ANALYSIS OF THE TECHNICAL-SCIENTIFIC PRODUCTION OF SCHOLARS GRANTS CNPQ ON PRODUCTION ENGINEERING IN BRAZIL: AN ASSESSMENT OF YEARS 2007-2009

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ABSTRACT

This paper analyses the academic production of researchers that have the so called “productivity grants” awarded by CNPq, the Brazilian research funding agency, in the field of Production Engineering in the period 2007-2009. The data was extracted from the resumes of Brazilian researchers in the Lattes Platform. The population of 101 researchers was grouped according to the level of their grants: 1ABSenior, 1CD, 2PQ and 2DT. The aggregate level 1ABSenior was found to be the one with the largest volume of high impact publications. Researchers in the aggregate group 1CD are the ones with the most publications in mid-impact journals. 2PQ and 2DT grant holders are the ones that supervise the most students at a masters’ level. The 2DT researchers are more focused on hands-on technology and innovation. Based on that, one concludes that CNPq usually follows the award criteria for the grants. There seems to be logical coherence regarding the distribution of grants, at least with respect to the easily measurable progression criteria. However, there is some evidence that for criteria that are harder to assess, there may be some evaluation concerns that need to be addressed, in order to keep the process fair.

Key words: Production Engineering. Research grants. Scientific production.

INTRODUCTION

Society’s expectations in relation to the university’s involvement in knowledge production and the results of efforts carried out by Brazilian universities in this sense are still modest. Data from the Science and Technology Ministry – MCT (Brazilian abbreviation) reveal that the contribution of Brazilian researchers to the world’s scientific production has risen gradually since the 1980s. In 1981, Brazilian researchers were responsible for 0.43% of the scientific papers published worldwide in journals listed by the *Thomson Reuters* and *ISI Web of Knowledge.* Ten years later, in 1991, the

percentage was 0.66%. After another decade, in 2001, they represented 1.45% and in 2009 Brazilian papers published in journals listed on such bases reached 2.69% of the total (MCT, 2010).

Aiming to stimulate the growth and consolidation of graduate studies in Brazil, research supporting agencies such as Capes, CNPq, Finep and the Research Support State Foundations – FAPs (Brazilian abbreviation) have financed the development of academic research, distributing grants and other resources for its execution (DANTAS, 2004).

Although all these agencies play an important role in the development of the country's scientific research, each one has distinct specific objectives. Along its existence, CNPq has contributed with the national development in the science and graduate studies area, through the support given to research in higher education institutions and academic grants, both inside the country and abroad.

The agency offers several kinds of grants. One of the different initiatives in favor of research development in Brazilian universities is the productivity grant (research – PQ and innovative development and extension – DT) (CNPQ, 2010).

The public announcement of research productivity grant – PQ by CNPq emphasizes the aim of this kind of grant "destined to researchers that are outstanding among their peers, valuing their scientific contribution according to the regulation criteria set forth by CNPq, and specifically by the advisory committees – CAs (Brazilian abbreviation) of CNPq" (CNPQ, 2009a, p. 1). Although the DT grant is considered equivalent to the PQ grant, this modality tries to "distinguish the researcher, valuing his/her production regarding technological development and innovation" (CNPQ, 2009a, p. 1), and it was created with the aim to reward researchers whose research results are more practical, such as patents, products and software, differently from the PQ grant, which is more concerned with the more traditional scientific production (papers published in journals, for instance).

The requirements to apply for these grants provide an indication of the attributes valued by CNPq in a researcher, such as active participation in the development of scientific or technological research and researcher development at all levels. It is, therefore, believed that analyzing the performance of researchers who have grants, based on varied productivity measurements, might help other researchers to better understand what is necessary to deserve the same distinction.

Thus, this study aims to analyze the scientific-technical production of researchers holding CNPq productivity grants in the area of Production Engineering, based on data from the period 2007-2009.

This study is justified by the fact that its results might contribute to the discussion of productivity in graduate education in Brazil, providing researchers with means to compare their performance with the performance of those who are part of the reference group formed by the CNPq productivity grant holders.

GRADUATE STUDIES AND RESEARCH PROMOTION IN BRAZIL: A PERSPECTIVE BASED ON CNPQ'S PRODUCTIVITY GRANT AWARD CRITERIA

Regarding PQ grants, CNPq believes that the researchers' past performance represents a reasonable indicator of their future performance, justifying that they receive credits based on what they have already accomplished.

Depending the researchers' "productivity" in research, compared to other candidates applying for the same grant, researchers might receive a PQ or DT grant in one of their different levels: 1A, 1B,

1C, 1D or 2. Level 1A is the highest one, and level 2 is the lowest. There are also Senior grants, for "researchers with at least 15 years (consecutive or not)of PQ or DT grant in category 1, levels A or B, who have remained active in the development of scientific and/or technological research and supervising the work of new researchers" (CNPQ, 2006, p. 1) and 2F grants – an exclusive category for PQ grant, with the same characteristics of regular level 2 grants, but which are destined to researchers from *campi* of public higher education institutions that are located away from large metropolis (CNPQ, 2009b).

CNPq (2009a) sets a group of general criteria for awarding PQ and DT grants: i) the applicant's scientific production; ii) graduate level human resources development; iii) scientific and technological contribution to innovation; iv) main coordination or participation in research projects; v) participation in editorial activities, scientific management and administration of institutions or scientific and technological excellence centers.

In addition to these general criteria, there are distinct specific criteria for each grant category (PQ and DT), employed to the analysis of new grant award or revision of existing grants.

Specific criteria employed to award PQ grants, at different levels are presented in Table 1.

Table 1: Specific criteria for awarding PQ grants (Source: adapted from CNPq (2009a; 2012))

Previous experience		**Considered production and award criteria**
Senior	At least 15 years, consecutive or not, holding PQ or DT grants in category 1, level A or B.	All production within the productivity grant period in category 1, level A or B.
1A	At least eight years since completion of doctorate program when the grant is implemented.	Last ten years. Grant awarded to applicants who have demonstrated continuous excellence in scientific production and human resources training, who mastered consolidated research groups. This researcher's profile must overcome productivity exclusive aspects to include additional aspects that reveal significant leadership within their research area in Brazil and their ability to explore new scientific borders in risky projects.
1B	At least eight years since completion of doctorate program when the grant is implemented.	Last ten years. The criteria to award this grant are the same used for level 1C. The distinction is provided through direct comparison between the researchers' resumes.
1C	At least eight years since completion of doctorate program when the grant is implemented.	Last ten years. In addition to the criteria defined for level 1D, the criteria to award this grant are associated to the growing contribution to human resources training and the scientific and technological production, contribution to the organization of research groups as well as to undergraduate and graduate programs in their institutions. Membership in research funding institutions.
1D	At least eight years since completion of doctorate program	Last ten years. The criteria to award this grant privilege the quality and the researcher's collection

Previous experience		Considered production and award criteria
	when the grant is implemented.	of work. The level progression is associated to independent and regular scientific production and leadership and recognition "inter-peers". It is expected that this researcher have national and international recognition, proved through invitations to lectures and a*d hoc* counseling to national and international journals as well as research funding institutions, besides being involved in scientific management activities.
2 and 2F	At least three years since completion of doctorate program when the grant is implemented.	Last five years. The researcher productivity is evaluated, with emphasis on papers published and the supervision of graduate students.

Regarding DT grants, the researchers' classification, admission and level progression, as well as recommendations for researchers' downgrading and/or exclusion from the system, are the responsibility of the General Evaluation Committee, without the existence of specific Advisory Committees (CAs) for each area (CNPQ, 2009c). Specific criteria used for the DT grants are presented in Table 2.

Table 2: Specific criteria for awarding DT grants (Source: adapted from CNPq (2009c))

Specific criteria for awarding DT grants	
Prerequisite	1. Doctorate title or equivalent technological profile. Being Brazilian, or a foreigner in regular situation, dedicated to the activity related to grant application; may be retired, since their academic-scientific and technological activities are kept officially linked to research and teaching institutions. Applicants linked to one of the Brazilian Technology academic institutions shall be given priority. Criteria shall be revised every three years.
	2. Technological production: a) deposited patents in Brazil or abroad; b) non-patented products or processes; c) publications of technological nature – papers in journals, handbooks and technical leaflets; d) software.
	3. Technology transfer: a) organization of technology-based companies; b) organization or management of technology-based enterprise incubator; c) technological service; d) technological counseling; e) enterprise initiatives – participation in the organization and management of technological development projects, in partnership with enterprises.
	4. Human resources training: a) organization of technological training programs – residence, internship, specialization; b) supervision of students and/or fellows in technological training – graduate education, post-doctorate activity, overseas training and fellows in the technological development modality in acknowledged programs; c) organization and participation in technological events – courses, seminars and workshops.
Category	Researcher 1: at least eight years since completion of doctorate program when the grant is implemented or at least ten years of experience in technological development activities and innovative extension and technology transfer

Specific criteria for awarding DT grants	
	activities.
	Researcher 2: at least three years since completion of doctorate program when the grant is implemented or at least five years experience in technological development activities and innovative extension and technology transfer activities.
Level	For category 2, "in which there is no level specification, proof of technical production shall be evaluated with: patent application, registered software or process, publications in the technological area and technology transfer agreements (CNPQ, 2009c, p. 2).
	For category 1, "the researcher shall be admitted into four different levels (A,B,C or D), on comparison basis with their peers" (CNPQ, 2009c, p. 2). Differences between levels A, B, C and D are based on criteria listed in item 2.3.3 "and on others, which the Evaluation Committee might find important for the research area, and in the whole, which privileges the researchers' quality and collection of work" (CNPQ, 2009c, p. 2).

The duration of a PQ or DT productivity grant varies according to the level. Regarding the Senior level, the grant lasts 60 months. Level 1A grants also last 60 months, while levels 1B, 1C and 1D last 48 months and levels 2 and 2F last 36 months.

PQ grant projects are evaluated by a CA (Assisting Committee), formed by *ad hoc* consultants from the corresponding area, which inform the Capes Evaluation Board's (DAV in the Brazilian abbreviation) decision on the grant awarding. The CAs require that researchers who apply for grants, present a research proposal for evaluation (CNPQ, 2012). However, as they shall evaluate the researcher background regarding contribution to the area, it is understood that the evaluation is based on objective data contained in the applicant's resume, allowing for transparency throughout the researcher's selection process, and resulting that these researchers become a reference for other researchers regarding scientific production.

METHODOLOGY

The Lattes Platform was surveyed and data about PQ and DT grant researchers working in the area of Production Engineering, Sub-area Engineering III, was gathered.

Regarding PQ researchers, the search was carried out filtering the Lattes Platform database for "CNPq productivity grant researchers". The system offers the option to filter researchers with an active PQ grant, including the possibility of refining the search by identifying the grant level (1A, 1B, 1C, 1D or 2). The search was carried out taking the area of study into consideration in order to select PQ researchers in the Production Engineering area, only.

The DT researcher's identification process was the same up to the item "search resume" in the Lattes Platform. From this point on, the option "other CNPq researchers" was activated as well as the option "productivity, technological development and innovating extension". Next, the filter related to the area of study was applied, similarly to what had been done for the PQ researchers' identification, so that only researchers working in Production Engineering were selected.

Each researcher's resume was then surveyed to find the register of masters and doctorate supervisions in Production Engineering, both in progress and already concluded, for the period from 2007 to 2009, in order to make sure that the area of study was, really, Production Engineering. Thus, 101 PQ and DT researchers were obtained working effectively as graduate students' supervisors in Production Engineering.

Data collection was based on the information provided in the Lattes resume of PQ and DT grant researchers.

The scientific and technical production of all researcher's who had grants levels 1A (to which senior researchers were added), 1B, 1C, 1D and 2 (including the level 2F) was collected and stored in a data base. The same was done for the production of DT grant holders at level 2 (there are no DT grant researchers at the remaining levels in the Production Engineering area). Each researcher's data was divided into: (1) position in the research group (leader or member); (2) publications in journals; (3) publication in proceedings; (4) technical publication; and (5) performed supervisions. Each of these divisions comprised other variables, so that a suitable evaluation of the scientific productivity of different category and level researcher could be carried out, according to Table 3.

Table 3: Data collected from the Lattes resume of PQ and DT researchers (Source: authors)

Data collection guide	Study variables
1. Position in the research group	Leader Member
2. Publication in journals	High impact production (JCR, A1, A2) Medium impact production (B1, B2) Low impact production (B3, B4, B5) Number of papers with JCR (*Journal Citation Reports)*
3. Publication in proceedings	Total number of published papers
4. Technical production	Registered software Software without registration Products Processes Technical works
5. Concluded supervisions	Doctorate level Master's level Undergraduate Undergraduate scientific initiation

For the data analysis, each of the divisions presented in Table 3 was evaluated in an isolated manner, through the calculation of absolute values, mean (or frequency) and standard deviation, whenever suitable.

In order to make the data analysis easier, taking into consideration that some levels of grants have very low numerical representativeness, researchers were grouped into the following aggregate categories: i) 1ABSenior (including the levels PQ 1A, 1B and Senior); ii) 1CD (including levels PQ 1C and 1D); iii) 2 (including levels PQ 2 and 2F); iv) 2DT (including only level DT 2).

Even if the idea was initially to consider the possibility of grouping levels 2PQ and 2DT, which would make sense from the viewpoint of a hierarchical analysis of these categories, it was realized that there was a distinction between the groups in many of the relevant analyses, justifying the option to keep these groups apart, so that their differences could be highlighted.

For the calculation of descriptive statistics and graph elaboration, *Minitab 15*, *Microsoft Excel 2007* and Statistical Package for the Social Sciences (SPSS) 17.0 were employed.

Data contained in the Capes triennial evaluation comparative spreadsheets comprising 2007-2009 (CAPES, 2010b) and the Capes area document for 2009, regarding Engineering III (CAPES, 2010a) were also used in data analysis. The triennial comparative spreadsheets made it possible to account for: the total number of permanent professors in the Production Engineering graduation programs evaluated by Capes and the total number of papers published by these professors in journals classified in each *Qualis* Extract (this is a ranking of journals, performed by Capes, which goes from A1 to B5). From this source, it was possible to calculate the mean number of publications per graduate professor, so that it could be compared with the PQ and DT grant researchers' productivity.

In order to assign marks to the publications in journals (2007-209), the punctuation metrics established in the Capes area document regarding year 2009 (CAPES, 2010a) was employed, as shown in Table 4.

Table 4: Marks set forth by the area document for 2009 for publications in journals in the different Qualis extracts. (Source: Capes (2010a))

Extract	Mark
A1	1
A2	0.85
B1	0.7
B2	0.5
B3	0.2
B4	0.1
B5	0.05

Papers published in journals classified as B3, B4 and B5, in the sub-area Engineering III, presented saturation of three triennial publications (CAPES, 2010a). That means that, according to the Capes' area document, each researcher could accumulating the maximum of 0.6 points for B3 publications; 0.3 for B4 publications and 0.15 for B5 publications.

ANALYSIS OF THE RESULTS

Among the 101 researchers that were detected as being grant holders, nine were DT researchers and 92 were PQ researchers.

Senior, 1A and 1B researchers were grouped, aiming at the analysis, in one only category and the same happened to 1C and 1D, 2 and 2F researchers. This grouping of levels was carried out due to

the reduced number of researchers in some extracts, in order to make some of the statistical analyses viable. Table 5 presents the number of researchers in each of the groupings.

Table 5: Number of researches in each aggregate level (Source: research empirical data)

Aggregate level	Number of researchers
1ABSenior	10 (9.9%)
1CD	18 (17.8%)
2PQ	64 (63.4%)
2DT	9 (8.9%)
Total	101 (100%)

The analysis of the collected data takes into consideration four of the five general criteria (CNPQ, 2009a) for awarding PQ and DT grants, as those are valid for both categories of productivity grants: (1) the applicant's scientific production; (2) human resource training at graduate level; (3) scientific and technological contribution to innovation; (4) coordination or main participation in research projects. Only criterion (5), participation in editorial activities, scientific management and institution, and scientific and technological excellence centers administration was not evaluated, due to the difficulty found to obtain this information, as not all researchers made this information accurately available in their Lattes resumes.

Researchers' scientific production

Regarding the general criterion *scientific production* for the award of PQ or DT grants, the total number of publications, mean and standard deviation is presented for each of the aggregate levels defined in Table 6. In the results, journals were grouped into three groups: high impact (A1 and A2 journals), medium impact (B1 and B2 journals) and low impact (B3, B4 and B5 journals). Also, publications in journals which are listed in the *Web of Science with JCR* were indicated separately.

Table 6: Academic journals publication[1] (Source: research empirical data.)

Level		JCR	A1	A2	High impact	B1	B2	Medium impact	B3	B4	B5	Low impact	Capes punctuation
1AB Senior	∑	40	9	10	59	6	14	20	6	11	9	26	31.4
	μ	4.0	0.9	1	5.9	0.6	1.4	2.0	0.6	1.1	0.9	2.6	3.14
	σ	4.06	1.20	1.25	2.13	0.70	2.76	2.94	0.84	1.29	1.20	2.32	2.94
1CD	∑	38	12	4	54	18	56	74	15	28	38	81	61.6
	μ	2.11	0.67	0.22	3.0	1	3.11	4.11	0.83	1.56	2.11	4.5	3.42
	σ	2.03	0.77	0.42	1.02	1.24	3.79	4.07	1.54	2.50	3.55	6.20	2.65
2PQ	∑	132	12	27	171	46	128	174	64	64	149	277	152.45
	μ	2.06	0.19	0.42	2.67	0.72	2	2.72	1	1	2.33	4.33	2.38
	σ	3.28	0.47	0.77	0.85	1.25	2.36	2.61	1.44	1.74	3.77	5.33	1.65
2DT	∑	3	0	1	4	0	10	10	4	4	14	22	7.65
	μ	0.33	0	0.11	0.44	0	1.11	1.11	0.44	0.44	1.56	2.44	0.85
	σ	0.52	0	0.33	0.33	0	0.78	0.78	0.73	0.73	1.81	1.94	0.36

[1] Capes punctuation index was calculated using the following formula:
=A1+A2*0,85+B1*0,7+B2*0,5+MIN(B3*0,2;0,6)+MIN((MAX(B3-3;0)+B4)*0,1;0,3)+MIN((MAX (B3+B4-6;B4-3;0)+B5)*0,05;0,15), which provides marks respecting the 'saturation' for the punctuation of B3, B4 and B5journals.

When analyzing high impact publications (JCR, A1, A2), the researchers in the aggregate level 1ABSenior show performance above the aggregate level 1CD (mean of 5.9 papers per researcher against 3.0 papers per researcher). In publications of medium impact (B1, B2) the performance of 1CD researchers is better than that of 1ABSenior researchers (mean of 4.11 papers per researcher against 2.0 papers per researcher). 2PQ productivity grant researchers show a frequency of publication lower than that of level 1 researchers, both in high impact publications (2.67 papers per researcher in the triennium) and in medium impact journals (2.72 papers per researcher).

JCR index is also a plausible indicator to attest the concern of researchers for publishing in high impact journals and the degree of internationalization of the researchers' publication, since a very limited number of Brazilian journals is listed in the *Web of Science* data set. 1ABSenior and 1CD researchers published, respectively, 4.06 and 2.11 papers on average on JCR listed journals. In turn, 2PQ researchers present a 2.06 mean for publications in JCR listed journals, very close to 1CD researchers. The 2DT researchers present the lowest mean, only 0.33 papers in these journals.

It was noticed, therefore, that 1ABSenior researchers are more demanding when choosing the journals where they publish their papers, since they publish relatively more papers in journals that are in extracts A1 or A2 of Qualis and also on JCR listed journals and fewer papers in journals B1 and B2 than 1CD researchers. The perception of higher selectivity on the part of 1ABSenior researchers is reinforced by the analysis of level of publication in low impact journals. Researchers in this aggregate level published, on average, 2.6 papers each in these journals, while 1CD researchers published 4.5; 2PQ researchers published 4.33 and 2DT researchers published 3.56. This information reveals that low impact publications interest researchers that are at the top levels of the academic seniority pyramid less than other researchers.

With the marks set forth in Capes document that analyzes the progress of the Production Engineering research field for 2009, a calculation of the marks for all researchers holding productivity grants in the Production Engineering area, both PQ and DT, was carried out. Later on, the mean and standard deviation were calculated for each grant aggregate level, according to the information in the last column of Table 6 It is important to remember that the marks obtained from paper publication in lower impact journals had a saturation of three publications in the triennium (CAPES, 2010a). That is, it was only possible to accumulate a maximum of 1.05 points with publications on B3, B4 and B5 journals.

The means obtained by 1ABSenior and 1CD researchers in were very close (3.14 and 3.42, respectively). The fact that 1ABSenior researchers published less in medium and low impact journals caused them to have a lowered average punctuation. This unexpected inversion happened because, although 1ABSenior researchers are more selective in choosing where to publish, 1CD researchers publish more.

2PQ researchers presented a lower mean than the top groups, as expected. This is justified by the fact that this group of researchers concentrates their publications in lower impact journals, which are assigned lower marks and are subject to the already mentioned saturation criterion. The same occurs with 2DT researchers, who presented the lowest marks among all grant holders. It was noticed that for the criteria regarding the more traditional scientific publication (papers published in journals), 2DT researchers always appear in disadvantage when compared to the others. This fact points to the right decision made by CNPq of creating a distinct category for such researchers, since

the objective was to value more practical aspects of the scientific activity, such as obtaining patents, developing software, products and other technical work, for which the performance of researchers holding this grant was expected to be better.

Analyzing the boxplot presented in Graph 1, it is noticed that Capes punctuation of the researchers, distributed in quartiles, are very similar for groups 1ABSenior and 1CD, with a slightly higher median for group 1CD, but with a slightly narrower and higher upper quartile for the 1ABSenior group. Curiously, the medians are close for all researchers' levels, except for the 2DT group. This means that, when the means are examined, as previously done, the meritocracy of grant distribution seems to be respected. There is no big difference between the punctuations obtained by researchers who are in the two lower quartiles in the different groups (1ABSenior, 1CD and 2PQ). That is, if the criterion *Capes punctuation* were the only one adopted to define the researchers' level, discrimination could happen, and the ones with better marks in the lower levels could possibly be promoted to the higher levels, while the ones with lower performance in the higher levels could be downgraded.

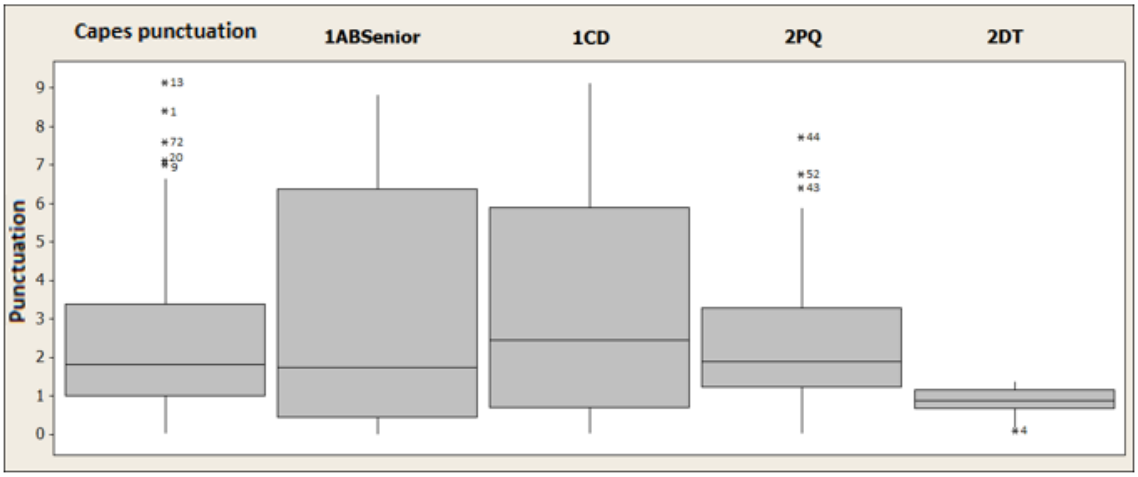

Figure 1: Capes punctuation boxplot for the productive grant for the grouped levels2 (Source: research empirical data)

In the diagrams for levels 2PQ and 2DT it is possible to notice that there are some outliers. While cases 44, 52 and 43 present a much higher performance when compared to the remaining of their group, case 4 is much below those in his/her group.

Human resources training at graduate level

CNPq establishes that PQ researchers at levels 1B and 1C should be also supervisors of master and graduate students, when linked to institutions that hold graduate programs (CNPQ, 2009a, 2012). For level 1A researchers, the demand for supervising graduate students becomes mandatory.

Table 7 shows the number of graduate supervisions carried out by grant holders during the triennium 2007-2009.

[2] The numbers next to the outlier indications are a reference to the researcher's number in the data set.

Table 7: Human resources (graduate student supervisions) per aggregate level (Source: research empirical data)

Aggregate level	Procedure	Undergraduate scientific initiation	Masters	Doctorate
1ABSenior	Total	21	38	37
	Mean	2.1	3.8	3.7
	Standard deviation	2.92	2.74	4.65
1CD	Total	40	88	31
	Mean	2.22	4.89	1.72
	Standard deviation	3.28	3.60	1.93
2PQ	Total	144	337	67
	Mean	2.25	5.27	1.05
	Standard deviation	3.15	4.67	1.51
2DT	Total	8	55	1
	Mean	0.89	6.11	0.11
	Standard deviation	1.36	6.05	0.33

The 1ABSenior aggregate level is represented by a homogeneous group regarding the number of supervisions, with focus on graduate students (masters and doctorate). The standard deviation for doctorate supervisions is higher when compared to masters supervisions, which means that some researchers have a higher number of doctorate students in relation to others in the same group. All 1ABSenior grant holders supervise master students. However, only four grant researchers take part in doctorate programs and the only senior productivity grant holder does not supervise doctorate students. Only two level 1B grant holders supervise doctorate students. The two level 1A grant holders supervise at the doctorate level.

When compared to the 1ABSenior aggregate level grant holders, for whom more than 50% of the supervisions are at doctorate level, 1CD grant holders tend to supervise more masters than doctorate students. The standard deviation indicates that there is greater disparity among researches regarding the number of masters than doctorate supervisions at this level.

When data regarding the 2PQ researchers is analyzed, it is possible to notice that those “beginner” grant holders present lower participation in doctorate students supervision, since the mean of doctorate students for them is 1.05 in the triennium, much lower than for groups 1CD (1.72) and 1ABSenior (3.7). On the other hand, 2PQ and 2DT researchers supervise more master students. 2PQ grant holders supervised, on average, 5.27 master students in the triennium, while 2DT researchers supervised 6.11 master students. These means are slightly higher than those for 1CD and 1ABSenior researchers, although it should be mentioned that level 1 researchers have a higher number of doctorate students under supervision, as previously reported.

It is also worth mentioning that the mean of master supervisions tends to increase when the level of grant decreases. This relation is contrary to what happens with doctorate supervisions, which increase when the level of grant increases.

Scientific and technological contribution to innovation

In relation to the general criterion for awarding productivity grants regarding *scientific and technological contribution to innovation*; the information referring to technical production (registered software, software without registration, products, processes and technical work) of productivity grant researchers was also collected from Lattes resumes. This information is believed to give some idea, even if partial, of the researchers' performance regarding this item. Table 8 presents the obtained result.

Table 8: Scientific and technological contribution to innovation (software and products) (Source: research empirical data)

Aggregate level	Procedure	Registered + unregistered software	Product
1ABSenior	Total	8	0
	Mean	0.8	0
	Standard deviation	2.20	0
1CD	Total	8	0
	Mean	0.44	0
	Standard deviation	1.89	0
2PQ	Total	9	1
	Mean	0.14	0.02
	Standard deviation	0.47	0.13
2DT	Total	7	5
	Mean	0.78	0.56
	Standard deviation	0.83	0.73

The development of software (with or without registration) produced by researchers at aggregate levels 1ABSenior and 1CD happened at about the same intensity, and totaled eight units per group. However, when the group mean is observed, the 1ABSenior level presents a mean that is almost twice as high, due to the fact that this group is formed by only ten researchers, while group 1CD involves 18 researchers.

The 2PQ group presents lower performance regarding software development and products, while group 2DT is shown to be the one with the highest contribution to the technological area and innovation: only nine researchers have produced seven pieces of software and five products in the period under analysis. This result was expected, since the productivity grant at the 2DT level was created by CNPq to privilege researchers with production mainly directed to the technological area.

Leadership or participation in research groups

For the general criterion regarding productivity grants related to *leadership or participation in research groups*, the investigation covered aspects related to how often researches were leaders or members in research groups registered with CNPq (see Table 9 below).

Table 9: Participation or leadership in research groups[3] (Source: research empirical data)

Aggregate level	Member	Leader	Participants mean[4]
1ABSenior	6 (60%)	7 (70%)	1.30
1CD	15 (83.3%)	9 (50%)	1.33
2PQ	50 (78.1%)	42 (65.6%)	1.44
2DT	4 (44.4%)	7 (77.8%)	1.22

There is not a big difference among the several aggregate levels of researchers in relation to the participation in research groups and their role within the group. However, the fact that level 2 researchers are as active as level 1 researchers, in the leadership of research groups calls attention. However, leadership is a subjective factor, since factors such as the research group popularity, national recognition and the international insertion/influence are difficult to measure. One way of evaluating the leadership degree could involve the verification of the number of researchers participating in a research group, their origin (whether belonging to different institutions, institutions in different states or even in different countries), the alignment of the research with the themes that characterize the leader's scientific production and, finally, the research group productivity.

CONCLUDING REMARKS

A small part of the professors in a graduate program have a CNPq productivity grant. The concession of this award is regulated by general criteria, which are valid for both PQ and DT grants, and specific distinct criteria for each category. The 101 productivity grant holders in the Production Engineering area were grouped into four corresponding grant levels which are 1ABSenior, 1CD, 2PQ and 2DT.

From the five general criteria to award productivity grants presented by CNPq (2010), only for the criterion *participation in editorial, scientific management, administration of institutions and scientific and technological excellence centers* there was no quantitative measurement, due to the difficulty to collect such information from the researchers Lattes online resumes. For all the remaining criteria, quantitative data was collected and assessed.

Referring to the objective of this study and linking it to the CNPq criteria to award the productivity grant, it could be noticed, regarding the *grant holder's scientific production* (item 1), that they actively contribute to the country's scientific production, through a higher number of publications in journals, mainly those publications with higher impact.

[3] Percentage values appearing for 'member' and 'leader' refer to the frequency researchers of a given level are in these positions within research groups.

[4] Members' average is given by the addition of participations as group member or leader divided by the number of researchers at that aggregate level.

Regarding *human resources training at graduate level* (item 2), the aggregate level 1ABSenior provides supervision to about the same number of master and doctorate students as the other levels. Considering group 1CD, the tendency is to supervise more masters students than doctorate students, while 2PQ researchers present lower participation in the supervision of doctorate students. There is a tendency towards the increase in the mean of supervisions to master students starting from the highest aggregate level of productivity grants going down to the beginner levels. There is an inverse relationship for doctorate supervisions, which increase as the productivity grant level increases. It was observed that grant holders actively contribute to human resources training in graduate research. With respect to the *scientific and technological contribution to innovation* (item 3), it was observed that the category DT outstands both in software development and the development of other products. Regarding the general criteria to award the productivity grant for categories PQ and DT, there is coherence between the proposed criteria and the evidence that was collected about the researchers' profile: PQ researchers usually present high scientific production ad low technical production, while DT researchers present low scientific production and high technical production.

Regarding *leadership or main participation in research groups* (item 4), data referring to leadership in research groups showed the maturity of researchers who have higher levels of grants. Data pointed out that there is no big difference between the researchers of different aggregate levels with respect to their participation and position in research groups (member or leader of a research group). It seems important to emphasize the fact that the lower grant levels obtained participation percentage similar to the higher grant levels. Since leadership in research groups should be an upgrade requirement, it is relevant to discuss ways of evaluating the researchers' performance in that respect.

Finally, it was noticed that CNPq follows, even if partially or not very explicitly, the criteria that were set for awarding productivity grants. For the criteria which are easily measured, such as *scientific production,* human *resources training and scientific and technological contribution to innovation*, there is a logical coherence between the criterion, the progression and the punctuation of the grant holders under evaluation, although fine adjustments might still need to occur; for criteria which are harder to measure, such as *leadership or main participation in research projects*, it is essential to create efficient mechanisms for performance evaluation.

The discussion developed in this study is believed to be useful for the researchers in the Production Engineering area, who hold a productivity grant or not, to reflect on the requirements to achieve such recognition. The possibility to compare one's own performance against that of other researchers who have been acknowledged by their accomplishments is an opportunity to evaluate aspects that need improvement in one's own performance so that s/he also has his/her work recognized by the academic community.

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