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Article

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Overcoming a legacy of racial discrimination: competing policy goals in South African academia

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Abstract

Because discrimination is systemic, efforts to counter it must also be systemic. The South African case is instructive because it is extreme: Apartheid deliberately excluded the majority of the population, Black South Africans, from fully participating in society, but post-Apartheid efforts to achieve transformation have had limited success. This article examines the university system, where transformation involves increasing the size of the system; improving scientific quality and changing the racial composition. This will require more Black South Africans to do PhDs, to select academic careers and to be selected into the top universities. Policy interventions can be developed for each of these elements, but will they be complementary or contradictory? We simulate a calibrated model to address this question. Results reveal direct trade-offs, with different combinations resulting in different benefits. By highlighting the differential gains of different policy combinations, this article can support informed policy-making about a highly complex issue.

Keywords: discrimination, universities, public policy, labor market institutions, social change, Africa

JEL classification: I2 education and research institutions, J15 economics of minorities, races, indigenous peoples and immigrants, non-labor discrimination, J7 labor discrimination

1. Introduction

In recent decades, we have seen once again the growth of negative attitudes and stereotypes about 'others'. Throughout the world, the rise of nationalist populism and anti-immigrant views has threatened to further exclude groups that have long struggled to achieve full

integration into society.[1] In many societies, this resurgence interacts with legacies of the past in which specific groups have been excluded from desirable, attractive or prestigious positions, creating a very difficult challenge in terms of integrating, and not (re-)excluding, 'minority' groups. There are two aspects to this issue: the presence of discrimination in various forms and origins; and the effect that past and present discrimination has on various features of a society.[2]

In this article, we focus on the second: are there policies that can mitigate the effects of existing discrimination? The context we examine is higher education in South Africa: South Africa because it has a long and extreme form of racial discrimination, and is currently in the throes of a transformation to a 'color-blind' society; higher education because opening the system to previously excluded groups is important both as regards fairness, and as a way of improving the pool of human capital that underlies social and economic development.

The question is investigated using a simulation model of faculty turnover through hiring and retirement. When faculty members retire, they are replaced by newly minted PhDs. In the hiring process we model, both sides of the market (hiring departments and PhD graduates) care about two things: quality and race. Candidates prefer to work in high-quality departments, and departments prefer to hire high-quality candidates. At the same time, candidates prefer an environment that is welcoming to those of their race (reflected in the current racial composition of the department); department preferences (may) include homophily,[3] that is, a preference to hire candidates whose race 'fits' the current department composition. On the basis of those preferences, candidates are matched to job openings using the Gale–Shapley marriage-matching algorithm. Endogenous dynamics arise because PhD candidates, constituting the supply side, are (in-)bred by the faculties, constituting the demand side. Key is the assumption (based on recent data from the Department of Higher Education in South Africa) that PhD graduates 'inherit' both quality and race from their graduating departments.

The policy analysis assumes that policy makers could have four items on their menu of policy options: the principle governing the overall growth of the system (uniform over universities, by excellence, or by race); the proportion of Black candidates in the pool of prospective PhD students; the number of PhD students competing for each job; and the extent to which 'incestuous' hiring is discouraged. On the other hand, it is assumed that policy has

1 For discussion, see the symposium in Ethnopolitics (2018).

2 Pager and Shepherd (2008) provide a good overview on past and present discrimination (theory and practices). We adopt in the following their broad definition of racial discrimination as 'unequal treatment of persons or groups on the basis of their race or ethnicity' (Pager and Shepard, 2008, p. 2). Loury (1977) clarifies how past discrimination perpetuates into the future despite (superficial) 'equal opportunity'; and Reskin (2003) argues for research on the transmission mechanisms that generate group inequality rather than explaining discrimination.

3 In the following, we use 'homophily' broadly to denote 'a preference for similar others', in order to emphasize that, in one way or the other, this may be a decision criterion. Note that our use is slightly different from others, e.g. McPherson *et al.* (2001) focus on the social outcomes that reveal such preferences. For us, homophily is a generic term that ignores the causes of such preferences, but homophily may lead to differential treatment by group membership; be it warranted or unwarranted. Reskin (2012) uses the term 'discrimination' only in the latter case. Note that we do not discuss under what conditions race homophily in academia could be warranted, but simply refer to any differential treatment resulting from race homophily as discrimination.

no effective means to end existing discrimination or to intervene directly in the hiring decisions of individual universities. Policy success is similarly multidimensional: success is measured not only by the prevalence of Black academics in the system but also by the system's overall size, overall quality and whether there is a general difference in quality between the incumbent groups and the formerly excluded groups. We compare different combinations of policies with the currently implemented policy mix, as the system develops over two generations.

What we find is that it is possible to do better, but no policy mixture we examine produces a future that is strictly worse than the future produced under the policy mix as calibrated. Over the future we examine, there are alternative policy mixes that perform better in every policy objective than the currently implemented policy mix (i.e. some policy mixes strictly dominate the current mix); but there is no alternative policy mix that is worse in every objective (i.e. no alternative policy mix is strictly dominated by the current policy mix). Importantly, though, most policy mixes are better in some dimensions and worse in others. Quality-oriented policies, here allocating new positions to departments based on excellence, and increasing competition among candidates by reducing patronage in hiring, tend to increase quality at the cost of crowding out Black job candidates due to the initial correlation of 'whiteness' and quality at the department level. In the same vein, a policy that favors growth of the formerly disadvantaged institutions tends to increase the presence of Black faculty in the system, but at the risk of reducing overall quality as well as increasing racial inequality within the system. This risk, however, can be mitigated. If the production of PhDs is increased, then formerly disadvantaged institutions are in a better position to grow by hiring high-quality (mostly White) PhDs from formerly advantaged institutions, and thereby increasingly train higher quality (mostly Black) PhDs who can apply successfully at formerly advantaged institutions. Our simulations suggest that the resulting convergence in terms of race and quality lifts the system onto a higher quality trajectory.

Our model builds on the observation that in academia an important step of human capital formation of the next generation takes place inside the faculty (and is thus subject to local externalities). Applicants for positions are not created 'exogenously' to the system. Indeed, individuals are selected into, and trained within the system to which they later apply for permanent positions. Modern academic systems, since their foundation in the 17th history, are hierarchical in that faculties and the individuals composing them tend to be ranked by status—'scientific excellence' or 'scientific merit' (Beaver and Rosen, 1978)—which we refer to as 'quality' in the following. This hierarchy is to a large extent self-reproducing. Academics transmit some of their quality to their PhD graduates who enter the academic job market to become the next generation of academics (Clauset *et al.*, 2015; Cowan and Rossello, 2018; Lee *et al.*, 2021). What makes this particularly apposite is that in many countries, and particularly in South Africa, we can observe racial stratification along the status hierarchy—Black academics tend to be found in lower tier universities, and the top universities are disproportionately staffed by White academics. We observe further that PhD graduates of universities in South Africa tend to 'inherit' not only quality, but also the racial distribution of the faculties from which they graduate. Given that PhD graduates are the applicants to academic job openings, this is an important source through which the system will tend to reproduce itself.

The inheritance of race and quality from faculty to PhD graduates is akin to local externalities in human capital formation of racially segregated groups as studied by Bowles *et al.*

(2014), for example. They model a nondiscriminating but segregated society where the decision of the young generation to invest in human capital (pre-labor market) depends on the human capital of the older generation in their social environment. They show that if segregation is sufficiently high, then group inequality in occupation may persist in the long run due to higher within-group spillovers in human capital formation. Further, they find that even were integration to occur, the process through which it happens may involve an aggregate decrease in human capital, and in particular of that of the previously advantaged group. Given that the disadvantaged group in South Africa comprises more than 80% of the population, this result is particularly relevant, and calls for an examination of policy that can address both integration and quality. The policy implication that follows directly from Bowles *et al.* (2014) is that racial de-segregation may be a relevant necessary condition to achieve racial equality in economic outcomes, even in the absence of discrimination. Different from Bowles *et al.* (2014), though, in our model racial segregation of the local social environments (here departments) is not fixed but is endogenously determined through the academic job market. Our analysis delivers the insight that, even in the presence of race homophily, the job market can contribute to racial mixing to the extent that local applicant pools are dominated by applicants of different color than the hiring institution. That can be influenced by national science policy — in our model by steering the growth of institutions and number of PhD graduates.

To clarify the intuition, imagine a case where there is one low-quality red institution and one high-quality blue institution. De-segregation only occurs if there is a flow of graduates from one institution to the other. This is trivially achieved if one institution constitutes all the demand and the other all the supply. In a less extreme case, this will be achieved if there is a sufficient number of high-quality applicants of the other color in the local pool. Consider an initial phase where the higher quality, blue institution is the dominant supplier. This has two effects: It causes integration of blue into the red institution; and raises the quality of the red institution. The latter effect can create a second phase where the graduates of the red institution (still mostly red) are of high enough quality to be hired by the blue institution. This process can overcome color homophily in hiring if departments care about quality and quality differentials are strong enough.

Our focus on changing organizational composition also relates to, and complements, research on biased referral hiring as an organizational practice. That literature tends to center on how a firm's social composition (gender, racial or ethnic) creates a local bias in the (firm specific) labor pool, which tends to sustain the firm's social composition.[4] However, in that literature it is often assumed that all potential employees are equal except for their group membership and, therefore, *hiring is uniformly at random among the applicants*.[5] This assumption permits one to model changes in the organizational composition as a statistical Markov process that permits mean-field analysis. In our model, after PhD training, applicants are characterized both by social group membership (race) and by scientific quality. Thus, we replace the analytical Markov mean-field device prevalent in that literature by an explicit job market that matches small numbers of applicants to faculties by quality and

4 See, for example, Arvidsson *et al.* (2021), Rubineau and Fernandez (2013), Rubineau and Fernandez (2015), Tassier (2005, 2008).

5 Even models of referral hiring in academia (Hopkins, 1980; Becker and Williams, 1986; Johnson and Wiley, 2000) ignore the formation of and sorting by scientific human capital.

potentially further characteristics. This changes the model's dynamics.[6] Moreover, it shifts the focus from organisational hiring practices to institutions beyond the organisation. For example, Rubineau and Fernandez (2013) suggest that hiring biases due to referrals can be mitigated by letting members of one (incumbent employee) social group more often provide referrals than members of the other group. Our results, in contrast, suggest options for national policies governing the whole population of organisations in the presence of organisational hiring biases. Finally, unlike much of the literature on population mixing, we are concerned not only with the racial composition of the institution, but also its performance, measured here as both aggregate quality, and the correlation between race and quality. The upshot here is that more traditional science policies focusing on scientific excellence and massification should and can complement 'redress policies'. We return to this point in the analysis.

Our model includes further features of the academic system that immediately affect de-segregation dynamics. For example, the model allows for preferential hiring of own graduates—as observed in the South African data—through a parameter that we call 'same department attraction'. There are multiple causal explanations for this phenomenon (transaction costs, risks, fit, etc.). The formation of social job contact networks may be part of the explanation, and the same department attraction in our model may be considered a condensed form of the social network effects described in the literature on (endogenous) job contact networks.[7] However, our analysis does not address the origins or exact workings of such effects but rather their impacts on organisational composition dynamics.

Notice that our work departs from all the literature discussed above most importantly by addressing a different research question. Related research in economics and sociology dealing with formal models tends to ask whether a certain factor or process in isolation may create or sustain a racially segregated society. Scholars typically note that 'their' proposed mechanism is certainly only one of many relevant factors that sustain inequality, but then examine that mechanism in isolation. Because these analyses address an 'in principle' question, they tend to focus on the long-run, using equilibrium (steady-state distribution) solutions of the theoretical dynamic system. In contrast, we ask how to overcome a racially segregated system that is subject to various mechanisms within the foreseeable future (the 'long run' may be many generations in the future after all) without compromising other

6 Partly because both applicants and hirers have quality standards and outside options which means that not every applicant gets a job, and not all job openings are filled; and partly because mean-field approaches, in general, 'smooth' stochastic processes.

7 Bramoullé and Saint-Paul (2010) model a Markov process where employment and social ties co-evolve as the working place itself is a place where friendships are created. Thus, people who have been working are better connected to the working world once unemployed. Calvó-Armengol (2004) models strategic formation of inter-individual job contact networks. Buhai and van der Leij (2021), in a multistage game, model a homophilous network formation process, which is simply a consequence of bonding during human capital formation at a prior stage. Tassier and Menczer (2001) propose an evolutionary model of job contact tie formation where strategies (in terms of number of connections) reproduce if they are profitable. Gemkow and Neugart (2011) propose an agent-based model with endogenous network formation as an investment that yields benefits through (potential) referrals. Galeotti and Merlino (2014) endogenize the intensity of job network investments by varying their payoff with labor market conditions, but they do not consider group inequality.

relevant policy objectives. This research question becomes more pressing with every year that (racial) group inequality, for whatever reasons, persists.

It is worth noting that South Africa is not alone in facing such a problem. India, for example, reserves faculty positions for members of scheduled tribes, scheduled castes or 'other backward classes', but in September 2021 only 449 of 1439 such positions had been filled.[8] This is particularly discouraging given that the Indian government actively encourages applications from those groups.

The USA faces similar issues: in 2015 the Washington Post asked, 'Where are all the Black college faculty?'[9] Still in 2021, people who self-identified as Black constituted about 14% of the US population, yet (in 2020) among all university faculty in the USA only 7% are Black, and of full professors only 4%. The American Council on Education (Griffin, n.d.) observes that improving the representation of ethnic minorities in academia involves addressing the academic pipeline. Griffin goes on to state that this addresses only one part of a complex problem. The system must, among other things, make academia an 'attractive option' (p. 275) for currently 'excluded' groups. We similarly argue in our case that it is not sufficient to focus on one remedy.

The article proceeds as follows: Section 2 provides some background on South African higher education policy issues, providing a basis for the model structure and calibration in Section 3, and the policy analysis in Section 4. The effect of ongoing homophily in the race and quality dimension, taken as given in the policy analysis, is discussed in Section 5. Robustness checks are presented in Section 6 and conclusions in Section 7.

2. Background on South Africa

Arguably, few countries have struggled with issues of discrimination as much as South Africa. Moreover, the underrepresented 'minority' is in fact an overwhelming majority. In spite of their dominance in the economy and also the university system, White South Africans account for only about 10% of the population. Our focus on the university system is motivated by the fact that the university is increasingly important in generating economic growth. Equal participation in the education system has become a precondition for equal opportunity in all other spheres of social life. Yet, the denial of such opportunities was one of the pillars of Apartheid, where educational opportunities for Black South Africans were explicitly and systematically limited (Reddy, 2004).

When Apartheid ended, a key goal was to provide Black South Africans with access to educational opportunities. This required the transformation of the university system itself: Academic staff across the country at the time was overwhelmingly White (83%) and male (69%), and almost all of the few Black faculty members were found in the under-resourced and low-quality historically Black universities (Badat, 2010).

In a series of policy papers, the national government followed a science and higher education strategy centering around the two-fold objective of achieving equity to overcome the legacy of apartheid, and performance in education and research to support the knowledge

8 Lakshman (2022) accessed at https://www.thehindu.com/news/national/only-30-of-sc-st-obc-faculty-vacancies-filled-at-iits-central-universities-in-a-year-centre/article66289565.ece on March 24, 2023.

9 Strauss (2015) accessed at https://www.washingtonpost.com/news/answer-sheet/wp/2015/11/12/its-2015-where-are-all-the-black-college-faculty/ on March 24, 2023.

economy.[10] Public higher education institutions—research or comprehensive universities and technical universities—are autonomous but not independent (RSA, 1997). The Ministry of Education exercises control as the main funding agency.[11] Its main steering mechanism is a formula-based distribution of block grants to universities that rewards education (student intake and throughput) and research (papers, doctorates). In 2004, the approach shifted from applying the formula on historical accounts to applying it on forward-looking 3-year rolling plans (MoE, 2004). This new budgeting process strengthened control by the ministry. Universities provide detailed 3- and 5-year plans that include targets on various indicators that can be mapped to government's objectives—for example number of doctorates and staff to be hired by position and by race and gender (see e.g. Stellenbosch University, 2017). How to organize is then largely left to the university. Early on, affirmative action officers were hired, programmes instituted to target potential Black academics, and flexible hiring principles introduced, e.g. that Black candidates with potential might be appointed on a lower rank than advertised (Hugo, 1998). Typically, the faculty takes an important role in planning (bottom-up) as well as in implementation processes (Arumugam, 2019). In particular, the selection of doctoral candidates and academic staff is decided on that lower level (Badat, 2015, p. 191; Cloete *et al.*, 2015, p. 142). A national system of qualifications provides the pre-condition for a national academic job market, but faculties may also specify additional eligibility requirements for (doctoral and faculty) applicants.

Growth of the system post-1994, plus various policies encouraging Black participation have supported the growing presence of Black students and faculty. However, the stratification along quality lines (present in virtually all university systems) is reflected along racial lines. By 2018, on aggregate faculty were more representative of the demographics of the country than in 1996.[12] But the chances of meeting a Black academic in a historically disadvantaged (i.e. Black) university are still twice as large as in a White university.[13] These universities by and large still have only limited participation in research activity. In contrast, at the seven universities that deliver three-quarters of the PhDs in South Africa, 73% of faculty were White. At the three most highly ranked South African universities, the Universities of Cape Town, Stellenbosch and Witwatersrand, 80% were White.

10 Most relevant are the 'White paper on science and technology' (DST, 1996), 'South Africa's national research and development strategy' (DST, 2002), 'White Paper on Science, Technology and Innovation' (DST, 2019). Emphasis shifted from equity in the 1990s to expansion and performance in the 2000s, recently shifting back to equity again.

11 Numbers vary over years and institutions, the ministry provides roughly 60% of the university budget (90% through block grants, 10% through earmarked grants), student fees 30%, 10% from other sources. Additionally, there are national initiatives. For example, the National Research Foundation of South Africa set up the 'South African Research Chairs Initiative' to fund 250 research chairs (mostly for Blacks).

12 The ratio of white to Black academics decreased from 0.92 to 0.68. This and all other figures in this paragraph are based on own calculations using the calibration data, described in the Appendix.

13 See the Appendix A for definition and listing of historically (dis-)advantaged universities. Racial classification under Apartheid was complex, with a hierarchy of White, Indian, Colored (mixed-race) and Black Africans. Redress policies are similarly complex. In this article, we focus on the most disadvantaged, Black Africans, but acknowledge the discrimination suffered by other people of colour. We are aware that our focus on White and Black academics simplifies a more complex reality.

This distorted distribution touches more than fairness. Research-intensive universities are key in generating new knowledge, and the underrepresentation of Black scholars is likely to skew the process of knowledge creation. To allow Black academics into the system but *de facto* only as consumers rather than as producers of knowledge limits their full integration into academia and by extension the society it serves. In other words, to measure the transformation of the South African university system by looking simply at the proportion of Black relative to White academics is not enough. While the proportion of Black academics has been increasing, the social mixing needed to de-segregate the system has not yet taken place. To achieve meaningful transformation, Black and White academics should be indistinguishable in terms of their quality, and in terms of the quality of the institutions where they are located. Thus, equality in their quality as scholars as well as in the distribution of academics must be pursued.

An initial step in transforming the university system is to develop quality Black scholars. Prof Max Price, Vice-Chancellor of the University of Cape Town in 2014 explained that transformation was slow because many competent Black students choose careers outside academia.[14] Although he was challenged for making the claim, the absence of appropriate Black applicants for faculty positions in South Africa could be partly due to perceived occupational (non-) opportunity or opting out; as research in the US context suggests (Beasley, 2012; Byars-Winston *et al.*, 2015). On the other hand, persistent discrimination on the demand side of the academic job market, taste-based (Becker, 1957) as well as statistical (Phelps, 1972; Arrow, 1973), seems hard to reject: Although White academics insisted that they were impartially upholding quality standards, the experience of Black academics was often that quality criteria were inconsistently applied and that they were held to higher standards than White candidates (Mabokela and Mawila, 2004; Thaver, 2006). Furthermore, after decades of Apartheid (literally: apart-hood), it seems plausible that White academics faced relatively high search and evaluation costs when hiring from the other group. Although scientific evidence is clearly lacking on the extent of demand- and supply-side biases in the South African academic job market (and even more so on what exactly causes them), biases are most likely present. This sort of homophily is present in our model, but as an exogenous factor about the strength of which we are uncertain.

Another relevant contextual factor is the expansion of the university system with the aim to provide tertiary education access to more of the population. 'Massification' entails diversification into different types of institutions (e.g. research-oriented universities or teaching-oriented technical universities) as well as growth within institutions, and is often seen as involving a quality–quantity trade-off (Guri-Rosenblit *et al.*, 2007). In South Africa, that discussion has a strong relation to the discussion on (racial) transformation (see e.g. policy documents cited above). Increasing the size of the university system has the dual consequence of increasing learning opportunities for South Africans and of creating more vacancies for new entrants into academia. A larger system could help allay the anxieties of White academics about being displaced—the pie is growing rather than being redistributed. On the other hand, (historically White) universities of high reputation in particular are concerned about a potential reduction in quality for various reasons: intake of lower quality students, reduction of teacher–student ratios and/or hiring lower (teaching) quality faculty

14 http://www.theguardian.com/world/2014/oct/06/south-africa-race-black-professors (accessed February 15, 2016; February 1, 2023).

members—in a context where signals of quality tend to be correlated with skin color. Massification is complex (Guri-Rosenblit *et al*., 2007) and it seems likely that it is not massification per se that threatens quality, but the lack of appropriate management of the evolving academic and policy landscape. In other words, policy interventions to increase the size of the academic system can co-exist with policy interventions to increase quality in the academic system.

In the next section, we develop a model that includes the features of a transforming academic system discussed here.

3. Model

Section 3.1 sets up the structure of the model, Section 3.2 specifies the implementation of the model, and Section 3.3 presents some typical simulations showing how different parameter settings yield different policy outcomes.

3.1 Model structure

The focus of the model is on the changing (racial) profile of the faculty of the university system. Because faculties evolve through changing personnel, the model is essentially about movements of PhD graduates into faculty positions.

The basic structure is that every period a given proportion of the faculty exits academia (by retirement or other channels) and is replaced by recent PhD graduates. A given number of PhDs graduate every year, and are placed in faculty vacancies using the Gale–Shapley marriage-matching algorithm (Gale and Shapley, 1962). Formally, the model is constructed as follows.

There are 20 departments each having 20 faculty members. Each period the oldest 3% of the faculty retire.[15] Similarly, each year G PhDs are graduated looking to pursue an academic career.[16] Every agent in the system has both a race, r — Black or White — and a quality, $q > 0$. The G graduates form one side of the labor market, departments with vacancies due to retirement form the other. Graduates are placed using the Gale–Shapley algorithm, which involves each graduate evaluating each department, and vice versa. We can speak of 'utilities' of a department hiring any particular graduate, and the 'utilities' of a graduate being placed in any particular department.

Utility functions

We will speak of the 'race' of a department, R, as the mean value of the race of its members, and similarly its quality Q as the mean quality of its members. For both job candidates and hiring departments we assume Cobb–Douglas utility functions.[17]

15 Three percent because an academic career lasts approximately 35 years.

16 This is consistent with (many) more than G PhDs graduating, but only G of them intent on pursuing an academic career.

17 We note that race and quality are of course not the only considerations of a graduate considering a position. University management, natural or urban surroundings . . . all matter in reality. But these are hard to model and also distract from the processes we examine, so they have been excluded from the utility functions.

The utility graduate j receives from being hired by department i is written as:

$$U_{j,i} = Q_i^{(1-h_g)} \times (2 - |R_i - r_j|)^{h_g}, \tag{1}$$

where Q_i is the quality of the hiring department; $2 - |R_i - r_j| \in [1, 2]$ measures how close are the race of the graduate and the department; and h_g is a measure of homophily in preferences of graduates. Department preferences are similar (with q_j being the quality of graduate j):

$$U_{i,j} = q_j^{(1-h_d)} \times (2 - |R_i - r_j|)^{h_d}. \tag{2}$$

We add two nuances to those utility functions. First, both departments and applicants may have quality thresholds below which they are unwilling to consider a placement. We define this threshold such that a department will not consider an applicant whose quality is less than a given fraction of its own quality. That is, an applicant i such that $q_i < T \times Q_j$ will not be considered. Similarly, an applicant will consider no department whose average quality is such that $Q_j < T \times q_i$.[18]

Second, Cowan and Rossello (2018) show that close to two-third of first jobs for PhD graduates are in their own graduating department. Departments appear to have a preference for their own graduates (and graduates for their own departments). Thus, in the utility that a department receives from a new hire, there is a bonus if it is an internal candidate, and a similar bonus for the graduate (*Same department attraction S*).

Combining those additions the utility functions become:

$$U_{j,i} = \begin{cases} Q_i^{(1-h_g)} \times (2 - |R_i - r_j|)^{h_g} \times S_{i,j} & \text{if } Q_i \geq Tq_j \\ -\infty & \text{otherwise} \end{cases} \tag{3}$$

$$U_{i,j} = \begin{cases} q_j^{1-h_d} \times (2 - |R_i - r_j|)^{h_d} \times S_{i,j} & \text{if } q_j \geq TQ_i \\ -\infty & \text{otherwise,} \end{cases} \tag{4}$$

where $S_{i,j}$ takes a fixed value $S \geq 0$ if $i = j$, and 1 otherwise. We vary the parameter S to introduce the possibility of 'anti-nepotism' policies of the type that do exist (to varying extents and effectiveness) in several countries.

Graduate quality

Graduates inherit the quality of their graduating department, with noise. Specifically, if the mean quality of the faculty in a department is Q with a standard deviation of σ, then the quality of a graduate is drawn from a normal distribution, $N(Q, \sigma)$.

Graduate race

Empirically, there is a strong correlation between the race of PhD graduates and the race of the graduating departments. A graduate from department j is Black with probability $f(R_j)$ and White with probability $1 - f(R_j)$. The function $f(R)$ is described below.

18 With this parameter (when $T < 1$) we introduce some homophily in quality.

Job market

Each period M faculty members exit, and $G \geq M$ PhD graduates enter the academic job market. Departments with open positions rank the applicants using equation (4), and each graduate ranks the departments using equation (3). Applicants are placed into departments with open positions using the Gale–Shapley marriage-matching algorithm with untility functions as defined above.[19]

We run the model for 70 periods, representing about two generations of faculty.

3.2 Implementation and calibration

The implementation of the model is based on a calibration using data from the Department of Higher Education and Training (DHET), made available at the Higher Education Data Analyzer (HEDA) website[20] and excel files additionally provided by DHET. These are administrative data filed each year by all universities in South Africa. The currently available data run from 1995 to 2020, covering all universities in the country.[21]

Departments. In the model, we have 20 departments each having initially 20 faculty members.

To initialize department quality, we treat the first seven departments as the research-intensive departments. They have quality evenly spaced between 7 and 10; the other 13 departments have quality evenly spaced between 1 and 4. Initially, within each department, an agent's quality q_i is department quality multiplied by a uniform random number $\epsilon \in [0.95, 1.05]$. Initially faculty in the first 10 departments are 80% White, 20% Black; in the remaining 10 departments the reverse: 80% Black and 20% White. Thus, initially while all departments are dominated by one or the other color, departments are not completely homogeneous. And in the initialization, department quality is strongly associated with its race composition.

Retirements and graduations. Each period, the oldest 3% of the faculty exits. Each period, G PhDs enter the academic job market. G is a parameter we vary, being a multiple, *gradscale*, of the number of retirements, that multiple ranging from 1.2, for a thin market, to 1.6 for a thick market. There are always more applicants than jobs, sometimes many more.

Productivity in PhD production. We base the department allocation of PhD graduates on their historical trends. In our simulation, the first 10 departments, representing the historically White universities, account for 62% of PhD graduates, 38% are allocated to the second 10 departments. Within each subgroup in any period, the distribution of PhD graduates over departments is (probabilistically) equal to the size of the department multiplied by its historical productivity.

19 The thresholds in the utility functions imply that some applicants may not be hired, and some vacancies may not be filled. In the former case, we assume that the applicant leaves academia. In the latter, the department retains the vacancy and tries to fill it in the next round. It retains vacancies indefinitely. It is in principle possible for a department to shrink to size zero. We have assumed that if a department shrinks too far, then drastic measures will be taken to prevent its disappearance. So, in the model, if a department shrinks to 15, we arbitrarily add a faculty member who resembles the average of the current faculty in quality and race, to prevent the size from falling below 16.

20 https://www.heda.co.za/PowerHEDA/dashboard.aspx\#divPDS (accessed December 2022).

21 More details of the calibration are presented in the Appendix B.

Race of graduates. Each graduate also has a race. Between 1995 and 2020, there has been a very strong relationship between the racial compositions of a faculty, its Honours graduates,[22] and its PhD graduates. Thus, the race of a PhD in the simulation is modelled such that the probability that a graduate of university j is Black is:

$$f(R_j, H_j) = 0.5R_j + 0.5H_j \tag{5}$$

where R_j is the proportion of Black faculty, and H_j is the proportion of Black Honours graduates.

Composition of Honours graduates. Honours graduates at the formerly Black universities have been and remain predominantly Black, whereas at formerly White universities there has been a change from essentially White in 1994 to a mixed composition today. We assume that Honours graduates at formerly Black universities remain 80% Black, and we estimate the changes in formerly White universities by fitting an inverse exponential curve to their Honours graduates, which allows us to project into the future

$$H_j = 0.8 \times (1/(1 + \exp(-(a + b \times t))), \tag{6}$$

with 0.8 being the expected final proportion of Black students among Honours graduates (equal to the proportion of Black people in the general population) and estimated $a = -1.081$ and $b = 0.105$.

In the simulation, we vary b to reflect faster or slower transformation of the Honours population, parametrizing such that the time to reach 75% Black Honours graduates varies from 25 to 45 years (using a latent parameter we refer to as *timetrend*).

Homophily in preferences. Race homophily h appears in the utility functions of graduates and departments. We treat this as a reduced form parameter, capturing all forms of racial discrimination or preferences. Because it is hard to measure or change, we treat homophily as a random variable. For each run of the simulation, h_g and h_d are drawn independently from a uniform distribution $\mathcal{U}[0, 0.3]$. When $h = 0$ only quality matters; when $h = 0.3$ preference for own race is high. Within a run all departments have the same homophily, and all graduates have the same homophily, but the values differ from one replication to the next.

The quality threshold T in the utility functions may be interpreted as homophily in quality. Also, as this parameter is difficult both to observe and to affect, in each run of the simulation T is drawn from a uniform distribution, $\mathcal{U}[0.5, 0.9]$, (and is the same for both departments and applicants).

System growth. Current higher education policy in South Africa calls for a growing university sector, including a growth in the number of PhDs produced annually. We include that in the model. The system as a whole grows at 2% per year for the first 50 periods, as reflected in recent policy documents. We model three prospective expansions. The first is a random expansion, such that every period extra faculty positions are created (accounting for 2% of the current total faculty) and are allocated randomly among the departments. In the second, the allocation is done by quality, higher quality departments being more likely

22 Honours is a 1-year degree following a 3-year bachelor's degree and is predominantly taken by students interested in pursuing advanced research-oriented degrees.

Table 1. Ranges of parameter values considered in the policy analysis

Parameter	Value
Number of departments	20
Initial department size	20
Retirements per period	3% of faculty
System growth	2% of faculty
Expansion type	$\{random, quality, race\}$
Homophily	$h_g,\ h_d \in \mathcal{U}[0, 0.3]$
Quality threshold	$T \in \mathcal{U}[0.5, 0.9]$
Scale of PhD graduates	$gradscale \in \mathcal{U}[1.2, 1, 6]$
Time to 75% Black Honours	$timetrend \in \mathcal{U}[20, 40]$
Same department attraction	$S \in \mathcal{U}[0.8, 1.1]$
Length of history	$\tau = 70$

See text for the initial initialization of departments along race and quality.

to receive extra places. In the third, allocation is done by race, whereby departments that have a higher proportion of Black members are more likely to receive extra places.

Simulations run for $\tau = 70$ periods, representing approximately two generations of faculty appointments, recording racial composition and quality of departments over time. Table 1 summarizes the parameter values we use.

Our main concern is with the effects of policy, and how different mixtures of policies affect the policy outcomes mentioned above. We do this by comparing the system as it evolves with no changes to current policy (i.e. under the calibrated parameter values) with its evolution under different policy scenarios. Before turning to that, though, we present a more general discussion of the model's dynamics, providing some intuition on the mechanics that drive it.

3.3 Model dynamics

In this section, we present time series results of typical runs of our model for different parameter values. Figures 1 and 2 show the evolution of the racial composition and quality of the 20 departments. The parameter settings are chosen from two ends of the parameter spectrum set out in Table 1, except for race homophily which is fixed to an intermediate value in both figures. Although discrimination is equally strong in both systems, two contrasting histories unfold. In Figure 1, departments segregate in racial composition but converge in quality. Figure 2 shows the opposite.[23]

Parameters in the simulation run of Figure 1 describe a policy focused on quality. Faculties expand proportionally to their quality (*expansion by quality*) but the system produces relatively few PhDs ($gradscale = 1.1$). This results in a supply side that is rather thin but of relatively high quality. Interfaculty hiring is facilitated by a low-quality threshold

23 We note, though do not present here, that under other parameter settings the model produces histories in which both quality and racial composition converge and histories in which they both diverge.

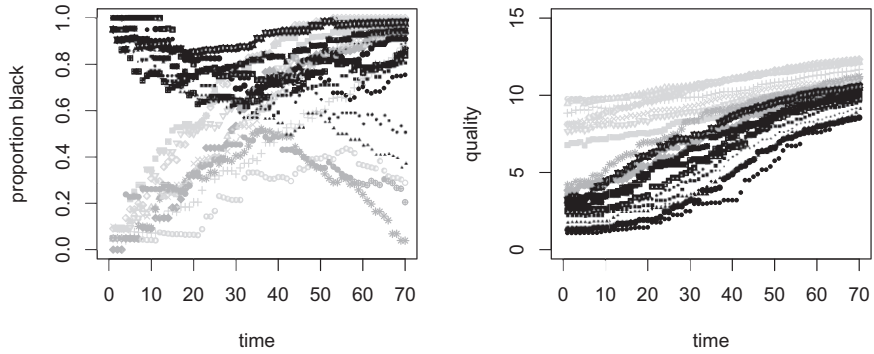

Figure 1. One representative run showing evolution over time of proportion of Black faculty per department (left panel), and Department quality (right panel). Different symbols indicate different departments; white represent research-focused departments; light gray are initially White but not research-focussed; black are the initially Black departments.

Parameter settings: expansion type by *quality*; race homophily $h = 0.15$; quality threshold $T = 0.5$; PhD *gradscale* = 1.1; Honours *timetrend* = 40; same department attraction $S = 0.8$.

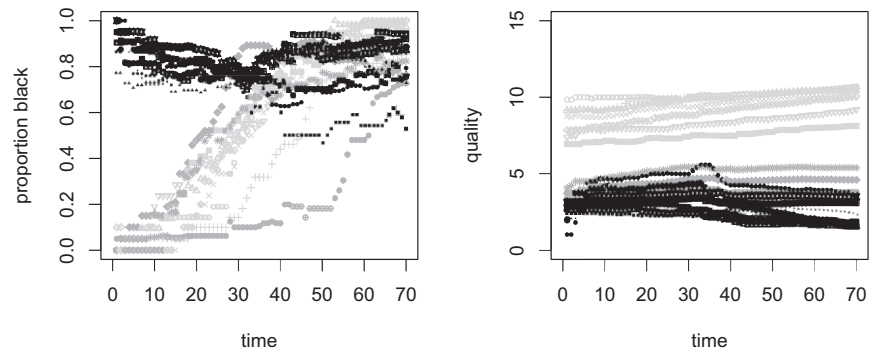

Figure 2. One representative run showing evolution over time of proportion of Black faculty per department (left panel), and department quality (right panel). Different symbols indicate different departments; white represent research-focused departments; light gray are initially White but not research-focussed; black are the initially Black departments.

Parameter settings: expansion type by *race*; race homophily $h = 0.15$; quality threshold $T = 0.9$; PhD *gradscale* = 1.6; Honours *timetrend* = 20; same department attraction $S = 1.1$.

($T = 0.5$) and enforced with a strong anti-nepotism policy ($S = 0.5$). The transition to 75% Black Honours, the pool of potential PhDs, is long: 40 periods (*timetrend* = 40).

The combined effect of the parameters change over the course of the history. Initially, the highest quality graduates are being produced by largely White departments, so graduates are largely White. The faculty hiring market in this early stage acts as a strong racial mixing device. The thin supply side of PhDs in combination with strong hiring across faculties ensure that faculties hire candidates of different color. In particular, formerly Black universities

integrate White candidates of high quality, which allows them to catch up in terms of quality. However, as quality differences across faculties and PhD graduates get smaller, race homophily becomes relatively more important in the hiring decision. As a consequence, departments start to diverge again in terms of their racial composition. Thus, over the history in Figure 1, the faculty hiring market first supports racial mixing by diffusing high quality PhDs across faculties, but then allows for racial (re-)segregation by drawing from a pool of applicants of increasingly similar quality. We note though, that some formerly White departments do transition to having mostly Black faculty.

Figure 2, in contrast, shows a convergence of departments towards the same proportion of Black faculty (left panel) but sustained segregation in terms of faculty quality (right panel).

Overall, the settings of this run could be interpreted as having a policy focus on racial transformation and system expansion. The transition of the race composition of Honours towards that of the population is very fast (*timetrend* = 20), departments expand proportionally to their racial composition, and the system forms relatively many PhDs (*gradscale* = 1.6). However, the interfaculty hiring market is mostly nonexistent. Inbreeding of new faculty is high, because of a strong 'stayer bonus' ($S = 1.1$) and neither departments nor applicants are willing to make a compromise on quality ($T = 0.9$).

The trajectory in Figure 2 is readily explained as follows. The integration of Black academics into formerly White faculties is mostly achieved through the strong exogenous trend in the population of Honours experienced by all departments. But departments face a local hiring market that is limited to their own quality stratum. Therefore, the initial quality stratification by racial composition persists. Finally, note that quality increases remain modest at best despite efforts to generate a thick supply side (*gradscale* = 1.6). The main reason is that many PhDs, particularly those who would increase its average quality, leave the system due to high-quality thresholds on both sides. Relatively good PhD graduates of lower tier departments leave (no upward mobility), and relatively bad PhD graduates of higher tier departments leave the system (no downward mobility).[24]

The two simulation runs provide several insights. First, for a given level of race homophily in the system, a functioning faculty hiring market may contribute to racial mixing or racial segregation depending on the initial heterogeneity in terms of quality (Figure 1) and on quality thresholds. In a race discriminating system, same race employees are hired if they are (sufficiently) equally qualified. Second, a strong exogenous trend in the race composition of the population feeding PhD formation can contribute to racial convergence. This is true as long as departments face the same exogenous trends, even if departments mostly hire from within their own faculty. However, without interfaculty hiring initial quality differences may become cemented and quality development of the overall system severely limited.

4. Policy analysis

4.1 Methodology

In South Africa, higher education and science policy deals with two major themes. On the one hand, there is expanding and upgrading higher education and science for economic

24 Another related reason is the stronger growth of formerly Black departments in the beginning which shifts PhD production somewhat to the (persistent) lower quality tier stratum.

development. On the other hand, there is the ongoing social transformation after apartheid. The overarching question is how to scale up the science system such that both scientific (and educational) quality and social transformation are fostered. In policy discussions, quality and transformation are often handled as opposing objectives, and individual policy measures as trading one off against the other. The analysis here lays out consequences of possible policy changes on the achievement of general policy objectives. Special attention is paid to the effect of combinations of policy measures on multiple policy objectives, knowledge of which seems indispensable for formulating an appropriate strategy in the policy discourse.

In this setting, policy can be seen as having three general goals: quality, equality and integration. The first refers to the overall quality of the higher education system. Equality refers to the goal of eliminating the apartheid-based strong differences in quality along racial lines. Integration refers to the transformation of the racial composition of the university sector, again attempting to overcome the enforced segregation of the apartheid era.

To address these goals, we pose four policy actions: (targeted) expansion of the system; increasing the number of PhDs seeking academic careers; changing the composition of Honours graduates who might seek a PhD and policy to encourage interuniversity mobility.

Policy objectives and parameters

Here, we consider the two key types of variables in the model: 'policy objectives' are the outcomes about which a policy-maker might care; and 'policy parameters' are real-world factors that are subject to policy intervention.

Policy objectives are naturally connected to model outcomes. We measure the *size* of the system by the total number of academics. *Integration* is measured by how close the racial composition in the academic system is to the population share of 0.8 in the overall society and is denoted as p_b.[25] *Equality* captures the idea that quality of academics in the system should be independent of skin color. We measure this by the difference in means test statistic z_q, comparing average quality of Blacks and Whites in the system.[26] Quality is measured by the average quality of academics in the system (*average quality*, $\overline{q}$); and by the maximum quality over departments (*maximum quality*, q_{max}), because scientific excellence is often perceived as instrumental for participating in global knowledge flows.

Policy parameters are those subject to purposeful policy intervention. The government is planning a growth of the HE sector of 2% per year for the next 50 years. Policy focussed on integration might argue that expansion should be race-based, creating positions at predominantly Black institutions. Concerns over quality would suggest that positions should be created at high-quality institutions. The HEDA data suggest that neither one nor the other strategy has been purely applied in the past, but our model allows for a comparison of how the mode of expansion affects policy objectives. We consider three modes: *random expansion* where all departments are equally likely to open new positions; *quality expansion* where new positions are probabilistically given to higher quality departments and *race expansion* where expansion favors departments with higher proportions of Black academics.

25 Calculated as the negative of the absolute difference between share of Blacks in academia and the population share of 0.8.

26 Formally the *z*-value is calculated as the absolute of the difference between average quality of Blacks ($\overline{q}_b$) and quality of Whites ($\overline{q}_w$), normalized by their average empirical variance, i.e. $z_q = -|\frac{\overline{q}_b - \overline{q}_w}{\sqrt{\hat{\sigma}_b/n_b + \hat{\sigma}_w/n_w}}|$

The number of qualified job seekers relative to the number of open positions affects the development of faculties: More job applicants gives greater choice in hiring. The size of the supply side in the academic hiring market can be decomposed into the number of PhD graduates forming the pool of potential applicants, and the propensity to actually apply for an academic position. Policy may work on both aspects. Better financing of PhD positions may increase the pool of potential applicants; and with more generous university financing, for example, an academic career can be made more attractive relative to a career in industry or government institutions. The model parameter *graduation scale* sets the ratio of (applying) PhD graduates to open positions.

The development of the prevalence of Black students in higher education generally is likely to depend largely on factors outside the university system and subject to economic, social and higher education policies. Individuals climb step-by-step up an 'education ladder', with the result that the time trend of 'proportion of Black Honours' influences the development of the proportion of Black PhD graduates. The *time trend* of Honours graduates is modeled by a parameter that determines the expected number of years to reach a proportion of Black students among Honours graduates that is close to the proportion of Black people in the general population.

Various universities, and countries, throughout the word have policies to prevent hiring of own graduates. The general idea is to prevent nepotism, and to foster integrity and scientific excellence through competition. If the racial composition of graduates reflects the racial composition of the faculty, and the faculty mostly hires its own graduates, then the racial composition of faculty will be maintained. This suggests that the movement of PhD graduates into other faculties may be instrumental for social transformation. Thus we can consider the (utility-)bonus for staying at the graduating university, (*same department attraction*), as a relevant policy parameter.

The objectives described above focus on faculty composition, in terms of race and quality. One could easily imagine that another goal would be the composition of graduates (regardless of whether or not they become faculty).[27] We have examined this variable as part of our exploration of the model. We have not explicitly included it though, because the correlation between graduates and faculty in the simulation data is very high. The unconditional correlation between faculty quality and graduate quality is about 0.9. The correlation between faculty and graduates in terms of race is smaller but still high (0.4 after 1 generation, 0.67 after 2). And considering the link between race and quality, the correlation between the two race-quality correlations is roughly 0.77. Given these high correlations and the already large number of policy outcomes, we do not examine this specific policy goal.

Policy effects

We are ultimately interested in how *policy changes* with respect to the status quo affect the future state of the South African science system.[28] Our goal is not to reproduce observed, and predict future quantities characterizing the South African science system. Such a task would not be possible due both to a lack of data and to the level of abstraction of the model.

27 Thanks to an anonymous referee for suggesting this.

28 We are not comparing the modeled future state with the current state, but rather we are comparing two future states: one based on our calibration of the current state of affairs projected into the future, and one based on our policy changes, also projected into the future.

Table 2. Policy goals

Policy goal	Description	Column name (Table 4)	symbol
Size	Number of faculty in the system	size	
Proportion Black faculty	Ratio of Black faculty to total faculty	Prop. Black	p_b
Equality	Equality in quality across racial groups	Equal quality	z_q
Average quality	Average quality of faculty in the system	Average quality	$\overline{q}$
Maximum quality	Maximum quality of faculty in the system	Max. quality	q_{max}

However, we believe that the model captures relevant aspects of the system dynamics, and our aim is to discover general tendencies of policy effects.

Because the model is nonlinear, policy effects in general depend on the location in the parameter space. On the other hand, the model is not chaotic such that small changes in initial conditions have large effects. Therefore, we can reasonably identify a region in the parameter space that represents the current state in South Africa (the base case), based on the discussion above.

A single policy then corresponds to shifting one parameter into a neighboring region of the policy space (the policy case). Because there is randomness in the model, we replicate any change many times such that average outcomes approach expected outcomes.

To judge the effects of policy we compare the average behavior of the model in the base case (averaged over 500 runs of the model) with the average behavior of the model in the different policy cases. To recall, we have as policy levers the time trend of Honours graduates (*time trend*); the degree of competition among graduates for jobs (*graduation scale*); and the extent to which graduates are encouraged to change institutions (*same department attraction*). Each of these policies can be active or not, giving eight cases, and each of those eight cases is observed for each of the three types of expansion (random, quality-based and race-based). This gives 24 scenarios in all (including the base case), and we replicate each scenario approximately 500 times.

We say an alternative policy (mix) has an effect on a certain policy objective, when it yields a different expected outcome than the base policy. Policy effects are quantified depending on the objective: policy effects on size and quality (i.e. $\overline{q}$ and q_{max}) are measured by percentage changes of the average outcome when moving from base policy to alternative policy. Positive (negative) policy effects thus mean that the alternative policy yields a larger (smaller) system of higher (lower) quality than the base policy. Policy effects on the proportion of Black faculty (p_b) and on the z-statistic of quality difference along race (z_q) are measured in absolute differences. This way a positive policy effect signals movement towards an academic system that comes closer to the racial composition in the population (case of p_b) and toward equality of average quality of Black academics and White academics (z_q).

Table 2 shows the policy goals and their descriptions.

The base and policy cases

Here, we define the parameter ranges for the base and alternative cases.

In the past 30 years, SA universities have grown between 1% and 6% in terms of faculty. Observed university growth rates do not correlate with either race or quality, so the

Table 3. Parameter settings in policy and base cases

Parameter	Column name (Table 4)	Base case	Policy case
Expansion type	Expansion type	Random	{Quality-based; race-based}
Scale of PhD graduates	Grad. scale	[1.2, 1.4]	[1.4, 1.6]
Time to 75% Black Honours	Time trend	[35, 45]	[25, 35]
Same department attraction	Same dept. attr.	[1.0, 1.1]	[0.8, 0.9]

observed pattern best corresponds to a random strategy: New jobs are created uniformly at random across universities. We consider as alternative policies 'expansion by quality' and 'expansion by race'.

The number of applicants per open position is not present in publicly available data. For the base case, we assume that the number of applicants is sufficiently high for a functioning labor market, but that overhang on the supply side is limited. Thus, we consider for the base case a range of [1.2, 1.4] for the parameter *graduation scale*. As policy case, we consider a region with more graduates: *graduation scale* in [1.4, 1.6].

The time trend of the proportion of Black Honours is estimated on the system aggregate, assuming an exponential function with a ceiling equal to the population share (see Appendix B). The estimation predicts that at the earliest 35 years after the process begins the proportion of Black Honours will be close to the population share. Because of the considerable uncertainty involved, we assume a *time trend* that approaches population shares within a period of [35, 45] years for the base case. The policy case is a faster *time trend* approaching within [25, 35] years.

In South Africa, roughly two-thirds of newly hired academics are hired by their graduating PhD institutions (Cowan and Rossello, 2019). This is captured by a simple bonus in the utility function of applicants and hiring faculty, *same department attraction* set to [1, 1.1], which reproduces roughly the observed pattern. We consider a policy that punishes stayers (reduces the attraction) in order to foster cross-faculty hiring up to the point of neutralizing the effect, by setting this parameter to [0.8, 0.9].

Parameter values in base and policy cases are presented in Table 3.

4.2 Main results

Table 3 indicates that there are 24 possible policy mixtures, and we examine all of them, comparing the history that emerges in any given policy mix with what we refer to as the *status quo* history. By the latter, we refer to the case as calibrated to recent data from the South African university system, as described above.

In Table 4, we present the results of our policy experiments. Each line in the table represents one policy mix. In columns 3–5, a zero indicates that the policy parameter takes on the base value (as described in Table 3); a one indicates that the parameter has been changed to the policy case. Columns 6–10 indicate the effects on the policy output variables, relative to the status quo. We look at values after two generations, and the values in the table indicate the improvements relative to the base case; with positive values indicating that the policy mix improves the outcome relative to the base case, and negative values indicating that it makes the outcome worse. (Recall that for size and quality more, as measured in percentage

Table 4. Effects of different policy mixtures

	Policy variables				Policy goals				
	Expansion Type	Grad. Scale	Time Trend	Same dept. Attr.	Size	Prop. Black p_b	Equal Quality z_q	Avg. Quality $\overline{q}$	Max Quality q_{max}
1	Random	0	0	0	0.00	0.00	0.00	0.00	0.00
2	Random	0	0	1	0.01	0.01	0.94	0.02	−0.01
3	Random	0	1	0	−0.00	0.03	0.67	−0.02	−0.01
4	Random	0	1	1	0.01	0.04	1.31	0.02	−0.01
5	Random	1	0	0	0.10	−0.05	3.58	0.28	0.06
6	Random	1	0	1	0.12	−0.05	4.63	0.32	0.06
7	Random	1	1	0	0.10	−0.02	4.07	0.26	0.05
8	Random	1	1	1	0.12	−0.02	5.27	0.31	0.05
9	Quality	0	0	0	0.07	−0.02	2.36	0.09	−0.02
10	Quality	0	0	1	0.08	−0.01	3.31	0.12	−0.02
11	Quality	0	1	0	0.06	0.01	2.65	0.07	−0.03
12	Quality	0	1	1	0.08	0.02	3.69	0.11	−0.03
13	Quality	1	0	0	0.12	−0.07	4.36	0.30	0.04
14	Quality	1	0	1	0.13	−0.06	4.73	0.32	0.04
15	Quality	1	1	0	0.12	−0.04	4.89	0.29	0.03
16	Quality	1	1	1	0.13	−0.03	5.53	0.32	0.04
17	Race	0	0	0	−0.10	0.07	−2.21	−0.22	0.01
18	Race	0	0	1	−0.09	0.08	−1.95	−0.22	0.01
19	Race	0	1	0	−0.09	0.09	−1.27	−0.21	0.02
20	Race	0	1	1	−0.08	0.09	−1.00	−0.20	0.01
21	Race	1	0	0	0.06	0.01	2.98	0.17	0.08
22	Race	1	0	1	0.08	0.02	3.81	0.23	0.09
23	Race	1	1	0	0.07	0.04	3.84	0.19	0.08
24	Race	1	1	1	0.08	0.04	3.99	0.20	0.07

For policy variables 0 indicates the base case and 1 indicates the policy case. For the policy goals, positive indicates an improvement, negative indicates a deterioration. Policy variables described in Table 3 and policy goals in Table 2.

change, is better, and for proportion of Black faculty (equal quality) coming closer to population share (perfect equality) as measured in absolute changes is better; see definition of policy effects above.)

To begin, mixtures 2, 3, 5, 9 and 17 each involve the change in only a single policy parameter. In each of those cases that change improves the outcome in some dimensions but makes it worse in others. So individual policies involve trade-offs. Some of the trade-offs are familiar from other discussions: Expansion that favors high-quality departments improves average quality, but reduces the presence of Blacks in the system (mixture 9). In contrast, expansion based on racial composition of departments will increase the presence of Blacks but reduce quality (mixture 17). However, there are some subtleties: quality expansion does harm average quality, but it reduces the correlation between quality and skin color—the Black graduates who do enter are of necessity high quality. The converse is also true: race-based

expansion increases the number of Black faculty present, and also increases the (undesirable) correlation between quality and skin color: Black graduates enter, but tend to be cloistered in weaker departments.

Both increasing the number of graduates (mixture 5) and increasing the propensity to change departments (mixture 2) effectively increase competition in the job market, permitting departments to hire better graduates, and improving average quality. But increasing the number of graduates has the further effect of improving equality (reducing the correlation between quality and race). In this case, all positions can be filled from the right-hand tail of the quality distribution since that tail is fatter under this policy, but with the same distribution of race.

Given these results, based on the four highlighted lines, a naive approach would be to select a set of policies which, when summed, produce a satisficing goal. As the rest of the table implies though, policies interact and can reduce or increase the effects of each other. Consequently, it is important to examine each of the possible policy mixtures as an ensemble rather than as a sum of parts. This is done exhaustively in the remaining lines of the table.

Considering all the rows of this table we can extract two general messages. The first is that there is no policy mix that produces a future that is worse than that produced by the *status quo* in every dimension. Many are better in some but worse in others, but none is worse with regard to all goals.

In addition, there are four policy mixtures that are better in every dimension, namely mixtures 21–24. The second message comes from examining those four strategies. The four dominating strategies result from race-based expansion and a thicker job market, wherein more graduates seek academic positions. Reducing the 'same department attraction' (but keeping time trend unchanged), line 22, makes people change departments when they transition from student to faculty and this also increases competition for places. This has strong effects on all objectives except for integration (prop. Black, p_b) on which the positive effect is relatively weak. If integration is the primary goal policy, then it could have the contrary construction: leaving the department attraction as it is, but increasing the speed of transformation at the Honours level. Implementing both policies together dominates neither individual policy, though it does improve in most dimensions.

But it is important to observe that there is no free lunch. The cost of progressing on all goals simultaneously is that progress will be slow on some. The estimates of the sizes of effects on the different policy goals arising from policy mixtures 21–24 tend to be small relative to the highest entries in any column. For example, if equality in quality is a strong concern, then mixtures 15 or 16 (quality expansion, with the anti-nepotistic same-department-attraction policy invoked) give the largest effect ($z_q > 4.89$). In contrast, among the mixtures that involve no reductions in any goal, the best one can do on the equality goal is $z_q = 3.99$ (mixture 22). Thus, even though it is possible to find policy mixes that advance all goals simultaneously, there can still be tensions that need to be resolved if different goals are of different importance.

Finally, if only a single policy can be implemented, then increasing the number of graduates competing for jobs tends to produce larger effects than other policy options. This is true for all types of expansion and for all goals with the exception of integration. However, such a policy has two drawbacks. It may be expensive: The way to implement such a policy is to make an academic career more attractive than the alternatives. An obvious tool here would be academic salaries, and so will demand some budget. The second drawback is that

encouraging more graduates to chase academic positions means that more will be disappointed. Even in the base case we have more graduates than positions; increasing the excess demand for positions will of necessity mean that more graduates leave academia unwillingly. If this fact circulates, then it will reduce the attractiveness of PhD study generally, and thus may in fact defeat itself. So such a policy would have to be pursued very subtly.

5. Two parameters, and taste for 'the same'

There are two parameters in the model that we have not treated as policy parameters, but do affect model behavior: *homophily* and *threshold*. These both create a taste for the same: the former for departments or graduates of similar race and the latter for departments or graduates of similar quality.

Trivially, race homophily affects racial integration and quality thresholds affect system quality, both through sorting (along the race or quality dimension). However, we observe also adverse effects across dimensions. Broadly, racial homophily can be considered as disturbing quality considerations in hiring, yielding sub-optimal decisions with respect to the development of (department- or system-level) quality. On the other hand, quality thresholds induce sorting by race if there is an initial, historical positive correlation between race and quality.

5.1 Homophily

If hiring exhibits racial homophily on either or both sides of the market, then at the system level both academic quality and racial integration suffer. In terms of racial integration, the process is clear: Departments consisting of predominantly one race will tend to re-create themselves if racial homophily is strong. With respect to quality, one source of improving aggregate quality is 'trickling down'—the weaker graduates from high-quality departments could be hired by lower quality departments. But if high-quality departments are White, their weaker graduates will leave academia rather than be hired by a Black department if homophily is high (on either side of the market). Trickling down as a source of quality upgrading is prevented. Alternatively, a strong graduate from a weak department could be hired 'above', raising quality in better departments, but again if the former is Black and the latter White, then homophily will prevent hiring up. And if quality thresholds exist, then that graduate will decline to be hired by a poorer department and so will leave academia. In this context, this is most likely to represent high-quality Black graduates leaving academia. In either scenario, quality suffers, and particularly in the latter case, racial integration will suffer as well. These intuitions are borne out in the simulation. The correlation between homophily and the size of the system and the proportion of Black faculty are both negative; and the correlation between homophily and the correlation between race and quality is positive (i.e. the higher the homophily, the greater the extent to which a department's quality improves with the extent to which the faculty are White). A final observation is that the effects of policy changes relative to the status quo policy are much stronger when homophily is strong. That is, when there are strong prejudices in the system, well-constructed policy changes can improve the performance of the system quite significantly, and the more relevant are the final four lines of Table 4. And in contrast, if homophily is very low, then it is not necessary to focus on race-based expansion to effect a rapid racial transformation.

5.2 Quality thresholds

Quality thresholds, which imply that departments will not hire candidates that are of significantly lower quality, and graduates will, similarly, not accept a position at a lower quality department, have different effects on quality and integration. Perhaps surprisingly, high thresholds reduce aggregate quality levels. This is largely because high-quality graduates refuse to move down the quality ladder of departments—they prefer to leave academia. The negative effect on racial integration arises largely because of the initial correlation between quality and race, coupled with the fact that graduates inherit race and quality from their departments. If thresholds are high, then good candidates refuse to move down, implying that White candidates are not hired by Black departments. Departments refuse to hire from below, so Black candidates are not hired by White departments. Those candidates not hired are the weaker candidates from strong departments and the stronger candidates from weak departments. Both leave academia, thereby weakening the average quality of those who are hired. Generally speaking, high thresholds for departments prevent upward mobility; high thresholds among graduates prevent downward mobility; combined they preserve the stratification along quality and racial lines. Reducing quality thresholds improves performance on all policy axes. One could imagine imposing such a change on departments, but it is much more difficult to imagine a policy that would have that effect on graduates. And we have observed in various experiments that reducing department thresholds but leaving graduate thresholds high have essentially no effect as a policy measure. Again, calculating simple correlations in the simulation data between thresholds and outcome variables, confirms these intuitions.

We also observe that both thresholds and homophily tend to preserve the *status quo*. What we have observed in particular is that when homophily is low, the system will tend naturally to evolve towards a more integrated position. When homophily is high, the system transforms much more slowly. One might expect then, that it is in the latter case that policy can be most effective. This is indeed borne out in the simulation. When we look at two regimes, $h \in [0, 0.15]$ and $h \in (0.15, 0.3]$ in the latter case policy has a significantly larger effect on our measured policy outcomes than it does in the former. This suggests that the policies that we have modeled can be effective in overcoming legacies of past exclusion, and are the more useful the stronger are those legacies.

To summarize, our model suggests that quality as well as integration would, generally, benefit from both low racial and low quality homophily.[29] Both types of homophily are certainly present in the South African (and indeed most) academic systems, but both are difficult to affect through policy. Though what we have seen is that policies aimed at other intermediate variables can overcome the tendencies driven by racial and quality homophily.

6. Robustness

The model presented above is in essence very simple: some people retire from academia; others receive PhDs and from the second group replacements for the first group are hired. Nonetheless, there is a small number of assumptions that might be checked for robustness.

29 A partial exception is within a race expansion strategy, where high race homophily and high-quality thresholds would foster the inclusion of Black academics into Black, lower tier universities. This, however, would be a partial success at most. While it would help the entry of Blacks into the system at large, it would also corner them in lower quality tiers.

Utility functions. We have implemented the model with standard Cobb–Douglas utility functions. We have explored simpler multiplicative functions, and additive functions. While both demand re-calibration, neither has any qualitative effects on the results.

Quality initialization. We have assumed a continuous scale of initial quality for departments, with each of the three groups of departments spread over a particular region of that scale. That there were three types of universities is commonly accepted. However, we did explore the possibility that within a group the departments are indistinguishable—implying that initial quality be modeled as a step function. We also considered the case where universities are evenly distributed between 4 and 10 in initial quality (keeping the general ordering the same). Neither of these changes has qualitative effects on the results.

Job market. While the Gale–Shapley algorithm generates a unique outcome, it is known that the outcome can change depending on which side of the market proposes. In the model, we have assumed that the graduates propose (apply to advertised job openings) that seems to mimic actual academic job markets. But for the sake of robustness, we also ran the model having departments propose. This did not change the results.

Growth of the system. Recent policy from the department of higher education forecasts a growth rate of 2% for 50 years, which is what we have implemented. We also looked at scenarios with other growth regimes. Consider first that the current (relatively high) growth rate of 2% might decline. We examined a case in which it slowly declines from 2% to 0 over 50 years. The results presented above are unchanged. Much of the transition we observe takes place early in the process, so decreasing growth especially later, has little effect. In another experiment we also observed that with zero growth the general policy outcomes are the same with one exception. The four 'pareto dominating' policy mixtures (mixtures 22–24 in Table 4) no longer dominate the base policy case when there is no growth. In those four policy mixtures the effects on equality (z_q) become weakly negative. This suggests that some growth is needed to provide the dynamism necessary to remove some of the quality inequalities currently present. Indeed by extensive exploration of the effects of the growth rate we observed that a shift takes place around 1.4%. Below that growth rate, we lose the dominance of the policy mixtures 22–24.[30] In fact, below that rate any policy mix is worse on some dimension; above that rate the dominant strategies associated with race-based expansion are present. Generally speaking, the lower the growth rate, the smaller the effect of 'race expansion' (relative to 'random expansion') on the integration of Black PhDs into faculties (p_b). This is because when growth is slow, formerly Black universities do not grow much more in the race expansion regime than they do in the random expansion regime. This seems to have two implications. On the one hand, the number of open positions created in Black universities is similar in either expansion form. On the other hand, as formerly Black universities remain small, the output of (relatively more Black) PhDs remains more limited, implying that the proportion of Black PhDs in the pool of faculty applicants remains small.

Calibration. Results of simulation studies are dependent on their calibration. In the results presented above, where possible we have calibrated the model on data for the period 2000–2020. To check whether these calibrations are robust we have run the experiment two more times, once calibrating on the first half of the period (2000–2010) and once calibrating on the second half of the period (2011–2020).[31] The calibrations are very similar to each

30 Thanks to an anonymous referee for suggesting this exploration.

31 Thanks to an anonymous referee for pointing to this issue and this check.

other, with two possible differences: Calibration on the first period suggests a slightly faster transition of Honours graduates; in the second period the link between graduate race and Honours and faculty racial composition is more heavily tilted toward Honours graduates.[32] In either case, calibrating on the first or on the second period, the general results are maintained. We note, though that in the first case, with a faster Honours transformation, mixtures that include race-based expansion perform better in terms of equality between the races and system quality. With a heavier focus on Honours graduates in determining PhD graduate race (calibrated on the second period) the improvement of race-based expansion over random expansion may be somewhat less strong. Reducing the extent to which a department (in particular the initially higher quality 'White' departments) reproduces itself facilitates the mixing needed for transformation.

7. Conclusions

In this article, we start from the observation that various forms of discrimination have existed and continue to exist. Our interest is not in policies to remove that discrimination but rather in whether policies can be designed to mitigate its effects. We have examined a particular case of what might be considered as racial discrimination and the various policies that have been proposed to overcome its consequences. By building a model to capture the effects of different policies and analyzing both their direct impact and the results of the interaction between the measures, we sought to identify the most effective combination of policies.

The interlinkages between the measures themselves and their effects lead to the conclusion that those which, when considered individually, seem to be effective in achieving one goal may have less desirable effects on other goals. Thus, the best strategy may be to use a combination of policies that are individually not optimal with respect to all objectives or possibly not even optimal for a single objective. This is a general lesson when considering measures to reduce the consequence of discrimination while trying to attain other goals, which has led to an extensive literature on 'affirmative action' (see Loury and Garman, 1993; Fischer and Massey, 2007; Howell, 2010).

Here we examine, as our case study, the process of transition in the make-up of faculty members in South Africa since the abolition of apartheid. The government's aim has been to increase the representation of the Black population amongst university faculty. However, this is not the only goal; it should be combined with an improvement in the academic 'quality' of both faculty and students in these institutions. We also assume that policy is concerned with equality: academic achievement should be independent of skin color.

A number of features emerge and, as might be expected, policies cannot be considered in isolation: their complementarity has to be examined. As we have shown, implementing a policy to support one objective may impede the attainment of another. Consider, for example, the policy to preferentially increase the size of departments with higher shares of Black academics to support integration of Black PhDs. In isolation, such a policy will impede both system quality and equality. In this case, a natural response may be to offset this negative impact by introducing another policy. However, if the resultant combination is not

32 In the main simulation, $gradRace = 0.5 \times HonoursRace + 0.5 \times FacultyRace$; calibrating on the second period alone gives $gradRace = 0.6 \times HonoursRace + 0.4 \times FacultyRace$.

complementary, then the two may simply negate each other. A trivial, but realistic, example would be to also expand high-quality departments, which together with expansion by race corresponds pretty closely to the random expansion of the policy base case currently observed. Another example would be to try to offset the negative impact of an expansion by race on equality by increasing the graduation scale. This could work, but at the same time is likely to reduce the positive effect of race expansion on the proportion of Black academics in faculty. Closer examination of our results shows that there are cases where individual policies look strong in only one dimension and poor along the others but when several such policies are combined the effect is positive (almost) everywhere. In the analysis, this is the case for policy mixtures that combine race expansion and increased graduation scale. However, it is also the case that insisting on a policy mix that will improve all policy goals simultaneously runs the risk of sacrificing some of the *potential* improvement on one goal to ensure that another goal does not look worse. Given this, the decision has to be made as to the weights to put on the different goals to be pursued.

Observations similar to our results are very likely to be present in other contexts, and one value of the model we have built is that it should be easily generalizable to other contexts.

But there are specific features of the South African case which are important. In many cases where discrimination is detected, those discriminated against are a minority. The major exception to this is of course gender discrimination that has not been considered here. However, the situation in which 81% of the South African population are Black and 8% are White is in radical contrast to the composition of university staff in that country. The 'best', by conventional standards, universities were still predominantly White, although there has been a shift towards a more balanced composition. Yet, our model suggests that the universities that were essentially White and favored during apartheid will not necessarily converge to the same composition as those that were Black and not favored. Indeed, depending on the policy assumptions, a focus on integration there may produce a tendency for the gap to widen as universities with high proportion of Black academics, for the reasons we have explained, increase their proportion of Black academics.

As we have emphasized, homophily, or desire to be with people like oneself, is clearly an important factor both in hiring faculty and choosing which institution to attend. However, homophily should not be thought of as a purely racial phenomenon. Its influence leads to discrimination but it can also be the result of a desire to be with people of similar academic quality, which tends to perpetuate the hierarchy of universities. We considered a rather broad categorization of homophily to encompass these considerations. In particular, we considered how homophily in multi-dimensional space (here quality, race, and alumni relations) affect segregation through social mixing by the academic job market.

What then are the main lessons from our analysis? First, 'you can do better, but it's hard to do worse': It turns out that there are combinations of policies that strictly dominate the current policy mix (i.e. do better in all the objectives we look at). On the other hand, there is no combination that is worse in all dimensions (is strictly dominated) than the current state of affairs.

Second, we can suggest a direction in which to move. All the dominating strategies involve 'race expansion', that is, favouring the Black universities when allocating new posts, and 'more grads', expanding the pool of potential applicants. There are other patterns though. Regardless of other policy strategies, expanding the number of PhD graduates

looking for academic jobs gives larger positive effects on all goals except increasing the preponderance of Black faculty (p_b). This is particularly the case for equalizing quality across the racial groups. Similarly, regardless of other policy changes, forcing (or strongly encouraging) mobility between PhD and first job yields better outcomes in all dimensions (possibly excepting maximum quality). Again this change has a striking effect on *equal quality*. Both policies can be seen as increasing competition on the supply side of the job market, pushing it towards, in effect, a buyers market. We should note though, that while good for aggregate policy goals, it comes at the cost of individuals—there will be more aspiring academics who cannot find academic jobs.

Finally, for the future we should emphasize that our analysis has focused on what happens as students move on from their first degree and some of them choose to pursue an academic career. However, what is also needed is a consideration of the impact of early schooling on the final pool of candidates for university positions as emphasized by the Heckman program (see Garcia *et al.*, 2020). Such a development would lead to a stronger pool of candidates for university posts and, no doubt, to an improvement in the 'quality' of the system. This, of course, is a longer term goal but the sort of analysis that we have proposed gives a clear indication as to how measures can be put in place to improve the current situation and shows how one can implement better combinations of policies that will act in a complementary rather than self-defeating way. The lessons from this exercise are applicable to situations far from those that we have discussed here.

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Appendix A: Observations on the South African university system

In this appendix, we give more details about the data.

Data

Our empirical observations on racial compositions within the SA HE system are based on the DHET/HEMIS data.[33] The data provide information on the racial composition of academics and graduates for all South African universities and technikons (higher education institutions with focus on education rather than research) over the period 2000–2020. Included in that data is the hiring year of university faculty members, which we use to infer on the racial composition of faculties between 1995 and 1999. Information on (racial composition) of graduates from 1994 to 1999 is available from excel files provided by DHET.

We consider as academics those having PhD degrees with permanent employment at the institution for research and teaching. Regarding graduates, our focus is on PhDs and Honours. Bachelors are of secondary importance to us because they have mostly a professional orientation. Masters on the other hand is often seen already as a first step in getting a doctoral degree. Honours is the first academic degree beyond bachelor and often mandatory in SA to become PhD student. Therefore, we consider the racial composition of Honours as a good proxy of the population of potential PhD students. Proportion of Black people in a stratum is calculated throughout as the number of Black people over the sum of Black and White people in that stratum (ignoring other 'races' and cases with no information on race).

University reform in 2005

In the years 2004–2005, a major reform of the university system resulted into the merger of multiple institutions into (formally) new establishments. In constructing our dataset, we take into account these mergers by artificially applying the mergers to the entire period. For example, in 2004 the merger of University of North West and Potchefstroom University resulted into North West University. Thus, in the analysis, we refer to the aggregate of University of North West and Potchefstroom University as the North West University prior to 2004. In case an antecedent consisted of multiple campuses that merged with different universities, we ignore these mergers as information is only available on the level of the institution.

After antedating the mergers in 2005, 30 institutions remain. Of these, we drop 14 smaller institutions (mostly technikons) from the sample because they have been dissolved during the observation period or data is obviously misleading. These institutions account for around 10% of overall academics in faculties as well as PhD and honours graduates, but 30% of bachelors. The remaining 16 institutions are listed in Table A1. We differentiate institutions by their apartheid legacy—institutions that served higher education for people of color have been formerly disadvantaged (*fd*), institutions for Whites formerly advantaged (*fa*). The table only displays major antecedents, not shown are re-organizations of individual

33 https://www.heda.co.za/PowerHEDA/dashboard.aspx\#divPDS (accessed December 2022).

Table A1. Focal institutions and major antecedents (*fd*: formerly disadvantaged; *fa*: formerly advantaged)

University (*fa*/*fd*)	Antecedents (*fa*/*fd*)
University of Fort Hare (*fd*)	–
University of Limpopo (*fd*)	Medical Uni. of South Africa (*fd*), University of the North (*fd*)
University of Western Cape (*fd*)	–
University of Zululand (*fd*)	–
Unversity of Venda for Science and Tech. (*fd*)	–
Nelson Mandela Metropolitan University (*fa*)	Port Elizabeth Technikon (NA), University of Port Elizabeth (*fa*)
North West University (*fa*)	University of North West (*fd*), Potchefstroom University (*fa*)
Rhodes University (*fa*)	–
University of Cape Town (*fa*)	–
University of Johannesburg (*fa*)	Rand Afrikaans University (*fa*), Witwatersrand Technikon (NA)
University of KwaZuluNatal (*fa*)	University of DurbanWestville (*fd*), University of Natal (*fa*)
University of Pretoria (*fa*)	–
University of South Africa (*fa*)	Vista University Distance Education Center (*fd*)
University of Stellenbosch (*fa*)	–
University of the Free State (*fa*)	–
University of Witwatersrand (*fa*)	–

campuses. Note that there is only one merger of a formerly disadvantaged with a formerly advantaged university, resulting into North West University. All other major mergers are among formerly disadvantaged and formerly advantaged universities.

Time trends on proportion of Black people for individual institutions are given in Figure A1. First, the racial composition of *fd* universities differs from the racial composition of *fa* universities. More precisely, *fd* universities start with a higher proportion of Black faculty (red), and with a proportion of Black Honours graduates close to one. On the other hand, academics in *fa* universities are mostly White at the end of apartheid (1994) and the proportion of Black Honours is around 20%. Regarding dynamics, one notes that the transition of the faculty is stronger in *fd* universities than in *fa* universities. Furthermore, the proportion of PhDs that is Black seems to be bounded below by the proportion in faculty and bounded above by the proportion in Honours graduates for all universities over the whole period.

Two universities stand out: University of South Africa starts with a relatively high share of Black students among honours and undergoes a very rapid transformation in terms of PhD graduates and faculty. Part of this trend is probably due to its special role as distance education inherited from Vista University. University of Kwazulu-Natal is atypical compared to other *fd* universities in that it starts with a relatively small fraction of Black Honours, with a spike in 1999 and then approaching rapidly one.

The overall system has been growing considerably since 1994. In the more recent period, since the mergers, data are more reliable, however. Academics grew in *fa* (*fd*) universities by 5% (6),

honours (postgraduates) 4.5% (9), PhDs by 7% (14). Accordingly, the share of honours and PhD graduates produced by *fd* universities rose from 35% to 45% and from 22% to 35%, respectively, while the share of academics remained relatively constant. This high growth is probably difficult to sustain in the long run. Current government plans contain a more modest growth of 2% for roughly 50 years. Our simulations build on this envisaged growth.

Appendix B: Calibration

Here, we give more detail on the calibration described in Section 3.2.

Departments

Initial department quality is based on Cowan and Rossello (2019) in which prestige rankings of the South African universities are estimated. In that ranking, the research-active universities are ranked the highest, though within the group there is variation and a clear ordering. There is also variation within the other universities, with the formerly White universities tending to be higher ranked than the formerly Black universities. But the ordering derived in Cowan and Rossello is much less definitive for this group. To initialize quality, we treat the first seven departments as the research-intensive departments, with quality evenly spaced between 7 and 10; the other 13 departments have quality evenly spaced between 1 and 4, with the 'formerly White universities', or formerly advantaged, having higher quality than the 'formerly Black universities', or formerly disadvantaged. Initially, within each department, an agent's quality q_i is department quality multiplied by a uniform random number $\epsilon \in [0.95, 1.05]$. The first 10 departments represent the formerly White universities, and are initially stocked with faculty of which 80% are White and 20% Black. The second 10 departments represent the formerly Black universities, and comprises a 20%/80% composition of White and Black faculty. Thus, initially while all departments are dominated by one or the other color, most departments are not completely homogeneous.

Productivity in PhD production

Since 2003, PhDs have graduated disproportionately from the formerly White universities, and in particular from the research-intensive group. Combined, the seven formerly White, research-oriented universities account for 62% of PhDs annually. Nonetheless, we allow for graduate numbers to change over time, if departments shrink or grow. We can observe a 'productivity' in PhD production: the ratio of number of graduates to number of faculty. In almost all universities between 2003 and 2019 this productivity has been growing, as policy has encouraged more PhD production. However, the relative productivities of the research intensive to the other universities have been essentially unchanged over that period.[34] This suggests that productivity in producing PhDs is difficult to change, and can be seen as part of the culture of a department. Thus in any period, the distribution of PhD graduates over departments is (probabilistically) equal to the size of the department multiplied by its historical productivity. Formally, we use the 62/38 split for research intensive and other departments, calculate for each department an initial productivity based on that division, and

34 The exception is the University of Fort Hare, a formerly Black university, whose productivity has risen sharply, now approaching that of the research-intensive universities.

retain that productivity throughout the simulation.

Composition of PhD graduates

Successful transformation demands a supply of Black PhD graduates. The racial composition of PhDs is determined by many things outside our model. But many of those things are mediated by factors in our model, namely the racial composition of the population of Honours graduates (people who might enter PhD programs) and the composition of faculty in different departments.

The relationships are shown graphically in Figure A1. This shows, by university, the proportion of a group's members that is Black (shorthand 'proportion Black') at different levels of the academic system: Honours graduates in blue, PhD graduates in orange and academic faculty in red. The first five universities—University of Fort Hare up to Venda—are *formerly disadvantaged* (largely Black) universities. The historically disadvantaged universities have a proportion Black among Honours (dark blue line) close to one throughout the observation period, whereas for the *formerly advantaged* (largely White) universities the proportion Black in Honours increases gradually from the end of apartheid. Also, the proportion of the (PhD-holding) faculty who are Black (red line) starts off much higher in formerly Black universities, and tends to develop more dynamically than proportion Black in the formerly White universities. At all universities, however, the proportion Black in PhD graduates tends to be bounded below by the proportion Black in faculty and bounded above by the proportion Black of Honours degrees.

To get at the relationship between PhDs, Honours graduates and faculty, we estimate four versions of a simple linear regression model on the panel of universities. In all four models, the dependent variable is the proportion Black in PhD graduates at a focal institution in a given year. Right-hand side variables are proportion Black of Honours at the focal institution as well as in the national population of current Honours graduates,[35] and proportion Black in the focal faculty. Based on the assumption that a PhD takes 5 years, all right-hand-side variables are lagged by 5 years to proxy the environment at the start of PhD. Intercept and coefficients are allowed to vary by *fa* and *fd* universities.

The four models arise from four different possibilities to include time fixed and individual fixed effects. The main question, to be answered for model calibration, is the extent to which there exists a feedback from proportion Black in faculty to the proportion Black in PhD graduates relative to other factors, possibly outside the system. Time fixed effects control for parallel development of proportions due to third factors, whereas university fixed effects control for level differences across universities. Either fixed effect, if wrongly left out from the regression, could create a positive bias in the feedback from faculty proportions. In order to identify the 'true' model, we calculate the mean squared error (MSE) on leave-one-out jackknife sample predictions (without bias correction) as described in Lu and Su (2020).[36]

Results are given in Table A2. We consider the MSE as our main statistic to judge which model is most appropriate. Model (3) includes university fixed effects and has the lowest MSE, while adding time fixed effects in Models (2) and (4) increases MSE. This suggests that

35 The aggregate is obtained over all formerly advantaged universities.

36 Besides a linear model on proportions, we also estimated a logit model on individual probabilities on which we obtained qualitatively the same results.

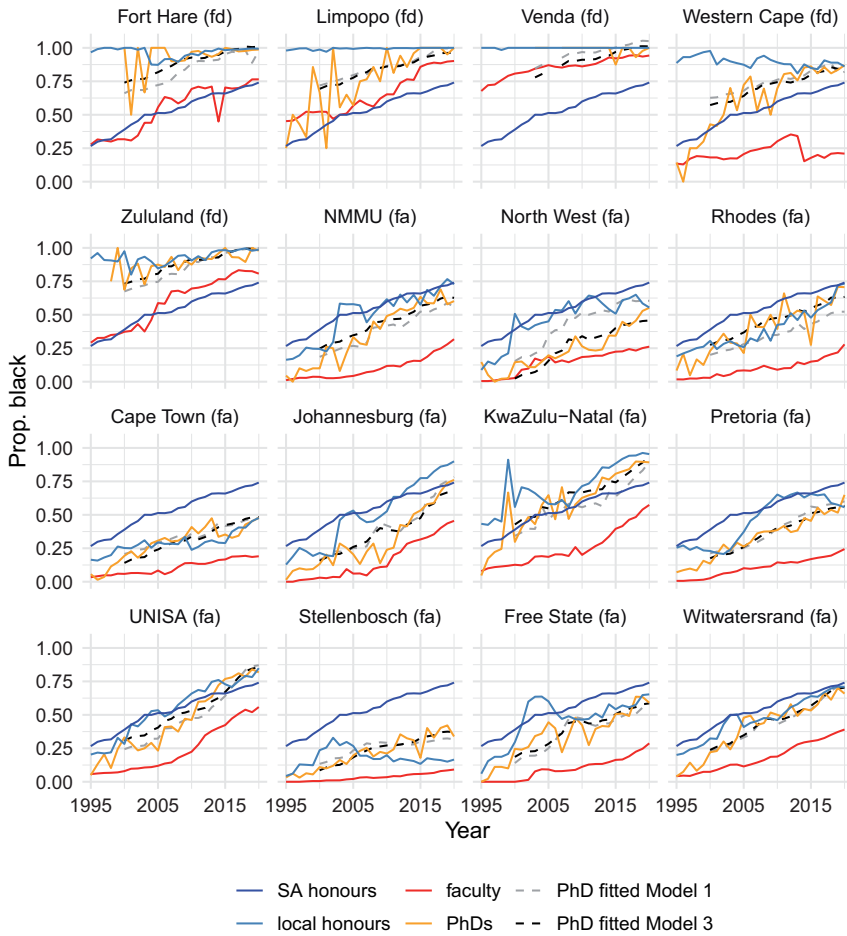

Figure A1. Time trends of proportion Black in SA Universities. First five universities are formerly disadvantaged (*fd*), the rest formerly advantaged (*fa*) institutions. Solid lines are observed proportions, dashed lines are fitted values on PhD graduates based on regressions (see below).

introducing time fixed effects leads to overfitting, but clearly supports heterogeneity in the level of proportions in PhD graduates across universities. This makes Model (3) our preferred model.

Comparing Model (1) with Model (3) for White universities, we see that the estimate somewhat drops, suggesting that an upward bias is removed by the inclusion of university fixed effects. Furthermore, the explanatory power of Honours graduates shifts from local Honour graduates to global Honour graduates. As a result, in Model (3) the feedback from local faculty and (local and global) Honours is equally strong.

For Black universities, regression results are less stable in that the estimated feedback of local faculty goes essentially to zero and insignificant when university fixed effects are introduced in Models (3) and (4). The estimated effect of global Honours is high (0.682) in

Table A2. Regression of proportion Black in PhD graduates on proportions in lagged Honours and faculty

	(1)	(2)	(3)	(4)
Black universities (fd)				
Intercept	0.632	0.835**		
	(0.409)	(0.424)		
SA Honours (lagged)	0.439**	0.177	0.682***	0.033
	(0.191)	(0.205)	(0.169)	(0.183)
Local Honours (lagged)	–0.191	–0.229	–0.178	–0.266
	(0.431)	(0.443)	(0.333)	(0.336)
Local faculty (lagged)	0.347***	0.350***	0.008	0.004
	(0.108)	(0.111)	(0.157)	(0.159)
White universities (fa)				
Intercept	0.054*	0.214***		
	(0.029)	(0.027)		
SA Honours (lagged)	0.246***		0.601***	
	(0.061)		(0.063)	
Local Honours (lagged)	0.340***	0.352***	0.100**	0.128**
	(0.046)	(0.049)	(0.049)	(0.050)
Local faculty (lagged)	0.962***	0.930***	0.710***	0.596***
	(0.102)	(0.113)	(0.099)	(0.115)
Time fixed effects	No	Yes	No	Yes
Univ. fixed effects	No	No	Yes	Yes
Observations	333	333	333	333
R^2	0.973	0.974	0.988	0.989
Adjusted R^2	0.972	0.972	0.987	0.987
MSE	0.0117	0.0127	0.0078	0.0082
F Statistic	1459.050***	421.495***	1123.984***	613.991***
df	(8; 325)	(27; 306)	(22; 311)	(41; 292)

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Model (3) but then goes down to zero in Model (4) where time fixed effects are added. A third observation is that the estimated effect of local Honours is negative throughout, albeit insignificant. All three observations on estimation results for Black universities are probably explained by (i) the small number of observations (five Black universities), (ii) high correlation between proportion Black in local faculty and global doctoral graduates leading potentially to multicollinearity issues and (iii) proportion Black in local Honours being rather invariably fixed over time close to one (see Figure A1). Therefore, estimation results for Black universities remain somewhat ambiguous.

Taken together, regression results suggest that there are idiosyncratic differences across universities, but also support a dynamic influence of proportion Black in faculty on proportion Black in PhD graduates. The development of Honours is also significant in most regressions. On the other hand, although individual fixed effects improve model fit, its introduction has a limited effect on the relative feedback strength of local faculty to (global plus local) Honours. Figure A1 includes fitted proportion Black of PhD graduates with Model (1) and Model (3). Fitted lines

are often intertwined; when not, they run in parallel. The theoretical model abstracts from this pure level effect. The model, however, takes up the feedback effect from proportion Black in faculty and Honours on PhD graduates. Because empirical evidence on Black universities is relatively limited, we assume in the model that both types of universities are subject to the same feedback effect.

This leads us to base our main simulation results on the estimates of Model (3) for White universities, assuming that the feedback from Honours and local faculty on PhD composition is equally strong (see Equation (3) in the main text). Robustness checks show that with unequal feedback strength, e.g. local faculty feedback twice as strong as Honours feedback, simulation results remain qualitatively stable and yield the same policy implications.

Thus, the race of a PhD in the model is modelled such that the probability that a graduate of university j is Black is

$$f(R_j, H_j) = 0.5R_j + 0.5H_j$$

where R_j is the proportion of Black faculty, and H_j is the proportion of Black Honours graduates relevant to that university.

Composition of Honours graduates

Honours graduates at the formerly Black universities have been and remain predominantly Black, whereas at formerly White universities there has been a change from essentially White in 1994 to a mixed composition today. To capture that observation, we assume that Honours graduates at formerly Black universities remain 80% Black, and we estimate the changes in formerly White universities[37] by fitting an inverse exponential curve to their Honours graduates, which allows us to project into the future.

In detail, we measure H_t as the number of Black Honours over Black and White Honours graduating in formerly advantaged universities over 26 years (t) from 1994 to 2020, and linearly transform the equation

$$H_t = 0.8 \times (1/(1 + \exp(-\eta_t)))$$

to estimate with OLS, the linear predictor $\hat{\eta}_t = \underset{(0.0749)}{-1.081} + \underset{(0.0048)}{0.105}\ t$ (standard deviations in parentheses underneath the coefficient estimates). Taken the estimates at face value, we would expect that within 37 years from the end of apartheid, 75% of Honours will be Black students.

For two reasons, we consider this to be a lower bound: First, South Africa attracts many, predominantly Black, students from other African countries. The trend towards population shares in the composition of Honours students with South African nationality, which is more relevant to the policies we consider, is most likely weaker. Second, the apartheid system categorized individuals as White, Indian, Asian, colored, or Black. Black and White people constituted the largest groups in that system, with White people being most privileged and Black people by far the most discriminated. This is where we focus on by considering

37 One formerly advantaged university, the University of South Africa, is dropped from the estimation sample of the Honours trend because it is a distance university that focusses on lower degrees and not likely to fuel PhD programs.

only Black and White Honours. For the proportion Black in the larger pool of all Honours, we estimate a longer time of 42 years to reach a share of 75% Black Honours.

These considerations lead us to assume, for the base policy case in the main analysis, that within a period of 35–45 years, 75% of Honours will be Black students.