Breaking through the glass ceiling in academia:

A model simulating more positions available and gender quotas

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PRELIMINARY VERSION

Abstract

The low proportion of women in the highest positions of the academic ladder and the "leaky pipeline" phenomenon are well known facts in all OECD countries, and the recent debate focuses on the policies that can be adopted to increase the gender balance in the university systems. We build an agent-based model to study the possible dynamics of the gender composition in a virtual academia that is a scale reproduction of the Italian academia in 2019. We consider a one-hundred-year period, and we simulate the effects of different measures: (1) the variation in the resources available for recruitment and promotions; (2) the introduction of gender quotas; and (3) the combination of them. Results show that despite a slightly better gender balance in recruitment and promotions when more resources are available, relevant and reasonably quick changes can be obtained only by implementing a gender balancing policy that introduces gender quotas at full professor promotions level.

Keywords

Gender quotas; Academic career; Vertical segregation; Agent-based modelling.

Introduction

Gender discrimination in academia has been deeply investigated over the last years. Women still represent a minority of professors in OEDC countries' universities even where the number of female graduate students overtook those of male ones (OECD, 2016). In particular, women are a small minority in the highest academic rungs, *i.e.* among full professors, heads of department, deans and rectors. This is the so-called "leaky pipeline" phenomenon, that describes the progressive disappearance of women as we move upwards in the academic ladder. Some progress has been done, but only in the lowest levels of the academic career.

The reasons for the under-representation of women in the highest level of the academia are several: a lower productivity (being the result of their family responsibilities), less professional networking, worse evaluation of their research, less willingness to compete for promotions, more teaching and service activities with respect to their male colleagues. These mechanisms are often the consequences of the universities being 'gendered organizations' in which norms and practices are based on a stereotyped vision of male and female workers (Dubois-Shaik and Fusulier, 2019). As a consequence, female researchers suffer discrimination and women in the same scientific sector, with the same seniority and scientific productivity than men are less likely to be recruited and promoted (Ginter and Kahn, 2004; De Paola and Scoppa, 2015; De Paola *et al.*, 2018, Filandri and Pasqua 2019).

Promoting gender equality policies has not only equal opportunity aims, but it is also needed to guarantee heterogeneous and non-gendered approaches to research and teaching and to promote gender roles especially in those disciplines (mainly STEM) in which female students are still a minority. Universities and research institutes where women do not have the same opportunities as men are also proved to be characterised by a worse climate: people are less effective, and this has negative consequences on the whole organisation and not only on women's productivity (Tindal and Hamil, 2004; Casad *et al.*, 2020). For all these reasons, the European Union invited universities and research funding organizations to develop gender equity plans (GEPs) to overcome gender imbalance in the academic institutions (Council of the European Union, 2015; Clavero and Galligan, 2020).

The debate about the most effective policies to reach gender balance in academia is still open. Beside mentoring, supporting women in their research and networking activities, promoting a more equal distribution of teaching and administrative tasks between men and women in the universities, gender quotas in funders and selection committees have been proposed, but the results on having more women in the committees are not conclusive (Zinovyeva and Bagues, 2011; Vernos, 2012; De Paola and Scoppa, 2015; Bauges *et al.*, 2017; Checci *et al.*, 2019; Bennouri *et al.*, 2020). Furthermore, some studies also found that gender discrimination is reduced when more resources are available (Bianco, 2000; Marini and Meschitti, 2018).

Our paper contributes to the existing literature on policies for gender equality by simulating with an agent-based model the effects of two possible policies: increasing the resources available for recruitment and career promotions and/or introducing gender quotas in the promotions to full professor positions. The structure of the academia that we simulate in our model is the Italian academia, in which we observe the evolution of the gender gap dynamics over a time period of one-hundred years comparing the effects of those policies with the case of non-intervention. The Italian case can be used as representative of a common situation as data show that Italy is in line with the other European countries in terms of gender composition in the universities (European Commission, 2019): in 2019 less than 25% of full professors and only 6 out of 84 rectors were women, while among associate professors and tenure track assistant professors the percentages increase to 39% and 43% respectively (data MIUR, 2019).

With our simulations we aim at answering to three main research questions:

1) given that the recruitment of new assistant professors shows a greater gender balance, will this be sufficient to reach a more gender balanced composition of the Italian academia in the long run?

2) are more resources available for recruitment and promotions sufficient to reduce the gender gap in the Italian universities?

3) what would be the effect of introducing gender quotas in promotions to full professor under different turnover regimes? would quotas be effective to achieve a perfect gender balance?

The paper is organized as follows. In Section 1 we present and discuss the state of the art on gender discrimination in academia and on possible policies to overcome it. Section 2 presents the institutional context of the Italian university system. In Section 3 the method and the data used are presented. In Section 4 we present and discuss the results of our simulations. Conclusion follows.

1. The gender gap in academia

A flourishing literature investigated the causes of gender gap in academia to identify possible interventions to reduce the bias. One possible explanation for the difference in the probability of being recruited or promoted between men and women is the difference in their scientific productivity. Because of family responsibilities, female researchers are involved in fewer research projects and international networks and therefore they publish fewer papers (Dubois-Shaik and Fusulier, 2019). Moreover, female professors are often assigned with more teaching and administrative tasks that reduce the time they can devote to research (Coate and Howson, 2014; Babcock *et al.*, 2017; Guarino and Borden 2017; Marini and Meschitti, 2018). Having smaller networks has proven to impact negatively on the

probability of being hired and promoted especially in a country like Italy where connections with the selection committees' members are proved to increase the chances of success (Bauges et al., 2015; Checchi *et al.*, 2019).

However, also studies in which scientific productivity is controlled for show that gender discrimination persists, and women are less likely to be recruited and promoted (De Paola and Scoppa, 2015; Marini and Meschitti, 2018; Filandri and Pasqua, 2019). This discrimination is particularly high for the promotion to full professor of female associate professors that are 17 percentage points less likely to be promoted than their male colleagues with the same level of scientific productivity (the corresponding gender difference in the promotion of assistant professors to associate is 8 percentage points) (Filandri and Pasqua, 2019).

Psychological traits and attitudes could also matter. On the one hand, over-commitment and strain are stronger for female than for male, resulting in higher work stress and intention to leave academia of female postdocs (Dorenkamp and Weiß, 2017). On the other hand, women are often characterized by less competitive traits and lower attitudes to bargaining for promotion and wage increase (Bertrand, 2011), probably as a result of being in an environment that discourage them to act as their male colleagues do. This can explain why less women apply for positions in the highest rungs of the academia (Howe-Walsh and Turnball, 2016; De Paola *et al.*, 2017; Pautasso, 2015; Doherty and Manfredi, 2006; Chesterman and Smith, 2006).

Mentoring is considered an important tool to support women professional development in university that has been a male environment for centuries. Previous literature shows that mentoring had positive effects on the mentees, but it is still not clear if it helps institutions to become more gender equal and diversity oriented (Meschitti and Lawton Smith, 2017). In fact, scholars have emphasized the importance for organizations to fix their own structures and cultures, instead of aiming at 'fix the women' (Voorspoels, 2018).

Among the possible policies that have been suggested to tackle the gender gap in the universities is the increase in the number of women in the selection committees. Men and women might have different preferences and might evaluate differently CVs of researchers that focus on different topics or might evaluate differently different dimensions of the candidates' CVs. Men and women tend to do research in different subfields and evaluators overrate the importance of their own research topics and approaches (Gillies, 2014; Burges *et al.*, 2017). Therefore, the presence of women in a selection committee could lead to outcomes that are less gender biased than those of all-male committees. The Code of Conduct for the Recruitment of Researchers adopted by the European Commission in 2005 sets some general principles that employers and funders should follow when recruiting researchers. One of these recommendations is an adequate gender balance in the selection process to ensure that diversified career path, and not only the number of publications, are taken into account as well as career breaks due to maternity or other care needs are not penalizing for women.

The analyses on the effect of more women in the section committees, however, did not lead to conclusive results. For the Italian academia, De Paola and Scoppa (2015) found that, controlling for scientific productivity, female candidates are less likely to be promoted by all-male committees and their probability increases with mixed-sex commissions while Bauges *et al.* (2017) show that having a woman in the selection committee makes male evaluators even harsher towards female candidates, with an overall negative effect on the chances of success for them. Vernos (2012) found no effect of the share of women in the evaluation panels and the success rate of female scientist that applied for an ERC grant. Opposite results have been found by Zinovyeva and Bagues (2011) for competitions to full professorship in Spain where the presence of one women in the committee makes men and women equally likely to succeed. In a different context, Bennouri *et al.* (2020) found that gender quotas in the boards of directors do not affect the likelihood of appointing a female CEO.

Some studies seem to indicate that discrimination is reduced when more resources are available (Bianco, 2000; Marini and Meschitti, 2018), but this relation has not been deeply investigated yet. Universities allocate their financial resources for personnel between recruitment and career advancements and usually the availability of positions at highest levels of the academic rungs is very limited (Verner, 2008). Budget cuts in personnel costs and in research funds have particularly hit women both in the financial support of their research and in their career opportunities (Evans and Amery, 2016; Sauer, 2016).

In other domains, gender quotas have been introduced on outcomes of selections. Gender quotas in the boards of directors of listed companies as well as in electoral competitions are the most popular examples. In academia gender quotas policies are considered dangerous because they might imperil a system in which merit guarantees the highest quality in research and teaching. However, Bennouri *et al.* (2020) show that the introduction of mandatory gender quotas in the boards of directors improved firms' performance indicators. In the academia the current merit system seems to have favoured men since the definition of merit itself is often a gendered concept that reflects social values and constructs favouring men over women (Van den Brink and Benschop, 2012) and anyhow women's chances of being recruited and promoted are lower to those of their male colleagues with the same scientific productivity. For these reasons actions are urgently needed to reach more gender balance in academia in a reasonable time span (Wallon *et al.*, 2015).

In our agent-based model we simulate how more resources available for academic personnel and gender quotas on promotions at full professor could act to reduce and even close the gender gap in the university system.

2. The Italian academia: recruitment and promotions

Simulating the effect of different policies in an academia that is the scale reproduction of Italian academia is particularly interesting for several reasons. In Italy, in fact, gender discrimination is still a newsworthy fact, and the Italian university system is characterised by strong gender imbalance especially at the highest rungs. Furthermore, the recent reforms in recruitment and the budget cuts suffered by the Italian university over the last ten years did not contribute to reduce the gender imbalance.

In the Italian academic system, there are four hierarchical levels: full professors, associate professors, assistant professors with permanent contracts and assistant professors with temporary contracts. As the effect of recent reforms (Law no. 240/2010 better known as Gelmini's reform), assistant professors are only hired with temporary contract and permanent assistant professors currently in the system are those entered before 2010. In the category of temporary assistant professors there are both assistant professors holding non-tenure track contracts (known as Type-A) and tenure tracked assistant professors (Type-B). In our analysis we do not consider non-tenure tracked assistant professors as when their contracts expire, they have to participate to new competitions to re-enter into the system. Moreover, the positions for Type-A assistant professor are decided at single university level, out of the mechanisms that we are going to describe below. Permanent assistant professors will disappear in the next years since either they become associate professors or they become old and they retire, being this contract type abolished by the Gelmini's Reform.

Recruitment and promotions are the results of a two steps procedure. Every year the Ministry of University defines the total amount of resources that can be used for recruitment and promotions and it allocates them among the different universities. These resources are defined in terms of "Punti Organico" (hereafter POMs), that correspond to expenditure authorizations. The rationale of this mechanism is to keep under control the personnel expenses at single university level (Rossi, 2015). There is a correspondence between POMs and budget costs, as one POM correspond to around 100,000 euros. For this reason, the cost in POMs' value of each category of professors is different: a full professor position corresponds to 1 POM, an associate professor position to 0.7 POM and an assistant professor to 0.5 POM (Table 1). Every year the Ministry communicates to each university the total amount of POMs that can be used, and the universities decide how to spend them either for recruitment or for promotions of tenured professors. Therefore, recruitment and promotions compete on the same resources. Table 1 summarizes the value of each category and the cost of the promotions in terms of POMs.

	Temporary assistant professor	Permanent assistant professor	Associate professor	Full professor
POM	0.5	0.5	0.7	1
Cost of promotion	-	-	0.2	0.3

Table 1: cost in term of POMs of each category of Italian professors and of promotions

Every year some professors retire and free up resources (and therefore POMs). By defining the turnover rate, the Ministry decides in which proportion the resources coming from retirements re-enter the system in the next year. If the turnover is set equal to 1, then the same amount of resources is available in the next year. Turnover rates lower than 1 correspond to personnel budget cuts, while turnover rates greater than 1 correspond to increased resources for recruitment and promotions.

Recruitment of assistant professors is done at each university level with open competitions. For the associate professorship and full professorship, a two-step mechanism has been introduced by the Gelmini's reform in 2010. The first step is the National Scientific Qualification (NSQ): assistant professors that want to be promoted associate professors and associate professors that aspire to become full professors apply for the qualification, that is granted by national committees (one for each scientific disciplinary sector). The National Scientific Qualification has been introduced to limit local favouritism (Nieddu and Pandolfi, 2018; Sala and Bosisio, 2017; Abramo *et al.* 2015) and to improve the quality of research and teaching in the Italian university system.

Temporary assistant professors Type-B holding the NSQ obtain a tenure as associate professors when their contracts expire. This promotion is done with a simplified procedure and is nearly automatic. Those that do not get the qualification (actually a minority not relevant for statistical purposes) exit the system at the end of their three-years contract. Permanent assistant professors and associate professors holding the NSQ participate to competitions for associate professor and full professor positions respectively. These positions are decided and opened at each university level.

In our simulation model we reproduce the university system as a whole, conceiving it as it was a single university in which, at the begging of each year, resources for recruitment and promotion are set in terms of POMs. The total number of POMs depends on the turnover rate, *i.e.* by the personnel cost policy defined at Ministry level.

Focusing on the Italian context is an interesting case as the turnover rate has been lower than 1 for many years in the last decade, allowing for studying the combined effect of gender discrimination and number of positions available on the evolution and gender composition of the academia over the next century.

3. Methods and data

3.1. The methodological choice: why an agent-based model?

We study the gender gap dynamics in the Italian academia using an agent-based model (ABM). ABMs are computational models simulating actions and interactions of

heterogeneous and autonomous agents to observe the aggregate effects they produce on the system they act into. They allow to state some initial conditions, to define a set of rules depicting how a given dynamic evolves over time, and to observe the explanatory patterns and the emerging scenarios that are the results of those dynamics (Eason et al., 2007; Leombruni and Priori, 2020). ABMs are increasingly used in both hard and social sciences, and in these last they represent interesting tools to investigate social phenomena in systems characterized by complexity, displaying new emerging properties for each level of agents' aggregation. In particular, they can be used to evaluating policy measures and to formulate recommendations (Dawida and Neugart, 2011)

For our analysis we build an agent-based model to observe the evolution of gender gap dynamics in the Italian academia in a time period of one-hundred years using the software NetLogo 6.1.1.. We set up an initial scenario that is a scale reproduction in terms of gender and hierarchical composition of the Italian academia in the year 2019, and we simulate the possible outcomes, *i.e.* the dimension and the gender composition of each hierarchical level, under three different turnover hypotheses when we apply gender quotas in promotions of associate professors to full professors (or when we do not).

3.2. Overview of the computational model: starting setting

To define our starting setting we use information from administrative data of the Italian Ministry of University for the year 2019. Our model simulates a population of 1,000 agents, being a scale reproduction of the academic community in each hierarchical level and of the gender composition of each of them. Agents are therefore classified according to four *breeds*, *i.e.* the classes each agent may belong to, that are those listed in Table 2, reflecting the four steps of the academic career that we are focusing on. The composition of our initial population is as follows:

	MALES (%)	FEMALES (%)	TOTAL
TEMPORARY ASSISTANT PROFESSORS	49 (58.4%)	35 (42.6%)	84
PERMANENT ASSISTANT PROFESSORS	106 (50.5%)	104 (49.5%)	210
ASSOCIATE PROFESSORS	265 (60.8%)	172 (39.2%)	437
FULL PROFESSORS	202 (75.2%)	67 (24.8%)	269
TOTAL	623	377	1000

Table 2: the starting population of our simulation

Each agent is characterized by an AGE and GENDER[1]. GENDER is represented as a binary variable taking value "M" if the agent is male and "F" if she is female. The percentage of males and females in each hierarchical level are those reported in Table 2.

As far as AGE is concerned, since there are no data available on the age distribution of Italian professors, we assume different age ranges for each academic career rung, and age is assigned randomly to agents according to the range corresponding to the rung they belong to. In particular, for TEMPORARY ASSISTANT PROFESSORS the age range is 35-44, for PERMANENT ASSISTANT PROFESSORS it is 45-70[2], for ASSOCIATE PROFESSORS the age range is 45-70, whereas for FULL PROFESSORS it is 52 -70.

3.3. Overview of the computational model: dynamics

The starting setting evolves in a series of one-hundred subsequent cycles in which the two characteristics that define each agent, AGE and GENDER, are crucial in determining the 'behaviour' of the agent over time. AGE is a crucial variable as it rules RETIREMENTS, and RETIREMENTS determine the amount of RESOURCES available each year for recruitment and career progressions in the universities. The mechanism works as follows. At each cycle of the simulation agents increase their age by one year. Those who get 70 years old retire and are removed from the model. When retiring, agents 'free up' resources that are used to hire new professors to substitute them or to finance the career progressions of professors already in the system.

In our simulation we reproduce the mechanism of the POMs and therefore each agent in each breed is assigned with the corresponding POM values as in Table 1. The retirement of a full professor, for example, 'frees up' resources corresponding to 1 POM that can be used either to hire temporary tenure track assistant professors (at the cost of 0.5 POM each), to promote assistant professors to associate professors (at the cost of 0.2 POM) or to promote associate professors to full professors (at the cost 0.3 POM), in any combination of them. At each cycle (each year) the model computes the sum of the POMs of all the agents that retire in that period and these are made available in the next year for recruitment and promotions.

Furthermore, this amount of resources is multiplied each year by a TURNOVER parameter which expresses the personnel policy the Ministry of University chooses to adopt. In our model the TURNOVER can take three discrete values: 0.8, 1 and 1.2. If TURNOVER takes value 1, the University is investing for its staff exactly the same amount of resources of the previous year; whereas if it takes a value smaller than 1, it means that the resources available for the personnel costs are lower than those in the previous year. Vice versa, if the TURNOVER it is greater than 1, the resources for the academic staff are increasing.

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1 Conventionally, agents and variables in the model are referred to by using capital letters.

2 Because the last permanent associate professor has been hired before the Gelmini's reform in 2010.

Given the amount available, *i.e.* the total amount of POMs, the Universities choose how to spend them. This choice is not neutral as recruiting means to keep or even to increase the dimension of the academic staff and boosting the services that a university can offer, while promoting those who are already in tenured positions means to keep constant or even decrease (if all POMs available are used for promotions) the number of professors in the university. These choices depend on decisions taken at each university level, but this is not an issue we consider in our model. For simplicity, in fact, we define a standard set of rules the university system follows in spending the POMs. These are, in order of priority:

1. First, all TEMPORARY ASSISTANT PROFESSORS who are in their third and last year of contract are promoted as ASSOCIATE PROFESSORS at the cost of 0.2 POM.

2. If some POMs are left from the previous step, the resources are used to recruit new TEMPORARY ASSISTANT PROFESSORS at the cost of 0.5 POMs to substitute professors that retired: in the model they are spawned as new agents. We define a rule according to which the number of new TEMPORARY ASSISTANT PROFESSORS spawned in the model equals the number of agents retiring in the corresponding year (regardless of the academic position of the agents exiting the model) multiplied by the TURNOVER parameter. If the available resources do not cover the cost of all of them, we progressively reduce the number of new TEMPORARY ASSISTANT PROFESSORS recruited until the university can afford the cost[3].

3. In the final step, the model computes the amount of POMs left after the two previous steps and, if some resources are left (and it may be not the case in some "unlucky" periods when there are few retirements) these are used to promote PERMANENT ASSISTANT PROFESSORS to ASSOCIATE PROFESSORS at the cost of 0.2 POM or ASSOCIATE PROFESSORS to FULL PROFESSORS at the cost of 0.3 POM. In particular, we set a rule, that is a good proxy of what we observe actually occurring, such that 90% of the left resources are invested in the promotions of ASSOCIATE PROFESSORS to FULL PROFESSORS, whereas the remaining 10% are used to promote PERMANENT ASSISTANT PROFESSORS to ASSOCIATE PROFESSORS. When all the permanent assistant professors expire, all the resources are invested in promoting ASSOCIATE PROFESSORS to FULL PROFESSORS.

3 Actually, universities can also decide to hire associate professors or full professors from other universities paying them the full cost in terms of POMs. This frees up resources in the university of origin and therefore, in our model that looks at the university system as a whole, we do not consider this case.

4. At the end of this process, in the case of resources are still left (it may happen that some decimal points of POMs could not be invested), these are set aside and reinvested in the next year.

In the actual mechanism for each position opened an evaluation committee selects among candidates the one who will be promoted. Since our focus is not on the individual patterns of the agents, but on the aggregate output in terms of gender gap dynamics, we exclude such a selection dynamic to simplify the model, and we look at recruitment and promotions in a collective dimension: we calculate how many positions are opened at each cycle and how they are distributed between males and females. In fact, the second agents' characteristic that affects the evolution of our academic population is GENDER. We plug the gender gap observed in empirical evidences into our model by setting different probabilities of being recruited and promoted for males and females.

As far as the probabilities for men and women to be recruited as new TEMPORARY ASSISTANT PROFESSORS is concerned, we use the share of females (and males, respectively) temporary assistant professors hired in the year 2019 (i.e. 41,52%)[4]. After the first cycle, this probability is built recursively at each cycle taking the probability of the previous year adjusted to take into account an increasing rate of 0.5 p.p. as the share of female full professor increases. Filandri and Pasqua (2019), in fact, found that in the scientific sectors in which there are more female full professors the gender difference in the probability of promotion deceases (see Filandri and Pasqua, 2019). We therefore apply the same rule to our probabilities, and we assume that when this share of female full professor reaches the threshold of 50%, the probabilities of being recruited become equal for males and females.

More complicated is to define the probabilities of career advancement of PERMANENT ASSISTANT PROFESSORS and of ASSOCIATE PROFESSORS. We take the probabilities of being promoted for males and females from Filandri and Pasqua (2020) in which these probabilities are computed as marginal effects with of a logistic regression in which individual's scientific productivity, seniority, university size, and macro-disciplinary sector are controlled for. Using the results of those estimates, we compute the combined probabilities of having the NSQ and of being promoted on the overall population, and we transform them into complement percentages to be used into the model at the initial time. Again, we assume a decreasing gender gap as the share of female full professor increases. Following Filandri and Pasqua (2019) we assume an increasing rate of 0.5 p.p. in the probability of promoting a woman up to a share of 40% at which gender differences disappear. Furthermore, administrative data show that also different turnover policies affect the probability of promotion of women with respect to that of men. In particular, we observe an increase of 1% in the probability of promoting women with respect to men as

4 This proportion of women employed as assistant professors has been stable over the last 5 years.

the turnover increased from 80% to 100%, and we project the same increase when we assume an increase in the turnover to 120% (for which data are not available. Table 3 and Table 4 report respectively the probabilities of permanent assistant professors to be promoted as associate professors and of associate professors to be promoted as full professors that we use for males and females at the first cycle of the model.

PERMANENT ASSISTANT PROFESSORS	MALES	FEMALES
TURNOVER = 0.8	61.2%	38.8%
TURNOVER = 1	60.2%	39.8%
TURNOVER = 1.2	59.2%	40.8%

Table 3: combined probability of permanent assistant professors of being promoted to associate professors for males and females, under different turnover regimes

ASSOCIATE PROFESSORS	MALES	FEMALES
TURNOVER = 0.8	80.4%	19.6%
TURNOVER = 1	79.4%	20.6%
TURNOVER = 1.2	78.4%	21.6%

Table 4: combined probability of associate professors of being promoted to full professors for males and females, under different turnover regimes

After the "time zero", the model updates these probabilities at each cycle, taking into account the increasing trend of the share of females and some possible stochastic fluctuations in the range between -2% and +2%.

According to the above defined probabilities, we therefore simulate promotions of PERMANENT ASSISTANT PROFESSORS to ASSOCIATE PROFESSORS and of ASSOCIATE PROFESSORS to FULL PROFESSORS.

3.4. Personnel policies and gender policies

Having set the baselines dynamics of our academia, we observe its evolution and gender composition under the above defined rules, and then we investigate how this evolution changes under different personnel policies, *i.e.* under the three different TURNOVER values (1, the 'vanilla' scenario, 0.8 and 1.2). Finally, we simulate the effects of implementing a gender balancing mechanism on the promotions of ASSOCIATE PROFESSORS to FULL

PROFESSORS reserving a quota of 40% to each gender. The competition for the remaining positions reflects the mechanism of dynamic probabilities discussed above. Then, we test this gender quotas hypothesis under the three different TURNOVER regimes. Therefore, we simulate six different scenarios, combining these two different policies as reported in Table 5.

	Personnel policy (expressed as turnover levels)		
Gender balancing policy	Turnover = 1	Turnover = 1.2	Turnover = 0.8
No gender quotas	A1	A2	A3
Gender quotas on promotion to full professor	B1	B2	B3

Table 5: summarization of the scenarios

4. Results

For each of the scenarios presented in Table 5, we perform 1000 replications of our model, each reproducing 100 cycles (*i.e.* simulating one-hundred years). The results that follow are computed by calculating the average values of each cycle across the 1000 replications and considering their relative fluctuations within their 95% confidence intervals. While presenting the results we do not mention the dynamics affecting permanent assistant professors since their participation to the model is limited to the first 25 cycles of the simulation and then their agents class expires. In any case their dynamic seems to be relevant only as long as it impacts the available resources dedicated to promotions of associate professors to full professor.

Administrative data currently available display that the recruitment of new assistant professors is more gender balanced that it was in the past and with respect to promotions. The first question we aimed at answer is whether such a trend is sufficient to yield a more gender balanced composition of the Italian academia and how long this process will take to reach a perfect gender balance. Figure 1 reports the gender distribution of each academic ladder expressed in absolute numbers, under a turnover regime equal to 1 and with no gender quotas (scenario A1) and it clearly displays that with no gender quotas an equilibrium in promotions of males and females at the highest ladders of the academic career will be achieved only in 87 years. In other words, this means that a young woman getting today her Ph.D. has will never see the gender equality in academia until her retirement, and the same is valid for all her youngest colleagues entering the academia from now onwards at least for the next half of century and more.

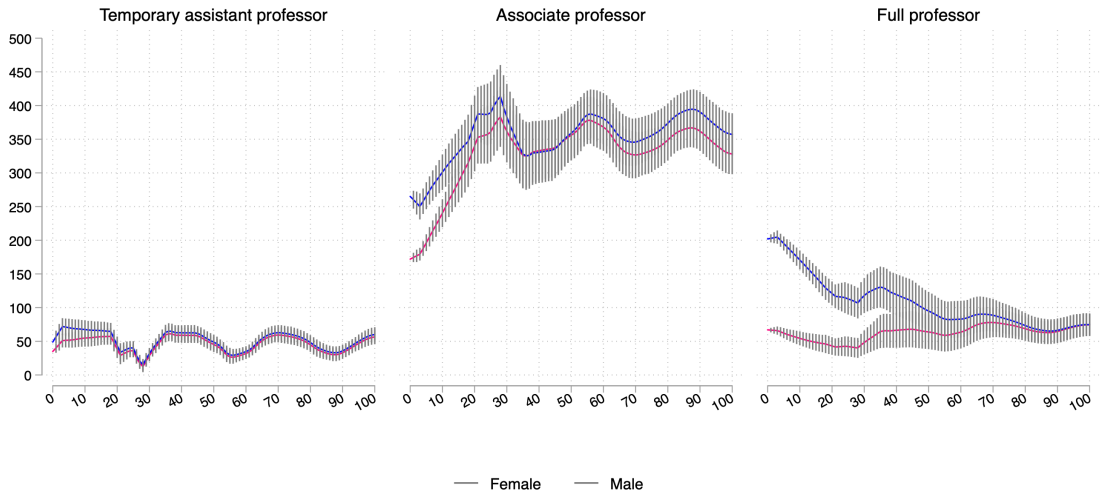

Figure 1: evolution of the academic composition under the "vanilla case"

How does the previous result change with an increase in the resources available for recruitment and promotions, *i.e.* assuming a value for the TURNOVER greater than 1? Figure 2 shows the share of females (expressed as a percentage) for each academic rung under the three different turnover regimes, if no gender quotas are introduced. As the sequence of graphs clearly points out, even if a slight improvement emerges (*i.e.* the curve representing female full professors gets a bit steeper) as the turnovers increases, the gender gap is far to be filled, and the system is not able to achieve gender equity in the next 80 years, especially if we look at full professors.

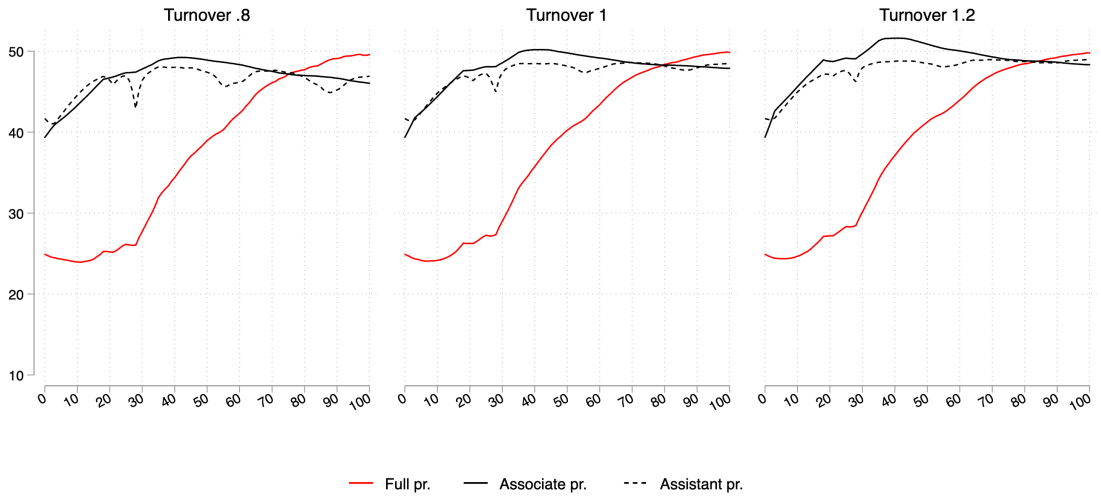

Figure 2: the effects of a turnover increase while no gender quotas are applied

The results discussed so far lead to the third – and main – research question of the present work: would the introduction of gender quotas be effective to achieve a perfect gender balance? And how long will it take to have perfect gender balance? Figure 3 shows gender distribution of each academic ladder in absolute numbers when the turnover is 1 and gender quotas applies: by applying from today the first year (*i.e.* starting today!) gender quotas at 40%, a perfect gender balancing also in the highest ladder of the academic career is reached in 30 years, with a consistent reduction of the gap yet in the first 20 years. After the first thirty cycles, the model reaches its steady-state equilibrium. Thus, gender balancing policy would be effective in anticipating gender equality in academia by more than half a century.

It is also interesting to compare the dynamic of complementarity between associate and full professors by comparing Figure 1 and Figure 3. In fact, as full professors reach the gender parity, associate professors seem to display a majority of male population and vice versa, *i.e.* when gender quotas are not applied, we observe more gender equality among associate professors whereas full professors show a greater gap. However, this is just the effect of the continuity of the two steps of the academic career: by emptying one basin the other is filled.

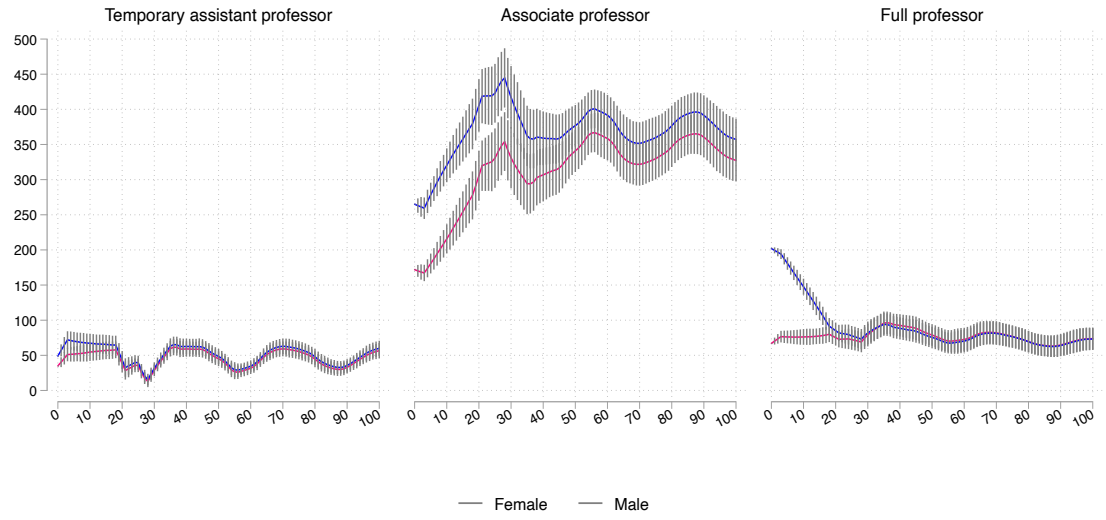

Figure 3: evolution of the academic composition introducing gender quotas

Finally, we simulate the effect of gender quotas under different turnover regimes. Figure 4 depicts the share of females (expressed as a percentage) of each component of the academic staff under different turnover scenarios. Increasing turnovers do not speed up significantly the process of gender balancing.

Our model seems to suggest that introducing a gender quotas mechanism in the promotions of associate professors to full professors would be effective in reducing and even closing the gender gap in academic career within a time period of thirty years, whereas, in the absence of such a policy, gender discrimination in academia will persist over almost all the next century.

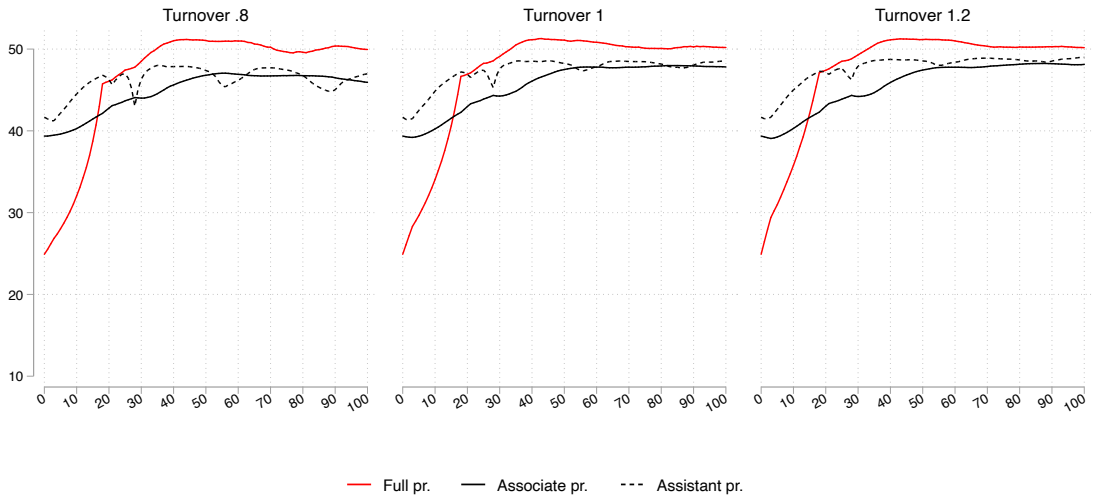

Figure 4: the effects of a turnover increase under a gender quotas regime

Conclusions

The article presents a simulation model to unfold how gender gap in the Italian university systems may evolve over the next century under different policy scenarios. An agent-based model is built in order to analyse the effect of two different policies: the application of different turnover regimes (displaying how many resources universities invest in recruitment and promotions of their staff) and the introduction of a gender quotas system in promotions to the highest ladder of academic career (*i.e.* to full professor level). Our simulations show that, even considering the current increasing trend in the share of females for each academic rung, if nothing will be done, gender parity will be achieved only in more than 80 years. Increasing resources available for recruitment and promotions yields results slightly better in terms of gender balance. It is only by introducing a gender quotas mechanism, reserving the 40% of the positions to each gender in the promotions to the highest ladder (*i.e.* to full professor) that would be possible to reduce and even close the gender gap in 30 years, anticipating such an achievement by fifty years.

Our simulation provides interesting suggestions to policy makers. In fact, the model allows to shed a light on the mechanisms yielding gender inequality in universities, and on those which, instead, may reduce and even close such gap. Further developments of such a study may interest the inclusion of selection committees to evaluate candidates to competition for recruitment and promotion, with dynamics that allow to investigate agents' interactive behaviours. Moreover, even if the model is thought to represent gender inequalities in academia, it might also fit to analyse other discrimination issues acting within academic systems and/or other contexts where gender discrimination persists.

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