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Working Paper Series

#2016-072

An econometric investigation of the productivity gender gap in Mexican research, and a simulation study of the effects on scientific performance of policy scenarios to promote gender equality

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UNU-MERIT Working Papers
ISSN 1871-9872

Maastricht Economic and social Research Institute on Innovation and Technology
UNU-MERIT

Maastricht Graduate School of Governance
MGSoG

Title: An econometric investigation of the productivity gender gap in Mexican research, and a simulation study of the effects on scientific performance of policy scenarios to promote gender equality[1] [2]

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Abstract[3]

This paper provides evidence on the existence and determinants of the publication productivity gender gap in Mexico at the individual level and on its consequences on the Mexican scientific system and productivity at disciplinary and 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 2002-2013. It corrects for a selectivity bias: the existence of periods with no (or low quality) publication, and endogeneity bias: the promotion to higher academic ranks. We define and implement counterfactual simulations to both effects, 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, when correcting for the endogeneity and selectivity biases, we find that the average female researcher in public universities is around 8% 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. We find that barriers to promotion to higher academic ranks are highest among females in public research centres. Our macro scenarios on promotion practices, selectivity, collaboration and age show that eliminating gender gaps would increase aggregate productivity by an average of 7% for university females and 9% for females in research centres.

JEL classification: C23, I23

Keywords: scientific productivity, gender productivity puzzle, Mexico, economics of science, economics of gender

[1] **This paper is part of the research project "Science, Technology and Innovation Gender Gaps and their Economic Costs in Latin America and the Caribbean", led by the Competitiveness and Innovation Division of the Inter-American Development Bank (IDB) and financed by the IDB Gender and Diversity Fund. The information and opinions presented here are entirely those of the authors, and no endorsement by the Inter-American Development Bank, its Board of Executive Directors, or the countries they represent is expressed or implied.**

[2] This paper also circulates as part of the Inter-American Development Bank Working Paper Series.

[3] The authors thank José Miguel Benavente, Matteo Grazzi, Jocelyn Olivari and Janet Stotsky for discussions and valuable comments.

Men largely dominate academia. Studies on the presence of women in academia show that female researchers are seriously under-represented in the highest levels of hierarchy (Brouns, 2000, Timmers et al., 2010, Rivera León et al., forthcoming). This seems to be true in virtually every country that has been studied. But what is the reason for this relatively weaker position of women in academia? Is the low presence of women in the scientific community simply mirroring a struggling pattern that confronts 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 on the existence and magnitude of the gender gap in scientific publication productivity in Mexico, even when controlling for a variety of important determinants. The paper tries more generally to contribute to an improved appreciation of the reasons and consequences of the inequality in scientific performance and standing of female researchers relative to male researchers in the Mexican context.

This paper includes results of an econometric panel data analysis at the individual level following an adapted version of an econometric approach developed by Mairesse and Pezzoni (2015) to understand gender gaps in scientific publication productivity. After giving a short contextual background, we explain our data and sample, and our econometric framework. We then proceed with a presentation of the results of our panel data econometric analysis which we perform for two large samples of Mexican researchers affiliated to public universities and to public research centres members of the Mexican National System of Researchers (SNI). We then proceed with a series of counterfactual macro simulations with the dual purpose of assessing the magnitude of the macro-impacts of gender gaps and of illustrating the potential impacts of a range of policy scenarios aimed at reducing such gaps. We then conclude with policy implications.

Understanding the determinants of the gender productivity gap

This paper focuses on what Cole and Zuckerman (1984) first referred as the "productivity puzzle" or the lower comparative productivity of women in science, almost in all disciplines and regardless of the productivity measure used (Bellas and Toutkoushian, 1999). There are many studies that have documented this puzzle, but less has been done to understand its possible causes, and very few studies only have could assess whether and to what extent factors affecting differently female and male scientists differently can account for it. Neither theoretically nor empirically, have scholars could find a clear explanation for the productivity gap between female and male scientists.

As summarized in the survey part of Mairesse and Pezzoni (2015), past studies show the necessity of analysing 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", quantity and quality (such as number of publications, impact factor of journals citations).

Sonnert and Holton (1995) suggest that the explanations for women's lower productivity can be classified in two categories namely, the *difference model* and the *deficit model*. The difference model states that women act differently because they are simply different when compared to men, with respect to motivation and commitment to 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 believe it is the effect of social and cultural climate that drives women to choose specific educational patterns, to select their time allocation between work and family care, and in taking decisions about their careers. In contrast, the deficit model states that external barriers, not intrinsic reasons, prevent women from having the same performance 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, the more difficulties faced in their career, the 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. In our view also, the difference and deficit models should not be considered as providing alternative or contradictory explanations; in fact, they are both relevant and coexist, complementing rather than competing with each other. These factors may overlap, and in some cases they might 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 difference and 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 scientist's 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 particular interest for scholars because it is an easily identifiable event that may explain temporary shortfalls in the publication productivity of young women. Studies trying 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 it disappears when scientist's personal characteristics, discipline specificities, work environment and university characteristics are considered (Prozesky, 2008).

Similarly, scholars 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 time than 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 to be promoted to higher ranks. This bidirectional causal relation between promotion and productivity raises an endogeneity problem. Several articles on gender gaps have identified career status as an important determinant of productivity but 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 show that there are no gender differences in the technological outcome of inventors, but there are in terms of 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, because of the higher allocation of tasks at home 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, in 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 self-selecting against disciplines socially considered as a male realm.

Countries and organisations may also implement different policies aiming at limiting the gender gap. Strong gender policies may mitigate the effects of family duties on scientific productivity. While it is obviously important to know whether, and which, policies might affect gender imbalances, to date, the effects of the policies that favour women are still a largely unexplored field in economics and sociology of science.

With respect to the Mexican context, there are inequalities in research careers, both regarding gender and age. For young researchers, studies have shown that only 20 percent of researchers under the age of 40 can find an academic research position (UAM, 2010). Moreover, salaries are perceived as non-competitive if compared with employment in the private sector, especially in the early career stage. In this regard, the OECD (2009) has suggested that the base salary of academic staff in Mexico is very low and insufficient for sustaining a middle-class lifestyle. This clearly affects decisions taken at a young age which can have large knock-on effects, but in principle should affect men and women in a similar way. Evidence on the existence of the gender productivity puzzle in the context of developing countries and Latin American countries 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 the tolerance for unequal work arrangements between female and male researchers is higher in developing countries.

Evidence on 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 going back to 1981, found that gender gaps in scientific production and productivity were not large overall at an aggregate level, but more pronounced at the level of scientific disciplines. Padilla-Gonzalez et al. (2011), in a comparative study for Canada, Mexico and the United States, found important gender differences in scientific production and productivity not only across country but also within country 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 also 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 labour participation rates. A study by Thévenon et al. (2012) suggested conclusions like those of an OECD (2014) report which estimates that a 25% reduction of the gender gaps in labour force participation by 2025 would lead to an expected additional GDP growth of 1% in Mexico by the same year. There do not seem to be, however, such analyses focusing on the macro-effects of reducing gender gaps in scientific production and productivity in Mexico. Given that the number of women studying STEM disciplines has increased extremely rapidly in the last 20 years in Mexico (Patiño Barba and Tagüeña Parga, 2014), one would expect that such effects could also be very significant.

This paper intends to contribute to an improved understanding of gender differences in the scientific productivity of Mexican researchers, and to allow informed appreciations of the gains that reduction of these differences could have on the performance of the Mexican academic system.

The Mexican National System of Researchers

As it is detailed below, this paper uses data from the SNI. We therefore introduce in this section briefly the system and its main characteristics and functioning structures to contextualise the research.

The SNI is a policy instrument implemented in Mexico in 1984 aiming to identify, recognise, and stimulate economically, based on a merit scheme, the production of high quality scientific and technological knowledge (Cabrero Mendoza, 2014). 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 under request of the Mexican Academy of Scientific Research. It was established to mitigate the effects of worsening remuneration of researchers and their working conditions, and reducing the risks of brain drain, following the 1982 economic crisis in Latin America. The crisis brought important budget shortcuts at all government levels, and a way to control the financial expenses of public universities was through support Programmes in the form of differentiated incentives to researchers and professors.

Beneficiaries are individual researchers, who are involved systematically in research activities, and that either (1) have a research contract or institutional agreement with higher education institutions (HEIs) or research centres in the public, private or social sectors in Mexico[4]; or (2) are Mexican and doing research abroad, in HEIs or research centres 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

[4] In the case of affiliation to research centres 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.

a Mexican higher HEI or research centre for at least one year prior to the application date. The SNI is centrally managed by the National Council for Science and Technology (CONACYT). 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", symbolising 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 USD 234.8 per month), to 15 times the minimum wage (approximately USD 1,174 per month). It is a voluntary process (i.e. each researcher decides whether they want to be members and when). However, membership is usually a prerequisite for being hired or promoted at Mexican universities or for receiving public research grants from CONACYT.

Different managing authorities are involved in the selection of researchers for affiliation. First, the applications are reviewed by different Dictating Committees, one per each of the eight broad academic areas covered in the SNI[5]. 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 rank SNI members in each of the academic areas[6]. If a researcher disagrees with the committee's judgement, 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. A detailed description of SNI's managing authorities, composition and main responsibilities is presented in Annex 1. The requirements for acquiring each of the three SNI categories and sub-categories are presented in Annex 2.

The outcomes that are considered for entry, re-entry and continuation of the 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 the supervision of graduate and post-graduate students and teaching. Other criterion also taken into account for the evaluation of applications include the participation in scientific and technology councils, editorial bodies, and Dictating Commissions; 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, actualisation and strengthening of study and teaching plans and programmes. 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.

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[5] 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 (III); Humanities (IV); Social Sciences and Economics (V); Agronomy and Biotechnology (VI); and Engineering (VII) and Technology Sciences (VIII – usually not numbered and named 'Horizontal Area').

[6] In general, each Committee is composed of 14 evaluators.

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 are 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 it originality; the influence it has on the training of human resources and in the consolidation of research agendas and its impact for 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 individual's merits and compared to the average performance of researchers in that discipline (i.e. scientists do not compete with 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.[7]

A review and assessment of Mexican Innovation policy by the OECD (2009) 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 recognised Mexican researchers; developing a quality research base; and ensuring the attractiveness of research careers. However, the assessment also stated that the reward system as it stands, by evaluating individual researchers and their scientific outcomes, disincentives researchers in 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 a reformed consolidation to better account for researchers' innovation-related output.

The Mexican Science and Research Context

The higher education system in Mexico is composed of public and private universities, institutes, centres, normal schools for the training of teachers and colleges. HEIs have several missions, including the training of 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 centres; public and private universities, and the private sector (private research centres and individual enterprises). Public research centres (PRCs) can be either supervised by the CONACYT, which account for about a third of PRC's research activity; or by a sectoral ministry, notably Energy, Agriculture and Health (OECD, 2011). The 27 CONACYT research centres are grouped into three main S&T areas, notably mathematics and natural sciences, social sciences and innovation and technology development.

[7] Ricker et al. (2010) also argue that when applying to the SNI, the researcher has to 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 for the evaluator when granting membership to the SNI.

The most important HEIs performing R&D, in terms of scientific outputs in the period 2005-2011 were the National Autonomous University of Mexico (UNAM), the Centre for Research and Advanced Studies (CINVESTAV), the National Polytechnic Institute (IPN), and *El Colegio de México, A.C* (FCCyT, 2011). In 2011, 40% of all SNI researchers were from the UNAM, the IPN and the CINVESTAV, all located in Mexico City (Gutiérrez D., 2011). By 2014, 36% of SNI members were affiliated with state level public universities, followed by 34% members from federal universities, and 12% from PRCs (Cabrero Mendoza, 2014).

According to the Ibero-American Ranking SIR 2013, Mexico ranks 3rd 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 2nd just after Brazil (269 HEIs contributing to the country's scientific productivity). However, Mexican scientific production is highly concentrated at institutional level, with less than 10% of HEIs (23) producing more than 85% of the scientific outcomes. During the period 2009-2013, the most prolific Mexican HEIs were the UNAM (rank 2 in Latin America), the Centre for Advanced Studies of the IPN (12), the IPN (15), the UAM (27), and the University of Guadalajara (47) (SIR, 2013, SIR, 2015).

Regarding the performance of Mexican HEIs, the Shanghai ranking of 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 top 4th Latin American university. Regarding the performance of Mexican science measured by scientific production through the number of publications and citations in the period 2009-2013, Mexico was placed in 23rd position in the world rankings, representing about 0.82% of the world's scientific production. In 2013, the number of Mexican scientific articles was 11,547, which was 3% higher than in 2012. The academic topics that increased the most in number in the period 2008-2012 were Plants and Animals (14.4%), Medicine (11.5%), Physics (11.1%), Chemistry (10.2%) and Engineering (7.6%) (CONACYT, 2013). During the same period, the scientific articles produced by Mexicans received more than 175,432 citations, representing a growth of 5.8% with respect to the period 2007-2011.

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

The labour market for researchers is very competitive market, with a set of formal and informal rules set by experienced researchers. Competition is limited by the existence of "internal markets" with barriers to entry, depending on the level of research experience and sharing of similar (academic) ideologies. It is also a highly institutionalised market. Vacant positions are usually given to experienced researchers in the same research team, or to research assistants linked to the "old generations" inside the research institutions.

The base salary of academic staff in Mexico is very low and insufficient for sustaining a middle-class lifestyle (OECD, 2009). The salaries are perceived as non-competitive if compared with employment in the private sector, especially in the early career stage. In general terms, the salary of a Mexican researcher is composed of the base salary, a merit-based component, and a supplement for researchers being 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 regards to their pension, as this prevents many researchers to retire, as this implies losing about 75-80% of their total income. Recommendations by international panels of evaluators (OECD, 2009) have suggested that the non-taxable complement of the remuneration (i.e. SNI awards) should become part of the researchers' regular salary. However, this has important implications in terms of the provision of pensions and would also require modifications to labour laws that seem unlikely to happen.

Staff researchers (full-time and part-time personnel) of public universities and PRCs are civil servants and thus the federal and state laws pertaining to public servants govern the conditions of employment, remuneration and pensions. The pension benefits of the academic workforce are generally linked only to the base salary, which in the cases of researchers affiliated to the SNI only represents about one-third of their overall remuneration. Moreover, career structures are mostly defined at institutional level, 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 life (OECD, 2009).

Public universities concentrate a large part of their activities on teaching and training. In relative terms, research is still an under-developed 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 providing financial incentives based on productivity additional to the SNI awards. Publications are also in many cases a requirement for obtaining a promotion at universities and for membership to the SNI and promotion in the system itself. In public universities at state level, the Ministry of Education promotes that all full-time professors also undertake research activities and academic management and training since 1997.

About 67% of CONACYT's public research centres' personnel was research staff in 2006 (OECD, 2009), including 30% of researchers. Besides conducting R&D and S&T activities, CONACYT's PRCs also offer teaching programmes at the master's and PhD levels. The centres also work closely with industry, promoting technology transfer and commercialisation. In fact, an important share of PRCs' external funding comes from selling products and services to the private sector. Mexican PRCs are not only concentrated on research activities, which also affect the productivity and outcomes of the researchers.

Given the above contextual and theoretical frameworks, in this paper we try to understand the existence of gender productivity gaps in public universities and public research centres in Mexico. We define below our data, sample and methodological approach.

Data and sample

The study sample

This paper uses data of researchers affiliated with the SNI of Mexico in 2013 and their ISI Web of Science (WoS) publications in previous years. The working sample is constructed by matching the names of all SNI researchers in 2013 to the author and co-author names 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 the most internationally exposed are SNI members.

Details on how the study sample was built are presented in Annex 3. The final panel data used consists of a total of 44,535 WoS publications and 2,481 researchers, out of which 712 are female researchers (28.7%) and 1,769 are male researchers (71.3%). These researchers are affiliated to 41 public universities, and 18 public research centres.

Data description

We measure scientific productivity by looking at the WoS publications of SNI researchers in the period 1993-2014. We also look at the quality of the publications produced, looking at the five-years 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 they publish each year, taking as weights the five-years impact factors of the journals in which these articles are published.

We have little but important personal information on individual researchers affiliated to the SNI: mainly their dates of birth and hence their age, their gender, their achieved ranks in the period 2002-2013, their affiliation in 2013, the year of granting of the PhD (or latest academic degree), and the country of origin of the PhD. We thus know when each of the researchers are promoted across the different SNI ranks. Given the type of requirements needed for achieving each SNI rank, we classify them in two broad categories: Low Ranks, including the Candidate level and Level 1 researchers; and High Ranks, for Level 2 and Level 3 researchers. We exclude the researchers that have achieved an *Emeritus* level as these are very few and they are clear outliers relative to all other ranks.

Table 1 shows that about 40% of all researchers older than 40 have a high-rank. Among younger researchers, the share of high-ranked researches varies by gender and affiliation, being the least represented women, in particular in public research centres. Overall, women are under-represented in the High Ranks for all age groups and affiliations, and over-represented in the Low Ranks also in all age groups and affiliations. This under-representation is relatively most important for women in public research centres.

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 where we observe the first publication. Based on our publication data we constructed two unbalanced panels, one for university researchers and another one for those working in research centres.

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 non-publishing years. We define a 'non-publishing 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 non-publishing years and in logarithms respectively. The figures in logarithms also exclude the non-publishing years, with the benefit that this also normalises the statistical distribution of the observed productivity itself, which is preferable in econometrics. The data shows that men in public research centres are the most productive with 1.65 articles per year, followed by men in universities (1.59), women in universities (1.24) and women in research centres (1.14). The gender gap is much stronger in the case of SNI affiliates in research centres, where women have a lower productivity of about 31% relative to men. This gender gap is lower for SNI researchers in public universities, where women under-perform men by 22% on average. Overall, the gender gap is most marked and important among public research centres affiliates, as reflected in the median of productivity values when excluding the non-publishing years (middle part of Table 2).

Table 1. Number and proportion of female and male researchers in public universities and research centres in two age groups and low and high ranks in 2013

	Public Universities			Public Research Centres		Total Public Research Centres
Researchers	**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%
Sub Total	625	1498	2123	87	271	358
	100%	100%	100%	100%	100%	100%

The evidence given in the middle and lower panels of the table filter out the non-publishing years, showing gender productivity gaps that are less striking, but still very large. These correspond to 24% in the case of public research centres (down from 31%), and 16% for universities (down from 22%). 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 research centres.

Table 2. Descriptive statistics on average unweighted publication productivity for female and male researchers in public universities and research centres, including and excluding non-publishing years

Researchers	Public universities Women	Men	W/M (or W-M in logs)	Public Research Centres Women	Men	W/M (or W-M in logs)
Including non-publishing 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 non-publishing 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 non-publishing 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	

Table 3 presents similar statistics but dividing the publications sample according to the 5-years 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. Females publish in journals with higher impact factor (IF) than men, with an average of 1.55 and 1.47 IF respectively. Comparatively, SNI researchers working in universities publish in higher IF journals than those in public research centres: 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 IF higher than 2, and the bottom part those publishing in journals with IF higher than 4. The statistics show that the gender gaps are the same in universities and research centres for publications in journals with an average IF higher than 2. In contrast, the gender gap almost doubles for those working in research centres publishing in journals with an IF higher than 4. Interestingly, when we look at the publications in low impact journals (i.e. those in journals with an IF 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 centres (-0.31). Thus, we observe important differences in the gender gap not only by the affiliation type, 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 centres, it remains 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 centres, for different average Impact Factor levels

	Public universities			Public Research Centres		
All publications	**Women**	**Men**	**W-M**	**Women**	**Men**	**W-M**
In logs (excluding non-publishing 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 non-publishing 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 non-publishing 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	

Moreover, the number of non-publishing years is rather similar for men and women, and by affiliation. Differences are larger among SNI affiliates in research centres. Table 4 shows that conditional on ranks, both the frequency of non-publishing spells and log-productivity increase with age only for researchers in High Ranks, and notably in universities. Researchers that are older than 40 years of age and have a Low Rank have on average very similar number of non-publishing years if 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 include two other equations to measure promotion and another one for non-publishing spells. As explained below, these two equations will allow us correcting for the endogeneity of promotion and the selectivity of publishing spells in the productivity of SNI researchers.

Table 4. Proportion of non-publishing years for female and male SNI researchers in universities and research centres, in two age groups and Low and High Ranks

Researchers	Universities		W-M	Public Research Centres		W-M
	Women	Men		Women	Men	
Less than 40 years						
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 more						
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%

A first look at the data shows that about 77% of men in public universities are not promoted in the period 2002-2013, compared to 64% of men in public research centres. This compares to about 89% of women that are not promoted both in universities and research centres (Table 5).

Table 5. Promotion from Low Ranks to High Ranks by affiliation and gender

	Public Universities			**Public Research Centres**		
	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

We have also looked at the relationship between the composition of papers, gender and seniority. For this, we have calculated the harmonic average of the number of authors of the articles published by the researchers in each year. The medians of this harmonic average for universities and research centres are respectively 5.9 and 5.2 co-authors per article. We do not observe marked differences on the harmonic average of number of authors by gender or seniority. The medians of the harmonic average for females is 6 authors per article, compared to 5.5 for males. 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 females and males having both a median of 6 authors per article. When looking at the arithmetic mean and by level of seniority, all SNI researchers have a median of 6 authors per paper, except for Level 3 researchers that have a median of 5.7 authors per paper.

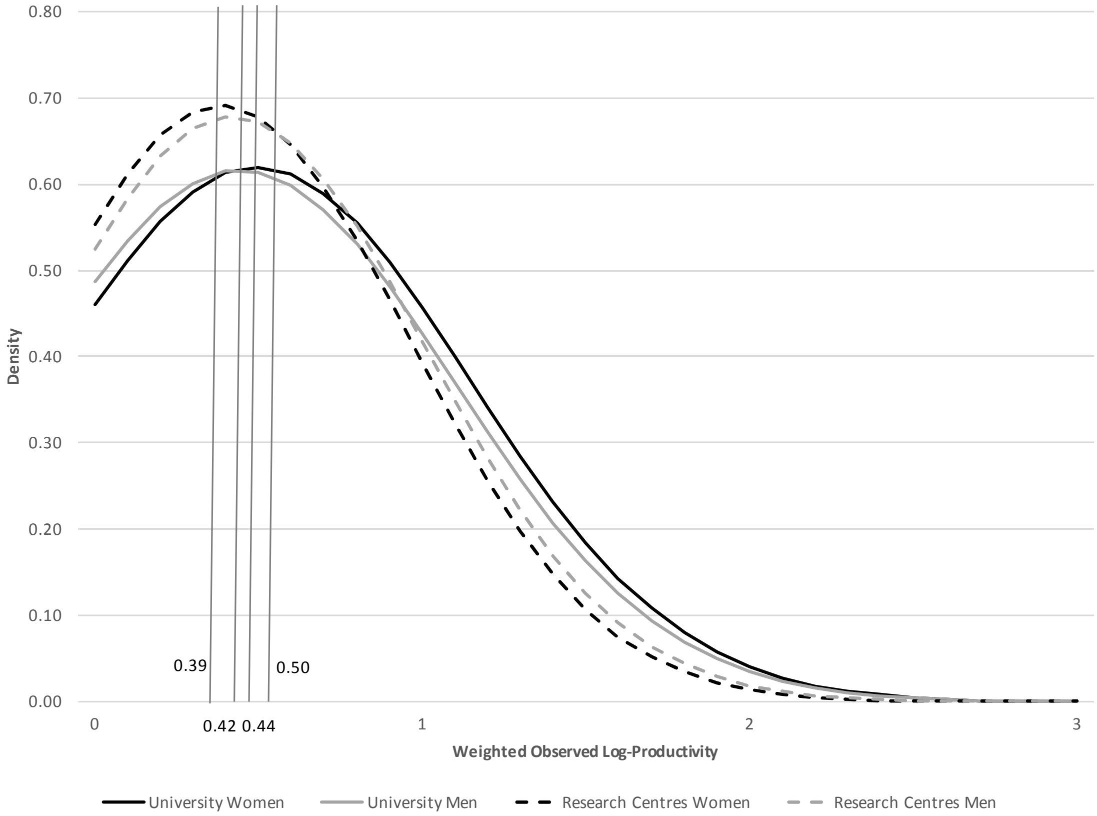
With regards the gender of the co-authors, Table 6 presents the share of observations in which a SNI researcher co-authored with other SNI researchers by affiliation and gender. The data shows that women and men in universities collaborate most frequently with men in universities; while women and men in public research centres 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 prefer university males as second most frequent co-authors. In most cases, women collaborate more with other women relative to men, except for researchers in public research centres, where men have a larger share of papers with university female co-authors than women (28% vs. 24% respectively).

Table 6. Gender and affiliation of SNI co-authors, share of total (multiple choice allowed)

	Universities		Public Research Centres	
	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

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, we highlighted above that the gender gap gets considerably reduced or even favours women in universities once we account for the quality of the publications measured by higher impact factor. The weighted log-productivity of the researchers is equal to 0.05 in universities and -0.03 for research centres). Unweighted publication productivity is higher for 43% of women in universities and for 38% of women in research centres than the average productivity of their male counterparts. As illustrated in Graph 1, once we account for the quality of the publications, publication productivity is higher for 53% of women in universities and for 48% of women in research centres compared to the average of the males.

Graph 1. Distribution of observed weighted log-productivity for female and male SNI researchers affiliated to public universities and public research centres



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

Methodological approach: Econometric panel data analysis at the individual researcher level

In the first part of the paper we implement 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 (“Le Centre National de la Recherche Scientifique”, which is the major French public research organisation 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 together with other variables that are possible to measure in practice. As concerns estimation methods, we have to face 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 take care of such biases by specifying and estimating jointly with the productivity equation two other equations, a *probit* for publishing occurrence '*selectivity'* and another one for '*promotion*'.

The Promotion Probit Equation

Career advancements 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 larger opportunities of 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 at correcting for endogeneity biases related to the correlation between career advancements 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 dependent variable, and explained by 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. Of importance is the introduction of interactions of gender with age, given the obvious conflicts that women face between personal, family and working life and the effect of these 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 starting in 2002 and up to 2013. Promotion of a SNI researcher is thus defined as a change achieved from Low Ranks to High Ranks.

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 where a researcher advanced in his/her career from Low Ranks to High Ranks. We consider age and gender, and age squared with and without the interactions, as well as past productivity as determinants of career advancements. Age is measured in years, and centred on 40 years (and divided by 10 for an 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 5-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 recognised in collaborative work when the co-author is a man, we include two variables related to the gender of the co-authors. The first one is a lagged dummy variable of whether the researcher had a male co-author in the previous year; and the second one is the interaction of this dummy variable with gender, to capture gender differences of the effects of the co-authors characteristics on promotion.

The Publishing Spell Selection Probit Equation

The selectivity equation takes care of the fact that during 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 occurred 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 one 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.

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 different 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 make a distinction 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 second one noting the average 5-years 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 non-publishing time spells[8], coming from the promotion and selection equations respectively. These are included in the productivity equation to correct for the endogeneity of being in a high academic rank and the selectivity of publishing spells. The fourth group refers to 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

[8] The correction for non-publishing 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 non-publishing spells. This is why the correction in the productivity equation is computed as the probability of non-publishing spells.

grouped these variables in three different blocks: the first with the overall characteristics of the collaborations (noted *Collaborations*); the second one referring to the *Seniority of the Co-authors*, and the last one 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 5-year impact factor) of the co-authors productivity (*log Impact Factor SNI co-authors in t-1*). We limit these two variables to 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 the publications where the co-authors published with our sample researchers. For completeness, we add one additional binary variable characterising whether the SNI co-authors did not have any 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 centre - *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 public research centre 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 public research centres (including the CONACYT research centres, and the Ministry of Education research centres – see Annex 4 and 5 for a full list of the institutions covered).

Econometric findings

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

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 on 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 public research centres (PRCs). The exception is the average IF of publications in year t-1 and the IF for t-3 for PRC researchers which are not significant for all models. This suggest that promotion has a ‘long(er)-term’ memory with regards 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 and inverted u-shaped curve, suggesting that this probability is lower for younger SNI researchers as well as for very senior researchers that are not already promoted.[9] Having a male SNI co-author in the past has a positive effect on promotion. However, collaboration with males has a negative effect on the promotion of university females. 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, both in 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 centres.

The Publishing Spell Selection Probit Equation

Similarly, the coefficient estimates of the publishing spell selection probit equation also confirm our expectations. The probabilities of publishing are 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 non-publishing is increasing more rapidly for women over 40 than for men at the same age.

The Productivity Regression

The productivity equation, as defined in the previous section, includes four groups of explanatory variables. We find that all these 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 predict a larger scientific productivity in the future for all SNI members, for those in public universities relative to research centres affiliates. The control for the endogeneity of rank by including the predicted probability of promotion to higher ranks has a very 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 non-publishing yearly predicted probability does not have a significant impact in productivity.

[9] The estimated maximum probability of promotion is on the high side 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 centres, and 55 for men in research centres.

Table 7. Promotion *probit* equation for SNI researchers affiliated with public universities and public research centres, with and without age*gender interactions

Rank Indicator	Universities	Research Centres	Universities	Research Centres
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

Table 8. Publishing yearly selection *probit* equation for SNI researchers affiliated with public universities and public research centres, with and without age*gender interactions

Publishing indicator	Universities	Research Centres	Universities	Research Centres
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

Table 9. Productivity equation for SNI researchers affiliated to public universities and public research centres, with and without gender interactions[10]

Productivity: (log) Prod	Universities	Research Centres	Universities	Research Centres
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 non-publishing spells				
Prob(promotion)	1.05***	0.39***	1.04***	0.35***
Prob(non-publishing 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 co-authors) 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 co-authors' co-authors) in t-1	-0.062**	-0.13**	-0.061**	-0.13**
SNI co-author 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 co-author Candidate in t-1	-0.024	0.020	-0.024	0.022
SNI co-author Level 1 in t-1	-0.053**	0.034	-0.054**	0.032
SNI co-author Level 2 in t-1	0.00057	0.0072	0.00020	0.0051
SNI co-author 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

[10] Estimated coefficients, based on OLS corrected for promotion endogeneity and non-publishing 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 matters 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.

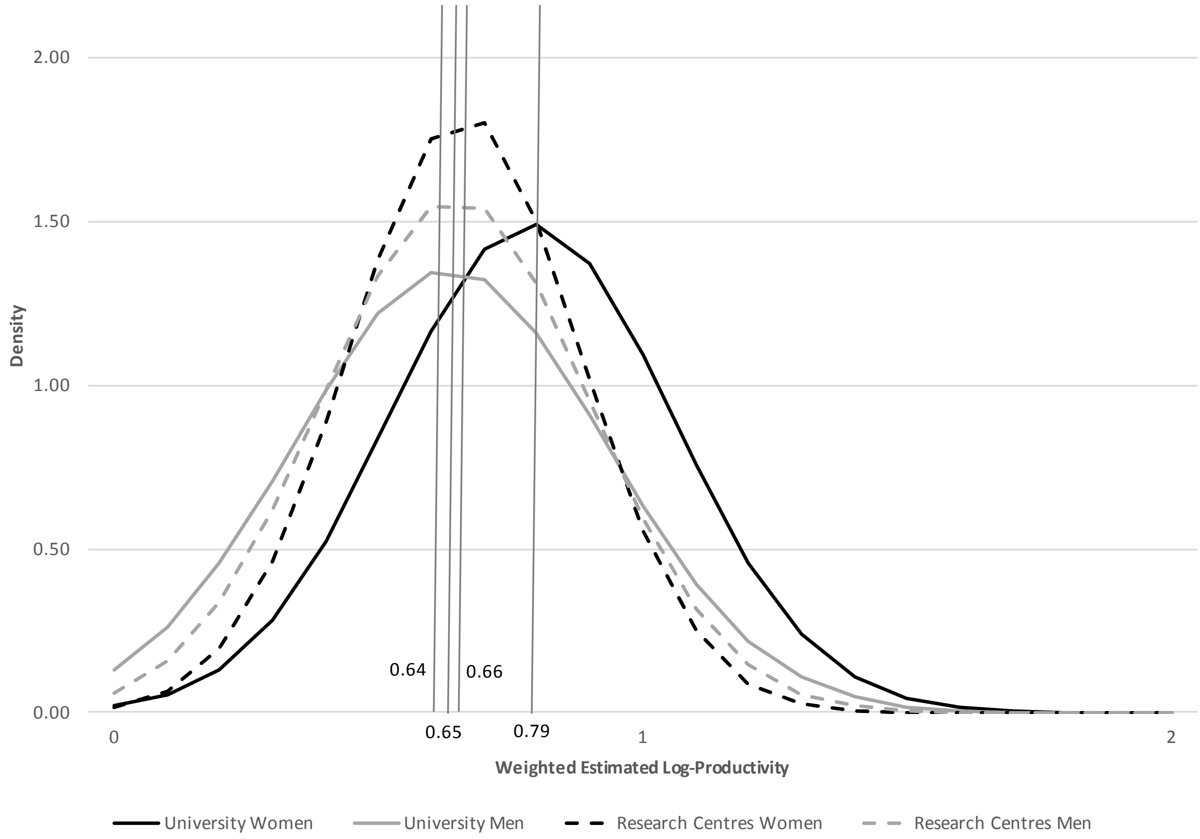
Inter-institutional collaboration, or that between a university researcher and one in a PRC, does not have any effect on productivity. One interesting result is that having no publications in a previous year is a significant predictor of being productive in the following year among all researchers. This is similar to the findings of Mairesse and Pezzoni (2015) for French physicists. In that case, the authors suggested that this might reflect that non-publishing years are usually followed, or alternated with publishing years.

Overall, the level or seniority of the co-authors, does not seem to have an effect on productivity, with the exception of Level 1 co-authors which seem 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 analysed group of factors, 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 in particular, for SNI members in public universities. In Annex 6, we try to understand in more detail the different pieces of the gender productivity puzzle.

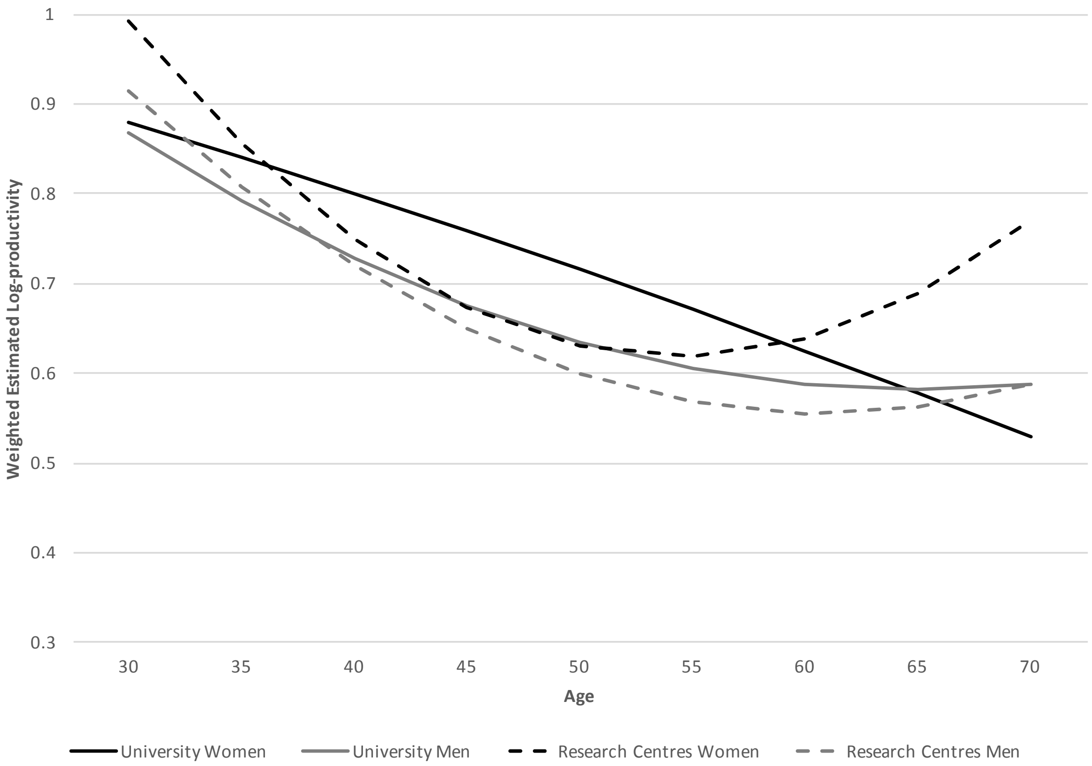
The results of Table 10 above can be illustrated in a simpler way by Graph 2, which can be compared to Graph 1. The model we have estimated proposes several factors that explain researcher productivity. Some are intrinsic to the researcher (gender, age); some due to academic choices (discipline, affiliation); 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 non-publishing 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 centres). This distribution of predicted productivity, holding constant all explanatory variables (at their average levels) are shown in Graph 2. Graph 1 showed observed productivity differences among the 4 types of researchers, in particular with high standard deviations. Graph 2 shows that the average predicted productivity of men and women by affiliation coincide is very similar, with an estimated average of weighted log-production of 0.64 for males in universities (or 1.89 equivalent articles per year in WoS journals IF-weighted); 0.65 for research centres males (1.91 equivalent articles); 0.66 for research centre females (1.94 equivalent articles), and 0.79 for university females (2.20 equivalent articles). After the introduction of our model's corrections, we find that the highest predicted weighted log-productivity is that of university females. We do not find a statistically significant role of gender in explaining productivity gaps in research centres after including our corrections. Gender and institution type have little effect on an individual's productivity, when other factors, including promotion and non-productive spells, are controlled for.

Graph 2. Distribution of weighted predicted log-productivity for representative female and male SNI researchers affiliated to public universities and public research centres



Graph 3 shows how age and gender interact significantly with regards to predicted productivity. It shows what could concern more an age productivity gap. It indicates that for all SNI researchers the estimated productivity decreases rapidly with age, in particular for females in public universities. Male researchers see their productivity slightly increase after 70, while females in research centres see their productivity increase after 60 to levels that are comparable to those they have at the age of 50. University females have always higher productivity than males and than females in research centres until between ages 40 to 55.

Graph 3. Change with age of estimated log-productivity for representative female and male SNI researchers affiliated to public universities and public research centres



To further understand the contributions of each of the corrections in accounting for the gender productivity gap, Tables 15 and 16 in Annex 6 include the productivity equations for researchers in universities and research centres 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 of the contributions especially because in many cases these represent external constraints that are difficult, or even impossible to change for the individual researcher. However, at the collective level, these constraints can be exogenous and justified from the public policy point of view. For instance, gender equality in promotion depends greatly on the working environment and can be stimulated through incentives. The issue of selectivity, or the absence of non-publishing spells is somehow more difficult to address from the policy point of view, as it can reflect a variety of external activities, such as conflicting teaching and management responsibilities, as well as other family engagements and responsibilities.

As previously discussed, we know that 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 then in a second step, we estimate the productivity equation, by including on it the predicted probability of promoting to High Ranks (denoted *Prob. Promotion*).

For calculating the selectivity correction alone (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 non-publishing (noted *Prob non-publishing spells*).

Tables 15 and 16 show that the endogeneity correction alone and the selectivity equation alone are responsible for making disappear the gender productivity gap among SNI researchers. When combined, women become about 8% more productive than men in public universities, and about 2% more productive in public research centres (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 females in public research centres relative to females in public universities.

One interesting finding from our models' results is the existing differentials with regards observed and estimated publication productivity. Table 10 compute these differentials in number of weighted and unweighted number of publications per year (de-logged). The results show that correcting for the existence of promotion and selectivity biases would represent an overall average gain of 1 weighted publication more every 2 years for females (0.56 publications per year for university women and 0.47 for research centres women) and broadly around 1 publication more every 3 years for males (0.33 for university males and 0.39 for research centres). In terms of the unweighted number of publications, the gains would be even higher, corresponding to broadly 1 publication more per year for all researchers, except for university men that would have on average 0.73 publications per year increase.

Table 10. Observed and predicted (weighted and un-weighted) publication productivity, individual and system gains

	University Women	University Men	Research Centres Women	Research Centres 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%

Table 10 also 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 for more than 30% for females and for between 21-25% for males. Productivity gains are observed for all SNI members, males and females, even if the expected gains are higher for women relative to men.

Counterfactual analysis at macro level

Given the results provided above, one of the main concerns from the policymaker's point of view is what would be the gains (or losses) to the science system from reducing or eliminating the gender productivity gaps. We aim to 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) (1); publication intensity (i.e. same probabilities of not publishing for men and women) (2); collaboration practices (3); and age (4).

Table 11 presents a summary of our findings related to the impacts of promotion, selectivity, collaboration and age on the log-productivity of the 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 both 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 would be the productivity gains if females had the same probability of promotion than men (1); and if females had the same probability of not publishing than men (2). The idea is to understand the gains if there were no discrimination of females in promotion, as well as no selectivity of researchers based on gender. We find that if women in our sample would have the same probability of promotion than men, they would have jointly produced a total of 157 publications more in universities and 21 publications more in research centres in our period of analysis, representing 17% of all publications in universities and 20% in research centres. Similarly, we find that having the same probability of not publishing as men would make females in universities produce 2.5% more publications in our period of analysis and 3% more for females in research centres. This relatively low gains stemming from equality in selectivity is in line with the rather similar with the number of non-publishing spells we find between men and women.

We have also tested what would be the overall productivity gains in our sample of SNI researchers if women had the same collaboration characteristics than 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 for understanding 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 different scenarios simulation

	University Women	University Men	Research Centres Women	Research Centres 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 have 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 have the same age as men	0.0%		0.0%	

Even though the contribution of the collaboration variables to productivity is rather similar between females and males with the same institutional affiliations, our predictions show that if women would have the same type of collaboration characteristics than men, an increase of around 10% more publications in universities would be achieved, compared to a 12% increase for women in research centres. We find that having the same age as men has no effect on the productivity of women.

Policies and Initiatives focusing on Decreasing Gender Gaps in the Promotion of Researchers

Our findings suggest that promotion is an issue impacting females in both public research centres and universities. In our econometric results, we showed that the endogeneity or promotion correction makes the gender gap more favourable 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 is an issue that has received attention in Latin America only for a few years, relative to the US or Europe when the issue has received attention for many years already, and thus the correction for this implicitly male-biased process is still in infant stages.

We mentioned above that the SNI evaluation process for entering and promoting to higher SNI ranks starts with the recommendations of the Dictating Committees. These Committees are usually composed of 14 members from the highest SNI levels making a first evaluation of the SNI applications. Table 12 presents the number of male and female members of the Dictating Committees by academic area in 2015-2016[11]. The table shows that only one Committee in 2015 and two in 2016 were gender balanced. Only 1 member of the Engineering Committee was female in both years. Moreover, only one President in 2015 and three in 2016 were female. One could say that the SNI has been unable yet to integrate women into its evaluation framework, and the male-dominated Dictating Committees could play a role in reinforcing gender biases in the promotion of researchers.

Table 12. Number of male and female members on the SNI Dictating Committees, 2015-2016

	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 Behavioural 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

CONACYT's PRCs have introduced a series of internal policies, projects and programmes to promote gender equality among their employees. These programmes 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 the constitution of Codes of Conduct and internal Committees focusing on the non-discrimination to women in the workplace and on the prevention and sanctioning of practices of sexual harassment (e.g. CIDE, CIATEQ, CIQA).

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

Our results showed 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 in eliminating 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

[11] 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

females and males. 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 females with effects that are as large as a 7% average productivity gains for university females and 9% for those in research centres.

Conclusions

Our paper provides evidence of gender productivity gaps in the Latin American and specifically Mexican context. We have introduced and tested an econometric framework including a scientific productivity equation, together with two additional equations for the promotion of researchers to higher seniority levels and another one for occurrence of non-publishing spells. We test this framework in a sample of Mexican researchers in hard sciences affiliated with the National System of Researchers, and working in Mexican public universities and public research centres. The results presented are interesting in several aspects. Our descriptive statistics show a productivity gender gap that gets reduced when the quality of publications measured by the impact factor of the journals of publication is considered. The analysed group of factors, 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 in particular, for SNI members in public universities.

We also find that scientific productivity declines with age. We show that, despite the common belief of a gender gap in publication consistency, female researchers only have between 5 to 6% more non-publishing years than males, and at Senior levels, females only have 1% more non-publishing years relative to men.

Our results suggest important impacts of collaboration with male researchers on the promotion and productivity of females. Overall we find that female researchers in universities have lower probabilities of promotion when co-authoring with a male; and that productivity increases overall when co-authoring with females.

Policies encouraging the promotion of female researchers and academics to higher ranks in the form of support grants exclusive to females (e.g. such as the Dutch Aspasia Programme)[12] could work as means to alleviate the under-representation of female researchers at high levels of seniority, particularly in male dominated environments (e.g. public research centres). As we mentioned above, several of the CONACYT PRCs have a gender agenda integrated into the research centres' activities. However, none of them seems to be tackling actively support for promotion and career development of female researchers.

With regards 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*

[12] The Dutch Aspasia Programme aims to ensure that more female assistant professors progress to the level of associate or full professor. Premiums 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

as a source of inequalities in the research system. It is however not straightforward to interpret in practice our findings. As we mentioned before, 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. Given that we find that this correction is not significant for productivity for all SNI researchers, it is plausible to think that the conflict between teaching and training activities and research activities does not play an important role in the presence of non-publishing years among SNI members.

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). We outlined above that this type of policies already exists in a number of PRCs. The SNI itself has adapted its regulations regarding women when they are pregnant, so that they are given an extra year to apply for extending their membership to the SNI, and that year is not considered when evaluating their scientific outcomes. These policies have however been implemented in the last years and their effects might not yet show in terms of scientific outcomes.

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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 Centres, 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 Honour 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, organisations and functioning of the SNI
Dictating Committees (*Comisiones Dictaminadoras*)	There is a Dictating 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
Honour Meeting Group (*Junta de Honor*)	Five members of the SNI (Level III) Director of the SNI	Analyse 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 those 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% of all researchers affiliated to the SNI in 2013. We also only focus on researchers on hard sciences, as our sample replicates adequately the population of SNI researchers in 2013. Moreover, hard sciences correspond to 97% of the matches obtained with WoS publication data, or to 5,706 SNI researchers[13]. We decided to exclude also 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 have decided to focus our analysis on researchers that are affiliated with a public university (at federal or state level), or to a public research centre, including the Ministry of Education research centres and the CONACYT research centres. We obtained matches for only 10 private universities, and the observations represented only 1.4% of all14. These relative low numbers led us to exclude all researchers that reported an affiliation to a private university, private research centre, private companies and other organisations including hospitals, and national ministries. We also excluded from our sample all those SNI researchers that had an affiliation to a foreign institution in 2013, as these researchers are certainly exposed to different institutional arrangements and have work environments that are very different to those with a Mexican affiliation. Finally, we exclude those researchers for which data was missing in relation to affiliation or personal characteristics, as well as those that had decreases in SNI ranks in the period of analysis, or received a rank in less than 3 years of 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 have 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 language and thus ensures a better coverage with regards a possible language gap. SciELO Mexico has data from 1997 and onwards, with a dominance of publications in Social Sciences and Humanities. In hard sciences, we have identified a total of 524 publications for the period 1997-2014. About 79% of the records obtained are articles in Spanish, and a large majority for the years 2010-201415. The matching of these records with the SNI affiliations in 2013 resulted in a match of 99 publications by SNI researchers in our final sample. About 81.5% of the SciELO publications matched are from male authors, compared to 18.5% for female. However, given that the number of SciELO publications is low

[13] Details on the number of researchers in the SNI population in 2013 and the WoS matches obtained are presented below in this same Annex 3. The number of matches in Social Science and Humanities disciplines obtained corresponds only to 3% of the population, compared to 41% in hard sciences.

[14] The classifications of private and public universities and public research centres were obtained from the 'Comparative Study of Mexican Universities' (see: http://www.execum.unam.mx/)

[15] When looking at social sciences, arts and humanities (SSH), the hits are much larger: 1334 in total, with 80% of the records in social sciences, and 94% of records in Spanish. 46% of affiliations are of Mexican authors, and most of the co-authors are from other Latin countries, being the largest Argentina.

representing only 0.22% of WoS core publications, our main econometric analysis presented below 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	Researchers in sample with affiliation to a public university or public research centre	Researchers with a foreign affiliation	Researchers with an affiliation to a private university, private company, and others (hospital, Ministries, etc.)	Missing data, promotion 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%
Technology 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%

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%
Technology 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%
Labour studies	1	0	0%	0%	0%
Electrical Engineering	1	1	0%	0%	100%
	19702	5896	100%	100%	30%

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

No.	Name
42	UNIVERSIDAD VERACRUZANA

Annex 5. List of Mexican public research centres covered in the analysis

No.	Name
1	CENTRO DE INNOVACION APLICADA EN TECNOLOGIAS COMPETITIVAS, A.C.
2	CENTRO DE INVESTIGACION CIENTIFICA DE YUCATAN, A.C.
3	CENTRO DE INVESTIGACION CIENTIFICA Y DE EDUCACION SUPERIOR DE ENSENADA
4	CENTRO DE INVESTIGACION EN ALIMENTACION Y DESARROLLO, A.C.
5	CENTRO DE INVESTIGACION EN MATEMATICAS, A.C.
6	CENTRO DE INVESTIGACION EN MATERIALES AVANZADOS, S.C.
7	CENTRO DE INVESTIGACION EN QUIMICA APLICADA
8	CENTRO DE INVESTIGACION Y ASISTENCIA EN TECNOLOGIA Y DISEÑO DEL EDO. D
9	CENTRO DE INVESTIGACION Y DESARROLLO TECNOLOGICO EN ELECTROQUIMICA, S.
10	CENTRO DE INVESTIGACIONES BIOLOGICAS DEL NOROESTE, S.C.
11	CENTRO DE INVESTIGACIONES EN OPTICA, A.C.
12	CIATEQ, A.C., CENTRO DE TECNOLOGIA AVANZADA.
13	CORPORACION MEXICANA DE INVESTIGACION 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 ECOLOGIA, A.C.
17	INSTITUTO NACIONAL DE ASTROFISICA OPTICA Y ELECTRONICA
18	INSTITUTO POTOSINO DE INVESTIGACION CIENTIFICA Y TECNOLOGICA, 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 non-publishing spells				
Prob(promotion)	0.12***	1.21***	0.095***	1.04***
Prob(non-publishing 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 co-authors) 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 co-authors' co-authors) in t-1	-0.056**	-0.045*	-0.069**	-0.061**
SNI co-author 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 co-author Candidate in t-1	0.00091	-0.020	-0.0090	-0.024
SNI co-author Level 1 in t-1	-0.032	-0.043**	-0.045*	-0.054**
SNI co-author Level 2 in t-1	0.013	0.0033	0.0097	0.00020
SNI co-author 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

Table 16. Productivity equation for SNI researchers in public research centres, 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 non-publishing spells				
Prob(promotion)	0.12***	0.51***	0.100***	0.35***
Prob(non-publishing 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 co-authors) 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 co-authors' co-authors) in t-1	-0.095*	-0.083	-0.14**	-0.13**
SNI co-author 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 co-author Candidate in t-1	0.036	0.028	0.026	0.022
SNI co-author Level 1 in t-1	0.082*	0.074*	0.035	0.032
SNI co-author Level 2 in t-1	-0.012	-0.011	0.0053	0.0051
SNI co-author 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

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