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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, and thus policy interventions, must also be systemic. The South African case is particularly instructive because it is so extreme: Apartheid deliberately excluded the vast majority of the population, black South Africans, from fully participating in society, but post-Apartheid efforts to achieve transformation have had limited success. This paper hones in on a key enabler of transformation, the university system. A successful transformation will be characterized by a larger academic system to accommodate the many previously disadvantaged students, by growing scientific quality and by more black academics so that the proportion of black to white academics resembles that of South Africans generally. This will require more black South Africans to do PhDs, to select academic careers, and to be selected into the top South African universities. Policy interventions can be developed for each of these many constituent elements, but it is not known whether policies will be complementary or contradictory. To determine the outcomes of different options, this paper uses computer simulations, calibrated with evidence from South Africa since the end of Apartheid. The simulations reveal very few direct trade-offs, although different combinations result in different benefits. By highlighting the (larger and smaller) gains and costs of different combinations of policies, the paper can therefore support informed policy-making about a highly complex issue.

JEL codes: I2; J15; J7
keywords: discrimination; universities; public policy; labor market institutions; social change; Africa

1 Introduction

The recent era has once again seen the growth of negative attitudes and stereotypes about "others". Trends such as the rise of nationalist populism and growing anti-immigrant views threaten to further exclude groups that have long struggled to achieve full integration into society. The literature that has evolved to understand this challenge is vast. In the field of economics, early scholars include Becker (1957) with his work on taste-based discrimination and Arrow (1973) and Phelps (1972) on statistical discrimination. It has also been an important topic in sociology. The preference for the own, homophily, has been extensively studied, with recognition that such preferences have multiple origins, both personal and structural (Kossinets & Watts, 2009; McPherson, Smith-Lovin & Cook, 2001). More recently, the systemic nature of discrimination has received increasing attention. Various scholars have pointed out that the issue is a systemic one in which different factors interact, reinforcing or mitigating each other (Ferguson & Koning, 2018; Fernandez-Mateo & Fernandez, 2016; Reskin, 2012). Many more contributions have come from applied disciplines, e.g. management and education.

From a policy perspective, this proliferation of insights and approaches can be challenging. What is key and what is not? How does the "system of discrimination" function, and specifically, how can different policy interventions be expected to interrelate and interact? This paper makes a contribution to that challenge in two ways, both further elaborated in the rest of the paper. First, the question is examined in a narrowly defined context: the university system in South Africa. This precise focus enables an analysis of the various mechanisms at work. Second, the evidence base for the paper consists of simulations that have been calibrated with empirical evidence from the South African tertiary education system. The use of simulation permits us to capture many of the complex interactions present is this context, in a way that is much more difficult with other methodologies. This approach makes it possible to both isolate and consider in combination a range of potential policy interventions. Two things about our approach are worth notice: First, we are not addressing the question of how to rid a context of discrimination. That question is outside the scope of our work. Rather we start from the premise that discrimination exists in the past and present, and that past discrimination has left a long-lasting legacy. Our objective is to analyse policies that can overcome those effects without (necessarily) removing the discrimination itself. Second, while our analysis is grounded in the South African case, which provides a rather extreme situation, the model we develop is very general. Its basic structure can be re-deployed to address related issues in similar contexts.

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 percent of the overall population. The decision to focus on the university system was 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 key 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 percent) and 69 percent male (Badat, 2010). Almost all of the few black faculty members were found in the under-resourced and low quality historically black universities. 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). But over the quarter-century since then, progress has been disappointingly slow.

One of the explanations offered for the slow progress has been a presumed trade-off between quality and equality, and the fear that having more black faculty will lower the quality of the best (historically white) universities in the system. But although white academics insisted that they were impartially upholding quality standards, the experience of black academics often was that quality criteria were inconsistently applied and that they were held to higher standards than white candidates (Mabokela & Mawila, 2004; Thaver, 2006). The fear of a trade-off between quality and quantity is not unique to South Africa. For example, low student-faculty ratios are increasingly used as a measure of quality, although Buckner and Zhang (2021) in a cross-national study point out complexities underlying the measure, and highlight that low student-faculty ratios are not necessarily related to positive student learning outcomes.

But in the South African case, white academics' concern about quality had a strong racial dimension so that they exhibited a strong preference for other white faculty members whom they perceived to be the carriers of quality. After decades of Apartheid (literally: apart-hood), it is hardly surprising that the hiring behaviour of white academics was shaped by the very high costs of searching for and meeting people who were from non-proximate backgrounds. But such views are hard to change, and policy interventions are likely to be more effective when dealing with issues of quality and quantity, than with this type of homophily.

Increasing the size of the university system, so-called massification, has the dual consequence of increasing learning opportunities for young South Africans and also of creating more vacancies for new entrants into academia. A larger system could help allay the anxieties of white academics about being displaced from their roles; the logic is one of growing rather than dividing the proverbial pie. Massification is complex, though, (Guri-Rosenblit, Šebková & Teichler, 2007) and the Hamburg Declaration on organising higher education for the twenty-first century[1] recommends that the growing diversity of academic institutions be supported in a scientific and value-oriented way, including by developing appropriate quality assurance systems. Their statement suggests 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.

However, the Hamburg Declaration essentially differentiates between two types of post-secondary institutions; research-intensive universities ("the apex academic institution") and the rest. Given both the history of Apartheid and the goal of achieving the transformation of the South African academic system and ultimately society at large, it is clearly untenable for black entrants into academia to be directed away from the apex institutions. Yet this is uncomfortably close to what has happened in the decades after

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[1] https://www.hrk.de/fileadmin/redaktion/hrk/02-Dokumente/
02-07-Internationales/final_9.6.17_Hamburg_Declaration.pdf

the end of Apartheid. By 2013, faculty were more representative of the demographics of the country than in 1994, although white males still predominated. But more than three-quarters of black faculty were found in the historically black universities.[2] 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, 62 percent of faculty were white. At the three most highly ranked South African universities, the Universities of Cape Town, Stellenbosch and Witwatersrand, the number increased to 70 percent. This distorted distribution is of concern not simply due to fairness concerns. 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 university 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. 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.

The South African case demonstrates how complex and layered is the achievement of inclusion. The first step to transforming the racial composition of the university system is arguably to develop quality black scholars. But that is only one step. 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.[3] Although he was challenged for making the claim, with critics arguing that it represented an abdication of leadership responsibilities, it is nonetheless useful for suggesting the value of policy interventions that aim to make academia more attractive for black faculty.

But what if large numbers of competent black South Africans do find academia an attractive career option? If the university system does not grow, then introducing black academics requires the displacement of white academics, with all the associated societal ramifications. At the same time, growing the size of the university system can introduce challenges in terms of loss of quality in the system overall. Those challenges are not insurmountable, in that the trade-off between quality and quantity is not inevitable. But they are challenges nonetheless, and will need to be met with appropriate policy responses. But because the best regarded positions in the academic system are likely to be occupied by people who have benefited most from the past, some policy interventions may be needed to ensure that the historically disadvantaged new entrants into the system are not trapped in the institutions with the lowest potential for transformative knowledge creation.

This description of the steps needed to achieve full inclusion of black academics into the academic system clearly shows that transformation consists of many related but distinct elements. Scholarly work has been done on each of the elements: Issues related to the size and quality of the university system have been addressed in the emerging literature on the higher education sector (Altbach, 2014). The limited pipeline of academics has been

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[2]Racial classification under Apartheid was complex, with a hierarchy of white, Indian, "Coloured" (mixed-race) and black Africans. Redress policies are similarly complex. In this paper, 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.

[3]http://www.theguardian.com/world/2014/oct/06/south-africa-race-black-professors, accessed February 15, 2016

studied under the banner of perceived occupational opportunity (Byars-Winston, Fouad & Wen, 2015) and in terms of opting out (Beasley, 2012). The non-selection of arguably competent faculty has been examined through taste-based (Backer, 1957) and statistical (Arrow, 1973; Phelps, 1972) discrimination lenses, and through the lens of network studies (Wimmer & Lewis, 2010). Different policy measures have been recommended for these different elements. Recently, there has been recognition that discrimination is systemic (Reskin, 2012), and we argue that its dismantling also has to be done systemically. But this raises the question of which policy interventions to select and in particular how they interrelate.

At the end of Apartheid, the university system excluded black South Africans. Twenty-five years later, it no longer excludes black South Africans as fully as before, but few would argue that the system had transformed. While this is in practical terms a disappointment, it does provide useful evidence that can be used to assess various policy options. There is a period of profound discrimination, there is a clear end point to that period and the well-documented and politically supported intent to change the situation. Then there is quite a long period in which various changes in the system were observed.

Thus it is possible to identify the effect of improving the pipeline from which universities can hire by growing the number of potential black academics. One can observe what are the implications when changing the proportion of black versus white academics relative to the proportion of black and white South Africans overall, and of improving the equitable representation of black and white academics in the different types of South African academic institutions. Implications for the system overall when increasing the size of the system and of emphasising quality in the system can also be considered. Because policy options can be introduced to support each of these goals, either individually or in combination, it is possible to see the workings of these policy options.

Given that there are many options and that it is key to consider how they operate collectively, a decision was taken to rely on computer simulations. The simulations (calibrated using the post-Apartheid evidence) allow for an understanding whether the policy goals are competing or complementary, and in which ways. The evidence is heartening: Although some trade-offs exist between policy options, it seems that system change is possible. The rest of the paper explains how this operates.

In the next section we develop a model of how PhD graduates are hired into faculty positions. In Section 3 we describe the data we use and the calibration of the model to the current state in South Africa. Section 4 gives a brief illustration of the model's dynamics, showing evolution of different universities over two academic generations in the model. In Section 5 we turn to policy analysis, discussing how the parameters in the model relate to possible policy tools and objectives. Therein we describe the results of the model and some of the implications for policy design. The paper concludes with a short discussion.

2   Model

The focus of the model is on the changing (racial) profile of the faculty of the university system. Because faculties evolve through transition 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 are 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 Shapleym, 1962). Formally, the model is constructed as follows.

There are 20 "departments" each having 20 faculty members. Each period the oldest 3 percent of the faculty retire.[4] Similarly, each year G PhDs are graduated looking to pursue an academic career.[5] 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 labour 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 given any particular graduate, and the "utilities" of a graduate being placed in any particular department.

2.1 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.

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

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

where Q_i is the quality of the hiring department; $2 - |R_i - r_j|$ ($\in [1, 2]$) measures the distance between 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):

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

2.2 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 and a standard deviation of σ, then the quality of a graduate is drawn from a normal distribution, $N(Q, \sigma)$.

2.3 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 $1 - f(R_j)$.

Each period then, R faculty members exit, and $G \geq R$ PhD graduates enter the academic job market. Departments with open positions rank the applicants using equation 2, and each graduate ranks the departments using equation 1. Applicants are placed into departments with open positions using the Gale-Shapley marriage matching algorithm. We run the model for 70 periods, representing about 2 generations of faculty.

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[4]3 percent is based on the notion that an academic career lasts approximately 35 years.

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

2.4 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.[6] These are administrative data filed each year by all universities in South Africa, regarding enrollments, graduations, staffing and research output. The currently available data run from 2003 to 2019, covering all universities in the country.[7]

In the model we have 20 departments each having 20 faculty members. We initialized the simulation to create 10 departments that represent the "formerly white" universities, and 10 that represent the "formerly black" universities. Among with "white" universities we differentiate between the 7 research intensive universities and the others. To construct these groups, initially the first 10 departments are stocked with white faculty, and the remainder with black faculty. We then change the race of 20% of the two sub-populations. That is, we switch 20% of the white faculty members to black, and 20% of the black to white. Thus initially while all departments are dominated by one or the other colour, most departments are not completely homogeneous.

Initial department quality[8] 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 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. We initialize quality at the department level, treating the first 7 departments in the simulation as the research intensive departments. The first 7 departments have quality evenly spaced between 7 and 10; the other 13 departments have quality evenly spaced between 1 and 4. Within each department, an agent's quality q_i is department quality multiplied by a uniform random number $\epsilon \in [0.95, 1.05]$.

Each period the oldest 3 percent of the faculty exits, initially implying 12 new vacancies per year. 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 2.0 for a very thick market. This way there are always more applicants than jobs, sometimes many more.

Since 2003, PhDs have graduated disproportionately from the formerly white universities, and in particular from the research intensive group. Combined, the 7 formerly white, research-oriented universities account for 62% of PhDs annually. Other universities account for the remaining 38%. However, we should 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 (in large part due to policy changes encouraging more PhD production). However the relative productivities of the research intensive to the other universities has been essentially unchanged over that pe-

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[6]https://www.heda.co.za/PowerHEDA/dashboard.aspx#divPDS

[7]Details of the calibration are presented in an appendix.

[8]Throughout, by "quality", we refer to traditional ideas of academic quality that results in publication. We acknowledge that ideas of what constitutes quality among academics may be changing, but for the moment at least the traditional definition has a large presence among science policy makers in South Africa, so it remains important in addressing the system.

riod.[9] 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.[10]

Each graduate also has a race. Empirically we observe that between 2003 and 2019 there has been a very strong relationship between the racial composition of a faculty, the racial composition of its Honours graduates,[11] and the racial composition of its PhD graduates. The relationship tends to be very localized, with the PhD composition of a university being "determined" (or at least predicted) almost entirely by the local faculty and local 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 both observations we assume that Honours graduates at formerly black universities remain 80% black, and we estimate the changes in formerly white universities by fitting a logistic curve to their Honours graduates. This which allows us to project into the future. (See equation 4.)

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

$$f(R_j, H_j) = 0.7R_j + 0.3H_j \tag{3}$$

where R_j is the proportion of black faculty, and H_j is the proportion of black Honours graduates:

$$H_j = 0.8 \times (1/(1 + \exp(-(a + b \times t)))), \tag{4}$$

with $a = -0.893$ and $b = 0.096$

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 10 to 100 years (using a latent parameter we refer to as *timetrend*).

A retirement creates a vacancy in a department; graduations create applicants for those vacancies. Assignment of applicants to vacancies is done with the Gale-Shapley algorithm with utility functions as defined above. 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, and applicant will consider no department whose average quality is such that $Q_j < T \times q_i$.[12] This parameter is difficult both to observe and to affect, so in each run of the simulation T it is drawn from a uniform distribution, $\mathcal{U}[0.5, 0.9]$, (and is the same for both departments and applicants).

Second, Cowan and Rossello show that close to 2/3 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

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[9]There is one exception, namely the University of Fort Hare, a formerly black university, whose productivity has risen sharply, now approaching that of the research intensive universities.

[10]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 retain that productivity throughout the simulation.

[11]Honours is a one year degree following a 3 year bachelor's degree and is predominantly taken by students interested in pursuing higher education.

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

a department receives from a new hire, there is a bonus if it is an internal candidate (*Same department bonus*):

$$U_{i,j} = q_j \times (2 - |R_i - r_j|)^{h_d} \times S_{i,j}, \tag{5}$$

where $S_{i,j}$ takes a fixed value $S \geq 1$ 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 vary extents and effectiveness) in several countries.

The thresholds 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.[13]

Homophily appears in the utility functions of graduates and departments. This is a parameter that is difficult to measure and difficult to change through policy intervention. Consequently we treat it as a random variable. For each run of the simulation, h_g and h_d are drawn independently from a uniform distribution, $\mathcal{U}[0, 1.5]$. 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.

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 over the history of the simulation, 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 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.

We initialize the model according the parameters as in Table 1 and run it for $\tau = 70$ periods, representing approximately two generations of faculty appointments, recording racial composition and quality of departments over time. We sample 4000 points in the parameter space for each of the three types of expansion.

Department size	20
Number of departments	20
Homophily	$h_g,\ h_d \in \mathcal{U}[0, 1.5]$
Quality threshold	$T \in \mathcal{U}[0.5, 0.9]$
Scale of PhD Graduates	$gradscale \in \mathcal{U}[1.2, 2]$
Time trend of black Honours	$timetrend \in \mathcal{U}[10, 100]$
Number of retirements per period	3% of faculty
Same department bonus	$S \in \mathcal{U}[0.8, 2]$
Length of history	$\tau = 70$

Table 1: Parameter settings

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[13]It is in principle possible for a department to shrink to size zero. We have assumed that if a department shrinks too far 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.
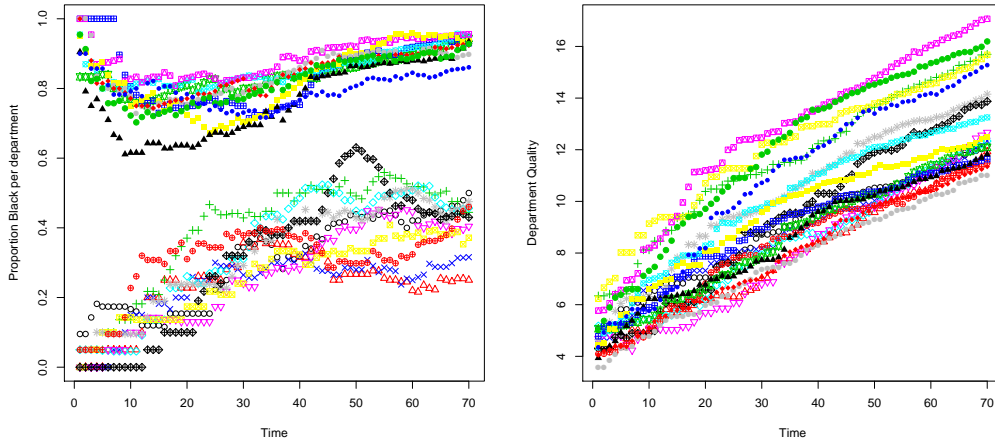
Figure 1: One representative run showing evolution over time of Proportion black faculty per department (left panel), and Department quality (right panel). Each colour and symbol represents one department. Parameter settings: expansion by racial composition; $h = 0.02$; (4) $timetrend = 30$; $Same\ dept\ bonus = 2$; $Threshold = 0.5$, $gradScale = 2$

3 Model dynamics

First, we present time series results of typical runs for different parameter values in Figures 1 and 2. They show the evolution of the racial composition and quality of the 20 departments.

From these two figures we can observe that very different histories are possible, depending on parameter values. As discussed above, different parameters are more or less susceptible to influence by policy, and we expand on this below. Here, though, we can see that racial transformation of the system does not necessarily take place (within the two generations of our histories). We can observe in Figure 1 that we do not see an integration of departments along racial lines — the formerly white departments do become "less white", but they do not approach the racial composition of the formerly black departments. There is movement towards convergence among departments, as both types of departments initially approach an intermediate composition. However, there is a limit to the movement of the white departments, and, around period 30, the formerly black departments begin hiring fewer white PhDs and move back towards their original composition. This is driven largely by issues of quality, coupled with the slow transition of Honours graduates, which slows down that transition of PhD grads, particularly at the high quality departments. Initially, highest quality graduates are being produced by largely white departments, and so graduates are largely white. They are attractive to all hiring departments, and so formerly black departments hire dis-proportionally white graduates. As their quality increases, so does that of their graduates who are still largely black. This eventually provides enough black graduates of high enough quality that the formerly black departments can recruit from their own graduates, and so their racial composition begins to revert. At the same time, in this particularly history, in the right panel we see a gradual divergence in quality among departments. The process just described is not strong enough to overcome initial conditions, and the initially higher quality departments remain so and in fact seem to diverge from the others. This is facilitated if are many graduates searching for jobs.
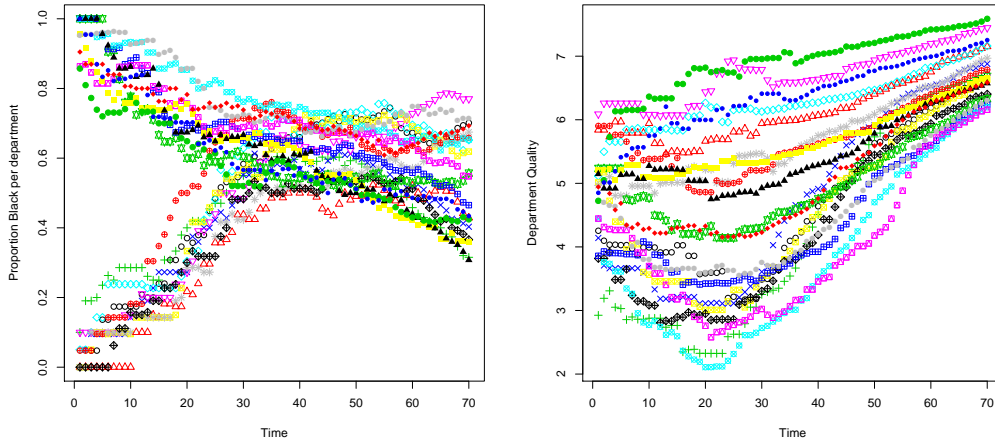
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Figure 2: One representative run showing evolution over time of Proportion black faculty per department (left panel), and department quality (right panel). Each colour and symbol represents one department. Parameter settings: expansion by racial composition; $h = 0.02$; $timetrend = 10$; $Same\ dept\ bonus = 0.5$; $Threshold = 0.9$, $gradScale = 1.7$.

Figure 2 by contrast, shows a convergence among departments to the same proportion of black faculty (possibly with some dispersion re-appearing at the end of the history). This is driven by the faster transformation of the Honours population, a large number of PhD graduates seeking academic jobs, and relatively low quality thresholds among both departments and graduates. The low quality thresholds implies that white PhDs are willing to move to the lower quality black departments, and so if those departments are attracted to high quality candidates, the latter are available. As the population of honours students rapidly transforms, this has a rapid effect on the composition of the PhDs at the high quality (white) departments changing the composition of their PhD graduates. Interestingly, under these parameter settings, department quality initially diverges then rapidly converges (right panel). This is driven by the high quality threshold. Initially poorer departments have difficulty finding high quality candidates that are willing to join their departments. This is true even of their own high quality graduates. What permits the poorer quality departments to catch up, particularly the formerly black departments, is the rapid transformation of the Honours graduates. Because homophily is present, a black graduate would prefer, all else equal, to work in a predominantly black department. If the high quality departments are producing many black PhDs, some of them will move to lower quality departments, thereby raising the average quality. Once this starts, a virtuous circle in quality emerges.

We turn now to a more careful analysis of the parameters of the model.

4   Two parameters

Before examining the effects of policy parameters, we briefly show the effects of homophiliy in the model. We mentioned above that there are two sorts of homophily present: race-based, and quality-based. The former we denoted simply as *homophily* and it appears in the utility functions of departments and graduates. The latter we have treated as a quality

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threshold: both departments and individuals have quality standards below which they will not consider an appointment. This creates an observed homophily in quality — most people in a department will be of similar quality.

In the model, both kinds of homophily, racial and quality, have some effect on both racial integration as well as quality in the system. Trivially, race homophily affects racial integration, and quality homophily affects system quality 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 (system-level) quality. On the other hand, quality homophily in the form of thresholds induces sorting by race as long as quality and race are not orthogonal to each other. This section discusses the main mechanics working in the model spurred by race and quality homophily.

4.1   Homophily

If department hirings exhibit racial homophily on either or both sides of the market, 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 in racial composition if race is a dominant consideration in hiring. The process by which this hurts quality is driven by the fact that initially the higher quality departments are predominantly white, and graduates resemble their departments both in terms of race and quality. Lower quality students from high quality departments, were they to be hired, could raise the quality of poorer departments. High homophily will prevent this "trickling down" of quality if high quality graduates are predominantly white and lower quality departments predominantly black (as is initially the case). When this happens, the graduate will leave academia. At the same time, 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 homophily could prevent the hiring up. At the same time though, if quality thresholds are high, the graduate will decline to be hired by a poorer department (and this can be particularly apposite if the graduate's department is not hiring this year) and so he or she leaves academia. In either scenario, quality suffers, and particularly in the latter case, racial integration will suffer as well.

4.2   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. High thresholds reduce aggregate quality levels. This 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 initially high quality departments are predominantly white; they retain high quality threshold, and since graduates inherit quality from their departments, "white" departments, in their desire to hire high quality graduates find them graduating from white departments, and, since they also inherit race from their departments, hire largely white graduates. The lower quality graduates of the top, white departments, themselves white, could move down the rankings, but the black departments tend to be significantly poorer in quality initially, so graduates with high thresholds will not consider them as employers, and so leave academia.

To summarize, our model suggests that quality as well as integration would, generally, benefit from low racial as well as quality homophily.[14] Both types of homophily are certainly present in the South African (and indeed most) academic systems, but both are difficult to affect through policy. Other features of the PhD to first job transition are susceptible to certain police measures however, and we turn to these now.

5   Policy analysis

In South Africa, higher education and science policy deals with two major themes. On the one hand, there is the need to expand and upgrade the higher education and science sector for economic development. On the other hand there is need is address the ongoing social transformation after apartheid. The overarching question therefore 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 two opposing objectives, and individual policy measures as trading one off against the other. The analysis in this section lays out potential 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, which is of concern to policy-makers in South Africa. Equality refers to the goal of eliminating the vestiges of apartheid whereby there was a strong difference 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 PhD; and policy to encourage inter-university mobility.

5.1   Methodology

5.1.1   Policy objectives and parameters

Formally, we distinguish three categories of variables in the model. Policy objectives, correspond to model outcomes. Some model parameters, termed policy parameters in the following, relate to real-world factors that are subject to policy intervention. Other influential factors that are difficult to observe, and difficult to change through policy, are captured by a vector of further model parameters. We discuss each in the following.

Policy objectives   are naturally connected to model outcomes. In total five policy objectives are considered: We measure the *size* of the system by the total number of academics in faculties. *Integration* is measured by the proportion of black academics in the system (p_b). *Equality* includes the idea that (potential) achievements of academics in the system should

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[14]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 black academics into the system at large, it would also corner black academics into lower quality tiers.

be independent of skin colour. We measure this by a difference in means test, comparing quality of black and white individuals in the system. Formally the statistic (p_q) is the probability that black and white qualities are drawn from the same underlying distribution of qualities.[15] Quality is measured by the average quality in the system (*average quality*, $\bar{q}$). Furthermore, we consider the maximum quality over faculties (*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 percent per year for the next 50 years, and much of the policy debate in South Africa circles around the question whether growth of formerly disadvantaged universities should be fostered to favour social transformation or whether funds should rather go to excellent universities to improve quality in the system. The HEDA data suggests 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* with equal chance for all faculties to open new positions, *quality expansion* with higher chances for higher quality faculties, and *race expansion* with higher chances for faculties with higher proportions of black academics.

The number of qualified job seekers relative to the number of open positions affects the development of faculties: more job applicants mean 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. Financing more 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* fixes the ratio of (applying) PhD graduates to open positions.

The development of proportion blacks in higher education graduates is likely to depend largely on factors determined outside the university system and subject to economic, social and higher education policies. The theoretical model follows the logic that individuals climb step-by-step up an 'education ladder', with the result that the time trend of proportion black in Honours influences the development of proportion black in PhD graduates. The *time trend* of honours graduates is modeled by a parameter that determines the expected number of years to reach a proportion black in Honours that is close to the proportion black 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 bonus*), a relevant policy parameter.

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[15]We obtain p_q through a standard, left-sided, difference-of-means test, where the z-value calculated as the average quality of blacks minus average quality of whites normalized by their average empirical standard deviations.

Further parameters are model parameters that are likely to be relevant in reality but hard to observe and to change through policy. The model allows for some homophily in the hiring process. Homophily of faculties and applicants are $hDepts$ and $hGrads$ respectively.

Candidates and hiring committees are likely have a certain quality threshold the other side of the market must exceed to be considered a potential match. Again that may be influential for the outcomes but is difficult to measure and to change through policy measures (not least due to being unacceptable for the stakeholders).

5.1.2 Policy effects

We are ultimately interested in how *policy changes* with respect to the status quo affect the state of the South African science system in the future. Our goal in this exercise is not to reproduce observed and predict future quantities characterizing the South African science system. Such a task would not be possible both due to a lack of data as well as due to the level of abstraction of the model. However, we believe that the theoretical model captures relevant aspects of the system dynamics, and our aim is to discover general tendencies of policy effects.

Because the model is non-linear, policy effects in general depend on the location in the parameter space. On the other hand, the model is also not chaotic such that small changes in initial conditions have large effects. Therefore, we are confident to ballpark a region in the parameter space that maps to the current state of affairs 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 in order to generate a robust idea of the changes that will result.

Policy effects are then obtained by comparing conditional expectations in the policy case to those in the base case. More precisely, we quantify policy effects in terms of percentage changes where objectives in the model are measured in terms of absolute numbers, i.e. for size, and quality. Policy effects are expressed in percentage points where the policy objective is expressed as a percentage (proportion black in the system), or a probability (equality inside the system).

5.1.3 The base and policy cases

In the following we define the parameter ranges for the base and alternative cases.

In the past 30 years SA universities have grown between one and six percent in terms of faculty. Ranking universities by growth rates is neither well explained by quality (in terms of university rankings) nor by the apartheid legacy of historically (dis-)advantaged universities. The observed pattern best corresponds to a random strategy in the model where new jobs are opened 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 somewhat limited. In the model we thus consider for the base case a range of $[1.2, 1.4]$ for the parameter *gradScale*. As policy case we consider the neighboring region with more graduates, i.e. a *gradScale* of $[1.4, 1.6]$.

The time trend of the proportion blacks among honours is estimated on the system aggregate, assuming a logistic growth function with a ceiling equal to the population share (see Appendix). The estimation predicts that around ten years from now, 35 years after the end of apartheid, 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 $[30, 40]$ years for the base case. The policy case is a faster time trend approaching within $[20, 30]$ years.

In South Africa, roughly two third of newly hired academics are hired by their graduating PhD institutions (Cowan and Rossello, 2019). This is captured by a simple stayer bonus in the utility function of applicants and hiring faculty, set to $[1.6, 2]$ (scaling utility) which reproduces roughly the observed pattern. We consider a policy that punishes stayers such that it fosters cross-faculty hiring up to the point of neutralizing the effect, by setting this parameter to $[0.8, 1]$.

Parameter values in base and policy cases are presented in table 2.

Parameter	Base case	Policy case
Expansion Type	random	{quality-based; race-based}
Scale of PhD Graduates	$[1.2, 1.4]$	$[1.4, 1.6]$
Time to 75% black Honours	$[30, 40]$	$[20, 30]$
Same department bonus	$[1.6, 2]$	$[0.8, 1]$

Table 2: Parameter settings in policy and base cases

5.2   Results of the Policy Analysis

The first step is to discuss the policy effect of individual policy changes on multiple policy objectives. In a second step, we turn to policy effects arising from the combined implementation of policy effects.

Table 3 shows the effects of single policy changes in the medium term, after 1 generation, and in the long-term, after 2 generations. To read the table, the value in the cell indicates the effect of the policy change, moving from the base case to the policy case, on the policy goal: positive entries imply an improvement in the goal relative to the base case negative entries imply a worsening of the system with respect to the objective. The absolute magnitude indicates (roughly) the size of the effect.

In general one observes that there is no policy that has an unequivocally positive effect on all objectives (all rows contain both positive and negative entries), neither is there any objective that is fostered (or harmed) by all policies (read along the columns). This precludes simple maximization solutions.

Some policy effects are in line with conventional wisdom. For example, policy discussions often raise the specter that expansion by quality raises quality at the cost of integration, whereas expansion by race fosters integration at the cost of quality. This intuition is born out by our results (see rows quality exp. and race exp. in combination with columns integration and average quality, after 1 and 2 generations). However, even at this point some nuances become clear. Although quality expansion does reduce integration into the system, resulting in fewer black academics than random expansion, it has a positive effect on *equality* within the system — the difference in quality between black and white academics is diminished (the probability that quality is the same in the two groups increases). On the

Table 3: Policy effects of shifting individual policy parameters

	size [%-change]	integration [%-points]	equality [%-points]	max quality [%-change]	avg. quality [%-change]
		After 1 generation			
quality exp.	0.112	-0.082	0.134	-0.004	0.206
race exp.	-0.123	0.144	-0.029	0.001	-0.280
more graduates	0.165	-0.038	0.281	0.036	0.348
faster time trend	-0.010	0.018	0.011	-0.0004	-0.017
fewer stayers	0.006	-0.034	-0.005	0.048	0.088
		After 2 generations			
quality exp.	0.240	-0.095	0.267	-0.002	0.196
race exp.	-0.156	0.215	-0.054	0.002	-0.381
more graduates	0.347	0.022	0.378	0.077	0.371
faster time trend	-0.018	0.004	-0.004	-0.009	-0.0001
fewer stayers	0.016	-0.038	-0.005	0.052	0.116

other hand race expansion may further cement existing inequality within the system by growing a larger black community in lower tier universities. We also observe that these effects grow stronger over time, from generation one to generation two.

Similarly, as one might expect, when more graduates apply for academic jobs, the effect is mostly positive. The size of the system increases, since fewer jobs are left vacant. Aggregate quality improves, since where there are more applicants there are more high quality applicants all else equal. Equality improves: more applicants means a thicker job market but with the same distribution of race and quality. The competition for jobs is stronger, any black graduate who is hired will be a strong candidate. That is, all jobs can be filled from the top tail of the distribution of quality, which will include more blacks (in number). But increasing the number of graduates has a detrimental effect on integration. The dynamic here is similar: jobs can be filled with the right hand tail of the quality distribution of graduates, and, given that they come from the top universities which are (still) predominantly white, there is a disproportionally large number of white job seekers, who squeeze out the black applicants.

A faster time trend in the black proportion of honours has relatively clear effects, aiding transformation in both integration and equality and reducing quality (maximum and average), but the effects are relatively small compared to the other policy measures. The policy effect of a faster time trend naturally reduces as time goes by because the model assumes that Honours graduates, in the long run, attain population composition. The exception is a sustained but minor policy effect on maximum quality.

Fewer stayers in the system has a clear competitive effect, improving quality. However, because whites tend to graduate from higher quality universities, black graduates are systematically disadvantaged in that competition leading to reduced integration and equality.

A naive approach to form a strategy based on this evidence would be to select a set of policies which, in sum, achieve a satisficing goal. One could be tempted for example to combine race expansion with more graduates as they seem to be largely orthogonal in their effects. We checked this. In many cases this is approximately true, but in particular

for race expansion there is a strong dilution effect on the positive effect of graduation scale on equality in the system.

What the model suggests, then, is that in the short run race expansion is the only policy measure to produce a stronger integration, increasing the proportion of black faculty in the system. But at the same time this has a deleterious effect on equal participation (the disparity in quality between white and black academics increases) no matter which additional policy is implemented. Consequently, quality expansion that fosters equality in combination with a strong time trend to increase participation looks relatively good in our results.

However, policy makers are not constrained to a single policy at a time.

5.3 Policy mix

Table 4 shows the effects of all possible policy mixtures. The first column, Mix, is simply the label of the policy mix. The next four columns: expType, gradScale, timeTrend and sameDeptBonus, show the state of that policy parameter in the policy mix represented by the row. A zero in a cell indicates that the policy parameter is set at the base case; a one in a cell indicates the policy parameter is set in the policy case. The next 5 columns show different policy goals, and whether they are improved in this policy mix relative to the base case. Thus in row 1, since the 4 cells are all zero, we are looking at the base case, and consequently the next 5 cells are all zero. By contrast, in row 10, we are looking at a policy experiment where expansion is by quality, the number of graduates seeking jobs is unchanged, the time trend is unchanged, but the same department bonus has shrunk, encouraging graduates to move to different departments for employment. The policy effects of that combination are that, relative to the base case, the size of the system is larger, black participation is smaller, the quality differences between blacks and whites are smaller, and quality in general has increased.

From this table we can extract two general messages. The first is that there is no policy mix that is worse than 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 to 24. The second message comes from examining those 4 strategies. All involve an expansion that probabilistically rewards departments that have a stronger presence of black faculty, but not an increase in the number of graduates (*gradscale*). The four dominating strategies result from race-based expansion and different combinations of time trend (speed at which Honours graduates transform) and extent to which graduates are "encouraged" to move departments when being hired. Reducing the 'same department bonus' (but keeping time trend unchanged), line 22, makes people change departments when they transition from student to faculty and increases competition for places. This has strong effects on all objectives except for integration (p_b) on which it still has a positive, but relatively weak effect. On the other hand, if integration is the primary goal policy should have the contrary construction: leaving the stayer bonus (*sameDeptBonus*) as it is, but increase the speed of transformation at the Honours level (*timeTrend*). If policy changes both, or keep both, it creates a trade-off between these two. 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. The estimates of the sizes of effects on the different policy goals arising from policy mixes 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 mixture 16 (quantity expansion, and all other policy measures invoked) gives the largest effect, estimated at 0.42. By contrast, among the mixtures that involve no losses in any goal, the best one can do on the equality goal is 0.17 (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 measures are of different importance.

Mix	expType	gradScale	timeTrend	sameDeptBonus	$size$	p_b	z_q	max_q	avg_q
1	random	0	0	0	0	0	0	0	0
2	random	0	0	1	0.01	-0.03	-0.01	0.05	0.09
3	random	0	1	0	-0.01	0.02	0.01	-0.00	-0.02
4	random	1	1	1	0.07	-0.03	0.06	0.06	0.20
5	random	1	1	1	0.17	-0.04	0.28	0.04	0.35
6	random	1	0	1	0.14	-0.06	0.24	0.07	0.38
7	random	1	1	0	0.15	-0.01	0.27	0.04	0.33
8	random	1	1	1	0.17	-0.04	0.28	0.06	0.38
9	quality	0	0	0	0.11	-0.08	0.13	-0.00	0.21
10	quality	0	0	1	0.10	-0.10	0.12	0.01	0.25
11	quality	0	1	0	0.14	-0.06	0.22	0.00	0.25
12	quality	0	1	1	0.15	-0.08	0.22	0.01	0.29
13	quality	1	0	0	0.18	-0.10	0.37	0.03	0.41
14	quality	1	0	1	0.18	-0.12	0.41	0.06	0.47
15	quality	1	1	0	0.18	-0.08	0.38	0.01	0.39
16	quality	1	1	1	0.18	-0.10	0.42	0.03	0.44
17	race	0	0	0	-0.12	0.14	-0.03	0.00	-0.28
18	race	0	0	1	-0.10	0.13	-0.04	0.05	-0.22
19	race	0	1	0	-0.11	0.15	-0.03	0.01	-0.26
20	race	0	1	1	-0.14	0.14	-0.05	0.05	-0.25
21	race	1	0	0	0.06	0.10	0.09	0.04	0.07
22	race	1	0	1	0.12	0.04	0.17	0.11	0.30
23	race	1	1	0	0.07	0.13	0.09	0.03	0.08
24	race	1	1	1	0.07	0.08	0.07	0.08	0.15

Table 4: Effects of different policy mixtures. For policy variables 0 indicates the base case, 1 indicates the policy case. For the policy goals, positive indicates an improvement, negative indicates a deterioration. Policy goal notation: $size$, total faculty in the system; p_b, proportion black faculty in the system; z_q, probability that black and white faculty are of equal quality; max_q, quality of "best" department; avg_q, average quality of faculty in the system.

6 Conclusions

In this paper 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 past and present. 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 analysing 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 leads 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 which are individually "second best". 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 Howell (2010), Fischer and Massey (2007), Loury and Garman (1993). Howell (2010) argues that removing affirmative action for minority students would diminish their representation in students in higher education in the U.S. by 2% but that representation would decrease at the most selective 4-year institutions by 10%. Two goals, that of increasing minority representation and of eliminating the stereotypic correlation between race and academic quality were in direct conflict.

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 aim of the government has been to increase the representation of the black population amongst university teachers. However, this is not the only goal, and this is to be combined with an improvement in the academic "quality" of the teachers and students in these institutions. We also examined the role of the size of the system in terms of the number of academics and its impacts on the other goals such as equality considered as a situation where achievement is independent of skin colour. A number of features emerge, and, as might be expected, policies cannot be considered in isolation and their complementarity has to be examined. As we have shown, putting in place a policy for one objective may impede the attainment of another goal. In this case a natural response may be to offset this negative impact by introducing another policy. However, if the resultant combination is not complementary the two may simply negate each other. Closer examination of our data and our results shows that there are cases where policies evaluated individually are second best but when combined produce a greater improvement than those which were best in isolation. Given this, the decision then has to made as to the weights to put on the different goals to be pursued. These observations on 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.

There are specific features of the South African case which are important. In many cases where discrimination, of the various types discussed in the paper, is detected, those discriminated against are a minority. The major exception to this is of course, gender discrimination which 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 to a somewhat more balanced composition. Yet our model suggests that the universities which were essentially white and during apartheid favoured will not necessarily converge to the same composition as those which were black and not favoured. Indeed, depending on the policy assumptions, a focus on integration there may produce a tendency for the gap to widen as the black universities become, for the reasons we have explained, blacker.

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 the controversial problem of universities employing their own PhDs a different

form of homophily which was positive on average for those involved but not good for the system as a whole.

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

Secondly, we can do more and 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. What did the strategies that made an overall improvement involve? All the possible combinations of acting on time trend (the speed at which Honours graduates transform) and on the extent to which graduates are "encouraged" to move departments when being hired, yield positive results. Reducing the 'stayer bonus' or making it impossible for universities to hire their own PhDs (but keeping time trend unchanged), makes people change departments when they transition from student to faculty and increases competition for places. This has strong effects on all objectives except for integration on which it still has a positive, but relatively weak effect. On the other hand, if integration is the primary goal policy should have the opposite orientation: leaving the stayer bonus as it is, but increase the speed of transformation at the Honours level (time trend). However, if we consider the other possibilities where policy changes both, or keeps both, it creates a trade-off between the two.

Finally for the future we should emphasise 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

In this appendix we give more details about the data and our calibration.

Some observations on the South African university system

Data   Our empirical observations on racial compositions within the SA HE system are based on the DHET/HEMIS data.[16] The data provides 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 to 2019. Information on (racial composition) of graduates from 1994 to 1999 is also available.

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 black is calculated throughout as the number of blacks over the sum of blacks and whites (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 out 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 percent of overall academics in faculties as well as PhD and honours graduates, but 30 percent of bachelors. The remaining 16 institutions are listed in Table 5. We differentiate institutions by their apartheid legacy — institutions that served higher education for people of colour have been formerly disadvantaged (fd), institutions for whites formerly advantaged (fa). The table only displays major antecedents, not shown are re-organizations of individual 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 black for individual institutions are given in Figure 3. 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 blacks in faculty (red),

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Table 5: 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)	Univ. of DurbanWestville (fd), Univ. of Natal (fa)
University of Pretoria (fa)	–
University of South Africa (fa)	Vista University Distance Education Centre (fd)
University of Stellenbosch (fa)	–
University of the Free State (fa)	–
University of Witwatersrand (fa)	–

and with a fraction of blacks in bachelor and 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 blacks in bachelors and honours is around 20 percent. Regarding dynamics one notes that the transition of the faculty is stronger in fd universities than in fa universities. Furthermore the proportion black in PhDs seems to be bounded below by the proportion blacks in faculty and bounded above by the proportion blacks among honours graduates for all universities over the whole period.

Two universities stand out: University of South Africa starts with a relatively high share of bachelors and 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 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. This leads us to investigate how estimation results change when these institutions are included or excluded. For now we keep them in.

The overall system has been growing considerably since 1994. In the more recent period, since the mergers, data is more reliable however. Academics grew in fa (fd) universities by 5 (6) percent, honours (postgraduates) 4.5 (9) percent, PhDs by 7 (14) percent. Accordingly the share of honours and PhD graduates produced by fd universities rose from 35 to 45 percent and from 22 to 35 percent 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 percent for roughly 50 years. Our simulations build on this envisaged growth.

Homophily in PhD formation The pool of applicants to academic positions is formed by PhD graduates. A high proportion of blacks among PhD graduates is therefore helpful for the transition of a white to a black faculty. This prompts us to consider the development

of proportion black among PhD graduates in the following.

Figure 3 shows for individual universities the 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 fd universities. The remaining 11 universities obtained preferential treatment during apartheid (fa). Clearly, historically disadvantaged universities have a proportion black among honours (dark blue line) close to one throughout the observation period, whereas the proportion black in Honours increases gradually from apartheid on in fa universities. Also, the proportion of black in faculty holding a PhD (red line) starts off much higher in fd universities, and tends to develop more dynamically than proportion black in fa faculties. At all universities however, the proportion blacks in PhD graduates tends to be bounded below by the proportion black in faculty and bounded above by the proportion black of Honours degrees.

In order to get some further insight, we estimate four versions of a simple linear regression model on that panel data. 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 of SA honours[17], and proportion of black in the focal faculty. Based on the assumption that a PhD takes five 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 white and black 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 feed-back 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 feed-back from faculty proportions. In order to identify the 'true' model, we calculate the mean squared error on leave-one-out jackknife sample predictions (without bias correction) as described in Lu and Su (2019).[18]

Results are given in Table 6. 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 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 the estimated coefficient of local faculty (lagged) at white universities in Model (1) and (3), we see that the estimate somewhat drops, suggesting that an upward bias is removed by the inclusion of university fixed effects. Yet, even in Model (3) local faculty remains a significant factor that dominates the effect of (local and global) honours proportions. For black universities we have a similar effect, a reduction from a significant 0.5 to an insignificant 0.3 estimate. In Model (3), the estimated coefficients for SA honours and local honours are opposing each other, cancelling out each other to some extent. Overall, estimation results for black universities remain somewhat ambiguous, probably due to the smaller number of observations (five universities).

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[17]The aggregate is obtained over all fa universities.

[18]Besides a linear model on proportions, we also estimated a logit model on individual probabilities on which we obtained qualitatively the same results.
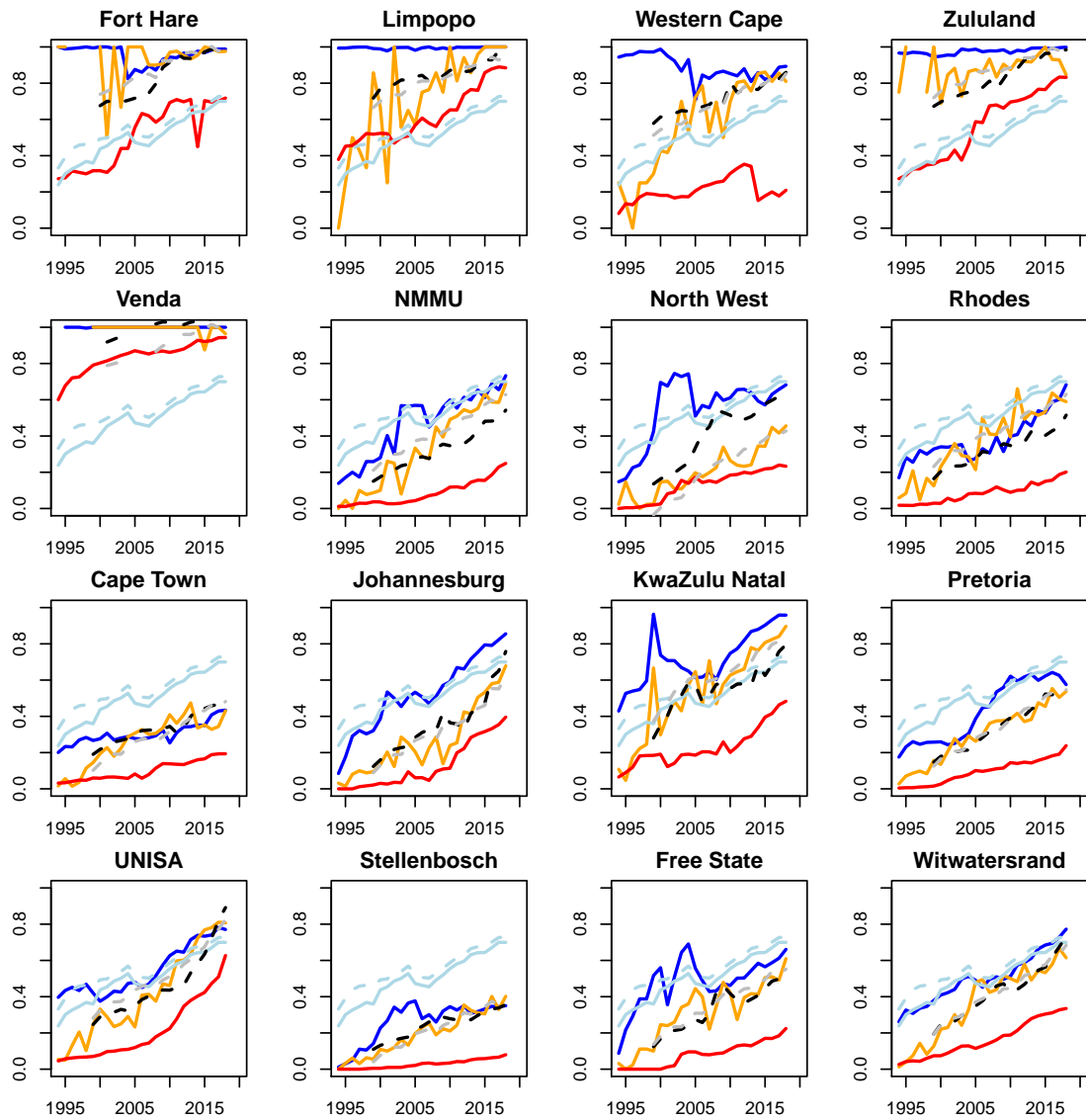
Figure 3: Time trends of proportion black in SA Universities. First five universities are formerly disadvantaged, the rest formerly advantaged institutions. Honours at the focal university in blue, honours in SA in light-blue, PhD graduates in orange, academics in faculty in red, PhD graduates fitted with Model (1) in black (dashed), and Model (4) in grey.

Table 6: Regression of proportion black in PhD graduates on proportions in lagged honours and faculty

	(1)	(2)	(3)	(4)
Black universities				
Intercept	0.951**	0.943**		
	(0.400)	(0.416)		
SA honours (lagged)	0.185	-0.016	0.427*	0.002
	(0.288)	(0.304)	(0.257)	(0.257)
Local honours (lagged)	-0.489	-0.317	-0.563^*	-0.369
	(0.384)	(0.395)	(0.290)	(0.279)
Local faculty (lagged)	0.549***	0.493***	0.315	0.002
	(0.137)	(0.140)	(0.212)	(0.206)
White universities				
Intercept	0.036	0.216***		
	(0.036)	(0.031)		
SA honours (lagged)	0.300***		0.607***	
	(0.080)		(0.084)	
Local honours (lagged)	0.191***	0.194***	0.102*	0.082
	(0.055)	(0.056)	(0.057)	(0.055)
Local faculty (lagged)	1.397***	1.361***	0.955***	0.691***
	(0.124)	(0.134)	(0.119)	(0.130)
Time fixed effects	No	Yes	No	Yes
Univ. fixed effects	No	No	Yes	Yes
Observations	312	312	312	312
R^2	0.964	0.966	0.984	0.987
MSE	0.0136	0.0147	0.0093	0.0099
F Statistic	1,023.283***	312.211***	814.173***	505.924***
df	(8; 304)	(26; 286)	(22; 290)	(df = 40; 272)

Note: *p<0.1; **p<0.05; ***p<0.01

Taken together, regression results suggest that there are idiosyncratic differences across universities, but provide also continuous support for a dynamic influence of proportion in faculty on proportion of PhD graduates. The development of honours is also significant in most regressions. On the other hand, although individual fixed effects improve significantly model fit, its introduction does not change the dominance of local faculty over honours. Figure 3 includes fitted proportion blacks of phd graduares 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 takes up however the (dominating) feed-back effect from proportion black in faculty 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 feed-back effect.

Estimated trend of SA Honours graduates   In Figure 3 we can observe that most formerly black universities have a constant level of proportion black in Honours graduates close to one. Thus dynamics of this population will be driven by transformation within the white universities. Focusing on that group of universities, we assume a logistic growth curve with ceiling 0.8 (which is the proportion black in the general population of South Africa). We fit the following logistic curve:

$$ProportionBlack = 0.8 \times (1/(1 + exp(-\eta)))\tag{6}$$

where *ProportionBlack* is the proportion black in the total number of honours graduates from fa universities, and $\eta = a + b \times t$. Estimation results, through OLS on a linear model obtained after transformation, are shown in Table 7, and illustrated in Figure 4, with t is restricted to $t \in [-10, 50]$.

Table 7: Logistic growth of proportion black in honours

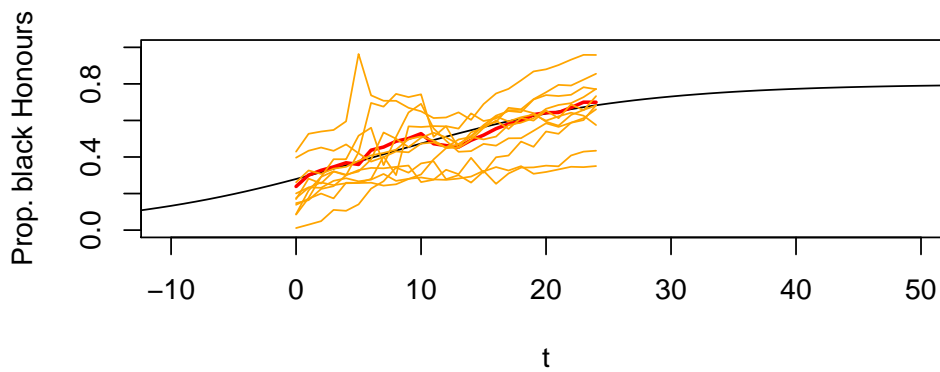|	
a	-0.893***
	(0.098)
b	0.096***
	(0.007)
Observations	25
R^2	0.891
F Statistic	188.938*** (df = 1; 23)
Note:	*p<0.1; **p<0.05; ***p<0.01

Figure 4: The estimated global trend of proportion black among honours graduates. Black estimated curve, red aggregate (white university) honours, orange curves show actual local honours curves of white universities.