Scientometrics (2016) 109:855–870
DOI 10.1007/s11192-016-2070-7

Comparison of performance of researchers recipients of CNPq productivity grants in the field of Brazilian production engineering

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Received: 13 December 2015 / Published online: 25 July 2016

Abstract This paper analyses the academic production of researchers that were called "productivity grants" awarded by CNPq, the Brazilian research funding agency, in the field of production engineering in the period 2007–2009. Was extracted the data resumes of 101 Brazilian researchers in the Lattes Platform. In relation to the scientific production, productivity grant researchers presented superior performance than the other professors working in graduate programs in the production engineering area. 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. In comparison with the other permanent professors in graduate programs, who do not hold

Paper based on dissertation "Analysis of technical–scientific production of CNPq researcher's grants: Production Enginnering in the period 2007–2009", defended at Federal University of Technology—Paraná in 2010. "Análise da produção técnico–científica dos bolsistas de produtividade do CNPq: a Engenharia de Produção no triênio 2007–2009", defendida na Universidade Tecnológica Federal do Paraná em 2010.

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productivity grants, the tutorial mean for both masters and doctorate students of the grant researchers' is exactly the same as group 2PQ. PQ researchers usually present high scientific production ad low technical production, while DT researchers present low scientific production and high technical production. 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 discrepancies.

Keywords Scholar activity · Productivity analysis · Scientifics · Research grants

Background

A nation potential to originate and convert knowledge into richness and social development is directly linked to the efficiency of institutional agents who generate knowledge, as well as those who favor knowledge generation through resources that make research viable (Brito Cruz 2004a).

Durham (2006) and Brito Cruz (2004b) point out that the university vocation is widely recognized not only as its ability to disseminate knowledge, but also generate and adequate it to the conditions of the community where it is located. According to these authors, while the Brazilian University gets more mature, the knowledge production activity becomes more relevant, in comparison to the teaching activities traditionally developed in the university environment.

Although the first steps of graduate in Brazil were given in the 1930s, the term graduate seems to have been used officially for the first time only in the 1940s and the first partnerships with North-American universities, which ended up shaping the graduate structure in Brazil, occurred in the 1950s (Miranda dos Santos 2003). The Research National Committee (currently CNPq) and the Higher Education Personnel Development Campaign (currently Capes) were created in 1951 and throughout the time were consolidated as vital organizations for the development of the graduate in the country, since they always acted promoting scientific research activities (Romêo et al. 2004; Amorim 1992). It was necessary, however, over a decade for the graduate courses to become definitive and be implemented in the country through the Statement 977 of the Education Federal Council (Festinalli 2005; Schwartzman 1979).

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). 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).

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: (1) the applicant's scientific production; (2) graduate level human resources development; (3) scientific and technological contribution to innovation; (4) main coordination or participation in research projects; (5) participation in editorial activities, scientific management and administration of institutions or scientific and technological excellence centers.

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.

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).

In essence, Capes plays an important role in the expansion and consolidation of graduation *stricto* sensu (Master and Ph.D.) nationwide. In other way CNPq is an agency linked to the MCT aims to research scientific and technologic grant and the training human resource about the country research.

However, the bibliometric indicators used as the assessment of researchers and graduate itself cause changes in the behavior of researchers to seek for better positions in the race for knowledge production (Abbott et al. 2010). As the basis scientific journals indexing start to use the quote as a measure of quality of published studies (Larsen and Von Ins 2010). The concern in studying these indicators has been evidenced with increasing frequency. It has been observed recent studies embracing such subject (Coutinho et al. 2012; Hoppen and Vanz 2016).

Many studies have analyzed the profile and the scientific production of CNPq researchers in various fields of knowledge. The following fields already have the profile of productivity grant mapped: Medicine (Martelli-Junior et al. 2010; Mendes et al. 2010; Oliveira et al. 2011a), Chemistry (Santos et al. 2010), Dentistry (Scarpelli et al. 2008), Public Health (Santos et al. 2009), Nephrology and Urology (Oliveira et al. 2011b), Cardiology (Oliveira et al. 2011c), Veterinary Medicine (Spilki 2013), Physiotherapy (Sturmer et al. 2013). In a different analysis, Oliveira et al. (2013) propose a study which the aim was correlation between journal impact factor (IF) and researchers' influence among a selected group of Brazilian investigators in the fields of clinical nephrology and neurosciences.

In general, all these studies were intended to identify the profile of researchers in a specific field, providing others researchers (non-grant) a benchmark wherewith could compare. However, these studies have not signaled to non-grant teachers what they lack to resemble the group of productivity grants in production engineering.

This study is explained by results might contribute to the discussion of productivity in Brazilian graduate. It provides researchers with means to compare their performance with

the performance whose are part of the reference group formed by the CNPq productivity grant. It has been used the Lattes Platform as tool for data extraction.

In opinion published in the journal Nature, Julia Lane, director of the Science Program of Science and Innovation Policy of the National Science Foundation, makes statements about the necessity to develop measurement systems to evaluate researchers and universities permanently. In this statement, Lane mentions the Brazilian experience with the Lattes Platform as an influential tool in academia, providing data with high quality researchers and institutions in the country and abroad (Lane 2010). The Lattes Platform has been used in national and international scope for registration of scientific production and also the academic careers of researchers (Sturmer et al. 2013).

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

In the general objective, two specific goals guided the data discussion: (a) to compare the production of productivity grant researcher and graduate studies permanent professors without grant, regarding their "productivity"; (b) to evaluate the efficacy of general criteria for the award of productivity grants and the ability of Assessor Committee in the Engineering III area to choose researchers that outstand among their peers as a result of the scientific–technical production developed.

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 using "CNPq productivity grant researchers", activating the specific indication in the Lattes Platform search tool. The system offers the option to filter researchers with active PQ grant, and includes the possibility of refining the search by identifying the grant level (1A, 1B, 1C, 1D and 2). The search was carried out taking the area of study into consideration in order to select PQ researchers in the Production Engineering area.

The DT researcher 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, as it had been done in the PQ researcher identification, so that only researchers working in Production Engineering would be selected.

Each researcher CV was then surveyed to find the register of masters and doctorate tutorial, both in development and already concluded, in Production Engineering, in 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 in the graduate in Production Engineering. Data collection was based on the information provided in the Lattes resume of PQ and DT grant researchers.

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Each PQ researcher's scientific and technical production at the levels 1A (in which category senior researchers were also included), 1B, 1C, 1D and 2 (including the level 2F) was collected and stored in a data basis as well as the DT researchers' production at level 2

(there are no DT grant researchers at the remaining levels working in the Production Engineering area). Each researcher's data collected was divided into: (1) position in the research group he/she takes part; (2) publications in journals; (3) publication in proceedings; (4) technical publication; and (5) tutorial given. 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. Bellow the data collected from the Lattes resume of PQ and DT researchers.

1. Position in the research group: (1) Leader; (2) Member.
2. Publication in Journals: (1) High impact production (JCR, *A*1, *A*2); (2) Medium impact production (*B*1, *B*2); (3) Low impact production (*B*3, *B*4, *B*5); (4) Number of papers with JCR (Journal Citation Reports).
3. Publication in Proceedings: (1) Total number of papers published.
4. Technical production: (1) Software with register; (2) Software without register; (3) Products; (4) Processes; (5) (6) Technical works.
5. Tutorial given: (1) Doctorate; (2) Masters; (3) Graduate; (4) Scientific Initiation

For the data analysis, each of the divisions 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: (1) 1ABSenior (PQ 1A, 1B and Senior); (2) 1CD (PQ 1C and 1D); (3) 2 (PQ 2 and 2F); (4) 2DT (DT 2). Because there are a small number of researchers in some grant categories, the representativeness of the analysis becomes limited. This is a limitation of this study. Another limitation is the fact that professors are evaluated aggregately, just to possess statistical significance. This causes a lower understanding of each category individually.

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 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, *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 *A*1 to *B*5). 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 (2007–2009), the punctuation metrics established in the Capes area document regarding year 2009 (Capes 2010a), for publications in journals in the different Qualis extracts was: 1 point for papers *A*1, 0.85 for *A*2, 0.7 for *B*1, 0.5 for *B*2, 0.2 for *B*3, 0.1 for *B*4 and 0.05 for *B*5.

Papers published in journals *B*3, *B*4 and *B*5, in the sub-area Engineering III, presented saturation of three triennial publications (Capes 2010a).

Analysis of the results

Among the 101 researchers that were detected as being grant holders, nine were DT researchers and 92 were PQ researchers (Table 1).

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 2. In the results, journals were grouped into three groups: high impact (*A*1 and *A*2 journals), medium impact (*B*1 and *B*2 journals) and low impact (*B*3, *B*4 and *B*5 journals). Also, publications in journals which are listed in the *Web of Science with JCR* were indicated separately.

When analyzing high impact publications (JCR, *A*1, *A*2), 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 (*B*1, *B*2) 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 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).

Productivity grant researchers 2PQ show a frequency of publication lower than researchers level 1, both in high impact publications (2.67 papers per researcher in the triennium) and in medium impact journals (2.72 papers per researcher).

The perception of higher selectivity on the part of 1ABSenior researchers is reinforced by the analysis of publication level in low impact journals. The researchers in this aggregate level published on mean 2.6 papers in these journals, while researchers 1CD published 4.5; researchers 2PQ published 4.33 and researchers 2DT published 3.56. This information reveals that low impact publications raise less interest in researchers that are at the top of the academic seniority pyramid.

Table 1 The 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
∑	101	100

Table 2 Academic journals publication. Source: Research empirical data

Level		JCR	*A*1	*A*2	High impact	*B*1	*B*2	Medium impact	*B*3	*B*4	*B*5	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

Capes punctuation index was calculated using the following formula

$=A1 + A2 \times 0.85 + B1 \times 0.7 + B2 \times 0.5 + \min(B3 \times 0.2; 0.6) + \min[(\max(B3 - 3; 0) + B4) \times 0.1; 0.3] + \min[(\max(B3 + B4 - 6; B4 - 3; 0) + B5) \times 0.05; 0.15]$, which provides marks respecting the 'saturation' for the punctuation of *B*3, *B*4 and *B*5 journals

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 respectively published 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.

With the marks set forth in the area document 2009, a calculation of the marks for all papers and researchers grant 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.

It is important to remember the marks obtained from paper publication in journals classified with lower impact had a saturation of three publications in the triennium (Capes 2010a). It was only possible to accumulate the maximum mark 1.05 with the addition of publications *B*3, *B*4 and *B*5.

Therefore, it was noticed 1ABSenior researchers are more rigorous when choosing the journals where they publish their papers, since they publish relatively more papers in journals that are in extracts *A*1 or *A*2 of Qualis and also on JCR listed journals and fewer papers in journals *B*1 and *B*2 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

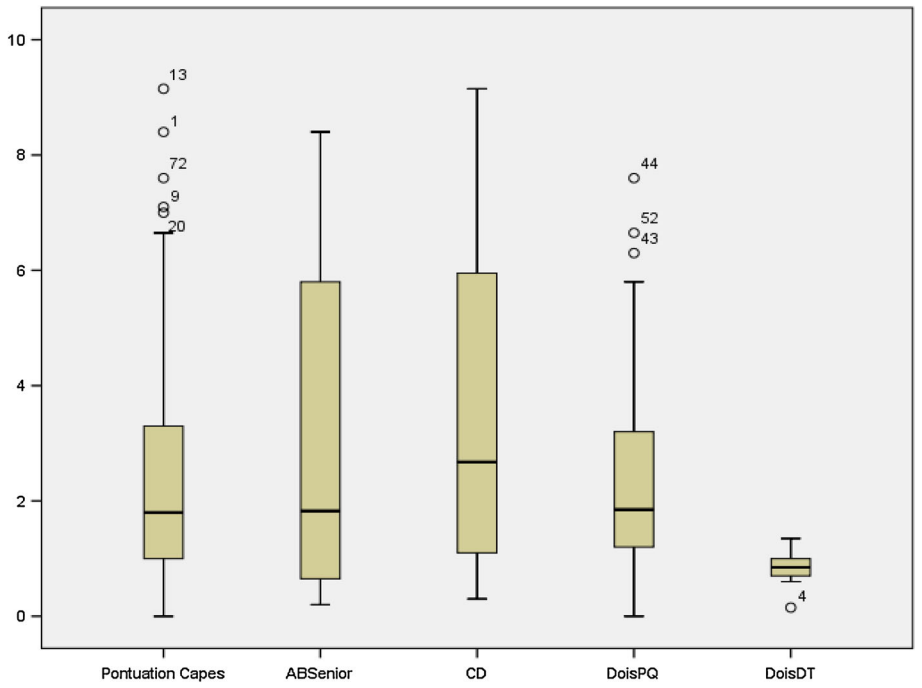

Fig. 1 Capes punctuation boxplot for the productive grant for the grouped levels (The *numbers* next to the *outlier* indications are a reference to the researcher's *number* in the data set). Source: Research empirical data

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.

The means obtained by 1ABSenior and 1CD researchers were very close (3.14 and 3.42, respectively). The fact that 1ABSenior researchers published less medium and low impact journals made they had an average score dropped. This unexpected inversion happened because, although 1ABSenior researchers are more selective in choosing where to publish, 1CD researchers publish more.

The category 2PQ researchers presented a lower mean than 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 productivity. 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 anothers. 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 Fig. 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). If the criterion *Capes punctuation* was the only one adopted to define the researchers' level, it could discriminate then. 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.

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.

The mean of outlier cases was: case 43 had average 6.3, case 44 had 7.6, case 52 had 6.65 and case 4 had 0.15. Cases 44, 52 and 43 that present marks above the remaining productivity grants in the group, also show higher marks than the mean of the aggregate levels 1ABSenior (3.14) and 1CD (3.41). Researchers in cases 44 and 52 are still in the category of 'beginner' productivity grant researcher (2PQ) once they do not meet the other requirements to enter category 1, as for example, having at least 8 years of doctorate when the grant is implemented. These researchers have only seven and 6 years, respectively, after having concluded the doctorate up to 2009. Case 43 completed 10 years of doctorate in 2009, which would entitle him the level progression had the other requirements been met. Case 4 has a negative effect on the scientific production mean; however, other requirements keep this researcher with a productivity grant such as the development of products and technical work.

Assuming PQ and DT researchers have an outstanding scientific production among their peers, this was verified through the comparison of these researchers grant and other

permanent professors working in graduate programs. These researchers' general performance in scientific production can be compared to the other permanent professors in graduate programs in the Production Engineering area based on data presented in Table 3.

In relation to the permanent professors linked to the Production Engineering graduate programs recognized by Capes, the researchers grant correspond to 24.34 % out of the total number of professors.

The productivity grant researchers' scientific production was also compared to the scientific production of permanent professors who are not productivity grant researchers in the Production Engineering graduate in the triennium 2007–2009 are in Fig. 2.

The first factor to be considered by this analysis is the number of productivity grant researchers in the Production Engineering field and the number of permanent professors who does not have grants, which are 101 and 314, respectively. Taking this information into consideration, comprising approximately one-third of the total number, the group of productivity grant researchers keeps a higher percentage regarding production than that of the permanent professors who have no grant, in relation to papers published in journals in all *Qualis* extracts.

Besides papers published in journals, the papers published in proceedings were also accounted for both permanent professors in the Production Engineering graduate programs in the triennium 2007–2009 and the productivity grant researchers.

Comparing the publications in Congress proceedings of productivity grant researchers and professors without grant in the Production Engineering area (2007–2009), the productivity grant researchers had average 14.62 and the professors without grant had average 17.88 (Capes 2010b).

The mean of papers published in proceedings is close for productivity grant researchers and other professors. In the scientific publication field, what differs mostly for these groups are certainly the publications in proceedings, basically for two reasons: (a) productivity grant researchers use these congresses to keep their network active. Besides, the publication in international events and the researcher's insertion in this environment is one of the evaluation items that CNPq uses to upgrade productivity grants; (b) professors who do not have productivity grants take the opportunity of publishing faster and more easily through congresses, mainly papers elaborated in partnership with scientific initiation students or the result of end of graduation course work tutorials. These two justifications contribute to the data that shows that the difference in publication mean between productivity grant researchers and other professors who do not have grants in this item is only 3.26 in the triennium.

Table 3 Scientific production compared between productivity grant researchers and other permanent professors in the production engineering graduate programs in the triennium 2007–2009. Source: Research empirical data *x* data extracted from the Capes comparative spreadsheets (2010b)

Level	∑	*A*1	*A*2	*B*1	*B*2	*B*3	*B*4	*B*5	∑ journal paper	∑ proceeding paper
∑ permanent professors	415	65	112	197	377	184	251	619	1805	6398
∑ researchs' grant	101	33	42	70	208	89	107	210	759	1806
% Researchs' grant/permanent professors	24.34	50.77	37.5	35.53	55.1	48.37	42.63	33.93	42.05	28.23

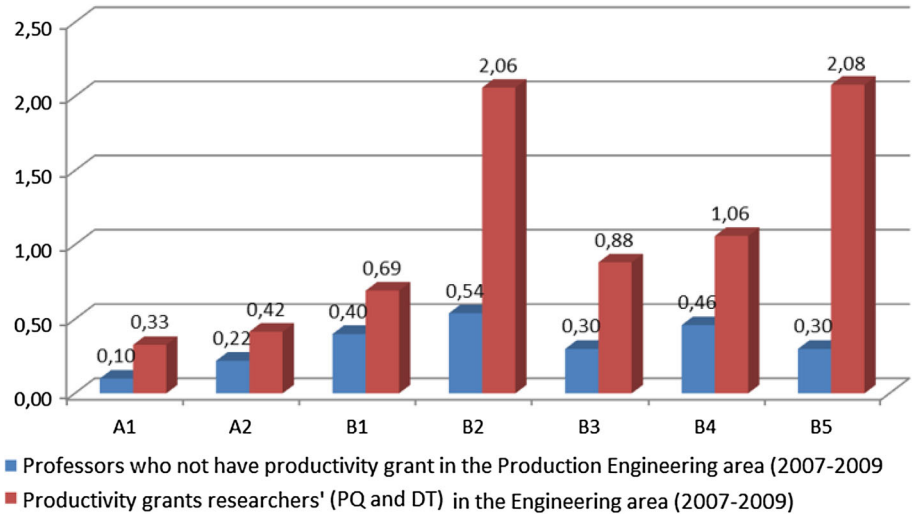

Fig. 2 Comparison of productivity grant researchers' scientific production and the scientific production of professors who do not have productivity grant in the Production Engineering area (2007–2009). Source: Research empirical data *x* data extracted from the Capes comparative spreadsheets (2010b)

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.

The researchers' performance regarding the criteria human resources training at the graduate level could be evaluated based on a quantitative approach, by calculating an index as a function of the number of graduate students being tutored, either taking into consideration or not the fact that they were masters or doctorate students. The index could also involve some mark regarding the evaluation of the graduate program quality, since this is objective data made available by Capes in its reports. Finally, human resources training could also be evaluated taking into consideration the productivity of these students when finishing their graduate programs. This would increase the complexity of data collection and treatment, but would be possible by employing computer resources available nowadays. However, the way this criterion is evaluated to give productivity grants is not clearly presented in the CA report (in the case of PQ and DT grants). Therefore, this work does not overvalue this item, valuing more doctorate tutorials or tutorials that result in publications authored by those students.

Table 4 shows the number of graduate supervisions carried out by grant holders during the triennium 2007–2009.

The 1ABSenior aggregate level is represented by a homogeneous group regarding the number of supervisions, with focus on graduate students (masters and doctorate). 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.

Table 4 Human resources (graduate student supervisions) per aggregate level, scientific and technological contribution to innovation (software and products), members or leadership in research groups. Source: Research empirical data

Aggregate level	Procedure	Undergraduate scientific initiation	Masters	Doctorate
Human resources, scientific and technological contribution to innovation and participation in research groups				
Human resources				
1ABSenior	∑	21	38	37
	μ	2.1	3.8	3.7
	Ơ	2.92	2.74	4.65
1CD	∑	40	88	31
	μ	2.22	4.89	1.72
	Ơ	3.28	3.60	1.93
2PQ	∑	144	337	67
	μ	2.25	5.27	1.05
	Ơ	3.15	4.67	1.51
2DT	∑	8	55	1
	μ	0.89	6.11	0.11
	Ơ	1.36	6.05	0.33
Other permanent professors	∑	–	1.654	331
	μ	–	5.27	1.05
	Ơ	–	–	–

Aggregate level	Procedure	Registered + unregistered software	Product
Scientific and technological contribution to innovation			
1ABSenior	∑	8	0
	μ	0.8	0
	Ơ	2.20	0
1CD	∑	8	0
	μ	0.44	0
	Ơ	1.89	0
2PQ	∑	9	1
	μ	0.14	0.02
	Ơ	0.47	0.13
2DT	∑	7	5
	μ	0.78	0.56
	Ơ	0.83	0.73

Aggregate level	Member	Leader	Participants mean
Participation in research groups			
1ABSenior	6 (60 %)	7 (70 %)	1.30
1CD	15 (83.3 %)	9 (50 %)	1.33
2PQ	50 (78.1 %)	42 (65.6 %)	1.44

Table 4 continued

Aggregate level	Member	Leader	Participants mean
2DT	4 (44.4 %)	7 (77.8 %)	1.22

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

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

Regarding permanent professors linked to graduate programs in the Production Engineering area, who do not have productivity grant, the mean of tutorials, both to masters and doctorate students, is exactly the same as the group of researchers 2PQ. Thus, it can be said a priori that the group 2 PQ and the other professors present similar profiles regarding this item.

It was not possible to present the standard deviation for permanent professors who do not have grant researchers', since the Capes comparative spreadsheets only show data regarding each program but not specific detailed information for each researcher.

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. Table 4 presents the obtained result.

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*, was in Table 4.

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

Despite society expectations in relation to the university involvement in the knowledge production, the results of efforts carried out by the Brazilian university in this sense are still modest. Data from the Science and Technology Ministry—MCT (Brazilian abbreviation) reveals that the presence of Brazilian researchers in the world 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 the bases previously mentioned reached 2.69 % of the total publication (MCT 2010).

A small part of the professors in a graduate program have a CNPq grant researchers'. The 101 productivity grant holders in the Production Engineering area were grouped into four corresponding grant levels which are 1ABSenior, 1CD, 2PQ and 2DT.

Referring to the objective of this study, it was observed that: (a) In relation to the scientific production, productivity grant researchers presented superior performance than the other professors working in graduate programs in the Production Engineering area; (b) 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. In contrast, there is an inverse relationship for doctorate supervisions; (c) The category DT outstands both in software development and the development of other products while PQ researchers usually present high scientific production ad low technical production, while DT researchers present low scientific production and high technical

production; (d) Data referring to leadership in research groups showed the maturity of researchers who have higher levels of grants.

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 field, 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 they also has their work recognized by the academic community.

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