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Gender Gaps and Scientific Productivity in Middle-Income Countries

Evidence from Mexico

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Abstract*

This paper provides evidence of the existence and determinants of the publication productivity gender gap in Mexico at the individual level, and its consequences for the Mexican scientific system and productivity at both the individual discipline and the aggregate levels. The paper specifies and performs a panel data econometric analysis based on a sample of Mexican researchers who are members of the National System of Researchers (SNI) of Mexico in the period 2002–13. It corrects for a selectivity bias: the existence of periods with no (or low-quality) publications, and endogeneity bias: promotion to higher academic ranks. It defines and implements counterfactual simulations to assess the magnitude of macro-impacts of existing gender gaps and illustrate the potential effects of a range of policy scenarios. The results show no significant gender gaps for an average SNI researcher. Moreover, after correcting for endogeneity and selectivity biases, the study finds that the average female researcher in public universities is around 8 percent more productive than her male peers, with most of the observed productivity being explained by gender differentials in the propensity to have periods of no (or low) quality publication. Barriers to promotion to higher academic ranks are highest among females in public research centers (PRCs). The study's macro scenarios on promotion practices, selectivity, collaboration, and age show that eliminating gender gaps would increase aggregate productivity by an average of 7 percent for university women and 9 percent for women in research centers.

JEL classifications: C23, I23
Keywords: economics of gender, economics of science, gender productivity puzzle, Mexico, scientific productivity

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1. Introduction

Men largely dominate academia. Studies on the presence of women in academia show that female researchers are seriously underrepresented in the highest levels of hierarchy (Brouns, 2000; Rivera León et al., forthcoming; Timmers et al., 2010). This seems to be true in virtually every country that has been studied. What is the reason for this relatively weaker position of women in academia? Is the scant presence of women in the scientific community simply mirroring a pattern that exists in society in general? How and why does career development differ among researchers? Do marriage, children, and other family-related factors influence research productivity? Are women in science in developing countries at a structural disadvantage relative to their male peers due to family responsibilities? Or, are women simply underperforming men in terms of research outputs?

The specific objective of this paper is to provide evidence of the existence and magnitude of the gender gap in scientific publication productivity in Mexico, controlling for a variety of important determinants. The paper attempts to shed more light on the reasons for and consequences of inequality in scientific performance and standing of female researchers relative to male researchers in the Mexican context.

The paper is organized as follows. Section 2 discusses the determinants of the gender gap in scientific publication productivity following a review of the literature. Section 3 provides an overview of the Mexican scientific and research context. Section 4 explains the data, sample, methodological approach, and econometric framework. Section 5 presents the findings of our panel data econometric analysis, following an adapted version of an econometric approach developed by Mairesse and Pezzoni (2015). The analysis is performed on two large samples of Mexican researchers affiliated with public universities and public research centers (PRCs) that are members of the Mexican National System of Researchers (Sistema Nacional de Investigadores, or SNI). Section 6 presents counterfactual macro simulations, to assess the magnitude of the macro-impacts of gender gaps and illustrate the potential impacts of a range of policy scenarios aimed at reducing them. Section 7 concludes, with policy implications.

2. Understanding the Determinants of the Gender Productivity Gap

This paper focuses on what Cole and Zuckerman (1984) first referred to as the "productivity puzzle," or the lower comparative productivity of women in science, in almost all disciplines and regardless of the productivity measure used (Bellas and Toutkoushian, 1999). Many studies have documented this puzzle, but less research has been done to understand its possible causes. A few studies have assessed whether and to what extent factors affecting female and male scientists differently can account for it. Scholars been unable to find, either theoretically or empirically, a clear explanation for the productivity gap between female and male scientists.

As summarized in the survey portion of Mairesse and Pezzoni (2015), past studies show the need to analyze the gender productivity puzzle together with dimensions other than gender, such as age and time period, disciplines and institutional frameworks, experience and professional status, personal capacities (usually unobserved but which can be proxied by observations on early performance), collaboration networks and “invisible colleges,” and quantity and quality (such as number of publications and impact factor of journal citations).

Sonnert and Holton (1995) suggest that the explanations for women’s lower productivity can be classified into two categories, namely, the difference model and the deficit model. The difference model states that women act differently because they are different than men, specifically with respect to motivation and commitment to a scientific career. These differences may be partly innate and partly due to social and cultural conditioning. Recent studies in sociology discard the argument of innate differences and posit that the effect of the social and cultural climate drives women to choose specific educational patterns, select their time allocation between work and family care, and make decisions about their careers. The deficit model states that external barriers, not intrinsic reasons, prevent women from performing the same as men in science. It argues that, although women have the same goals and aspirations as men, they are treated differently. Their lower performance is mainly due to the lower opportunities offered, more difficulties faced in their career, and difficulties in raising funds for their research and in collaborating with other scientists. Such obstacles prevent women from having the same career trajectory as men, for example, taking longer to be promoted, which has direct and indirect effects on productivity.

Although Sonnert and Holton (1995) distinguish the two models, they point out that the models are not mutually exclusive. We concur that difference and deficit models should not be considered as providing alternative or contradictory explanations; they are both relevant and complement rather than compete. These factors may overlap, and in some cases they may jointly be the source of other events affecting research productivity (Arensbergen et al., 2012).

A full model of the productivity puzzle would include explanatory factors from both the difference and the deficit models. Some of these factors can be easily measured and controlled for in a multivariate econometric model; others are more difficult to measure and fall in the mix of unexplained causes of productivity difference. Although motherhood, career status, quality of the work environment, and scientists’ personal characteristics are all measurable (or can be well approximated by other variables), past literature has focused only selectively on them without an extensive approach aimed at controlling for as many variables as possible.

Family engagements are perhaps the most frequently proposed explanations for the productivity puzzle. Among family engagements, motherhood is of interest to scholars because it is an easily identifiable event that may explain temporary shortfalls in the publication productivity of young women. Studies that attempt to explain the effects of family engagement on scientific productivity have found mixed results. In general, the effect of having children is not strong and often disappears when scientists' personal characteristics, academic disciplines, work environment, and university characteristics are considered (Prozesky, 2008).

Similarly, studies have shown that women are rewarded less than men for their research achievements. Women with comparable levels of scientific productivity and reputation have lower wages, and their career advancement takes longer than that of men (Fox, 1981; Levin and Stephan, 1998; Long et al., 1993; Pezzoni et al., 2012). Difficulties in promotion for women have an indirect impact on productivity by reducing the available resources for research, their prestige, and their influence. At the same time, lower productivity decreases the chances for promotion to higher ranks. This bidirectional causal relationship between promotion and productivity raises an endogeneity problem. Several articles on gender gaps have identified career status as an important determinant of productivity, without taking into account the endogeneity issue (Fox and Faver, 1985; Sax et al., 2002).

These patterns of remuneration appear not only in academic science but also in industrial science and innovation. Recent studies find no gender differences in the technological outcome of inventors, but do find difference in income (Hoisl and Mariani, 2012), particularly in women with children. These differences are explained in terms of the lower bargaining power of women in job negotiations, due to the higher allocation of household and childrearing tasks for women. The interest in this strand of literature remains high considering the large number of young, predominately female professors who choose to postpone decisions about marriage and having children until they have received tenure.

Discipline specificities may also affect productivity directly or indirectly related to the scientist's gender. Women may face more difficulties in becoming part of the scientific community, publishing in good journals, or entering prestigious institutions due to discrimination. Sonnert and Holton (1995) and Zuckerman et al. (1991) provide several examples. Consequently, women may behave differently by deciding not to pursue academic careers in traditionally male-dominated disciplines.

Countries and organizations may also implement different policies aimed at closing the gender gap. Strong gender-sensitive policies may mitigate the effects of family obligations on scientific productivity. While it is important to know whether, and which, policies might affect gender imbalances, to date, the effects of the policies that favor women are still a largely unexplored field in economics and sociology of science.

In the Mexican context, there are inequalities in research careers, regarding both gender and age. Studies have shown that only 20 percent of researchers under the age of 40 are able to find an academic research position (UAM, 2010). Moreover, salaries are perceived as noncompetitive compared with employment in the private sector, especially in the early career stage. In this regard, the Organisation for Economic Co-operation and Development (OECD) has suggested that the base salary of academic staff in Mexico is very low and insufficient for sustaining a middle-class lifestyle (OECD, 2009). This clearly affects decisions made at a young age, which can have large knock-on effects but in principle should affect men and women similarly. Evidence of the existence of the gender productivity puzzle in the context of developing countries in general and Latin American countries specifically is very limited, though highly relevant, because of the small number of research positions with good and competitive work conditions. It is also possible, and often believed, that tolerance for unequal work arrangements between female and male researchers is greater in developing countries.

Evidence of gender scientific publication gaps in Mexico remains relatively limited. González-Brambila and Veloso (2007), using data on researchers from SNI, from 1991 to 2002, and on their Web of Science (WoS) publications since 1981, found that gender gaps in scientific production and productivity were not large overall at an aggregate level, but were more pronounced in scientific disciplines. Padilla-Gonzalez et al. (2011), in a comparative study of Canada, Mexico, and the United States, found important gender differences in scientific production and productivity not only across countries but also within countries across disciplines.

The Mexican National Development Plan has outlined institutional and policy actions to achieve social inclusiveness as well as gender equality in general. The Mexican Law on Science and Technology was amended in 2013 to include aspects promoting gender equality in participation of men and women in scientific research and technology (Patiño Barba and Tagüeña Parga, 2014). Such a policy seems timely, given that the latest OECD (2015) Mexico Economic Survey showed that Mexico is the OECD country with the widest overall gender gaps with respect to labor participation rates. A study by Thévenon et al. (2012) suggested conclusions like that of an OECD (2014) report, which estimates that a 25 percent reduction of the gender gaps in labor force participation by 2025 would lead to an expected additional GDP growth of 1 percent in Mexico by the same year. There do not seem to be, however, analyses focusing on the macro effects of reducing gender gaps in scientific production and productivity in Mexico. Given that the number of women studying science, technology, engineering, and mathematics (STEM) disciplines in Mexico has increased rapidly in the last 20 years (Patiño Barba and Tagüeña Parga, 2014), one would expect these effects to be significant.

This paper contributes to the understanding of gender differences in the scientific productivity of Mexican researchers. It permits an informed appreciation of the positive effects that reducing these differences could have on the performance of the Mexican academic system.

2.1 The Mexican National System of Researchers

This paper uses data from the SNI. The SNI is a policy instrument implemented in Mexico in 1984 with the aim of identifying, recognizing, and stimulating the production of high-quality scientific and technological knowledge (Cabrero Mendoza, 2014) through a merit-based scheme. Its main goal is to promote and strengthen the quality of scientific research and innovation produced in Mexico. The SNI was launched by presidential agreement and at the request of the Mexican Academy of Scientific Research. It was established to mitigate the effects of the worsening remuneration and working conditions of researchers and to reduce the risk of brain drain following the 1982 economic crisis in Latin America. The crisis brought important budget shortcuts at all government levels. One way to control the financial expenses of public universities was through support programs in the form of differentiated incentives to researchers and professors.

Beneficiaries are individual researchers, who are involved systematically in research activities, and who either have a research contract or institutional agreement with higher education institutions (HEIs) or research centers in the public, private, or social sectors in Mexico,[1] or are Mexican and doing research abroad, in HEIs or research centers and institutions in other countries. Non-Mexican researchers can also be SNI members, but it is a requirement that the foreign researchers had worked in a Mexican higher HEI or research center for at least one year prior to the application date. The National Council for Science and Technology (CONACYT) centrally manages the SNI. The researchers can apply for affiliation (entry, re-entry, continuation, or upgrading of category/level) following an annual open call for applications launched by CONACYT.

Financial incentives are granted to member researchers based on a peer-review process, following the recognition of the researcher as a National Researcher, symbolizing the quality and prestige of the scientific contributions of the applicants. The financial incentives are granted in the form of non-taxable complements to remuneration according to the category and level received. The monthly monetary stimulus award from the federal government varies by category and level, ranging from three times the Mexican minimum wage (approximately US$234.8 per month), to 15 times the minimum wage (approximately US$1,174 per month). It is a voluntary process (i.e., researchers decide whether they want to be members and when). However, membership is usually a prerequisite for being hired or promoted at Mexican universities and for receiving public research grants from CONACYT.

Different managing authorities are involved in the selection of researchers for affiliation. First, different scientific committees review the applications, one per each of the eight broad

[1] In the case of affiliation to research centers and institutions in the private and social sectors, these must be part of the National Registry of Scientific and Technological Institutions and Enterprises (RENIECYT), and the institutions must have a collaboration agreement with the SNI.

academic areas covered in the SNI.[2] These committees make a preliminary selection of candidates and decide on the entry, re-entry, continuation of affiliation, or upgrade of category/level of the affiliation. The evaluators in these committees are selected from the highest ranked SNI members in each academic area.[3] If a researcher disagrees with the committee's decision, the researcher can appeal to an Appeals Committee. Then, an Executive Secretary formulates the proposals of the committees after consulting with the Advisory Forum for Science and Technology (FCCyT) and grants the affiliations to the SNI. Annex 1 presents a detailed description of SNI's managing authorities, composition, and main responsibilities. Annex 2 presents the requirements for acquiring each of the three SNI categories and subcategories.

The outcomes that are considered for entry, re-entry, and continuation of affiliation to the SNI are either research related (e.g., articles, books, book chapters; patents, development of new technologies, innovations, and technology transfer); and training activities, including supervision of graduate and post-graduate students and teaching. Other criteria taken into account for the evaluation of applications include participation in scientific and technology councils, editorial bodies, and scientific committees; participation as a technical evaluator in projects supported by CONACYT funds; linking research to the public, social, and private sectors; and active participation in the development and progress of the institution of affiliation, and in the creation, updating, and strengthening of study and teaching plans and programs. In this sense, the SNI aims to promote an integrated approach to research that includes student training, teaching, outreach, and written products (i.e., high-quality articles) with an emphasis on consistency and international recognition.

Journal impact factors are not officially used to determine research performance (i.e., this is not listed as a criterion for evaluation in the SNI's overall regulations). However, internal criteria for some of the academic areas (e.g., biology and chemistry) require that academic articles be published in journals that are indexed with specific impact factors (e.g., higher than 2.1 for biology and chemistry). Evaluations focus on the quality, consistency, and coherence of research activities, leadership, and international recognition (Williams and Aluja, 2010). The quality of the research outcomes of applicants is evaluated based on its originality; its influence on the training of human resources, and the consolidation of research agendas and their impact on the solution of scientific and technological problems. Evaluation criteria are tailored according to the academic products that are relevant to each discipline. The performance of researchers from each discipline is evaluated according to each person's merits and compared to the average performance of researchers in that discipline (i.e., scientists do not compete with

[2] The seven broad disciplines or 'SNI Areas' are: Exact Sciences (Physics, Mathematics and Earth Sciences – Area I); Life Sciences (Chemistry and Biology – Area II); Health Sciences (Area III); Humanities (Area IV); Social Sciences and Economics (Area V); Agronomy and Biotechnology (Area VI); Engineering (Area VII); and Technological Sciences (Area VIII) – usually not numbered and named 'Horizontal Area').

[3] In general, each committee is composed of 14 evaluators.

one another). Regardless of the above, Ricker et al. (2010) have argued that in practice a researcher is rejected from the SNI if he/she does not have at least three ISI publications over a period of three years, and that this remains the key element for determining the SNI level.[4]

An OECD review and assessment of Mexican Innovation policy highlighted the role of the SNI in improving the productivity of Mexico's science system, especially in increasing the volume of scientific production and its quality; contributing to the number and density of internationally recognized Mexican researchers; developing a quality research base; and ensuring the attractiveness of research careers (OECD, 2009). However, the assessment also stated that the reward system as it stands, by evaluating individual researchers and their scientific output, discourages researchers from undertaking long-term and multidisciplinary research and engaging in research collaboration with firms. Regarding the evaluation criteria for affiliation to the system, the assessment suggested reforming the system to better account for researchers' innovation-related output.

3. **The Mexican Science and Research Context**

Mexico's higher education system consists of public and private universities, institutes, centers, and teacher training (normal) schools and colleges. HEIs have several missions, including training human resources, undertaking scientific research, and technology and knowledge transfer. Universities can be public or private. Public universities are either financed by the federal budget (federal universities) or by the state budget (state universities), in which most cases they are autonomous.

Research is primarily conducted through research centers, public and private universities, and the private sector (private research centers and individual enterprises). PRCs can either be supervised by CONACYT, which accounts for about a third of PRCs' research activity, or by a sectoral ministry, notably Energy, Agriculture, or Health (OECD, 2011). The 27 CONACYT research centers are grouped into three main science and technology (S&T) areas, notably mathematics and natural sciences, social sciences, and innovation and technology development.

The most important HEIs performing research and development (R&D) in terms of scientific outputs in the period 2005–11 were the National Autonomous University of Mexico (UNAM), the Center for Research and Advanced Studies (CINVESTAV), the National Polytechnic Institute (IPN), and El Colegio de México*,* A.C (FCCyT, 2011). In 2011, 40 percent of all SNI researchers were from the UNAM, the IPN, and the CINVESTAV, all located in

[4] Ricker et al. (2010) also argue that when applying to the SNI, the researcher must enter online the journal name of each published article, and that the online system itself automatically reports the corresponding bibliometric indicators for each article, including the impact factor. This criterion thus becomes very important to evaluators when granting membership to the SNI.

Mexico City (Gutiérrez, 2011). By 2014, 36 percent of SNI members were affiliated with state-level public universities, followed by 34 percent from federal universities, and 12 percent from PRCs (Cabrero Mendoza, 2014).

According to the Ibero-American Ranking SIR 2013, Mexico ranks third in scientific production (i.e., number of scientific documents produced) in Ibero-America, just after Spain and Brazil. Considering the number of HEIs per country, Mexico ranks second just after Brazil (269 HEIs contributing to the country's scientific productivity). However, Mexican scientific production is highly concentrated at the institutional level, with less than 10 percent of HEIs (23) producing more than 85 percent of scientific output. During the period 2009–13, the most prolific Mexican HEIs were the UNAM (ranked second in Latin America), the Center for Advanced Studies of the IPN (12), the IPN (15), the UAM (27), and the University of Guadalajara (47) (SIR, 2013; 2015).

Regarding the performance of Mexican HEIs, the Shanghai ranking of the top 500 universities identifies only the UNAM among the top 300. UNAM also appears among the top 400 in the World University Rankings 2015–2016 of the Times Higher Education. Among Latin American countries, only two Mexican universities are among the top 10 of the QS University Rankings in Latin America 2015/2016, with UNAM being the fourth highest-ranked Latin American university. Regarding the performance of Mexican science measured by scientific production through the number of publications and citations in the period 2009–13, Mexico was 23rd in the world rankings, representing about 0.82 percent of the world's scientific production. In 2013, the number of Mexican scientific articles was 11,547, 3 percent higher than in 2012. The academic topics that increased the most in number in the period 2008–12 were Plants and Animals (14.4 percent), Medicine (11.5 percent), Physics (11.1 percent), Chemistry (10.2 percent), and Engineering (7.6 percent) (CONACYT, 2013). During the same period, the scientific articles produced by Mexicans received more than 175,432 citations, representing a growth of 5.8 percent with respect to the period 2007–11.

Mexico has experienced a slow increase in the number of FTE researchers in recent years. In 2012, it reached 43,592 (RICYT, 2015). Between 2008 and 2012, an average growth of 3.2 percent was recorded. This only represented 0.88 researchers per thousand in the labor force in 2012, which is below other Latin American countries, including Argentina (3.02 researchers per thousand labor force in 2012) and Uruguay (1.08); and is much lower than the OECD average (7.29), Spain (5.41), Greece (5), Italy (4.39), and Poland (3.86) (OECD, 2015).

The labor market for researchers is very competitive, with formal and informal rules established by experienced researchers. Internal markets limit competition with barriers to entry, depending on the level of research experience and adherence to similar (academic) ideologies. It is also a highly institutionalized market. Vacant positions are usually given to experienced researchers in the same research team, or to research assistants linked to established scholars within the research institutions.

The base salary of academic staff in Mexico is very low and insufficient to sustain a middle-class lifestyle (OECD, 2009). Salaries are perceived as noncompetitive compared with employment in the private sector, especially in the early career stage. The salary of a Mexican researcher is composed of the base salary, a merit-based component, and a supplement for those who are members of the SNI. For researchers affiliated with the SNI, the base salary usually represents only one-third of the overall remuneration. This composition has negative effects with regard to their pension. It prevents many researchers from retiring, as they lose some 75 to 80 percent of their total income. International panels of evaluators (OECD, 2009) have recommended making the nontaxable complement of the remuneration (i.e., SNI awards) part of the researchers' salary. This would have important implications for the provision of pensions and would also require amending labor laws, which is unlikely to occur.

Staff researchers (full-time and part-time) at public universities and PRCs are civil servants. Thus, federal and state laws pertaining to public servants govern the conditions of their employment, remuneration, and pensions. The pension benefits of the academic workforce are generally calculated based on the base salary only, which in the cases of researchers affiliated to the SNI represents about one-third of their overall remuneration. Moreover, career structures are mostly defined at institutional rather than at the national level, which encourages the majority of researchers that start their careers in a given institution to remain there throughout their working lives (OECD, 2009).

Public universities concentrate a large part of their activities on teaching and training. In relative terms, research is still an underdeveloped activity among university researchers, as many of them dedicate most of their time to teaching. There is thus a sort of self-selection in the research activity of university researchers. To promote scientific productivity, many public universities have implemented internal policies that provide financial incentives based on productivity additional to the SNI awards. Publications are also frequently a requirement for obtaining a promotion at universities and for membership in the SNI and promotion in the system itself. In public universities at the state level, the Ministry of Education has been encouraging all full-time professors to conduct research activities and academic management and training since 1997.

About 67 percent of CONACYT's PRC personnel were research staff in 2006 (OECD, 2009), including 30 percent of researchers. Besides conducting R&D and S&T activities, CONACYT's PRCs offer teaching programs at the master's and PhD levels. The centers also work closely with industry, promoting technology transfer and commercialization. An important share of PRCs' external funding comes from selling products and services to the private sector. Mexican PRCs are engaged in more than just research activities, which also affects researchers' productivity and output. The Mexican context for researchers provides the necessary background to understand gender-based productivity gaps in public universities and PRCs.

4. Sample, Data, and Methodological Approach

4.1 The Sample

This paper uses data provided by researchers affiliated with the SNI in 2013 and their ISI Web of Science (WoS) publications in previous years. The working sample was constructed by matching the names of all SNI researchers in 2013 to the names of authors and co-authors in Mexican WoS publications in the period 1990–2014. Considering the characteristics of the SNI system, it is expected that the most productive researchers and those who are best known internationally are SNI members.

Details on how the study sample was built are presented in Annex 3. The final panel data used consists of 44,535 WoS publications and 2,481 researchers, out of which 712 (28.7 percent) are women and 1,769 (71.3 percent) are men. These researchers are affiliated with 41 public universities and 18 PRCs.

4.2 Description of the Data

We measure scientific productivity by looking at the WoS publications of SNI researchers in the period 1993–2014. We also analyze quality of the publications produced, looking at the five-year impact factors of the journals in which the articles are published, using the WoS Journal Citation reports. Thus, our definition of publication productivity, following Mairesse and Pezzoni (2015), is the weighted sum of the articles published each year, taking as weights the five-year impact factors of the journals in which they are published.

We use demographic information on individual researchers affiliated to the SNI: their dates of birth, their gender, their academic rankings in the period 2002–13, their affiliation in 2013, the year the PhD (or highest academic degree) was granted, and the country where the PhD was obtained. This yielded knowledge of when each researcher was promoted across the different SNI ranks. Given the types of requirements needed to achieve each SNI rank, we classify them in two broad categories: low rank, including the Candidate level and Level 1 researchers; and high ranks, for Level 2 and Level 3 researchers. We exclude emeritus researchers, which are considered outliers.

Table 1 shows that about 40 percent of all researchers older than 40 years of age have a high rank. Among younger researchers, the share of high-ranked researchers varies by gender and affiliation, with women being the least represented, especially in PRCs. Overall, women are underrepresented in the high ranks for all age groups and affiliations, and overrepresented in the low ranks in all age groups and affiliations. This underrepresentation is relatively more important for women in PRCs.

We gathered the information on publications per year coming from the WoS data and considered the career of each researcher as starting from the year of their first publication. Based on these publication data, we constructed two unbalanced panels, one for university researchers and one for those working in PRCs.

Table 2 reports the annual average productivity of SNI researchers in our sample by gender and affiliation, as well as median, standard deviations, and corresponding number of observations. Productivity corresponds to WoS core publications. We have also looked at the means and medians of total publications, including WoS core and WoS SciELO, finding no differences at all, compared to what is presented on the table for WoS core only (see Annex 3 for details on WoS SciELO data). The upper part of the table presents statistics for all years, including the nonpublishing years. We define a 'nonpublishing year' as those where there are truly zero WoS articles for each researcher. The middle and bottom part of the table presents similar annual statistics, excluding nonpublishing years and in logarithms respectively. The figures in logarithms also exclude the nonpublishing years, with the benefit that this also normalizes the statistical distribution of the observed productivity itself, which is preferable in econometrics. The data show that men in PRCs are more productive, with 1.65 articles per year, followed by men in universities (1.59), women in universities (1.24), and women in research centers (1.14). The gender gap is much stronger in the case of SNI affiliates in research centers, where women have 31 percent lower productivity than men. This gender gap is lower for SNI researchers in public universities, where women underperform men by 22 percent on average. Overall, the gender gap is most marked and important among PRC affiliates, as reflected in the median of productivity values when excluding nonpublishing years (middle part of Table 2).

Table 1. Number and Proportion of Female and Male Researchers in Public Universities and Research Centers in Two Age Groups and Low and High Ranks in 2013

Researchers	Public universities			Public research centers		Total public research centers
	Women	Men	Total universities	Women	Men	
Less than 40 years						
Low Ranks (Candidate, Level 1)	235	422	657	33	56	89
	96%	94%	95%	97%	86%	90%
High Ranks (Level 2, Level 3)	10	25	35	1	9	10
	4%	6%	5%	3%	14%	10%
Sub Total	245	447	692	34	65	99
	100%	100%	100%	100%	100%	100%
40 years and more						
Low Ranks (Candidate, Level 1)	289	591	880	42	95	137
	76%	56%	61%	79%	46%	53%
High Ranks (Level 2, Level 3)	91	460	551	11	111	122
	24%	44%	39%	21%	54%	47%
Sub Total	380	1051	1431	53	206	259
	100%	100%	100%	100%	100%	100%
All						
Low Ranks (Candidate, Level 1)	524	1013	1537	75	151	226
	84%	68%	72%	86%	56%	63%
High Ranks (Level 2, Level 3)	101	485	586	12	120	135
	16%	32%	28%	14%	44%	38%
Subtotal	625	1498	2123	87	271	358
	100%	100%	100%	100%	100%	100%

Source: Authors' elaboration.

The evidence given in the middle and lower panels of the table filter out the nonpublishing years, showing less striking but still very large gender productivity gaps. These correspond to 24 percent in the case of PRCs (down from 31 percent), and 16 percent for universities (down from 22 percent). In logarithms, the log-differences between female and male SNI researchers are of similar magnitude, about -0.12 for university researchers, and -0.23 for those in PRCs.

Table 2. Descriptive Statistics on Average Unweighted Publication Productivity for Female and Male Researchers in Public Universities and Research Centers, Including and Excluding Nonpublishing Years

Researchers	Public universities Women	Men	W/M (or W-M in logs)	Public research centers Women	Men	W/M (or W-M in logs)
Including nonpublishing years						
Mean	1.24	1.59	0.78	1.14	1.65	0.69
Median	1	1	1.00	1	1	1.00
Std Dev	1.47	1.98		1.39	1.86	
Obs.	6525	18389		917	3703	
Excluding nonpublishing years						
Mean	2.00	2.37	0.84	1.84	2.42	0.76
Median	2	2	1.00	1	2	0.50
Std Dev	1.40	2.00		1.35	1.78	
Obs.	4049	12338		567	2516	
In logarithms (excluding nonpublishing years)						
Mean	0.51	0.63	-0.12	0.43	0.67	-0.23
Median	0.69	0.69	0.00	0.00	0.69	-0.69
Std Dev	0.57	0.65		0.55	0.64	
Obs.	4049	12338		567	2516	

Source: Authors' elaboration.

Table 3 presents similar statistics but divides the publication sample by the five-year average impact factor of the publications' journals. On average, the SNI researchers in our sample publish in journals with an average impact factor of 1.49. Women publish in journals with higher impact factors than men do, with an average impact factor of 1.55 and 1.47, respectively. Comparatively, SNI researchers working in universities publish in journals with higher impact factors than those in PRCs: 1.51 vs. 1.37 respectively. Table 3 presents in the middle part a sub-sample of observations for researchers publishing in journals with an impact factor higher than 2, and the bottom part those publishing in journals with an impact factor higher than 4. The statistics show that the gender gaps are the same in universities and research centers for publications in journals with an average impact factor higher than 2. In contrast, the gender gap almost doubles for those working in research centers publishing in journals with an impact factor higher than 4. Interestingly, when we look at the publications in low-impact journals (i.e., those in journals with an impact factor lower than 2), the gender gap is relatively low in the case of researchers in universities (-0.09) and remains very large in the case of those in research centers (-0.31). Thus, we observe important differences in the gender gap, not only by type of affiliation, but also in relation to the quality of the research produced. While the gap is more important when the quality of the research is higher for research centers, it is similar at all levels of publication quality in public universities.

Table 3. Descriptive Statistics on Average Unweighted Log Publication Productivity for Female and Male Researchers in Public Universities and Research Centers, for Different Average Impact Factor Levels

	Public universities			Public research centers		
All publications	**Women**	**Men**	**W-M**	**Women**	**Men**	**W-M**
In logs (excluding nonpublishing years)						
Mean	0.51	0.63	-0.12	0.43	0.67	-0.23
Median	0.69	0.69	0.00	0.00	0.69	-0.69
Std Dev	0.57	0.65		0.55	0.64	
Obs.	4049	12338		567	2516	
IF > 2 **In logs (excluding nonpublishing years)**						
Mean	0.46	0.59	-0.13	0.42	0.55	-0.13
Median	0.00	0.69	-0.69	0.00	0.69	-0.69
Std Dev	0.54	0.62		0.54	0.59	
Obs.	2416	6020		288	1077	
IF > 4 **In logs (excluding nonpublishing years)**						
Mean	0.36	0.48	-0.12	0.26	0.46	-0.21
Median	0.00	0.00	0.00	0.00	0.00	0.00
Std Dev	0.49	0.57		0.42	0.61	
Obs.	499	1111		39	173	

Source: Authors' elaboration.

Moreover, the number of nonpublishing years is similar for men and women, and by affiliation. Differences are larger among SNI affiliates in research centers. Table 4 shows that conditional on ranks, both the frequency of nonpublishing spells and log-productivity increase with age only for researchers in high ranks, notably in universities. Researchers that are older than 40 years of age and have a low rank have on average a similar number of nonpublishing years compared with researchers younger than 40.

However, since promotion to high ranks increases with age, and there are relatively very few SNI high ranks younger than 40, understanding the effects of seniority and age on the gender productivity gap is not straightforward. To assess both effects separately, we propose an econometric framework that is not only based on a productivity equation, but also one that includes two other equations to measure promotion and another for nonpublishing spells. As explained below, these two equations will allow us to correct for the endogeneity of promotion and the selectivity of publishing spells in the productivity of SNI researchers.

Table 4. Proportion of Nonpublishing Years for Female and Male SNI Researchers in Universities and Research Centers, in Two Age Groups and Low and High Ranks

Researchers	Universities		W-M	Public research centers		W-M
	Women	Men		Women	Men	
Less than 40 years of age						
Low Ranks (Candidate, Level 1)	33%	30%	3%	32%	29%	2%
High Ranks (Level 2, Level 3)	13%	10%	3%	14%	7%	7%
Sub Total	43%	38%	5%	45%	40%	4%
40 years and older						
Low Ranks (Candidate, Level 1)	32%	30%	2%	31%	29%	2%
High Ranks (Level 2, Level 3)	19%	18%	1%	15%	13%	2%
Sub Total	32%	29%	3%	29%	26%	4%
All						
Low Ranks (Candidate, Level 1)	32%	30%	2%	31%	29%	2%
High Ranks (Level 2, Level 3)	18%	17%	1%	15%	12%	2%
Sub Total	38%	33%	5%	38%	32%	6%

Source: Authors' elaboration.

A first look at the data shows that about 77 percent of men in public universities were not promoted in the period 2002–13, compared to 64 percent of men in PRCs. This compares to about 89 percent of women who are not promoted both in universities and research centers (Table 5).

Table 5. Promotion from Low Ranks to High Ranks by Affiliation and Gender

	Public universities			**Public research centers**		
	Men			**Men**		
	Last rating in period			Last rating in period		
First rating in period	Low Rank	High Rank	Total	Low Rank	High Rank	Total
Low Rank	1013	299	1312	151	84	235
High Rank	0	186	186	0	36	36
Total	1013	485	1498	151	120	271
	Women			**Women**		
	Last rating in period			Last rating in period		
First rating in period	Low Rank	High Rank	Total	Low Rank	High Rank	Total
Low Rank	524	68	592	75	9	84
High Rank	0	33	33	0	3	3
Total	524	101	625	75	12	87

Source: Authors' elaboration.

We also looked at the relationship between the composition of papers, gender, and seniority. For this, we calculated the harmonic average of the number of authors of articles published by the researchers in each year. The medians of this harmonic average for universities and research centers are respectively 5.9 and 5.2 co-authors per article. We do not observe marked differences in the harmonic average of number of authors by gender or seniority. The median of the harmonic average for women is 6 authors per article compared to 5.5 for men. These medians reduce slightly with seniority, where Candidates and Level 1 researchers have a median of 6 authors per article, compared to 5.6 and 5.4 for Level 2 and Level 3 researchers, respectively. Overall, this harmonic average of number of authors is slightly lower than the arithmetic average, particularly for men, with women and men having both a median of six authors per article. When looking at the arithmetic mean and by level of seniority, all SNI researchers have a median of six authors per paper, except for Level 3 researchers that have a median of 5.7 authors per paper.

Regarding the gender of the co-authors, Table 6 presents the share of observations in which a SNI researcher co-authored with other SNI researchers by affiliation and gender. The data show that women and men in universities collaborate most frequently with men in universities; while women and men in PRCs collaborate mostly with men in PRCs. Interestingly, the second most frequent co-author type for researchers in universities (either male or female), are female university researchers; while researchers in PRCs have university men as the second most frequent co-authors. In most cases, women collaborate more with other women relative to men, except for researchers in PRCs, where men have a larger share of papers with university female co-authors than women (28 percent vs. 24 percent respectively).

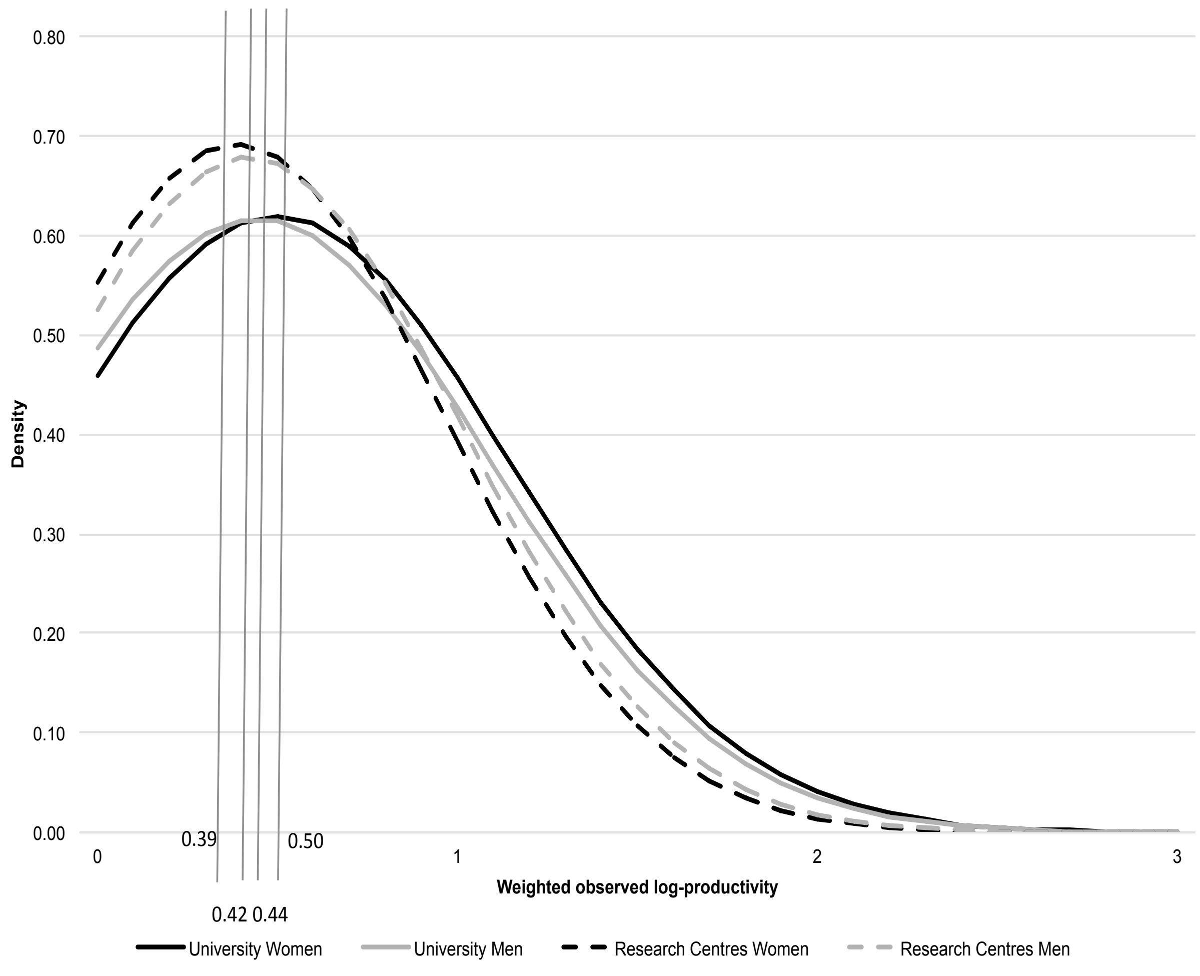
Table 6. Gender and Affiliation of SNI Co-authors, Share of Total (multiple choice allowed)

	Universities		**Public research centers**	
	Women	**Men**	**Women**	**Men**
Co-authored with University Female	51.12	43.57	23.61	28.04
Co-authored with University Male	77.29	79.30	43.78	58.00
Co-authored with Research Centre Female	15.26	13.45	33.48	29.84
Co-authored with Research Centre Male	46.37	32.58	69.10	68.23
Observations	1612	4058	233	831

Source: Authors' elaboration.

It is also important to keep in mind that the distributions of individual productivity are very dispersed, as shown in Table 2, with wide standard deviations in absolute levels and logarithms. Moreover, as we highlighted above, the gender gap is considerably reduced or even favors women in universities once the quality of the publications measured by higher impact factor is considered. The weighted log-productivity gender gap of the researchers is equal to 0.05 in universities (favoring women) and -0.03 for research centers. Unweighted publication productivity is higher for 43 percent of women in universities and for 38 percent of women in research centers than the average productivity of their male counterparts. As illustrated in Figure 1, once we account for the quality of the publications, publication productivity is higher for 53 percent of women in universities and for 48 percent of women in research centers compared to the average of the males.

Figure 1. Distribution of Observed Weighted Log-productivity for Female and Male SNI Researchers Affiliated with Public Universities and Public Research Centers



Source: Authors' elaboration.

The reductions in the average gender productivity gap, when nonpublishing years are considered, are equally pronounced for universities and research centers, as well as for women and men. We would have expected to see more differences between both types of organizations, especially since researchers in universities usually engage in other type of activities, such as teaching and mentoring, which one could argue reduces the time that they can devote to research. However, researchers in PRCs also focus a lot on commercialization activities and technology transfer, activities that also compete with scientific production.

4.3 Methodological Approach: Econometric Panel Data Analysis at the Individual Researcher Level

The first part of the paper implements an adapted version of an econometric approach developed by Mairesse and Pezzoni (2015) to account for the gender productivity gap for physicists in French universities and in the CNRS (Centre National de la Recherche Scientifique, which is the major French public research organization in this field). The same approach is currently being applied and further developed by Rivera León et al. (forthcoming) in an econometric analysis of publication productivity gender gaps and their determinants in the research and academic system of South Africa, focusing on rated researchers of the National Research Foundation (NRF), which is similar to the Mexican SNI system in several respects.

Ultimately, our goal is to specify and estimate an econometric productivity equation, relating publication log-productivity, as defined above, for both female and male researchers with other variables that can be measured in practice. With respect to estimation methods, there are three major specification errors regarding publishing occurrence selectivity, the endogeneity of promotion to higher professional ranks or status, and unobserved individual heterogeneity, which can result in significant biases in the estimated parameters of productivity determinants of main interest and hence on their impact on gender gaps. We address these biases by specifying and estimating, jointly with the productivity equation, two other equations: a probit for publishing occurrence selectivity and another for promotion.

4.3.1 The Promotion Probit Equation

Career advancement and scientific productivity are strongly related. The most productive researchers have more chances of being promoted from a lower to a higher rank and, when promoted, they have more opportunities for collaboration and better access to resources that in turn help them to be more productive. This two-way causality creates a source of endogeneity biases when including seniority as an explanatory variable in the productivity regression.

Thus, the promotion probit equation aims to correct for endogeneity biases related to the correlation between career advancement and scientific productivity by including the factors susceptible to greatly influence career achievements of individual researchers. It explains a binary promotion variable to a higher academic rank or status as a dependent variable, and gender, age, year dummy variables, past publications, quality of past publications, origin of the last academic degree completed (foreign degree vs. local degree), and academic discipline.

Particularly important is the introduction of interactions of gender with age, given the obvious conflicts that women face between personal, family, and working life and their effect on promotion (i.e., women have less effective time for career development relative to men).

We consider that advancements in SNI ranks can be interpreted as career achievements. We look at how changes happen from the first rating received by each researcher in the period of analysis, 2002–13. Promotion of an SNI researcher is thus defined as a change from a low to a high rank.

Our promotion equation is a simple probit equation built over a binary promotion variable that takes the value of 1 in the panel in the year when a researcher advanced in his/her career from a low rank to a high rank. We consider age and gender, and age squared with and without the interactions, as well as past productivity as determinants of career advancement. Age is measured in years, and centered on 40 years (divided by 10 for easy reading of the estimates). Regarding past productivity, we account for the number of publications and the absence of unproductive years before promotion, as well as the corresponding average five-year impact factor of the journals in which the articles were published in logarithms in the previous three years. We define the average impact factor as the share of the weighted average impact factor of the publication's journals divided by the number of publications in logarithms, or alternatively log(weighted average impact factor) – log(number of publications). We also introduce a variable on whether the PhD was obtained in Mexico or abroad.

Finally, and in line with recent research (Sarsons, 2015) showing that women's contribution to academic research is less recognized in collaborative work when the co-author is a man, we include two variables related to the gender of the co-authors. The first is a lagged dummy variable of whether the researcher had a male co-author in the previous year; the second is the interaction of this dummy variable with gender, to capture gender differences of the effects of the co-authors characteristics on promotion.

4.3.2 The Publishing Spell Selection Probit Equation

The selectivity equation takes care of the fact that in the course of a career, all researchers have periods when they do not publish (or publish in non-indexed, very low visibility journals) and that these periods do not occur at random. It thus estimates the probability of not having publishing periods subject to a set of determinants, such as past productivity history and the interaction of gender with age.

The publishing spell selection equation is a probit equation similar to the one for promotion, with a binary indicator of publishing years as a dependent variable, equal to 1 for a publishing year and zero otherwise. The variables on age and gender and their interactions are the same as for the promotion equation. We also include as explanatory variables the persistence of their publication activities in a past set of years by means of three binary dummies. These dummies (noted *Persistence* 111, *Persistence* 110/101/011, and *Persistence* 100/010/001), respectively, indicate that SNI researchers have published at least one article in three consecutive years, or in two, or in one. The three dummies are lagged by one year, covering the time span from *t-1* to *t-3*. We also control for calendar years by using time dummies.

4.3.3. The Productivity Regression

The productivity equation is a basic linear regression of log-productivity, weighted by the impact factor of the journals of the publications. It includes four groups of explanatory variables and time dummies. The first group is gender and age and their interactions, as implemented in the promotion and selection equations. The second group relates to the initial productivity of each researcher in the first year where we observe them, and that was kept aside in the construction of our panel data samples. We distinguish between the quantity and quality of the initial productivity through two variables, one measuring the number of publications in logarithms (noted *log first Article*), and the other noting the average five-year impact factor (*log average first Impact Factor*), also in logarithms. These variables act as a proxy for unobserved heterogeneity. The idea behind including initial productivity in the regression is to account somehow for the process of cumulative advantage and to reflect the effects of early career success (or lack of it) on scientific productivity.

The third group consists of the predicted probabilities of promotion and nonpublishing time spells,[5] coming from the promotion and selection equations, respectively. These are included in the productivity equation to correct for the endogeneity of holding a high academic rank and the selectivity of publishing spells. The fourth group is composed of collaboration variables. We computed 16 variables related to the characteristics of the collaborations and the co-authors of the researchers in our sample. We have grouped these variables into three blocks: the first with the overall characteristics of the collaborations (noted *Collaborations*); the second referring to the seniority of the co-authors, and the third related to the gender and affiliation of the co-authors. In the collaborations group, we include the harmonic average of the number of authors of the articles published by the researcher (lagged one year and in logarithms, noted *log No. of authors harmonic average in t-1*). We also include two variables of the average log-productivity of the co-authors, again in terms of quantity (number of co-authors – *log articles SNI co-authors in t-1*) and quality (average five-year impact factor) of the co-authors productivity (*log Impact Factor SNI co-authors in t-1*). We limit these two variables to

[5] The correction for nonpublishing spells comes from the results of the selectivity equation. The dependent variable of the selectivity equation refers to the probability of publishing. However, when obtaining the results, the model calculates the inverse correction, or the probability of nonpublishing spells. Therefore, the correction in the productivity equation is computed as the probability of nonpublishing spells.

those co-authors that are SNI researchers and for which we know their productivity in a given year. The fourth collaboration variable is the average number per year of co-authors of the SNI co-authors themselves of the researchers in our sample (*log SNI co-authors' co-authors in t-1*). To avoid double counting, we exclude publications where the co-authors published with our sample researchers. For completeness, we add one additional binary variable characterizing whether the SNI co-authors had no publication themselves (*SNI co-author No publications in t-1*). Finally, since we are lagging by one year all our collaboration variables, we include a final dummy variable for when the researchers did not have a publication in a given year (*No publication in t-1*).

In the group of variables *Seniority of co-authors*, we include four dummy (lagged) variables that show whether our sample researchers have co-authors that are Candidates, Level 1, Level 2 or Level 3 SNI researchers in a given year. Finally, in the block of variables *Gender and Affiliation of co-authors,* we note whether a researcher has foreign co-authors (*Foreign co-author in t-1*), whether the collaboration is inter-institutional between a researcher in a university and one in a research center - *Coll. University - PRC in t-1*), and four other dummy variables that take into account whether the researcher collaborated with a female or male researcher, respectively, in a university or PRC in the previous year.

Time dummies and academic discipline dummies are also included in the equation to control for general unobserved factors. Finally, for all equations, we proceed to two separate econometric analyses for researchers in public universities and researchers that are affiliated to PRCs (including the CONACYT research centers, and the Ministry of Education research centers. See Annex 4 and 5 for a full list of the institutions covered).

5. Econometric Findings

The estimates for public universities and PRCs are listed in Tables 7 and 8 for the promotion and publishing spell selectivity probit equations and in Table 9 for the productivity equation.

5.1 The Promotion Probit Equation

The coefficient estimates of the promotion probit equation confirm our expectations. Past publication productivity, the intensity of this productivity (number of WoS publications in the past), and the quality of these publications are major determinants of the probability of promotion from low SNI ranks (Candidate and Level 1) to high ranks (Level 2 and 3) both for researchers in public universities and PRCs. The exceptions are the average impact factor of publications in year t-1 and the impact factor for t-3 for PRC researchers, which are not significant for all models. This suggests that promotion has a long(er)-term memory regarding quality, especially for university researchers, and in the short term, what matters most is the intensity of the researcher's productivity. As expected, the probability of promotion varies with age following an inverted u-shaped curve, suggesting that this probability is lower for younger SNI researchers as well as for very senior researchers who have not already been promoted.[6] Having a male SNI co-author in the past has a positive effect on promotion. However, collaboration with men has a negative effect on the promotion of university women. Having acquired a foreign academic degree increases the probability of promotion for all SNI researchers. Finally, we also find that, conditional on past productivity and age, SNI female researchers, in both universities and PRCs, have significantly lower probabilities of promotion than their male colleagues. This is much more marked and important for SNI members in research centers.

5.2 The Publishing Spell Selection Probit Equation

Similarly, the coefficient estimates of the publishing spell selection probit equation also confirm our expectations. The probability of publishing is significantly higher for all SNI researchers who are more persistent in publishing in the previous three years relative to those who are less persistent or are not publishing at all in the previous three years. Also, since both the estimated coefficient of the interaction term (age*woman) and the estimated coefficient with age are positive. This implies that the probability of nonpublishing is increasing more rapidly for women over 40 than for men at the same age.

5.3 The Productivity Regression

The productivity equation, as defined in the previous section, includes four groups of explanatory variables. We find that all four groups of variables have statistically significant impacts on scientific productivity. The results suggest that some of these have long-lasting effects, such as the initial productivity variables. The quality of the publications at the beginning of the career supposes higher scientific productivity in the future for all SNI members, particularly for those in public universities relative to research center affiliates. The control for the endogeneity of rank by including the predicted probability of promotion to higher ranks has a large and significant impact on productivity, with particularly high intensity among SNI researchers in public universities relative to those in PRCs. The control for publishing selectivity through the variable of nonpublishing yearly predicted probability does not have a significant impact on productivity.

[6] The estimated maximum probability of promotion is high for all researchers, varying by gender and between university and PRCs, respectively about 65 years for university women, 60 for university men, 50 for women in research centers, and 55 for men in research centers.

Table 7. Promotion *Probit* Equation for SNI Researchers Affiliated with Public Universities and Public Research Centers, with and without Age*Gender Interactions

Rank indicator	Universities	Research centers	Universities	Research centers
Age and Gender				
Woman (=1)	-0.167***	-0.434***	-0.220***	-0.347*
(Age-40)/10	0.715***	1.156***	0.688***	1.217***
((Age-40)/10)^2	-0.230***	-0.531***	-0.230***	-0.542***
(Age-40)/10 * Woman			0.148*	-0.339
((Age-40)/10)^2 * Woman			0.00439	-0.159
Lagged productivity				
Publications in t-1	0.0750*	0.182*	0.0772*	0.179*
Publications in t-2	0.231***	0.413***	0.232***	0.414***
Publications in t-3	0.250***	0.210**	0.250***	0.205**
Log No. Publications in t-1	0.127***	0.184***	0.128***	0.195***
Log No. Publications in t-2	0.186***	0.254***	0.185***	0.261***
Log No. Publications in t-3	0.228***	0.330***	0.229***	0.343***
Log. Avg. Impact Factor in t-1	0.0213	0.0924	0.0240	0.0975
Log. Avg. Impact Factor in t-2	0.0623**	0.105*	0.0618**	0.106*
Log. Avg. Impact Factor in t-3	0.0903***	0.0859	0.0909***	0.0904
Co-authors				
Male co-author in t-1	0.261***	0.413***	0.291***	0.365***
Male co-author in t-1 * Woman			-0.151**	0.334
Foreign Degree	0.199***	0.176***	0.201***	0.187***
Time dummies	*yes*	*yes*	*Yes*	*Yes*
Discipline dummies	*yes*	*yes*	*Yes*	*Yes*
Constant	-2.500***	-7.435	-2.491***	-7.649
Observations	24914	4620	24914	4620
Pseudo R2	0.23	0.33	0.23	0.34

Significance: *** p<0.01, ** p<0.05, * p<0.1

Source: Authors' elaboration.

Table 8. Publishing Yearly Selection *Probit* Equation for SNI Researchers Affiliated with Public Universities and Public Research Centers, with and without Age*Gender Interactions

Publishing indicator	Universities	Research centers	Universities	Research centers
Age and Gender				
Woman (=1)	-0.106***	-0.119**	-0.116***	-0.0977
(Age-40)/10	0.111***	0.161***	0.107***	0.152***
((Age-40)/10)^2	-0.0502***	-0.0540***	-0.0517***	-0.0479**
(Age-40)/10 * Woman			0.0183	0.0316
((Age-40)/10)^2 * Woman			0.0101	-0.0351
Productivity persistence				
L. Persistence 111	1.128***	1.073***	1.128***	1.072***
L. Persistence 110/101/011	0.646***	0.673***	0.645***	0.672***
L. Persistence 100/010/001	0.388***	0.394***	0.387***	0.392***
Reference L. Persistence 000 (ref.)	-	-	-	-
Time dummies	*Yes*	*Yes*	*yes*	*Yes*
Discipline dummies	*Yes*	*Yes*	*yes*	*Yes*
Constant	0.659***	0.628***	0.661***	0.625***
Observations	24914	4620	24914	4620
Pseudo R2	0.10	0.12	0.10	0.13

Significance: *** p<0.01, ** p<0.05, * p<0.1

Source: Authors' elaboration.

Table 9. Productivity Equation for SNI Researchers Affiliated with Public Universities and Public Research Centers, with and without Gender Interactions[7]

Productivity: (log) Prod	Universities	Research centers	Universities	Research centers
Age and gender				
Woman (=1)	0.063***	0.039	0.083***	0.024
(Age-40)/10	-0.091***	-0.13***	-0.093***	-0.12***
((Age-40)/10)^2	0.018***	0.041***	0.023***	0.038***
(Age-40)/10 * Woman			0.0085	0.0015
((Age-40)/10)^2 * Woman			-0.026**	0.025
Initial productivity				
log(first Article)	0.0027	-0.016	0.0031	-0.017
log(average first Impact Factor)	0.19***	0.14***	0.19***	0.14***
Promotion and nonpublishing spells				
Prob(promotion)	1.05***	0.39***	1.04***	0.35***
Prob(nonpublishing spells: lambda)	0.033	-0.056	0.032	-0.064
Collaboration				
log(No. of authors harmonic average) in t-1	0.16***	0.15***	0.16***	0.15***
log(articles SNI coauthors) in t-1	-0.017	0.033	-0.017	0.034
log(Impact Factor SNI co-authors) in t-1	0.28***	0.17***	0.28***	0.17***
log(SNI coauthors' coauthors) in t-1	-0.062**	-0.13**	-0.061**	-0.13**
SNI coauthor No publications in t-1	0.069	-0.017	0.071	-0.021
No publication in t-1	0.23***	0.18***	0.23***	0.18***
Seniority of co-authors				
SNI coauthor Candidate in t-1	-0.024	0.020	-0.024	0.022
SNI coauthor Level 1 in t-1	-0.053**	0.034	-0.054**	0.032
SNI coauthor Level 2 in t-1	0.00057	0.0072	0.00020	0.0051
SNI coauthor Level 3 in t-1	0.021	-0.035	0.020	-0.034
Gender and affiliations of co-authors				
Foreign co-author in t-1	0.022	0.074*	0.021	0.076*
Coll. University - PRC in t-1	-0.054	0.041	-0.054	0.041
Female University	-0.0055	0.010	-0.0046	0.012
Male University	-0.036	-0.049	-0.036	-0.045
Female PRC	-0.020	0.050	-0.020	0.052
Male PRC	0.0044	-0.028	0.0045	-0.027
Time dummies	*yes*	*yes*	*yes*	*Yes*
Discipline dummies	*yes*	*yes*	*yes*	*Yes*
Constant	0.21***	0.41***	0.21***	0.42***
Observations	24,914	4,620	24,914	4,620
Observations npub != 0	16,387	3,083	16,387	3,083
Pseudo R2	0.189	0.167	0.189	0.167

Significance: *** p<0.01, ** p<0.05, * p<0.1
Source: Authors' elaboration.

[7] Estimated coefficients, based on OLS corrected for promotion endogeneity and nonpublishing triplet selectivity. See Annex 6 for details on the implementation of these corrections.

Among the collaboration variables, we find that the average number of co-authors has a positive effect on productivity, with similar intensity for all SNI researchers. The evidence also shows that the nature and quality of the collaborations matter for productivity. SNI researchers that are co-authoring articles in high(er) impact factor journals are themselves more productive. The results for these variables suggest that there is a process of co-optation between the most productive SNI researchers, pointing to the importance of the researcher's working environment and the research network.

Inter-institutional collaboration, or that between a university researcher and one in a PRC, has no effect on productivity. One interesting result is that having no publications in a previous year is a significant predictor of being productive in the following year among all researchers. This is similar to the findings of Mairesse and Pezzoni (2015) for French physicists. In that case, the authors suggested that this might reflect that nonpublishing years are usually followed by, or alternate with, publishing years.

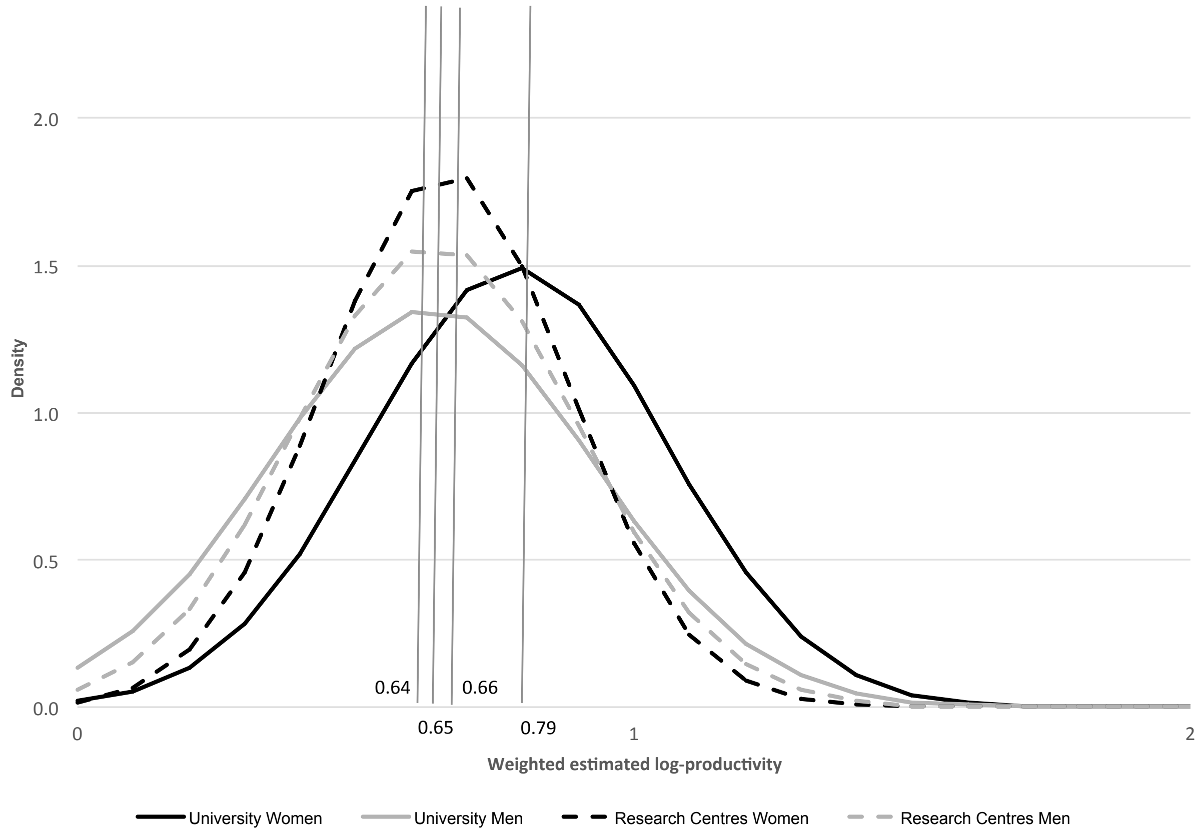
Overall, the level of seniority of the co-authors does not seem to affect productivity, except for Level 1 co-authors, where it seems to have a negative effect on the productivity of university researchers. The gender and affiliation of the co-authors do not seem to have a significant effect on the productivity of SNI researchers.

The group of factors analyzed, including collaboration, probabilities of promotion, and initial productivity, account significantly for differences in scientific productivity among SNI researchers. Taken together, we find that they invalidate the gender productivity puzzle and even reverse it for all SNI researchers; and particularly for SNI members in public universities. In Annex 6, we attempt to explain in more detail the different pieces of the gender productivity puzzle.

The results of Table 9 can be illustrated in a simpler way by Figure 2, which can be compared to Figure 1. The model we have estimated proposes several factors that explain researcher productivity. Some are intrinsic to the researcher (gender, age); some due to academic choices (discipline, affiliation); some due to feedbacks from the SNI promotion system; and some due to underlying unobserved factors, such as family engagements, which are likely to explain the occurrence of nonpublishing spells. Although our model only captures part of what drives publication productivity, it allows us to assess what will be the productivity, un-confounded by our explanatory variables, or predicted productivity, across different types of researchers (men, women, crossed with university, research centers). This distribution of predicted productivity, holding constant all explanatory variables (at their average levels), is shown in Figure 2. Figure 1 showed observed productivity differences among the four types of researchers, with high standard deviations. Figure 2 shows that the average predicted productivity of men and women by affiliation is very similar, with an estimated average of weighted log-production of 0.64 for men in universities (or 1.89 equivalent articles per year in

WoS journals IF-weighted); 0.65 for men in research center (1.91 equivalent articles); 0.66 for women in research center (1.94 equivalent articles), and 0.79 for university women (2.20 equivalent articles). After the introduction of our model's corrections, we find that university women have the highest predicted weighted log-productivity. We do not find a statistically significant role of gender in explaining productivity gaps in research centers after including our corrections. By and large, gender and institution type have little effect on an individual's productivity, after controlling for other factors, such as promotion and non-productive spells.

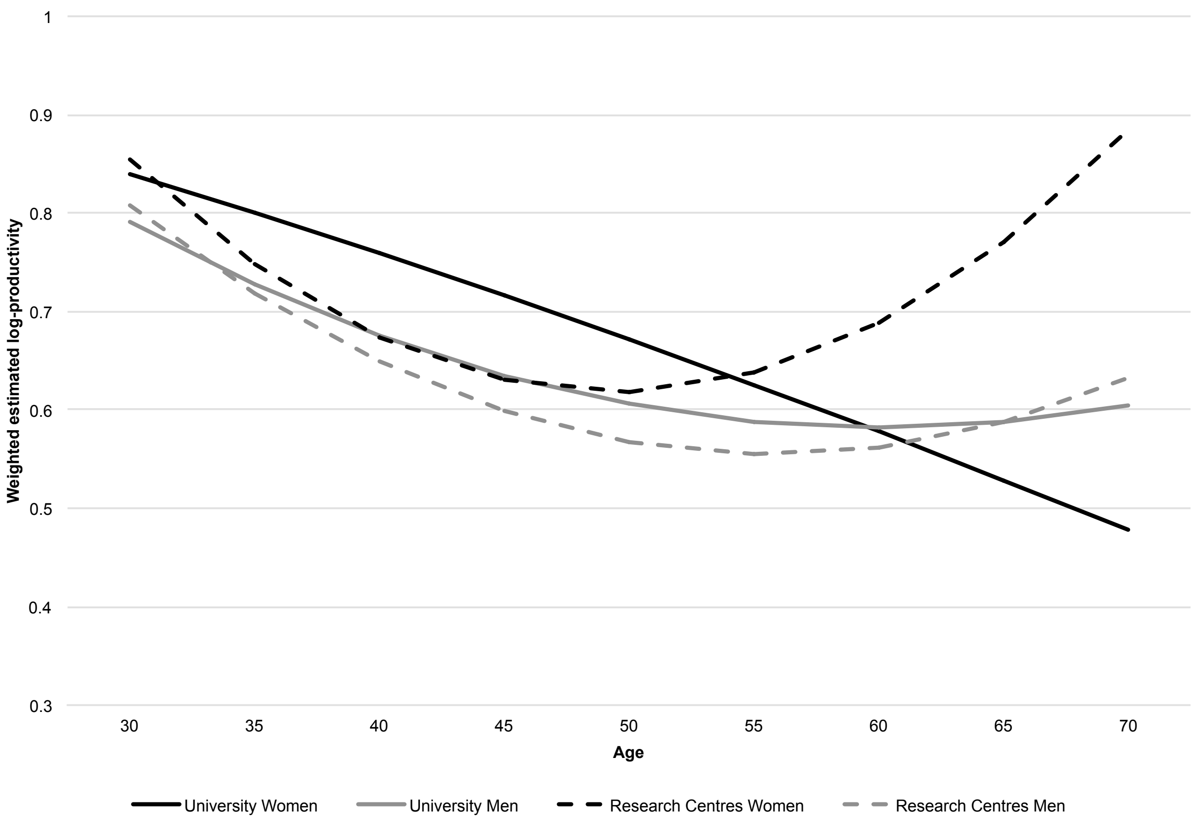
Figure 2. Distribution of Weighted Predicted Log-productivity for Representative Female and Male SNI Researchers Affiliated with Public Universities and Public Research Centers



Source: Authors' elaboration.

Figure 3 shows how age and gender interact significantly with regard to predicted productivity. It shows how the gender gaps change at different ages. It indicates that for all SNI researchers, estimated productivity decreases rapidly with age, particularly for women in public universities. Male researchers see their productivity increase slightly after age 70, while women in research centers see their productivity increase after age 55 to levels comparable to those that they had at age 45. University women are always more productive than men and than women in research centers between ages 35 and 50.

Figure 3. Change with Age of Estimated Log-productivity for Representative Female and Male SNI Researchers Affiliated with Public Universities and Public Research Centers



Source: Authors' elaboration.

To illuminate the contributions of each correction to the gender productivity gap, Tables 15 and 16 in Annex 6 include the productivity equations for researchers in universities and research centers, respectively, with no corrections, the endogeneity correction, the selectivity correction, and both corrections. At the individual level, it is difficult to understand the effect of each contribution, especially because in many cases they represent external constraints that are difficult, or impossible, to change for the individual researcher. However, collectively, these constraints can be exogenous and justified from the public policy standpoint. For instance, gender equality in promotion depends greatly on the working environment and can be encouraged through incentives. Selectivity, or the absence of nonpublishing spells, is more difficult to address from the policy standpoint, as it can reflect a variety of external activities, such as conflicting teaching and management responsibilities and other family engagements and responsibilities.

Rank and promotion are major sources of endogeneity for productivity. To control for this, and to calculate this correction alone (second column in Tables 15 and 16) we specify jointly the productivity and promotion equations to estimate them as a system of simultaneous equations. We assume that the lagged explanatory variables of promotion are predetermined in relation to productivity in time *t*. Thus, we can estimate separately the promotion equation in a first step, and in a second step, we estimate the productivity equation by including on it the predicted probability of promoting to high ranks (denoted *Prob. Promotion*).

To calculate the selectivity correction (third columns in Tables 15 and 16), we estimate jointly the selectivity equation with the productivity equation as a two-equation Tobit-type model. We rely on Heckman's two-step method, where the probit equation is estimated in the first step, and the productivity equation follows in the second step, including as an additional explanatory variable the first-step inverse Mill's ratio, or the predicted probability of nonpublishing (noted *Prob nonpublishing spells*).

Tables 15 and 16 show that the endogeneity correction alone and the selectivity equation alone are responsible for making the gender productivity gap disappear among SNI researchers. When combined, women become about 8 percent more productive than men in public universities, and about 2 percent more productive in PRCs (even if not significant in our model) (see also Table 9). The explanatory power of the models also increases when both corrections are introduced. Barriers to promotion are thus higher among women in PRCs relative to women in public universities.

One interesting finding from our models' results is the differentials with regard to observed and estimated publication productivity. Table 10 computes these differentials in number of weighted and unweighted publications per year (de-logged). The results show that correcting for the existence of promotion and selectivity biases would produce overall average gain of one additional weighted publication every two years for women (0.56 publications per year for university women and 0.47 for research center women) and broadly around one additional publication every three years for men (0.33 per year for university men and 0.39 for research centers). In terms of the unweighted number of publications, the gains would be even greater, corresponding to one publication more per year for all researchers, except for university men, who would have an average increase of 0.73 publications per year.

Table 10. Observed and Predicted (Weighted and Unweighted) Publication Productivity, Individual and System Gains

	University women	University men	Research center women	Research center men
Observed weighted productivity	1.64	1.56	1.47	1.52
Estimated weighted productivity	2.20	1.89	1.94	1.91
Differential gains in weighted productivity	0.56	0.33	0.47	0.39
Observed number of publications	1.24	1.59	1.14	1.65
Estimated number of publications	2.17	2.32	2.22	2.62
Differential gains in number of publications	0.93	0.73	1.09	0.97
Total observed weighted publications	666	1925	83	383
Total estimated weighted publications	891	2330	110	480
Overall productivity gains	225	405	27	97
Percentage increase	33.8%	21.0%	31.9%	25.3%

Source: Authors' elaboration.

Table 10 presents the overall gains for our sample of researchers. We have calculated this based on the non-censored observations in our panel. Our results show that controlling for selectivity and promotion in science would increase the total number of publications by more than 30 percent for women and between 21 and 25 percent for men. Productivity gains are observed for all SNI members, men and women, even if the expected gains are higher for women relative to men.

6. Counterfactual Analysis at the Macro Level

Given the results provided above, one of the main concerns for policymakers is what the science system would gain or lose by reducing or eliminating gender productivity gaps. We will use the results from our econometric models to formulate a set of policy scenarios to assess the magnitude of these potential impacts. We focus on understanding the impacts and effects of both corrections on the following issues: promotion practices (i.e., what would be the changes if women had the same probabilities of promotion than men) (i); publication intensity (i.e., the same probabilities of not publishing for men and women) (ii); collaboration practices (iii); and age (iv).

Table 11 presents a summary of our findings related to the impacts of promotion, selectivity, collaboration, and age on the log-productivity of researchers. The first part of the table shows a series of descriptive statistics by affiliation and gender. The second part of the table shows a summary of the contributions computed to log-weighted productivity of the different variables in our simulations. These contributions were calculated using our productivity model with corrections for selectivity and promotion. The third part of the table shows the total productivity of our sample, as well as the gains in total number of weighted publications following the different simulations. The last part of the table shows how much the computed gains represent in relation to the total number of publications of researchers in our sample.

In relation to promotion and selectivity, we explore what the productivity gains would be if females had the same probability of promotion as men (1); and if females had the same probability of not publishing as men (2). The idea is to understand the gains if there were no discrimination against females in promotion, as well as no selectivity of researchers based on gender. We find that if women in our sample had the same probability of promotion as men, they would have jointly produced an additional 157 publications in universities and an additional 21 publications in research centers in our period of analysis, representing 17 percent of all publications in universities and 20 percent in research centers. Similarly, we find that having the same probability of not publishing as men would enable women in universities to produce 2.5 percent more publications in our period of analysis and 3 percent more in research centers. This relatively low gain stemming from equality in selectivity is in line with the number of nonpublishing spells found between men and women.

We have also tested the possible overall productivity gains in our sample of SNI researchers if women had the same collaboration characteristics as men (3), and the same age as their male counterparts (4). For the collaboration variables, we obtained the contribution of the 16 collaboration variables used in our productivity equation as defined in our methodological approach section, including the overall characteristics of the collaborations, the seniority of the co-authors, and the gender and affiliation of the co-authors. We used a similar approach to understand the effects of age on productivity, by obtaining predictions based on the contribution of the age variables (squared and cantered) and our gender interaction variables.

Table 11. Summary Results of Individual and System Gains Based on Simulation of Different Scenarios

	University women	University men	Research centers women	Research centers men
Statistics				
Harmonic average authors	6.54	6.13	6.00	5.65
Arithmetic average authors	6.77	6.69	6.14	5.94
Non-censored observations	4049	12338	567	2516
Number of researchers	625	1498	87	271
Censored observations	2476	6051	350	1187
Contributions computed				
Log(IF weighted)	0.80	0.66	0.63	0.62
Probability of promotion	0.05	0.10	0.02	0.05
Probability of observing a non-productive spell	0.02	0.00	0.00	0.00
Collaboration variables	0.22	0.21	0.15	0.16
Age + gender interactions	-0.02	-0.01	0.03	-0.01
Constant	0.21	0.21	0.42	0.42
Productivity gains at system level - Scenario simulation				
Total number of publications – conditional	901.1	2387.1	106.5	467.7
If women have the same promotion probabilities as men…	156.6		21.5	
If women have the same probability of not publishing as men…	22.5		3.2	
If women have the same collaboration as men	90.2		13.0	
If women are the same age as men	0.0		0.0	
Scenario simulation - Percentage over total				
If women have the same promotion probabilities as men…	17.4%		20.2%	
If women have the same probability of not publishing as men…	2.5%		3.0%	
If women have the same collaboration as men	10.0%		12.2%	
If women are the same age as men	0.0%		0.0%	

Source: Authors' elaboration.

Although the contribution of the collaboration variables to productivity is similar between women and men with the same institutional affiliations, our predictions show that if women had the same type of collaboration characteristics as men, they would produce around 10 percent more publications in universities, compared to a 12 percent increase in research centers. We find that age has no effect on the productivity of women.

6.1 Policies and Initiatives Focusing on Reducing Gender Gaps in the Promotion of Researchers

Our findings suggest that promotion is an issue impacting females in both PRCs and universities. In our econometric results, we showed that the endogeneity or promotion correction makes the gender gap more favorable for women in public universities.

Promotion in science itself is a human process in which more senior researchers evaluate junior ones based on a set of pre-established criteria. Some authors have argued that this process is in most cases implicitly biased because the academic profession is stereotypically male (Castillo et al., 2014). Gender equality in science has received attention in Latin America only in the last few years. Thus, the correction for this implicitly male-biased process is still in its early stages.

We mentioned above that the SNI evaluation process for entering and being promoted to higher SNI ranks starts with the recommendations of the scientific committees. These committees are usually composed of 14 members from the highest SNI that make an initial evaluation of the SNI applications. Table 12 presents the number of male and female members of the scientific committees by academic area in 2015–16.[8] The table shows that only one committee in 2015 and two in 2016 were gender balanced. Only one member of the Engineering Committee was female in both years. Moreover, only one president in 2015 and three in 2016 were female. It is evident that the SNI has been unable to integrate women into its evaluation framework, and the male-dominated scientific committees could play a role in reinforcing gender biases in the promotion of researchers.

Table 12. Number of Male and Female Members on SNI Discipline Committees, 2015–16

	2015			2016		
SNI area	**Female**	**Male**	**President**	**Female**	**Male**	**President**
Physics, Mathematics, and Earth Sciences	2	12	M	3	11	M
Biology, Chemistry, and Life Sciences	7	7	F	5	9	M
Medicine and Health Sciences	4	10	M	7	7	M
Humanities and Behavioral Sciences	4	10	M	7	7	F
Social Sciences	4	10	M	4	10	M
Biotechnology and Agro-fisheries	4	10	M	3	11	F
Engineering	1	13	M	1	13	M
Technology Sciences	2	12	M	2	12	F

Source: Authors' elaboration.

CONACYT's PRCs have introduced a series of internal policies, projects, and programs to promote gender equality among their employees. These programs focus mainly on communication activities and awareness raising (e.g. CIMAV, CIDETEQ). Some others have implemented research projects to map women's needs with a focus on indigenous women (e.g., CIESAS). Some have more formal structures, with codes of conduct and internal committees focusing on nondiscrimination against women in the workplace and on the prevention and sanctioning of sexual harassment (e.g. CIDE, CIATEQ, CIQA).

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[8] Public data obtained from CONACYT's website. See: http://www.conacyt.mx/index.php/el-conacyt/convocatorias-y-resultados-conacyt/convocatorias-sistema-nacional-de-investigadores-sni/miembros-de-comisiones-dictaminadoras

The CIATEQ research center, focusing on advanced technologies, has a more proactive approach to gender equality. Since 2012, it has provided subsidies for childcare for female employees, and since 2013 it has had policies in place to increase women's participation in higher ranks and management positions.

Our results show that when one looks at the impact factor-weighted number of publications (i.e., quality of the publications), the gender gap almost disappears for all researchers in our sample. It is clear from the results above that the two main controls we introduce, the endogeneity (promotion) and selectivity corrections, help to eliminate the gender gap among Mexican SNI researchers. Our results in Table 11 show that overall system gains would be achieved by correcting for both factors, benefiting both women and men. Moreover, our scenarios on promotion practices, selectivity, collaboration, and age show that by eliminating the less advantageous position of women in academia relative to men, further gains could be achieved for women with effects that are as large as a 7 percent average productivity gain for university women and 9 percent for those in research centers.

7. Conclusions

This paper provides evidence of gender gaps in scientific productivity in middle-income countries, specifically Mexico. We introduced and tested an econometric framework, including a scientific productivity equation, two additional equations for the promotion of researchers to higher levels of seniority, and one for occurrence of nonpublishing spells. We tested this framework in a sample of Mexican researchers in the hard sciences affiliated with the SNI, working in Mexican public universities and PRCs. The findings are interesting in several aspects. The study's descriptive statistics show a gender gap in productivity, which narrows when the quality of the publications, measured by the impact factor of the journals where they appear, is considered. The factors analyzed, including collaboration, probability of promotion, and initial productivity, account significantly for the differences in scientific productivity among SNI researchers. Taken together, we find that they invalidate the gender productivity puzzle and even reverse it for all SNI researchers, especially for SNI members in public universities.

We also find that scientific productivity declines with age. We show that, despite the common belief of the existence of a gender gap in publication consistency, female researchers only have between 5 and 6 percent more nonpublishing years than male researchers and, at senior levels, female researchers only have 1 percent more nonpublishing years than men. We also find that the gender of the co-authors has no effect on the productivity of SNI researchers.

Our previous research in France, using the same econometric framework, also found that gender inequalities prevent women scientists from being promoted to higher academic ranks.[9] Examining French physicists working in the Centre National de la Recherche Scientifique (CNRS) and in French public universities, we learned that female physicists are 6.3 percent less likely to be promoted within CNRS and 16.3 percent less likely to be promoted within universities, conditional on past productivity and age (Mairesse and Pezzoni, 2015).[10] The French case also revealed an observed average publication productivity gap of female physicists relative to male physicists of about one-third in both CNRS and universities. It disappeared for women in the CNRS and favored women significantly in universities when we controlled for promotion and frequent nonpublishing spells.[11]

Policies encouraging the promotion of female researchers and academics to higher ranks in the form of support grants exclusive to females (e.g., the Dutch Aspasia Program)[12] could alleviate the under-representation of female researchers at high levels of seniority, particularly in male-dominated environments (e.g., PRCs). Several of the CONACYT PRCs have integrated a gender agenda into the research centers' activities. However, none of them seems to be actively providing support for promotion and career development of female researchers.

With regard to selectivity, science systems in middle-income countries should ensure that there are similar working conditions for women and men in academia, including policies that reduce self-selection as a source of inequality in the research system. Interpreting our findings in practice, however, is not straightforward. Our selectivity correction can account for a variety of external activities, such as conflicting teaching and management responsibilities, as well as other family engagements and responsibilities. Since this correction is not significant for productivity for all SNI researchers, it is plausible to conclude that the conflict between teaching and training activities and research activities does not play an important role in the presence of nonpublishing years among SNI members.

[9] In this paper, we have used the same econometric framework originally used for the case of France by Mairesse and Pezzoni (2015). The two studies are not, however, completely comparable. The French study focused on exclusively on physicists, while this study for Mexico covers a variety of hard sciences. The two countries also differ in academic context and institutional characteristics and functions. For example, some Mexican public research centers have also a training function; thus, affiliated researchers split their work time between teaching and research. In the French CNRS, researchers can focus primarily on academic research.

[10] These lower probabilities of promotion for female physicists correspond to the case of a representative physicist, with an average productivity of six articles every three years and an average journal impact factor of 5 and aged 40 in the period 2003–2005.

[11] Regarding the quality of the publications, important differences exist in the studies conducted in Mexico and France. In the French study, the average publication productivity in a three-year period for female CNRS physicist is equal to a 38.5 impact factor weighted by number of articles, or 3.9 in terms of an equivalent number of articles in a three-year period in journals with an impact factor of 10. In Mexico, the impact factor of the journals where SNI Mexicans publish is considerably lower. On average, the SNI researchers in our sample publish in journals with an average impact factor of 1.49. Females publish in journals with higher impact factor than men, with an average of 1.55 and 1.47 impact factor, respectively.

[12] The Dutch Aspasia Program aims to ensure that more female assistant professors progress to the level of associate or full professor. Prizes are awarded to universities which promote female recipients of research grants to senior lecturer or professorial positions within one year of the award of the relevant grant. See: www.nwo.nl/en/funding/our-funding-instruments/nwo/aspasia/aspasia.html

Policy solutions that have proved to be successful in a number of developed countries to address women's family responsibilities as a source of selectivity issues include public support for childcare, maternal leave, and flexible work schedules (Castillo et al., 2014). As we outlined above, these types of policies already exist in a number of PRCs. The SNI itself has adapted its regulations regarding researchers who become pregnant. They are given an extra year to apply to extend their membership to the SNI, and that year is not considered when evaluating their scientific output. These policies have been implemented only recently, and their effects might not yet be evident in terms of scientific output.

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Annex 1. SNI's Managing Authorities, Composition, and Main Responsibilities

Authority	Composition	Main responsibilities
Approval Council (*Consejo de Aprobación*)	CONACYT's Director General Director of Scientific and Academic Development, CONACYT Director of Technology Development and Innovation in Businesses, CONACYT Director of Groups and Research Centers, CONACYT Director of Training and development of researchers, CONACYT Director of the SNI Undersecretary of Higher Education, Ministry of Education Head of Planning and Evaluation of Education Policies, Ministry of Education General Coordinator of the Advisory Forum for Science and Technology	Designate (yearly) the members of the Dictating Commissions, and the Honor Meeting Group, based on the proposals presented by the Executive Secretary Approve the yearly 'Open Calls' Approve the evaluation criteria by scientific discipline presented by the Dictating Commissions Decide on the research distinctions based on the proposals presented by the Dictating Commissions and the Reviser Commissions
Consulting Committee (*Comité Consultivo*)	Director of the SNI Presidents of the different Dictating Committees President of the Committee	Propose the formulation and application of SNI policies in the support of the development of science, technology, and innovation Provide expert inputs about the regulations, organizations and functioning of the SNI
Scientific Committees (*Comisiones Dictaminadoras*)	There is a Scientific Committee for each of the SNI's scientific areas (7 in total)	Evaluate the academic quality, transcendence, and impact of scientific and technology research outputs
Appeals Committee (*Comisiones Revisoras*)	There is an Appeals Committee for each of the scientific disciplines represented by the Dictating Committees	Resolve and reconsider claims made by researchers relative to their entry and re-entry to the SNI
Honor Meeting Group (*Junta de Honor*)	Five members of the SNI (Level III) Director of the SNI	Analyze special cases of professional ethics faults committed by members of the SNI
Executive Secretary	Director of Scientific and Academic Development, CONACYT	Formulate the proposals of the Dictating Commissions after consulting with the Advisory Forum for Science and Technology Present for consideration and approval the evaluation criterion and processes of the SNI Designate the Presidents of the Dictating Commissions and the members of the Reviser Commissions Subscribe the distinctions and agreements of approved researchers as members of the SNI
Director of the SNI	Director of the SNI, elected by Government Board of the CONACYT, following the proposal of the Director General	Elaborate (in coordination with the Consulting Committee) projects of norms and regulations for the functioning of the SNI Formulate the yearly Open Calls Receive the applications of researchers for membership to the SNI Supervise the evaluation mechanisms of the SNI

Annex 2. Definitions of SNI Levels

Category/level and sub-category		Main requirements for granting
Candidate		PhD level Had passed less than 15 years after obtaining a Bachelor's degree
National Researcher	1	PhD level Had produced original and high-quality scientific and technology research Had participated in activities of dissemination of science and technology
	2	All requirements of Level 1 Had undertaken, individually or in a group, original research where a new research line or agenda is achieved Had supervised graduate students and trained highly qualified human resources
	3	All requirements for Level 2 Had developed research that represents a transcendental scientific contribution for the generation and application of knowledge Had become a leader in the scientific and technology community in Mexico Been recognized at national and international level for their scientific and technology activity, and had realized a remarkable achievement in the training of highly qualified human resources
Recognized National Researcher (Emeritus)		Being at least 65 years old at the moment of application Had received the distinction of National Researcher Level III for at least 15 consecutive years Demonstrate an exceptional career in Mexico, through a fundamental contribution to the generation of scientific knowledge, and the training of new generations of researchers, through leadership and international recognition Been recommended by at least 9 members of the relevant Dictating Commission

Annex 3. Building the Study Sample

The study sample was limited to researchers that had at least one WoS publication in the five years prior to the ranking acquired in 2013. This resulted in a matching of 5,896 researchers, or 29.9 percent of all researchers affiliated with the SNI in 2013. We also only focused on researchers in the hard sciences, as our sample replicates the population of SNI researchers in 2013. Moreover, the hard sciences correspond to 97 percent of the matches obtained with WoS publication data, or 5,706 SNI researchers.[13] We also decided to exclude those disciplines in which no female researchers were matched in our sample. This resulted in the exclusion of Logic and Electrical Engineering. Thus, the disciplines covered in our final sample are Mathematics, Astronomy and Astrophysics, Medicine and Human Pathology, Technology Sciences, Physics, Earth Sciences, Agronomy, Health Sciences, and Chemistry.

Finally, we decided to focus our analysis on researchers affiliated with a public university (at federal or state level), or a public research center, including the Ministry of Education research centers and the CONACYT research centers. We obtained matches for only 10 private universities, and the observations represented only 1.4 percent of all.[14] These relative low numbers led us to exclude all researchers that reported an affiliation to a private university, private research center, private companies, and other organizations including hospitals and government ministries. We also excluded from our sample all those SNI researchers affiliated with a foreign institution in 2013, as they were likely to be exposed to different institutional arrangements and to have work environments very different from those with a Mexican affiliation. Finally, we excluded those researchers on whom data on affiliation or personal characteristics were missing, as well as those whose SNI rankings had fallen in the period of analysis, or who received a rank in less than three years from the first observed publication. Table 13 presents the SNI population in 2013 by discipline, as well as the study sample.

To ensure completeness in relation to the scientific production of Mexican researchers, and as a way of running a robustness check, we also looked at publications in the WoS SciELO Mexico. The WoS SciELO Citation Index includes critically important regional content with international impact, where only high-quality regional journals are included. Most of the Mexican publications in SciELO are in Spanish. SciELO Mexico has publications dating back to 1997 forward, mostly in the social sciences and the humanities. In the hard sciences, we identified 524 publications for the period 1997–2014. About 79 percent of the articles obtained

[13] Details on the number of researchers in the SNI population in 2013 and the WoS matches obtained are presented below in Annex 3. The number of matches in social science and humanities disciplines obtained correspond only to 3 percent of the population, compared to 41 percent in the hard sciences.

[14] The classifications of private and public universities and public research centers was obtained from the Comparative Study of Mexican Universities (avalable at: http://www.execum.unam.mx/).

are in Spanish, and a large majority for the years 2010–14.[15] The matching of these records with SNI affiliations in 2013 resulted in a match of 99 publications by SNI researchers in our final sample. About 81.5 percent of the SciELO publications matched are by male authors, compared to 18.5 percent by female authors. We refer to SciELO data in some of the descriptive tables presented in the paper. However, since the number of SciELO publications is low, representing only 0.22 percent of WoS core publications, our main econometric analysis is based only on WoS core publications.

Table 13. Study Sample of SNI Researchers

Discipline	All SNI researchers in 2013	Researchers in sample after WoS match	affiliation to a public university or public research center	Researchers with a foreign affiliation	university, private company, and others (hospital, Ministries, etc.)	decreases or rating received earlier than 3 years after first publication observed	Share of final study sample in WoS match
Life sciences	3190	1317	690	34	323	270	52.4%
Technological sciences	2850	1228	440	7	362	419	35.8%
Physics	1685	601	326	10	119	146	54.2%
Agronomy	1601	822	300	3	254	265	36.5%
Medicine and human pathology	1477	687	206	7	387	87	30.0%
Chemistry	1085	464	233	11	99	121	50.2%
Earth sciences	842	313	183	2	41	87	58.5%
Mathematics	696	130	47	1	26	56	36.2%
Astronomy and astrophysics	203	45	25	1	4	15	55.6%
Health sciences	202	98	31	1	59	7	31.6%
Total	13831	5705	2481	77	1674	1473	43.5%

Source: Authors' elaboration.

[15] The hits in the social sciences, arts, and humanities (SSH) are much more numerous: 1334 in total, with 80 percent of the records in the social sciences, and 94 percent of records in Spanish. Forty-six percent of the affiliates are Mexican authors, and most of the co-authors are from other Latin countries, the largest being Argentina.

Table 14. Population of SNI Researchers in 2013 by Discipline and Corresponding Sample Obtained through Publication Matching with WoS Data

Discipline	All SNI researchers in 2013	Researchers in sample	Share of all SNI	Share of sample	Sample/SNI population
Life sciences	3190	1317	16%	22%	41%
Technological sciences	2850	1228	14%	21%	43%
Physics	1685	601	9%	10%	36%
Agronomy	1601	822	8%	14%	51%
Medicine	1477	687	7%	12%	47%
Chemistry	1085	464	6%	8%	43%
Economics	888	44	5%	1%	5%
Sociology	856	24	4%	0%	3%
Earth sciences	842	313	4%	5%	37%
History	730	10	4%	0%	1%
Maths	696	130	4%	2%	19%
Arts and literature	506	4	3%	0%	1%
Anthropology	498	9	3%	0%	2%
Political science	487	4	2%	0%	1%
Law	436	3	2%	0%	1%
Psychology	413	53	2%	1%	13%
Pedagogy	315	6	2%	0%	2%
Philosophy	225	2	1%	0%	1%
Astronomy	203	45	1%	1%	22%
Health sciences	202	98	1%	2%	49%
Geography	182	13	1%	0%	7%
Linguistics	171	5	1%	0%	3%
Demography	78	0	0%	0%	0%
Prospective studies	53	11	0%	0%	21%
Ethics	19	0	0%	0%	0%
Logic	12	2	0%	0%	17%
Labor studies	1	0	0%	0%	0%
Electrical Engineering	1	1	0%	0%	100%
	19702	5896	100%	100%	30%

Source: Authors' elaboration.

Annex 4. List of Mexican Public Universities Covered in the Analysis

No.	Name
1	Benemerita Universidad Autonoma de Puebla
2	Instituto Politecnico Nacional
3	Instituto Tecnologico de Sonora
4	Universidad Autonoma Agraria Antonio Narro
5	Universidad Autonoma Benito Juarez de Oaxaca
6	Universidad Autonoma Chapingo
7	Universidad Autonoma de Aguascalientes
8	Universidad Autonoma de Baja California
9	Universidad Autonoma de Baja California Sur
10	Universidad Autonoma de Campeche
11	Universidad Autonoma de Chiapas
12	Universidad Autonoma de Chihuahua
13	Universidad Autonoma de Ciudad Juarez
14	Universidad Autonoma de Coahuila
15	Universidad Autonoma de Guadalajara
16	Universidad Autonoma de Guerrero
17	Universidad Autonoma de La Ciudad de Mexico
18	Universidad Autonoma de Nayarit
19	Universidad Autonoma de Nuevo Leon
20	Universidad Autonoma de Queretaro
21	Universidad Autonoma de San Luis Potosi
22	Universidad Autonoma de Sinaloa
23	Universidad Autonoma de Tamaulipas
24	Universidad Autonoma de Tlaxcala
25	Universidad Autonoma de Yucatan
26	Universidad Autonoma de Zacatecas
27	Universidad Autonoma del Carmen
28	Universidad Autonoma del Estado de Hidalgo
29	Universidad Autonoma del Estado de Mexico
30	Universidad Autonoma del Estado de Morelos
31	Universidad Autonoma Metropolitana
32	Universidad de Colima
33	Universidad de Guadalajara
34	Universidad de Guanajuato
35	Universidad de Quintana Roo
36	Universidad de Sonora
37	Universidad Del Ejercito Y Fuerza Aerea
38	Universidad Juarez Autonoma de Tabasco
39	Universidad Juarez del Estado de Durango
40	Universidad Michoacana de San Nicolas de Hidalgo
41	Universidad Nacional Autonoma de Mexico
42	Universidad Veracruzana

Annex 5. List of Mexican Public Research Centers Covered in the Analysis

No.	Name
1	Centro de Innovación Aplicada en Tecnologías Competitivas, A.C.
2	Centro de Investigación Científica de Yucatán, A.C.
3	Centro de Investigación Científica y de Educación Superior de Ensenada
4	Centro de Investigación en Alimentación y Desarrollo, A.C.
5	Centro de Investigación en Matemáticas, A.C.
6	Centro de Investigación en Materiales Avanzados, S.C.
7	Centro de Investigación en Química Aplicada
8	Centro de Investigación y Asistencia en Tecnología y Diseño del Edo. D
9	Centro de Investigación y Desarrollo Tecnológico en Electroquimica, S.
10	Centro de Investigaciones Biológicas del Noroeste, S.C.
11	Centro de Investigaciones en Optica, A.C.
12	Ciateq, A.C., Centro de Tecnologia Avanzada.
13	Corporacion Mexicana de Investigación en Materiales, S.A. de C.V.
14	El Colegio de la Frontera Norte, A.C.
15	El Colegio de la Frontera Sur
16	Instituto de Ecología, A.C.
17	Instituto Nacional de Astrofísica Optica y Electrónica
18	Instituto Potosino de Investigación Científica y Tecnológica, A.C.

Annex 6. A Detailed Analysis of the Contribution of the Selectivity and Endogeneity Correction in Accounting for the Gender Productivity Gap

Table 15. Productivity Equation for SNI Researchers in Public Universities, without and with Corrections

Productivity: (log) Prod	No Corrections	Endogeneity correction	Selectivity correction	Endogeneity + selectivity corrections
Age and gender				
Woman (=1)	-0.0046	0.025**	0.064***	0.083***
(Age-40)/10	0.0089	-0.054***	-0.040***	-0.093***
((Age-40)/10)^2	-0.0075*	0.0049	0.014***	0.023***
(Age-40)/10 * Woman	0.015	0.036***	-0.012	0.0085
((Age-40)/10)^2 * Woman	-0.010	-0.022***	-0.016	-0.026**
Initial productivity				
log(first Article)	0.065***	0.042***	0.019	0.0031
log(average first Impact Factor)	0.13***	0.12***	0.19***	0.19***
Promotion and nonpublishing spells				
Prob(promotion)	0.12***	1.21***	0.095***	1.04***
Prob(nonpublishing spells: lambda)			-0.13***	0.032
Collaboration				
log(No. of authors harmonic average) in t-1	0.13***	0.14***	0.16***	0.16***
log(articles SNI coauthors) in t-1	0.020	0.014	-0.013	-0.017
log(Impact Factor SNI co-authors) in t-1	0.24***	0.23***	0.29***	0.28***
log(SNI coauthors' coauthors) in t-1	-0.056**	-0.045*	-0.069**	-0.061**
SNI coauthor no publications in t-1	0.18***	0.17***	0.070	0.071
No publication in t-1	0.037	0.065**	0.25***	0.23***
Seniority of co-authors				
SNI coauthor Candidate in t-1	0.00091	-0.020	-0.0090	-0.024
SNI coauthor Level 1 in t-1	-0.032	-0.043**	-0.045*	-0.054**
SNI coauthor Level 2 in t-1	0.013	0.0033	0.0097	0.00020
SNI coauthor Level 3 in t-1	0.016	0.0096	0.027	0.020
Gender and affiliations of co-authors				
Foreign co-author in t-1	0.072***	0.020	0.065***	0.021
Coll. University - PRC in t-1	-0.055*	-0.046	-0.065*	-0.054
Female university	0.041**	0.032*	-0.0024	-0.0046
Male university	0.011	-0.031	-0.0014	-0.036
Female PRC	0.017	0.0028	-0.0065	-0.020
Male PRC	0.040**	0.021	0.019	0.0045
Time dummies	*yes*	*yes*	*yes*	*yes*
Discipline dummies	*yes*	*yes*	*yes*	*yes*
Constant	0.35***	0.27***	0.29***	0.21***
Observations	24,914	24,914	24,914	24,914
Observations npub != 0			16,387	16,387
Pseudo R2	0.122	0.134	0.180	0.189

Significance: *** p<0.01, ** p<0.05, * p<0.1

Source: Authors' elaboration.

Table 16. Productivity Equation for SNI Researchers in Public Research Centers, without and with Corrections

Productivity: (log) Prod	No Corrections	Endogeneity correction	Selectivity correction	Endogeneity + selectivity corrections
Age and gender				
Woman (=1)	-0.010	0.013	0.012	0.024
(Age-40)/10	-0.0081	-0.051***	-0.098***	-0.12***
((Age-40)/10)^2	0.00066	0.014	0.030**	0.038***
(Age-40)/10 * Woman	0.0012	0.034	-0.025	0.0015
((Age-40)/10)^2 * Woman	0.0052	-0.0046	0.032	0.025
Initial productivity				
log(first Article)	0.0081	0.0092	-0.019	-0.017
log(average first Impact Factor)	0.10***	0.098***	0.14***	0.14***
Promotion and nonpublishing spells				
Prob(promotion)	0.12***	0.51***	0.100***	0.35***
Prob(nonpublishing spells: lambda)			-0.14	-0.064
Collaboration				
log(No. of authors harmonic average) in t-1	0.13***	0.13***	0.14***	0.15***
log(articles SNI coauthors) in t-1	0.061*	0.053	0.041	0.034
log(Impact Factor SNI co-authors) in t-1	0.17***	0.15***	0.18***	0.17***
log(SNI coauthors' coauthors) in t-1	-0.095*	-0.083	-0.14**	-0.13**
SNI coauthor No publications in t-1	0.10	0.12	-0.035	-0.021
No publication in t-1	0.048	0.066	0.18***	0.18***
Seniority of co-authors				
SNI coauthor Candidate in t-1	0.036	0.028	0.026	0.022
SNI coauthor Level 1 in t-1	0.082*	0.074*	0.035	0.032
SNI coauthor Level 2 in t-1	-0.012	-0.011	0.0053	0.0051
SNI coauthor Level 3 in t-1	-0.034	-0.026	-0.040	-0.034
Gender and affiliations of co-authors				
Foreign co-author in t-1	0.084**	0.077**	0.077*	0.076*
Coll. University - PRC in t-1	0.037	0.048	0.033	0.041
Female university	0.0023	-0.016	0.029	0.012
Male university	-0.056	-0.080**	-0.033	-0.045
Female PRC	0.054	0.055	0.049	0.052
Male PRC	0.018	-0.0098	-0.011	-0.027
Time dummies	*yes*	*yes*	*yes*	*yes*
Discipline dummies	*yes*	*yes*	*yes*	*yes*
Constant	0.38***	0.34***	0.45***	0.42***
Observations	4,620	4,620	4,620	4,620
Observations npub != 0			3,083	3,083
Pseudo R2	0.133	0.138	0.165	0.167

Significance: *** p<0.01, ** p<0.05, * p<0.1
Source: Authors' elaboration.