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Life-cycle productivity and gender differences in academic research: evidence from a Brazilian public university

Produtividade no ciclo de vida e diferenças de gênero na pesquisa acadêmica: evidências de uma universidade pública brasileira

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Abstract

Personal attributes and behavioral factors are key factors in determining researchers' scientific productivity. Investigating what determines the academic productivity among university researchers is the purpose of this study, which uses a sample of microdata from professors at a State university in Brazil (Federal University of Juiz de Fora) for the period 1999-2013. The main results show that age and academic productivity have an inverted-U-shaped relationship, revealing that experience enhances academic production. Regarding gender differences, we found that women generally have lower average productivity than men. However, at the end of their careers, women are subject to greater leverage effects in productivity and therefore achieve productive parity with men, especially during their production peaks.
Keywords: academic productivity, researcher life cycle, gender differences, aging effects.
JEL Codes: I23, J16

Resumo

Atributos pessoais e fatores comportamentais são fatores-chave na determinação da produtividade científica dos pesquisadores. Investigar o que determina a produtividade acadêmica entre pesquisadores universitários é o objetivo deste estudo, que utiliza uma amostra de microdados de professores de uma universidade estadual brasileira (Universidade Federal de Juiz de Fora) para o período 1999-2013. Os principais resultados mostram que a idade e a produtividade acadêmica apresentam uma relação em forma de U invertido, revelando que a experiência potencializa a produção acadêmica. Em relação às diferenças de gênero, descobrimos que as mulheres geralmente têm produtividade média menor do que os homens. No entanto, ao final da carreira, as mulheres estão sujeitas a maiores efeitos de alavancagem na produtividade e, portanto, alcançam paridade produtiva com os homens, principalmente nos picos de produção.
Palavras-chave: produtividade acadêmica, Ciclo de vida do pesquisador, Diferenças de género, Efeitos do envelhecimento.
Códigos JEL: I23, J16

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1 Introduction

Scientific publications are the means through which the communication of scientific discoveries and results takes place. Furthermore, publications are the channels scientists use to gain a sense of the relative importance of their work, receive feedback on their findings, achieve professional recognition, and advance in their careers (Fox, 1983). Academic distinction and high productivity based on publications go hand in hand with the university culture (Ramsden, 1994).

Estimating the number of publications researchers can produce is useful for public policymaking aimed at increasing scientific productivity or planning production balances of research groups. It is also valuable to offset the potential effects of aging, among other factors that might negatively affect productivity. However, to make productivity estimates of this kind, one needs to consider researchers' individual characteristics, personal history, and institutional variables. Therefore, in developing or emerging countries where most of the research is publicly funded, understanding the sociodemographic determinants of scientific publications is particularly useful for policymakers to induce a larger volume of high-impact scientific production (González-Bramila; Veloso, 2007).

Regarding the main sociodemographic determinants of academic production, the literature has explored the negative effects of aging on performance (Goodwin; Sauer 1995; Sturman, 2003; Kyvik, 1990; Skirbekk, 2004; Abramo *et. al.*, 2016), gender differences among scientists (Fox, 2005; Gander, 1999; Maske *et. al.*, 2003), and the relationship between productivity and experience (McDaniel *et. al.*, 1988; Warr, 1994; Dhillon *et. al.*, 2015). However, based on the literature, it is unclear whether experience can partially offset the effects of aging on academic productivity, and the peak production points are the same for women and men. Furthermore, it remains to be seen whether women's productivity can catch up with men's over the years.

This article adds to this literature by investigating how determinants such as age, gender, and experience affect academic productivity. For that purpose, we use a sample

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of microdata from professors of a State university in Brazil for the period 1999-2013. The following hypotheses are tested: 1) the relationship between age and academic productivity has an inverted U-shape; 2) women's average productivity is lower than men's; 3) gender differences in productivity vary depending on the age group; and 4) experience affects productivity positively and can compensate for the potential effects of aging.

The main results confirm that age and academic productivity have an inverted-U-shaped relationship and reveal that experience enhances academic production. Regarding gender differences, we found that women generally have lower average productivity than men. However, gender differences in productivity decrease over time so gender parity is reached in more advanced age groups.

This paper contains four sections in addition to this introduction. The second section presents a literature review on the determinants of academic productivity, followed by the hypotheses of this study. The third section offers the database, the variables, the models, and the descriptive statistics. The fourth section presents and discusses the main results. Finally, the fifth section delivers the conclusions.

2 Literature review

2.1 Academic productivity and researcher life cycle

As the average age of American researchers increased in the 1980s, Levin and Stephan (1991) published their seminal work assessing the relationship between age and the number of publications of American researchers in different research fields. They wanted to understand the role of the life cycle in researchers' academic production and categorized the life-cycle effects on academic production into different groups. The first is the aging effect, which can reduce intellectual production capacity. The second refers to experience and knowledge accumulation throughout a lifetime. Such factors could overcome the aging effect, making production grow until these factors expanded to exhaustion. Additionally, researchers' professional networks can develop and refine over time, affecting researchers' productivity positively even with advancing age.

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The life-cycle effects can be even more relevant when considering the motivations for engaging in research. According to Levin and Stephan (1991), two significant drivers must be viewed here. First, the choice to engage in research can be investment-motivated, meaning that scientists aim for future financial rewards. Second, research is self-motivated; that is, the focus on financial rewards is replaced with the pleasure of scientific discoveries. Levin and Stephan (1991) analyzed researchers' life cycle and the allocation problems they face related to each motivation for engaging in research: (i) researchers allocate time between research and other non-research activities; (ii) they allocate time to maximize utility through their careers, with utility being a function of research results and market goods (at constant prices); (iii) the relevance of publications erodes over time; (iv) in any period of time earnings are a function of previous publications no longer valued; and (v) learning is a by-product of research. Based on these statements, two assumptions are presented. The first determines that the greater the taste for research is, the more productive the researcher will be. The second claims that research activity decreases throughout life.

According to Levin and Stephan (1991), at that time, research productivity throughout a life cycle had received little attention in the economic literature, although several studies on the subject had been published in other disciplines. In addition, empirical evidence on life-cycle effects was weak and inconclusive, as most studies used cross-sectional data. Since scientists of different ages come from different cross-sections in a cross-sectional study, the effects of aging can be mistaken for cohort effects. In addition to differences in knowledge obsolescence rates and scientific opportunities over time, cross-section data can vary in skill or motivation according to the different research fields studied. One way to control for these effects is to follow a group of individuals over time. However, this approach ignores that the scientific state-of-art and the working environment change over time. Thus, time effects can also obscure the relationship between research productivity and age.

Diamond (1984) also intended to derive testable implications regarding life-cycle productivity. The author stated that researchers maximize income by discounting the sum of their current up to all future income. Income is defined as the product of working time, capital stock, and the rate of remuneration per unit of capital, considered constant, after

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using the internal rate of return as a discount factor, assumed constant over the years. The theoretical model points out two reasons for the decreasing time allocated in the production of scientific papers. The first reason is the decreasing marginal return as time goes by. The second reason is that the non-neutrality assumption for the production function of human capital, which results in less time to produce papers as the investment cost increases.

Cole (1979) also addressed the relationship between production and age and pointed out a curvilinear relationship between the variables. The author shows that age alone does not influence the quality and quantity of work scientists produce. The difference between the most productive group (40-44 years old) and the least productive group (+60 years old) is 3.06 articles. In most research areas, older scientists (over 60 years old) are not that much less productive than those under age 35. Thus, according to Cole (1979), the reward system and the overall characteristics of the researcher's scientific field explain the relationship between age and productivity. The author does not noted great differences in the reward systems across different scientific areas, which may be related to the existence of the same university rules for different scientific fields and to the pressure on each researcher to maintain her/his position in the career. As rewards are earned through publications, researchers whose work is rewarded are more likely to maintain high productivity.

Goodwin and Sauer (1995) concluded that the most productive researchers showed little or no tendency to decrease productivity up to about 20 years of working time. In their study, the authors considered variables such as the number of papers published, education, experience, the university's position in the ranking of excellence, and whether the researcher occupied any administrative position.

According to Sturman (2003), the potential adverse effects of aging, such as decreasing skills and decreasing motivation, will probably not increase at the same rate over time. So aging is likely to have little or no effect early in the career; in contrast, the potentially detrimental effects of aging are likely to start and accelerate later in the career. Therefore, the negative effects of aging are expected to become stronger as the individual ages. Among younger individuals, age is positively correlated with work performance, so

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the former and the latter increase accordingly. However, this relationship progressively decreases until around the age of 49. After that, the relationship between age and job performance becomes negative, so aging is associated with reduced job performance.

According to Kyvik (1990), academic productivity peaks in the 45-49 age group and decreases by 30% among researchers over 60. However, differences emerge across the knowledge fields. With the exception of social sciences, with similar productivity across age groups, the humanities and the medical sciences have different patterns. In the humanities, scientific production decreases after 55 years old though a new peak for 60 and older researchers is observed. In the natural sciences, productivity is monotonically decreasing with age while it decreases after 55 years old for researchers in medical sciences.

More recent studies also find evidence supporting an inverted U-shaped relationship between academic productivity and age (Barjak, 2006; González-Brambila; Veloso, 2007; Costas *et. al.*, 2010). Yen *et. al.* (2015) found that the productivity of Malaysian researchers had two peaks. The researchers were more productive between the ages of 36 to 40 and 46 to 50 years and became less productive after 51 years. Evidence from the College of Speech Therapy in India showed researchers to be more productive in the 25-30 age group and the over-55 age group (Subramanian; Nammalvar, 2017), with the second highest peak. The occurrence of the first peak may be linked to the desire of younger researchers to contribute to science and gain recognition in the scientific community. Regarding the second peak, which differed from the previous literature, the authors argue that the result may be influenced by the more significant number of collaborations and by the researchers' years of experience, given its importance for the field of speech therapy.

2.2 Academic productivity and gender

There seems to be a consensus in the literature on gender differences in academic production that female researchers are less productive than male ones (Prozesky, 2006; Padilla-Gonzalez *et. al.*, 2011; Lone; Hussain, 2017; Sasor *et. al.*, 2018; Sá *et. al.*, 2020;

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Kaba *et. al.*, 2021). For example, Cole and Zuckerman (1984) analyzed a group of Ph.D. scientists between 1969 and 1970 and found that women published barely more than half the number of articles (57%) published by men. In their view, the authors found it difficult to explain such gender differences in scientific production and called it "the productivity puzzle."

Xie and Shauman (1998) were, in part, successful in their attempt to unravel the "puzzle" left by Cole and Zuckerman (1984). The authors explained men's higher productivity because women have gender-specific characteristics, occupy fewer structural positions, and have less access to research resources. Additionally, the authors indeed found little direct effect of gender on research output. In other words, differences arising purely from gender would be smaller than previously seen.

However, according to Xie and Shauman (1998), such a finding replaced the old "puzzle" with a new one. Now one must explain the gender productivity differentials based on gender-specific personal and structural characteristics. On the contrary, the puzzle remained unsolved. Notwithstanding, one important discovery made by the authors was that general gender differences in research productivity decreased during the analyzed periods. According to the authors, such a decrease could be explained by the distribution of resources and structural positions over time, which despite still unfavorable to women, became more equitable over time. Similar results were found by Tran *et. al.* (2022). Some researchers point to motherhood and changes in gender roles as a possible justification for this decrease in the productivity gap (Okafor *et. al.*, 2020).

Maske *et. al.* (2003) examined the causes behind the gender disparity in publications and found that 41.3% of the difference between male and female publications was explained by experience, number of courses taught, overall university orientation (whether research-oriented or teaching-oriented), and other control factors. They argued that the non-explained differences could be related to discriminatory practices in the publication process.

Similarly, Chen *et. al.* (2006) observe no significant gender differences per se in publications. In fact, according to the authors, factors, such as time allocated to research, desire to contribute to her/his discipline, and academic experience, were among the main

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drivers of scientific production of professors. The greater the percentage of time permanent professors spend on research, the more motivated they are to contribute to the area and, therefore, the more papers they publish. This relationship was verified in a study carried out with Australian universities, in which the number of hours dedicated to teaching and the number of hours devoted to research showed different effects, a negative for the first and a positive for the second as the number of time increases (Bentley, 2012).

Mathews and Andersen (2001) offered, in turn, broader explanations for the gender disparities in academic publications. Non-permanent, part-time or temporary jobs for women could explain part of the differences. Besides, there are unequal access to institutional support, resources, and professional networks. Other reasons highlight the activities that deviate from the research or experience career interruption due to motherhood. This was the case found for some researchers within the health area. It was observed that it is more common for women to enter clinician-educator careers or careers of a practical nature within medicine than as academic researchers (Goel, 2002; Chauvin *et. al.*, 2019; Lau *et. al.*, 2023).

Leahey (2006) discusses a usually neglected aspect of academic research programs, which is researchers' specialization. According to the author, specialization plays a critical role in explaining gender differences in academic publications and the consistently lower productivity rates of women compared to men. The author found that a specialized research program can encourage research among its members. However, women are often part of less specialized research programs and thus lose the means to achieve greater productivity. Leahey (2006) also highlights that men and women engage in different professional networks and collaboration strategies. Men often engage in broader and more diverse professional networks that allow them to find collaborators whose interests and expertise overlap with theirs and where collaborations help consolidate their expertise in one or more areas of expertise. In contrast, women usually engage in smaller and more homogeneous networks, so they need to branch out to other areas to collaborate, resulting in less specialized research programs.

In line with Leahey's (2006) evidence, Mayer and Rathmann (2018) argue that women may sometimes be isolated in the academic environment due to the

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overrepresentation of men. In other words, departments and networks dominated by male researchers hinder women's access to collaboration, scholarly feedback, and scientific debate, eventually undermining female scientific productivity. This female underrepresentation is verified in some studies that analyze members of the medical faculty (Mayer *et. al.*, 2017; González-Álvarez; Cervera-Crespo, 2017; Rachid *et. al.*, 2021). In one case, it was reported that women faced disproportionately under-representation, in the sense that the number of male academic surgeons was more than twice that of women in the same field (Agaronnik *et. al.*, 2022).

Sax et al. (2002) offer another explanation for women’s lower productivity. According to them, female researchers in part substitute the desire to publish a high number of papers for the desire to change society. Therefore, many women might choose not to spend time on publications and otherwise spend it on activities perceived as having a more direct social impact. This can be seen about possible mentoring/supervising activities. It was reported that the researchers saw this type of activity as a moral obligation to future scientists, which should be fulfilled, despite their other responsibilities (Davies; Healey, 2019). The same mentality did not apply to men. In his view, this was a necessary part of his duties, but some compensation should be given in return.

2.3Academic productivity and experience

Quiñones *et. al.* (1995) showed that time is the most used proxy for experience. Time can be related to experience because, as time passes, individuals accumulate work-related knowledge (Sturman, 2003). Thus, according to Quiñones *et. al.* (1995), work experience involves accumulating specific knowledge derived from the performance, practice, and perception of tasks and duties associated with a given job or profession. Callaghan (2016) adds to the theme by concluding in his study that productivity in research can represent specific human capital, being a form of tacit learning accessible only through a “learning by doing” process.

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In Sturman's (2003) view, the Human Capital Theory holds that employees invest in their own experience, allowing them to expand their skills and enhance their own performance at work. The author also points out that the Learning Theory predicts that work experience increases the individual's ability to carry out work. Thus, Sturman (2003) states that accumulating relevant knowledge and skills through experience improves the individual's performance.

Therefore, performance models, such as the one presented by McDaniel *et. al.* (1988), postulate that work experience is positively correlated with performance. The authors also indicate that the correlation is positive for all levels of professional expertise and both low-complexity and high-complexity jobs.

Warr (1994) defends that the correlation between experience and performance is positive, especially when the work requires complex, knowledge-based judgments, as it does in academic research. In this case, experienced workers often have an advantage, as they have had more time to absorb relevant and specific knowledge in their field. The author also argues that professional experience can sometimes compensate for the decline in production capacity resulting from aging. In the author's view, although skills decrease due to aging, performance continues to benefit from the experience acquired by the individual over time. Therefore, performance enhancements due to experience compensate for the performance decreases associated with aging.

Experience can also be associated with a researcher's academic classification/title, as researchers with higher degrees are expected to be more experienced and have greater productivity (Nygaard, 2017). Once a higher degree is achieved, a cumulative theoretical advantage makes it easier for teachers to maintain high productivity (Bordons *et. al.*, 2003). In this way, it is expected that senior academics are more inclined to obtain a higher level of research output than those with lower titles in the academic hierarchy (Zhou; Volkwein, 2004).

In this line of study, Jung (2012) found that the number of doctors' publications is larger than that of non-doctors'. Additionally, the authors identified that the research productivity of professors with postdoctoral experience is greater than that of those without, especially in academic journals. This result can be explained, in part, by the

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additional opportunities to participate in academic exchanges and networking with international colleagues that are linked to more remarkable career advancement. The relevance of these factors acquired through experience, such as collaboration networks associated with the capacity of these older researchers, can mitigate the decrease in academic productivity resulting from the aging process (Yen *et. al.*, 2015).

2.4Hypothesis

This section describes the hypotheses regarding the relationship between research productivity and the factors mentioned in the literature review. First, it analyzes the relationship between the researcher's life cycle and academic productivity. Following what is predicted by the literature mentioned in section 2.1, especially regarding the relationship between age and productivity, it is expected that the relationship between age and scientific productivity is non-linear, assuming an inverted U shape, thus reflecting the peak productivity of researchers and its eventual decline.

From this, the first hypothesis is postulated:

H1. The relationship between age and academic productivity has an inverted U shape.

Next, this study analyzes the two hypotheses about gender and research productivity based on the works discussed in section 2.2, which analyzed possible determinants of the gender differential in publications:

H2a. The average productivity of women is lower than that of men.

H2b. Gender differences in research productivity depend on age group.

Finally, following the literature on experience and academic productivity discussed in section 2.3, and bearing in mind that experience is associated with the accumulation of knowledge and that its effect may offset the effect of age, the third hypothesis is established:

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H3. Experience makes a positive contribution to productivity and can offset the potentially harmful effects of aging.

3 Methodology

3.1Database, variables, and econometric model

We use the term scientific productivity as the number of researcher publications such as Levin and Stephan (1991); Abramo *et. al.* (2009) and (2016); Fox (2005); Sax *et. al.* (2002); Ramsden (1994); Xie and Shauman (1998); Goodwin and Sauer (1995).

Data on publications used in this study refers to the scientific publications by researchers holding a Master's or a Ph.D degree working at the Federal University of Juiz de Fora (UFJF) from 1999 to 2013. By researchers, we mean professors and administrative staff (1035 out of 1208 professionals) who have at least one paper published in a scientific meeting (including abstracts) or an indexed journal over 1999-2013. Considering the model used by Levin and Stephan (1991), we chose to use the number of annual scientific publications as a dependent variable, taking the information extracted from the Lattes Platform as a source. Our paper measures scientific production by papers published in journals, published abstracts, and papers presented in congresses. The number of publications is the most used productivity indicator in the literature (Xie; Schauman, 1998; Levin; Stephan, 1991).

Located in the city of Juiz de Fora, Minas Gerais, the UFJF is one of the 67 federal-funded universities in Brazil (ANDIFES, 2021).[1] The data have been retrieved from the Lattes Platform, an online government-funded comprehensive database aggregating the vitae curricula of personnel working in research and teaching in Brazil and information on research institutions and groups, among others.

Personal information on the UFJF professionals has been obtained from the Annual Social Information Report (RAIS), kept by the Ministry of Economy (2019). It contains information companies report on an annual basis about themselves, such as firm

[1] Public universities account for most of the country's scientific publications (Duarte *et. al.*, 2020; Chiarini; Vieira, 2012).

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size, and about their employees, such as income, age, gender, occupation, and municipality. Thus, the RAIS database allows the monitoring of individual employees over the years and enables the construction of a panel. In contrast, one disadvantage of the RAIS database is that the data are limited to the formal sector of the economy. In addition, it usually contains filling errors, as the companies themselves fill up the forms, and the information is made public with no prior analysis. Nevertheless, these disadvantages are offset in the present study because public universities only register professors under formal contracts and are subject to stricter regulations for reporting official data to the authorities resulting in better quality reports.

We used the individual’s age and age squared as explanatory variables to examine the relationship between productivity and the researcher's life cycle. Additionally, to observe gender differences in productivity, we chose to relate the researchers' age to their gender and consequently verify the results separately, through variables named “age of males” and “age of females”. We also created the explanatory variable “experience” based on the individual’s research career time span, starting from the publication date of the first paper the author published. From the first publication onwards, one point of experience is added every 5 years, up to the limit of 5 points. We did it to avoid serial correlation with age variables without directly affecting the role of experience in research.

As control variables, we used the number of coauthors counted by the annual average of coauthors in the papers extracted from the Lattes Platform and the average income in minimum wages provided by RAIS. Furthermore, to examine gender differences in productivity, we considered other factors affecting productivity directly or indirectly (Mayer; Rathmann, 2018). Levin and Stephan (1991) and other authors suggested that endogeneity between wages and productivity might occur. In the private sector, where wages are tied to production, this can really be a problem. However, since the UFJF is a federal autarchy, salary thresholds, and escalation rates are defined by career-specific federal law based on academic degrees and time of service. Therefore, the problem of inverse causality, from productivity to average income, does not apply here.

The work of Levin and Stephan (1991) has inspired the econometric models used in this study, which analyze drivers of researchers’ productivity by adding gender

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differences. In the function representing productivity, the dependent variable productivity, $Y_{i,t}$, is defined as the number of papers published by researcher *i* in period *t*. The explanatory variables are age (*AGE*), square of age (AGE^2), research time as a proxy for experience (*T*), average number of co-authors (*C*), and average income (*R*). To examine gender differences, a second equation was added where age is separated into different variables for men and women, according to the equations below:

$$Y_{i,t} = f_{i,t}(AGE, AGE^2, T, C, R) \tag{1}$$

$$Y_{i,t} = f_{i,t}\left(AGE_{ifmale}, AGE_{iffemale}, AGE^2, T, C, R\right) \tag{2}$$

Considering the countable nature of the dependent variable used as a proxy for academic production, $Y_{i,t} \in N$, we chose to use the Poisson estimator. In this way, we can incorporate natural censorship to the estimates since no negative production can occur, and $Y_{i,t} > 0$ as a means to define researchers. Regardless of the Poisson distribution validity, consistent and asymptotically normal estimators are still obtained (Wooldridge, 2012).

For comparative purposes, we also included a linear model (LM) and a negative binomial model (NBM) (Wooldridge, 2012). The linear model always helps understand the gains from the different approaches adopted. As for the negative binomial model, it provides an estimation alternative for discrete data, including controlling for fixed effects. However, the model is subject to criticisms, notably regarding the estimation method. Although Allison and Waterman (2002) remember that the NBM implementation using the Stata software has issues, the model is also compatible with count data and therefore still offers a comparison parameter to the Poisson model. Nevertheless, the Poisson estimator is the most adequate for the data used in this work due to its precision and non-biased results, especially in the control of fixed effects.

We used the fixed-effects control in the estimation methods here due to the presence of unobservable and time-invariant individual heterogeneity, such as psychological factors, work habits, innate ability, and motivation, which could explain the researcher's productivity. The fixed-effects estimator takes into account the arbitrary

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correlation between individual heterogeneity and other observable characteristics. For this reason, any explanatory variable that is constant over time for every researcher *i* is removed by the fixed-effects transformation (Wooldridge, 2012).

It is also noteworthy that observations of researchers with no publication in the period were disregarded in the estimates, as they fall out of the scope of the definition of researchers used in this work: only academic professionals linked to the UFJF who published at least one paper in the period analyzed. This limitation is meant to restrict the analysis to active researchers and ignore other activities that, being research-related or not, do not result in paper publications. For example, such a restriction excludes professors' participation in university extension initiatives and solely pedagogical activities.

3.2Descriptive Statistics

The UFJF faculty profile is 41 years of age on average, varying between 25 in the first year after obtaining the master's degree to 62. Researchers showed an average productivity of 2.8 publications per year. In relation to experience, the faculty profile accounted for an average of 2.16, which is equivalent to 10.8 years of research time (Table 1).

We also found an average annual income of 16 minimum wages, remembering we took into account only UFJF professors with active academic production. As for the number of co-authors, we found an annual average of 2.15 co-authors per paper. Additionally, the maximum number of co-authors per article was 8 in the period.

Table 1 – Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Productivity	2041	2.8055	2.5166	1	32
Age	2041	40.9417	7.1725	25	62
Experience	2041	2.1622	1.1835	0	5
Number of Co-authors	2041	2.1558	2.0059	0	8
Average Salary	2041	16.2358	4.9017	0	25

Note: In the experience indicator, one unit is added every five years of research.
Source: elaborated by the authors.

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Table 2 presents the descriptive statistics for both genders. Observing the average productivity, one can see that men published an average of 3 papers annually. In contrast, women published an average of 2.47 articles. As for the other variables, men and women show considerably similar results. The average age of male researchers is 40, while for women is 41. Concerning experience, men have an average score of 2.36 (approximately 12 years dedicated to research), while women have 1.9 years (less than 10 years on average). The average number of co-authors, in turn, was the same for both genders, as the average test for gender difference here is not significant. The data show that the size of publication networks is the same for men and women. Regarding income, gender differences are statistically significant, with women having an annual average income of 15.6 minimum wages, while men earn 16.8 minimum wages on average. Such a difference, however, is not due to gender bias, as salaries and wage escalation rates are defined by law, making no gender distinction.

Table 2 - Descriptive Statistics by Gender

Variables	Male			Female			
	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.	Difference
Productivity	1143	3.07	2.64	898	2.47	2.31	-0.60***
Age	1143	40.78	7.00	898	41.15	7.39	0.37
Experience	1143	2.36	1.21	898	1.90	1.09	-0.46***
Co-authors	1143	2.23	1.88	898	2.06	2.15	-0.17
Average Salary	1143	16.76	4.62	898	15.57	5.16	-1.19***

Notes: 1) Probability of the t test of difference between means, ***p<0.01, **p<0.05, *p<0.1.
2) In the experience indicator, the value must be multiplied by 5 to obtain time in years.
Source: elaborated by the authors.

Table 3 presents the correlations of all the variables considered. The results show that the dependent and the explanatory variables are positively correlated. Among the independent variables, correlations are not high, but the highest values were observed between age and average income (34.8%) and between the research time span (experience) and average salary (32.4%), indicating that salary trajectory reflect the age and time spent in research activities.

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Table 3 – Correlation coefficient of model variables

	Productivity	Age	Experience	Co-authors
Age	0.0343			
Experience	0.2109	0.4701		
Number of Co-authors	0.1445	-0.0253	0.1492	
Average Salary	0.1217	0.3481	0.3247	-0.0328

Source: elaborated by the authors.

When comparing the gender-related correlations (Tables 4 and 5), important findings come into notice. The correlation between the explanatory variables age and experience, on the one hand, and the dependent variable, on the other, is greater for women than for men. This means that women's academic productivity is more linked to aging and gains of experience over time than that of men. Similarly, the correlation between the control variable, average salary, and productivity is also greater for women. This result allows us to infer that female productivity may be more susceptible to motivations arising from salary. Unlike the other variables, the correlation between the number of co-authors and the dependent variable is slightly higher for males.

Table 4 – Correlation coefficient for male' variables

	Productivity	Age	Experience	Co-authors
Age	0.0010			
Experience	0.1849	0.5647		
Co-authors	0.1676	-0.0118	0.1312	
Average Salary	0.0742	0.3597	0.2729	0.0081

Source: elaborated by the authors.

Table 5 – Correlation coefficient for female' variables

	Productivity	Age	Experience	Co-authors
Age	0.0884			
Experience	0.2061	0.3801		
Co-authors	0.1092	-0.0373	0.1618	
Average Salary	0.1557	0.3480	0.3597	-0.0844

Source: elaborated by the authors.

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4 Analysis of results and discussion

This section discusses the results obtained from the regressions for the general case and for the gender differences among the UFJF researchers. Table 6 shows the variables' behavior using the Poisson (POISSON), the Negative Binomial (NBM) and the Linear (LM) methods, all with fixed-effects control (FE).[2]

[2] As we define a researcher as the individual with at least one publication over the period, we also performed a robustness test estimating a new set of regressions including individuals that were excluded due to not having published any paper between 1999-2013 (15% out of the total sample). All regressions, including those based on zero-inflated negative binomial models, show results quite similar to those of Table 6. This test is available upon request.

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Table 6 - Drivers of the UFJF researchers' productivity (1999-2013)

VARIABLES	(1) Linear Model (Fixed-Effects)	(2) Poisson (Fixed-Effects)	(3) Negative Binomial Model (Fixed-Effects)	(4) Linear Model (Fixed-Effects)	(5) Poisson (Fixed-Effects)	(6) Negative Binomial Model (Fixed-Effects)
Age	0.312***	0.0996***	0.0899***			
	(0.0858)	(0.0163)	(0.0180)			
Age for female				0.345***	0.119***	0.0902***
				(0.0875)	(0.0169)	(0.018)
Age for male				0.301***	0.0977***	0.0869***
				(0.0860)	(0.0163)	(0.0183)
Square of Age	-0.0024***	-0.0008***	-0.0008***	-0.0025***	-0.0008***	-0.0008***
	(0.0009)	(0.0002)	(0.0002)	(0.0009)	(0.0002)	(0.0002)
Experience	0.344**	0.0682**	0.126***	0.345**	0.0687**	0.128***
	(0.155)	(0.0291)	(0.0312)	(0.155)	(0.0291)	(0.0315)
Co-authors	0.356***	0.108***	0.0906***	0.345***	0.107***	0.0909***
	(0.0407)	(0.0082)	(0.009)	(0.041)	(0.0082)	(0.00901)
Average Salary	0.0408***	0.0109***	0.0081***	0.0397***	0.0103***	0.00821***
	(0.0121)	(0.0024)	(0.0028)	(0.0121)	(0.0025)	(0.00275)
Constant	-7.777***		-0.453	-7.915***		-0.418
	(2.034)		(0.423)	(2.035)		(0.425)
Observations	3,951	3,928	3,928	3,951	3,928	3,928
R-squared	0.110			0.111		
Number of individuals	460	437	437	460	437	437

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P-value for difference between men and women	0.0636	0.00	0.384

Note: Standard errors in parentheses, ***p<0.01, **p<0.05, *p<0.1
Source: elaborated by the authors.

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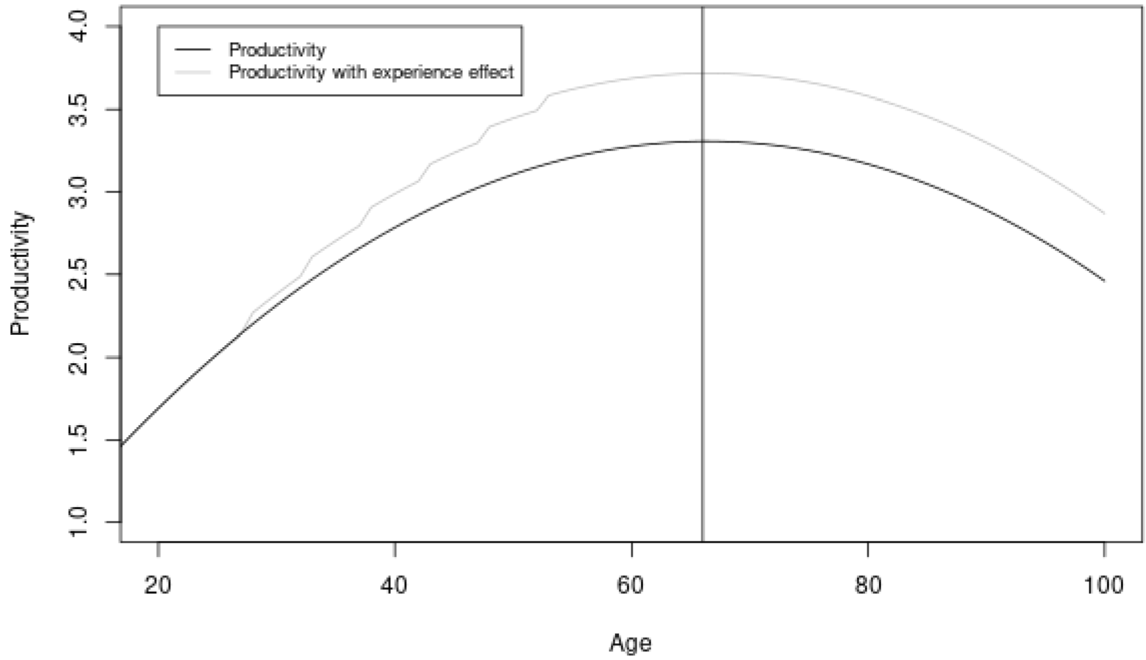
Models (1), (2), and (3) (Table 6) show that most variables influence researchers' productivity positively, except for the variable age squared. The age variable was positively associated with scientific production. However, this relationship is non-linear, considering that AGE square has a negative coefficient, indicating an inverted U-shaped relationship. Graphs 1 and 2 allow us to better visualize the relationship between age and productivity considering the results obtained through the Poisson and the Negative Binomial Models, respectively.

Figure 1 – Relationship between age and the UFJF researchers' productivity in the Poisson Model. Juiz de Fora (Brazil). Period: 1999-2013



Source: Elaborated by the authors.

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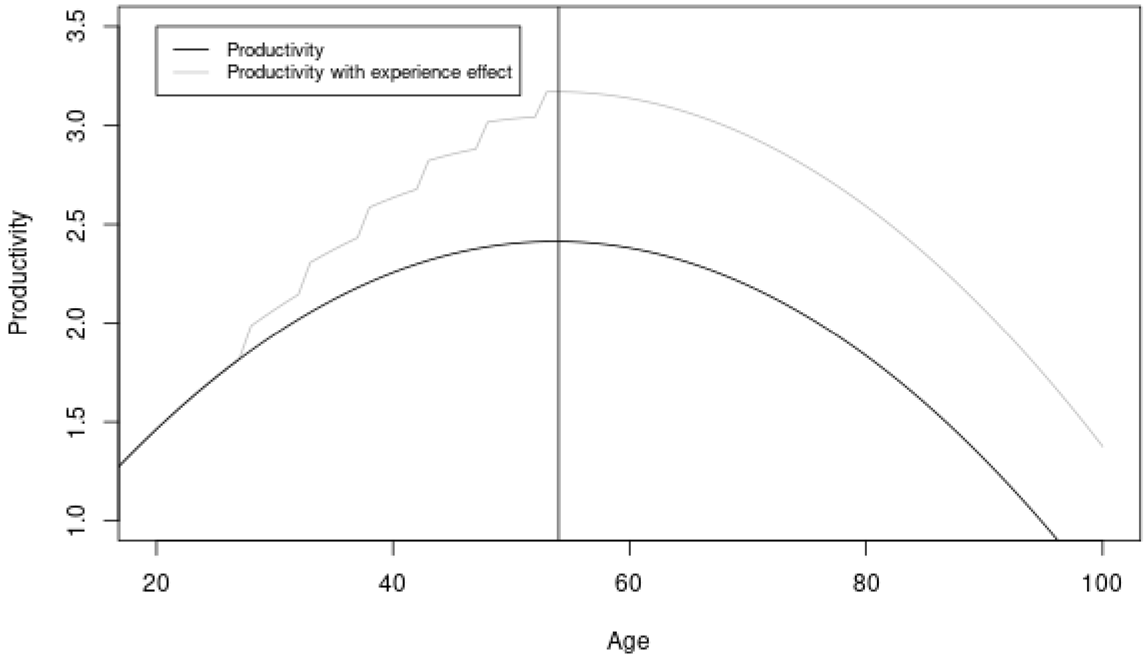
Figure 2 – Relationship between age and the UFJF researchers' productivity in the Negative Binomial Model. Juiz de Fora (Brazil). Period: 1999-2013



Source: Elaborated by the authors.

In other words, researchers are productive until a certain peak of production. After that, productivity declines gradually. These results validate the H1 hypothesis previously presented. The effects of aging on productivity are only significant when the productivity gains associated with experience and knowledge accumulation over time are exhausted, as seen in Cole (1979) and Levin and Stephan (1991). As for the Poisson Model, the depletion of productivity gains associated with the effects of experience and knowledge accumulation counteracting the aging effect occurs at the age of 66. In contrast, in the binomial model, depletion occurs at 54.

The variable experience has a significantly positive coefficient in all three models. Considering the positive correlation between research time span and productivity found in this study, we can say that, among the UFJF researchers, the research experience acquired over the years is a relevant scientific production enhancer, shifting significantly to above the researcher's average productivity, especially after the age of 50. Figures 1 and 2 show the different effects of age versus productivity with and without the experience effect.

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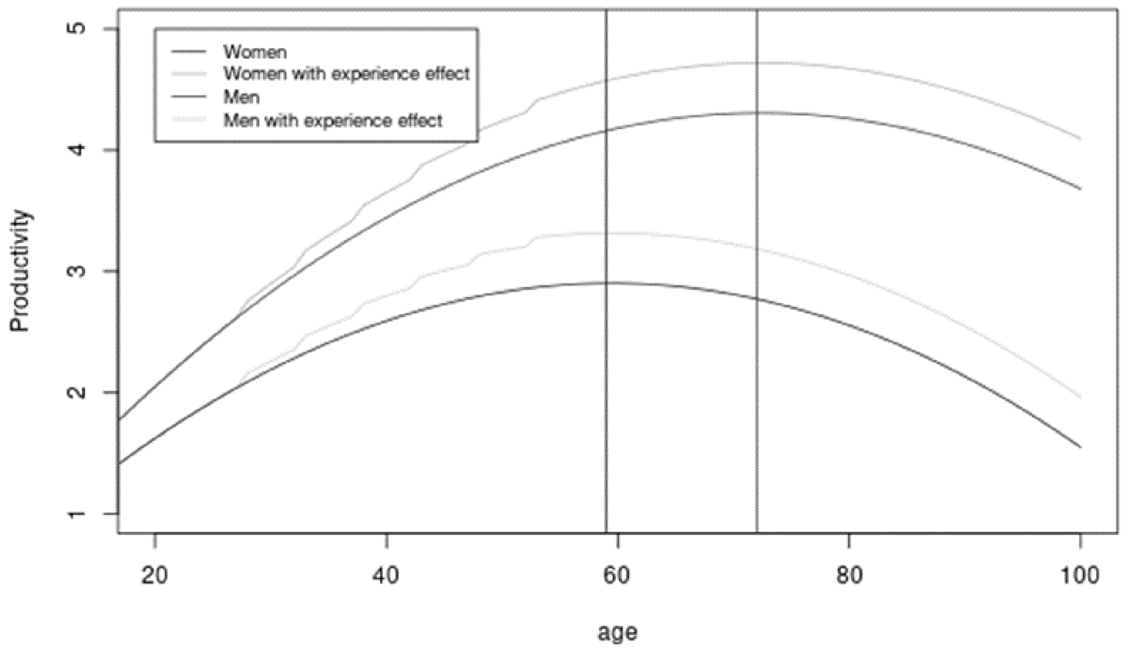
In both the Poisson and the Negative Binomial Models, adding the experience accumulated over time increased researchers' productivity, especially in the Negative Binomial Model. This result demonstrates that, though the aging effect is significant from age 60 and 50 onwards in the Poisson and the Negative Binomial Model, respectively, such an effect cannot interrupt productivity gains derived from experience and knowledge accumulation. Therefore, hypothesis H3 is confirmed.

As for the gender differences, in models (4), (5), and (6) presented in Table 6, results show that all variables have positive coefficients, except, again, for the variable age squared. As evidenced in the general case, the relationship between age and productivity must take an inverted-U shape for men and women. The meaning here is that productivity often increases until a certain age peak occurs in both genders (Figures 3 and 4).

Figure 3 - Relationship between age and the UFJF researchers' productivity by gender in the Poisson Model. Juiz de Fora (Brazil). Period: 1999-2013



Source: Elaborated by the authors.

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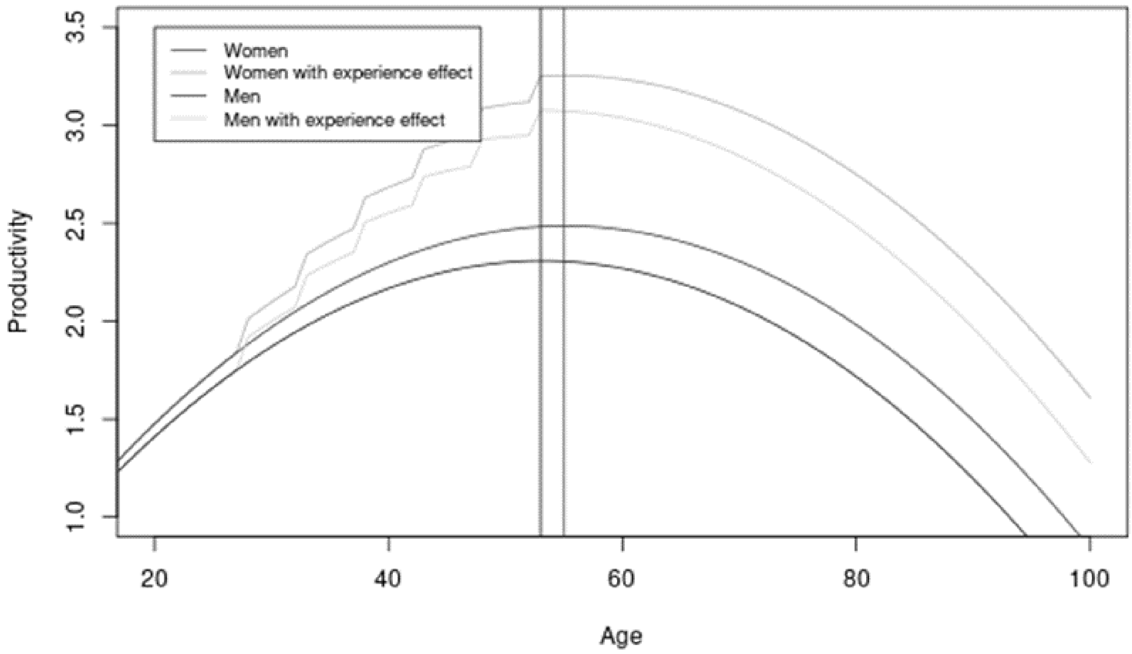
Figure 4 - Relationship between age and the UFJF researchers' productivity by gender in the Negative Binomial Model. Juiz de Fora (Brazil). Period: 1999-2013.



Source: Elaborated by the authors.

Although the relationship between age and scientific productivity is non-linear for both genders, the production peak is different in each model. In the Poisson Model, men reach the production peak in their 60s, while women in their 70s. In the other model, men and women reach the peak of production at the exact same age, both in their 50s.

As expected, we found that the research time span boosts academic production for men and women. Once again, results confirm that experience accumulation has a positive effect and can mitigate the effects of aging. However, the most surprising in this finding is that, in both models, women seem to be subject to leverage effects considering how their productivity evolves over time. Women's productivity growth curve proved to be steeper than that of their male counterparts, especially in the Poisson Model. It appears, therefore, that women remain productive for a longer period than men, once they have reached a production peak at an older age than men.

Hypothesis H2a postulated that women's productivity was lower than men's. Women showed lower average productivity throughout their lives than men. However, to

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better understand these gender differences in productivity, we shall consider how the average publication by age group evolved among men and women. As seen, in total, men's productivity is significantly higher (95% confidence), and this difference is even higher in the first years of their academic career. However, at the end of their careers, women are subject to greater leverage effects in productivity and therefore achieve productive parity with men, especially during their production peaks, as shown in Table 7. Thus, the expectation raised by H2b is confirmed.

Table 7 – Gender differences in productivity over work lifetime

Age	Women	Men	T-test Difference	Total
30 or less	1.99	3.05	-1.06***	2.55
31 to 40	2.35	3.01	-0.66***	2.73
41 to 50	2.56	3.14	-0.58***	2.89
More than 50	2.88	3.03	-0.15	2.95
Total	2.47	3.07	-0.60***	2.81

Source: elaborated by the authors.

These results demonstrate that men’s and women’s production capacities are the same once they have both reached their productivity peak. Mathews and Andersen (2001) provide adequate justification for such a statement, as they highlighted that for women, reduced workload, especially as a consequence of motherhood, often jeopardizes productivity. As seen, when women can dedicate more time to work, they reach the same productivity level as men. The productivity differences between men and women are strongly related to life-cycle differences, although we cannot disregard other hypotheses.

Another hypothesis might explain such differences in productivity at the beginning of research careers. Production networks may be less accessible to women at the beginning of their careers, in line with what Leahey (2006) suggested. Although women reach the same productivity level as men after their 50s, women may find it difficult to access research networks in the first years of their careers due to a lack of recognition. This gap could even explain how the leverage effects affect men and women differently over time. However, this problem needs to be further elaborated, especially concerning how women develop their production networks over time.

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The results also help reduce the field for some hypotheses to grow. If women reach the same productivity level as men over time, it does not seem credible that academic publications have any scrutiny regarding the researcher's gender as proposed by Maske *et. al.* (2003). Most journals adopt the blind test for paper approval, so that hypothesis loses relevance. Additionally, if this hypothesis is true, women would be expected not to reach the same production level as men; however, what truly happens is that women can publish as much as men at the peak of their careers and also spend more time producing articles. But even if that were true, the hypothesis of Maske *et. al.* (2003) could be tested by verifying women’s performance as journal editors and whether the editor’s being a female affects scientific publication by gender.

It is also worth highlighting the positive association between collaboration and research productivity. Such a finding reflects the growing number of worldwide scientific collaborations and the consequent productivity gains observed in recent decades (Abramo *et. al.*, 2009). The reasons may be the growing specialization of science, the increasing complexity of the problems investigated, and the high costs of the equipment to carry out experiments. Katz and Martin (1997) also address this topic and relate the productivity gains derived from growing collaborations to the benefits arising from collaboration itself. Such benefits include sharing knowledge, skills, and techniques, creating “intellectual companionship,” and achieving greater work visibility.

As for the average income variable, the positive association between productivity and income is explained by Coupé *et. al.* (2012) based on the Human Capital theory. Notwithstanding, concerning the UFJF researchers, the positive association between income and productivity suggests that the salary increases as time passes and researchers advance in their careers.

5 Conclusions

This study aimed to investigate the sociodemographic determinants of the scientific productivity among researchers at a public university in Brazil. The determinants include age, gender, and work experience. The research institution analyzed

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was the Federal University of Juiz de Fora (UFJF), located in the city Juiz de Fora, state of Minas Gerais.

The results indicate that all factors have a positive influence on researchers' academic production measured by publications in journals and scientific meetings, both for the complete sample and for men and women separately. We found an inverted-U-shaped relationship between age and scientific productivity, with researchers often showing a gradual decrease in productivity over time. However, the results also showed that the effects of reduced productivity arising from aging are only significant when the gains from accumulation experience are depleted over time. Concomitantly, experience accumulation played a significant role as a scientific production enhancer and, in a way, as a mitigating agent of the effects of aging.

Regarding gender differences, as expected, women show lower productivity, especially at the beginning of their careers. Also, man and women reach their productivity peaks at different moments of their lives, with women later than men. However, these differences are offset by the greater leverage effects in productivity women seem to experience over time compared to men, which allows them to achieve productive parity. So, women's productivity growth curve was steeper than that of their male peers. Therefore, as women reach their production peak at an older age, they are able to remain productive for a longer time than men.

These differences at the beginning of their careers can be explained by different situations women face in their academic careers. Especially motherhood makes it difficult for them to dedicate more time to research. It is also worth mentioning that gender bias might prevent them from gaining access to production networks during their careers. However, these hypotheses may require further testing to be conclusive.

The results found in this study can subsidize the design of public policies to tackle the inverted U-shaped relationship between age and scientific production. For example, one can think of incentives, such as productivity grants, to anticipate the peak of scientific production. Public policy could also be aimed at promoting research networks for researchers to reach their potential before their 50s or funding research projects led by researchers with notable academic production. Considering the gender differences in life-

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cycle productivity, public policy could also be gender-specific. For example, research-grant quotas for women could act on the hardships that cause a later peak of scientific productivity among women.

The main limitation of this work relates to the scope of our database, restricted to only one university. As our sample is based on a case study, the results are not generalizable. However, the academic career as a university professor in a federal university in Brazil is the same for everyone in all the 67 federal institutions existing in Brazil. So, salary structure is the same for both genders and depends only on the time of service and academic degrees, with no room for gender discrimination. Based on that, we believe that the same relationship patterns and productivity peaks by age found among the UFJF faculty also apply to the other federal universities in the country.

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Eduardo Gonçalves: Literature Review, Formal Analysis, Supervision, General Review, and Editing.
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Conflict of Interest Statement

The authors declare that there are no conflicts of interest of a personal, commercial, academic, or financial nature between the authors and the publication of this article.