility of scientific literature from peripheral and advanced countries and the educational history of scientists working in peripheral nations. There can be no doubt that taken together these factors go a considerable way to explaining the citation patterns reported here – in particular, the negligible proportion of citations in articles by both Brazilian and advanced country agricultural scientists to literature from the peripheral nations; and the relatively high proportion of citations by Brazilian researchers to advanced country literature in agricultural science. In a similar way, the existence of various forms of competition between the four Brazilian universities – where language and accessibility of literature should not present any major barriers –

explains, in part at least, the apparently low level of formal communication between scientists from the different universities.

Having said this, there is an element of choice shaping the availability of scientific literature from which an individual may cite. For example, many of the interviewees chose to subscribe to advanced country journals in their subfield rather than make any great effort to ensure that those produced by other national institutions were close at hand. The flow of scientific information between peripheral and advanced countries is also, to some extent, mediated by factors which are not wholly within the control of the scientist concerned. Perhaps most critical of these is the higher status of scientific knowledge generated in the central compared with that generated in peripheral countries. This feature would seem to be so pervasive that Brazilian agricultural scientists tend to select references from advanced country literature out of a belief that these confer prestige on their own research findings which the citation of articles from other peripheral countries does not. On the other side of the coin, there is evidence that some agricultural scientists in the advanced countries do not wholly trust the findings reported in scientific publications from peripheral countries.

To the extent that the international flow of scientific information is imperfect, citations do not allow us to judge the quality of the scientific research – at least not on their own. It is more difficult to make any categorical conclusions about the extent to which citations reflect the influence or even the impact of the research findings referred to by citing authors. Clearly, scientific literature which is not generally available to scientists cannot have any influence or impact on their work. In any case, given that references are commonly compiled *after* the research in question has been completed, citations cannot be taken as an accurate indication of patterns of influence on current research. This is not to deny the more general influence of, for example, advanced country scientists on agricultural research in Brazil. However, the level of citation by the Brazilian researchers of those in other peripheral countries may well understate the influence of those countries on agricultural science in Brazil. Considerable further analysis of the referencing behaviour of peripheral country scientists is required before we can with any certainty attribute "meaning" to the citations they make. In particular, it might be useful to develop additional means for measuring networks of influence between and within scientifically peripheral countries. Finally, citations do tell us something about the selection process whereby scientists "choose" which article to cite from the available literature. In this context, it might be useful to identify some of the "internal" factors, as well as the "external" ones, which mediate citation patterns.[5 1]

On a more specific level, the findings presented here tell us a considerable amount about the formal communication system of Brazilian agricultural science. They reveal, for instance, that agricultural scientific research in Brazil is fragmented, with different

institutions competing with one another, that the scientists find it easier to scan foreign periodicals than domestic ones, that the graduate training programme funded by government agencies is in need of revision and so on. Information of this type could prove invaluable to science policy makers in agencies like the National Council for Scientific and Technological Development (CNPq) in Brazil, wishing to improve the usefulness and efficiency of the national science effort. CNPq, which gives financial support to many Brazilian scientific journals, could, for example, promote meetings with the editorial boards of agricultural periodicals to discuss the specialization of their subject matter. Moreover, CNPq could stimulate that a central subject index for all agricultural journals and a central agricultural Abstract journal be established in Brazil. Another way in which CNPq could improve communication between different institutes would be to encourage them to work on joint research projects and to stimulate short-term exchange of personnel between them.

Finally, it is important to bear in mind that the study of citation practices should be based on qualitative as well as quantitative data, and be appraised on the basis of an intimate knowledge of the environmental determinants of the research activity in the community under study. The value of the insights provided by this approach attests also to the importance of conducting such studies within a specific country and on a specific field of scientific knowledge.

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I am immensely grateful to *Wendy Faulkner* of SPRU, University of Sussex, for both providing valuable contribution to the content of this paper and for helping me to overcome the "language barrier" and write this paper in English. I also would like to thank Dr. *M. J. Moravcsik* for valuable comments and suggestions on an earlier version of this paper. None of them, of course, are responsible for remaining errors and the viewpoints expressed here are strictly personal. This research work was carried out during my doctoral training at SPRU, University of Sussex, UK, for which I have a grant from CAPES (Federal Agency for Graduate Education), Brazil.

Notes and references

1. Quality of scientific output is referred here as the attribute of a scientific paper which has been subject to judgement by the scientific community to decide on the truth of particular research findings. See: N. G. GILBERT, Measuring the growth of science. *Scientometrics,* 1 (1978) 9.
2. M. J. MORAVCSIK, Measures of scientific growth, *Research Policy,* 2 (1973) 266, has suggested that there are three aspects of science which may be measured: scientific activity, scientific productivity and scientific progress.
3. E. GARFIELD, *Citation Indexing: Its Theory and Application in Science, Technology and the Humanities.* John Wiley & Sons, New York, 1979. Ch. 6; K. E. CLARK (1957) cited in: J. COLE, S. COLE, Measuring the quality of sociological research: Problems in the use of the Science Citation Index, *The American Sociologist,* 6 (1971) 23.

4. J. R. COLE, Patterns of intellectual influence in scientific research, *Sociology of Education*, 43 (1970) 381.
5. B. C. GRIFFITH, H. G. SMALL, J. A. STONEHILL, S. DEY, The structure of scientific literatures, II: Toward a macro- and microstructure for science, *Science Studies*, 4 (1974) 364.
6. W. FAULKNER, *Indicators of National Scientific Performance: Methods, Problems and Possibilities*, unpublished MSc dissertation, University of Sussex, SPRU, 1981, p. 43.
7. M. MULKAY, Methodology in the sociology of science: Some reflections on the study of radio astronomy. In: G. LAMAINE (Ed.), *Perspectives on the Emergence of Scientific Disciplines*, Mouton, The Hague, Paris, 1976, p. 211.
8. Ibid.; see also: D. CRANE. *Invisible Colleges*, The University of Chicago Press, Chicago & London, 1975 (2nd. ed.), p. 20.
9. M. J. MORAVCSIK, A progress report on the quantification of science, *Journal of Scientific and Industrial Research* (India), 36 (1976) 12, has suggested that the number of citations a publication receives is a measure of its impact on subsequent research papers. This idea has been extended and developed more in-depth by J. IRVINE, B. MARTIN. Es Possible Valorar la Investigacion Pura? , *Mundo Cientifico*, 12 (1982) no. 11, 182.
10. D. EDGE, Quantitative measures of communication in science: A critical review, *History of Science*, 17 (1979) no. 36, 122.
11. Ibid, pp. 110–1.
12. M. MULKAY, op. cit. note 7, pp. 210–1.
13. See: J. D. FRAME, F. NARIN, M. P. CARPENTER, The distribution of world science, *Social Studies of Science*, 7 (1977) 501, for a fairly clear picture of which are the "central" and "peripheral" scientific nations of the world. S. ARUNACHALAM, S. MARKANDAY, Science in the middle-level countries: A bibliometric analysis of scientific journals of Australia, Canada, India and Israel, *Journal of Information Science*, 3 (1981) 13, have proposed a third group of "middle-level" countries (from the point of view of scientific output), lying between the central and peripheral scientific nations.
14. J. D. FRAME, Measuring scientific activity in lesser developed countries. *Scientometrics*, 2 (1980) 133; Y. M. RABKIN, H. INHABER, Science on the periphery: A citation study of three less developed countries, *Scientometrics*, 1 (1979) 261; Y. M. RABKIN, T. O. EISEMON, J. J. LAFITTE-HOUSSAT, E. M. RATHGEBER, Citation visibility of Africa's science, *Social Studies of Science*, 9 (1979) 499.
15. For a discussion of the bias of the ISI database in favour of scientifically central nations, see: W. FAULKNER, op. cit. note 6; L. VELHO, Como medir a ciencia? *Revista Brasileira de Tecnologia*, 16 (1985) 35.
16. Some examples of how the environmental and social conditions under which scientific activity takes place may vary from nation to nation are: social and institutional location of the scientists, language and circulation of the journals in which they publish their research findings, the relative importance a specific nation attaches to the various modes of scientific communication available to scientists and the extent to which the scientists are committed to the norm of communalism.
17. J. D. FRAME, F. NARIN, M. P. CARPENTER, op. cit. note 13, for example, have shown that although the scientifically productive nations follow a similar "product mix" with regard to basic science, there is significant variation between them and all of the East European countries and many of the Third World countries.
18. L. VELHO, J. KRIGE. Publication and citation practices of Brazilian agricultural scientists, *Social Studies of Science*, 14 (1984) 45.
19. According to E. GARFIELD, Third World research. Part 1, *Current Contents*, (August 15, 1983) no. 33, 5–15, Brazil ranks third amongst Third World countries, in terms of the number of articles produced by its scientists.

20. See, for example, A. J. HERZOG. *Colleague Networks, Institutional Roles and the International Transfer of Scientific Knowledge: the Case of Ireland,* unpublished PhD. dissertation, Massachussetts Institute of Technology, 1975, N. W. STORER, The internationality of science and the nationality of scientists, *International Social Science Journal,* 22 (1970) 89.
21. W. KROHN, W. SCHAFER, The origins and structure of agricultural chemistry, In: G. LEMAINE (Ed.), *Perspectives on the Emergence of Scientific Disciplines,* Mouton, The Hague, Paris, 1976. p. 49.
22. C. DE MOURA CASTRO, F. SPAGNOLO, Science and Scientists in Agriculture: the Brazilian Case, paper presented at the Tercier Seminario Internacional de Investigacion Educativa, Mexico, February, 1982. p. 2.
23. J. PASTORE, E. R. A. ALVES. Reforming the Brazilian agricultural research system, In: T. M. ARNDT, D. G. DALRYMPLE, V. W. RUTTAN (Eds), *Resource Allocation and Productivity in National and International Agricultural Research,* University of Minnesota Press, Minneapolis, 1977, pp. 394–403.
24. C. DE MOURA CASTRO, F. SPAGNOLO, op. cit. note 22, p. 12.
25. Every regular series of research papers circulating widely were included in my sample. I excluded articles read at conferences because I found out that the great majority of them were published later in scientific journals. I also excluded research reports of restricted circulation, books, theses and articles written for the lay public.
26. Because of my background training and professional situation in the Brazilian National Council for Scientific and Technological Development (CNPq), I have gained a comprehensive knowledge of the Brazilian agricultural scientific community. This has been used, for example, to identify the institutional affiliation of authors referred to in the source papers – that is, the origin of references. By doing so, I have been able to distinguish in-house citation (H) from citation to work done in other Brazilian institutions (B).
27. The category (A) includes North America (Mexico excluded), Europe (including Eastern Europe), Australia and Japan. The category (L) includes all Spanish speaking American countries and the Caribbean. The category (P) refers to all developing countries of the world, Latin America excluded.
28. The six periodicals were: 5 American journals – *Agronomy Journal, Soil Science, Soil Science Society of America Journal, Plant Physiology* and *Crop Science* – and 1 journal published in the Netherlands – *Plant and Soil.*
29. The sample of papers from advanced country periodicals were not randomly chosen. As I said in the text, I searched for papers similar in content to those of my sample of Brazilian papers. For "papers similar in content", I mean similarity concerning the research problems studied, the theoretical framework with which the problems were approached and the experimental methods used for investigating them. Again, my background training in the agricultural sciences made it possible to analyse and compare the content of papers. Typically, the main research problems being studied by the scientists of my sample were: UFRGS and ESALQ place great emphasis on symbiotic nitrogen fixation in both beans and soya-beans; nutrient uptake and fertilization of different crops (mayze, beans, sugar-cane, soya-beans and the like) are studied by all four institutions; a range of different problems related with phosphorus in soils and the dynamics and efficiency of limes are also being examined in the four institutions. Thus, when I made the selection of papers from advanced country journals, I chose those which dealt with similar research problems, approached these problems from similar theoretical framework, using similar methodology.
30. I excluded those scientist-authors who were not current researchers in the specific subfields of my concern. These were engaged to the programmes studied as a means of providing research and teaching support in some basic fields related to agricultural science – botany, zoology,

chemistry, statistics and so on. Also, some scientists had to be excluded either because they had retired, left the university or were away during my visit.

31. It is important to note that 9 of the references in this category appeared in the same paper, which is the only one authored by Brazilian scientists in my sample of advanced country papers. Considering this, the actual number of references from foreign to Brazilian scientists is 10 (approximately 0.5%).
32. Y. M. RABKIN, H. INHABER, op. cit. note 14, p. 264.
33. WOOD, cited in: J. A. LARGE. *The Foreign Language Barrier: Problems in Scientific Communication,* Deutsch, London, 1983, p. 15.
34. *WIPIS: Who Is Publishing In Science* is a publication by the Institute for Scientific Information which contains the names of the authors recorded in *Current Contents* each year.
35. Y. M. RABKIN, H. INHABER, op. cit. note 14, p. 264.
36. Ibid., 265.
37. *Webel* and *Lonquist*'s results as well as those of *Paterniani* were published in the same periodical: *Crop Science* [WEBEL and LONQUIST, *Crop Science,* 7 (1967) 651; PATERNIANI, *Crop Science,* 7 (1967) 212]. Thus, it seems that even when a researcher from a peripheral country reports his findings in advanced country periodicals, the truth of his findings may be doubted by his peers in central countries. Moreover, I must say that I checked on these informations and I was able to obtain a copy of the handout where the statements referred to were made.
38. J. IRVINE, B. MARTIN, op. cit. note 9.
39. Y. M. RABKIN, H. INHABER, op. cit. note 14, p. 271, for example, found that 73% of the references by Brazilian scientists were to work published in scientifically central nations. Only about 1% of their references were to material published in other Latin American countries and 17% of the references were to Brazilian scientists. E. F. FUENZALIDA, *Investigacion Cientifica y Estratificacion Internacional,* Editorial Andres Bello, Santiago de Chile, 1971, and M. ROCHE, Y. FREITES. Produccion y flujo de informacion cientifica en un pais periferico Americano (Venezuela), *Interciencia,* 7 (1982) 279, also report similar findings.
40. H. M. COLLINS. The TEA set: Tacit knowledge and scientific networks, *Science Studies,* 4 (1974) 165, suggested that competition between several British laboratories building a TEA laser influenced these laboratories' relative indifference to each other's work and their unwillingness to be completely open about their own progress.
41. The exceptions are the Agronomic Institute of Campinas (IAC) – see L. VELHO, J. KRIGE, op. cit. note 18 – and some specific research centres of EMBRAPA. Scientists of the universities studied seemed to have a certain degree of awareness of the work conducted in the above institutes and made some references to it.
42. J. A. LARGE, op. cit. note 33, p. 15.
43. A. M. R. ABOU-ID, *Produção no Centro de Ciências Agrárias da Universidade Federal de Viçosa,* unpublished MSc dissertation, UFV, 1982, p. 99.
44. The Abstracts mentioned by the interviewees as the most heavily used were: *Current Contents; Agriculture, Biology & Environmental Sciences,* which indexes only 5 Brazilian periodicals of which only 1 – *Pesquisa Agropecuaria Brasileira,* published by EMBRAPA – publishes articles related to the subfields of this study; *Horticultural Abstracts, Field Crop Abstracts/Herbage Abstracts, Plant Breeding Abstracts, Soils and Fertilizers* and *Weed Abstracts.* The last 4 are published by the Commonwealth Agricultural Bureax, UK, which indexes 135 Brazilian serial titles in agriculture. However, the most important Brazilian journal in soil science, *Revista Brasileira de Ciencia do Solo,* is not used as source by this organisation; neither is *Ciencia Agronomica,* the agricultural scientific journal edited by UFC.
45. *Current Contents: Agriculture, Biology & Environmental Sciences* covers more than 1200 publications each year; 0.4% of them emanate from Brazil. In the same vein, out of the over

10000 serial titles covered by the Commonwealth Agricultural Bureax's publications, only about 1% emanate from Brazil.

46. C. DE MOURA CASTRO, F. SPAGNOLO, op. cit. note 22, p. 8.
47. J. A. LARGE, op. cit. note 33, pp. 35–6.
48. Similarly, M. J. MORAVCSIK, P. MURUGESAN, Some results on the function and quality of citations, *Social Studies of Science,* 5 (1975) 86, set about to quantify the "error" in the use of citation counts as a measure of quality. Of the references occuring in a random sample of articles from *Physical Review* between 1968 and 1972, they found as many as 31% to be "redundant" (all cited in support ,of the same point) and of the remainder, 41% were "perfunctory" (not vital to the development of the citing paper).
49. For a discussion of the general point that citations can be used as a tool of persuasion, see G. N. GILBERT, Referencing as persuasion, *Social Studies of Science,* 7 (1977) 113.
50. For a discussion of the notion of transference of prestige through citation see R. D. WHITLEY, Communication nets in science, *Sociological Review,* 17 (1969) 219.
51. I mean by "internal" factors those which are intrinsic to the cognitive domain. One example of internal factor influencing a scientist's citation behaviour would be his commitment to a given scientific paradigm. By "external" factors I mean those which are social rather than cognitive in nature, for example: the prestige, language and circulation of the journals in which research findings are published; the scientist's habits to scan the literature; the social and institutional location of the scientists and so on.