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Emergent structures in faculty hiring networks, and the effects of mobility on academic performance*

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Abstract

This paper is about the South African job market for PhDs. PhD to first job mobility involves the preferences of both the hiring institution and the candidate. Both want to make the best choice and here institutional prestige plays a crucial role. A university's prestige is an emergent property of the hiring interactions, so we use a network perspective to measure it. Using this emergent ordering, we compare the subsequent scientific performance of scholars with different changes in the prestige hierarchy. We ask how movements between universities of different prestige from PhD to first job correlates with academic performance. We use data of South African scholars from 1970 to 2004 and we find that those who make large movements in terms of prestige have lower research ratings than those wo do not. Further, those with higher prestige PhD or first job have high research ratings throughout their careers.

JEL codes: D7; I2; J15; O3; Z13

Keywords: Academia, South Africa, faculty hiring network, institutional prestige, institutional stratification, scholars research performance, university system, matched pair analysis.

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1 Introduction

This paper is about the South African job market for PhDs. In particular, we ask whether PhD-first job mobility is correlated with future research performance. Given the increasing number of people with PhDs and the shortage of funds (David et al., 2011), academic recruiting is receiving growing attention in policy design of many countries (Dill and Soo, 2005). Our contribution looks at the South African PhD job market as a system where universities' prestige plays a role not only in hiring but correlates with individuals later academic performance. In particular we ask how movements between universities of different prestige from PhD to first job correlates with academic performance.

Young faculty hiring is a classic problem of asymmetric information (Connelly et al., 2011). PhDs usually have only a thin record of citations and publications, which means that their intrinsic quality is largely unobservable by any hiring committee. In this type of situation, a committee will look for signals of quality, one of which is the status of the university granting the PhD (Clauset et al., 2015). Moreover, since PhD to first job mobility involves the preferences of both the hiring institution and the candidate (Barnard et al., 2016; Conti and Visentin, 2015), and both want to make the *best choice*, hiring decisions are pairwise assessments of quality between the two agents. The sorting of PhD graduates through the first-job market thus implies an emergent prestige ordering of universities, encoding the collective assessment of each others' quality (Clauset et al., 2015).

In our analysis we first develop a new measure of prestige of the South African universities, based on the idea that the PhD job market contains information about how universities judge each other's graduates, and so, by implication, how they view each other's quality. The ordering that emerges implies what "typical" PhD to first job movements look like. We then examine those graduates who have "unusual" movements from PhD to first job, and ask whether these movements are correlated with future academic performance. This analysis is aimed at increasing the understanding of the university system, looking at social inequalities, and career trajectories. The literature generally finds that prestige is persistent across time and typically changes very slowly (Burris, 2004). Because it changes slowly, prestige can in fact be an effective signal with which to discriminate among job candidates, and if it corresponds to the "ability" of the graduate to pursue a successful career it represents the available way to select. But when the graduate's "ability" and the prestige of his/her institution do not perfectly overlap, prestige may not be the best operational variable for selecting the scholars because it will reproduce social hierarchies and inequalities among institutions, by disregarding (or failing to assess) the intrinsic merit of the candidates (Burris, 2004).

Our results are of particular interest in the South African context. The country is still struggling to achieve social transformation, especially within the university

system (Barnard et al., 2016). A part of this could be due to bottlenecks of the general university hiring process. Most of the under-represented groups, including people of colour, typically are less likely to consider an academic career than their white counterparts (Barnard et al., 2016). Studying the processes by which people get into this profession is one of the first knowledge gaps to cover. In recent years, mobility within an academic career, has been emphasised and promoted in many developed and developing countries. Mobility of scholars among institutions can have two opposing effects: at the micro level it could facilitate knowledge diffusion and individual careers, while at macro level it could pauperise sending communities (Ackers, 2005). From the individual perspective mobility permits agents to match and recombine knowledge, capabilities and aspirations by enlarging the network of interaction of both the migrant and the receiving institution. This can be beneficial also at macro level when the migrant acts as a bridge preserving the connections with his sending community (Barnard et al., 2012), but when this is not the case and he stops this interaction, local communities can experience a net loss from brain-drain. The scientific and political debate between academic mobility and knowledge is still open; contrasting results underline that different contexts, system design and incentives produce diverse outputs. In particular, it is unclear how mobility affects scholars' academic performance and whether these effects are different in systems with different maturity levels.

Our contribution reveals how the transition from PhD to first job, operating within a hierarchical system made of interactions among the different institutions, has long-run effects also on scientific performance. We show that the 5 most prestigious South African universities produce more than the 50% of PhDs in the country and they tend to hire their own or each other's graduates. Moreover, under-represented groups are more likely to move down in prestige than are white males. These findings are in line with previous US based works which find that faculty hiring obeys a hierarchical structure based on institutional prestige that produces social inequalities (Clauset et al., 2015; Burris, 2004). Our main concern is with the relationship between different prestige transitions from PhD to first job and performance. In this respect we find two results: a positive role of inertia, comparing scholars who stay in prestige with those who move; and a positive role of prestige, comparing scholars who experience similar mobility but with different starting or ending points. Inertia shows that scholars who make large movements in prestige have a lower performance then those who do not. While the role of prestige is evident looking within the group of scholars making large prestige movements; it is also the case that those with more prestigious PhD or first job have higher performance in terms of research ratings.

2 University prestige and young faculty hiring

To measure university prestige is not easy, this is mostly due to the definition of prestige people have in mind. Generally speaking prestige is associated to formal university rankings such as the Shanghai Jiao Tong Academic Ranking, or the Times Higher Education Ranking. But there are many other measures and methods that scholars have found to rank prestige of departments and universities. Some of those are subjective survey based measures, output based measures, labour market based, or some combination of thereof. During the 70s and the 80s many works analysed the relationship between subjective reputational rankings based on surveys and objective rankings based on research outputs and productivity (e.g. citations, citations per capita, number of paper published). Hagstrom (1971) for example uses survey data of department prestige for hard sciences in US, looking at the correlations between prestige and input/output variables of the universities; He finds that prestige correlates with size, research output, research facilities and opportunities, quality of faculty background, number of postdoctoral fellows, selectivity of the undergraduate program, and awards. In this respect, Webster et al. (1991) present an extensive review of this debate looking at work published between 1965 and 1982. The authors collect 28 articles aimed at ranking Sociology departments in the US, and find similarities and differences between reputational rankings and productivity rankings. In particular they underline the strong correlations between these two measures when the sample is restricted to the top departments. Additionally they highlight, as in a more recent contribution of Burris (2004), the persistence over time of department prestige, finding previous prestige to be the best predictor for current prestige no matter the level of previous productivity. Webster et al. (1991) conclude that future research on prestige rankings should incorporate the sociological stratification perspective in order to explain the link that universities' status have with job market placement and research performance.

In sociology, institutional stratification in higher education refers to a social process that causes a hierarchical differentiation among the universities, with elite and prestigious schools on one side and lower status ones on the other (Shavit et al., 2007). University prestige enhances stratification, as Jung and Lee (2016) summarise, because it engages and attracts the talented experts and resources. This causes structural inequalities within the higher education system. For example Mai et al. (2015) study the hiring network of PhDs in the field of communication in the US. They find that the hiring patterns follow a strict hierarchy, in line with the stratification hypothesis. The article also finds that the institutions' placement capacity of their PhD graduates in other universities is particularly stratified. This supports the idea that the hiring network represents bilateral assessment of quality among institutions because it signals an acknowledgement towards the university that trained the PhD, and suggests further that an examination of hiring patterns will reveal the consensus prestige ranking.

Bair (2003) studies the link between university prestige of American finance PhD programs and hiring. He finds that top ranked PhD programs in finance preserve their reputations by hiring each other's graduates or directly their own graduates. His findings are also linked to previous work, where this pattern is evident in prestigious doctoral programs in other fields: law schools, mathematics, physical sciences, social sciences, chemical, engineering, psychology, and social work (Bair and Boor, 1991; Bair and Bair, 1998).

Bedeian and Feild (1980) study the stratification hypothesis using US data from 24 top graduate departments of management. They find that the academic placement in management departments is influenced by doctoral prestige (measured by a subjective survey-based measure); in particular they find a significant relationship between the prestige of scholars' PhD and the prestige of their current position. The article ends with two possible opposite explanations: Either merit is irrelevant and hiring processes rely on prestige only; or the prestige of people's PhD department is related to an unobserved variable indicating the scholar's intrinsic ability. But instead of looking at the scholars' PhD prestige alone, we look at individual prestige transitions from PhD to first job and whether those are correlated with future research performance.

The relationship between prestige of a person's former university and current position is also well known in non-academic job placement. Jung and Lee (2016) look the relationship between university prestige and subsequent wages of workers in South Korea. The article finds that university prestige, measured using standard university rankings, matters in terms of job market outcomes particularly in terms of salaries earned.

Araki et al. (2016) study employee promotion in Japanese manufacturing industries, finding again the crucial role of the prestige of the universities where the workers got their degrees. To measure prestige they rely on standard university rankings and they find that in the early stage of workers career university prestige is crucial because it corresponds to the employer's prior distribution of abilities among workers. So, among young employees the likelihood of being promoted is higher for those with prestigious degrees because the employer will decide who to promote according to his prior.

In this paper we explore the relationship between university prestige, young faculty hiring and individual research performance. Past research underlines how young faculty hiring follows a rigid stratified hierarchy (Clauset et al., 2015; Burris, 2004). So in line with this literature we develop a network-based measure of the prestige of South African universities. We then compare the future research performance of scholars with different prestige movements in their PhD to first job transition. We find that inertia and university prestige are positively related with scholars' rating performance. Related to inertia we find that the scholars who make large movements in prestige have lower ratings than those who do not. Related to prestige, instead, we find, looking those who experience large movements in pres-

tige, that those with higher prestige PhD or first job have higher ratings. Our work addresses the knowledge gap regarding the relation between the role of university prestige in young faculty hiring and the subsequent individual performance of the scholars. This will increase awareness about the functioning of the higher education system in an emerging country as South Africa and show whether it displays similarities with previous, mostly US based, work.

3 Data and variable construction

We use data from the South African National Research Foundation (NRF[1]) from 1970 to 2004 which contains detailed personal information of the scholars (i.e. gender, ethnic group, affiliation, career history, scientific field, and NRF rating). Our main variable is the NRF "rating" for years 1983-2012, which is a measure of individuals' academic performance. The process by which the NRF grades researchers is rigorous, because it involves international referee reports looking at the CVs and the scientific output of each candidate applying to be rated. This process ends with a grade: a scientific committee evaluates the quality content of the referee reports and assigns the rating based on 13 ordered categories. The rating is unsuccessful when the referee reports are of poor content and/or the committee lacks the information to make a judgement. Strong institutional incentives imply that almost all academics with a research oriented career apply to be rated: NRF data cover the 30% of scholars in the country who produced about 90% of all South African peer-reviewed research outputs (Barnard et al., 2012; León et al., 2016).

Our analysis focuses on scholars in the field of Science, Engineering and Technology (SET), but for completeness we also provide information on the field of Social Sciences and Humanities (SSH). In the field of SSH language and schools of thoughts usually put constraints on the PhD to first job transition. These constraints are particularly relevant and represent a bottleneck in the South African context. Separately for each field (SET and SSH) we construct the hiring network among the different South African institutions, based on scholars who found their first jobs within 5 years of receiving the PhD. We then calculate our network-based measure of university prestige (*prestige ranking*) and for each individual his prestige rank-change from PhD to first job (i.e. the difference between the prestige ranking of PhD and that of the first job). In the next sections we present the details of the faculty hiring network, prestige ranking, and prestige rank-change.

3.1 Faculty hiring network

The hiring networks of SET and SSH are two weighted and directed adjacency matrices. Each matrix M has 22 rows and columns that are the 22 South African uni-

[1]NRF (`www.nrf.ac.za`) is a state agency that has as its mission the promotion of research and the development of national research capacity

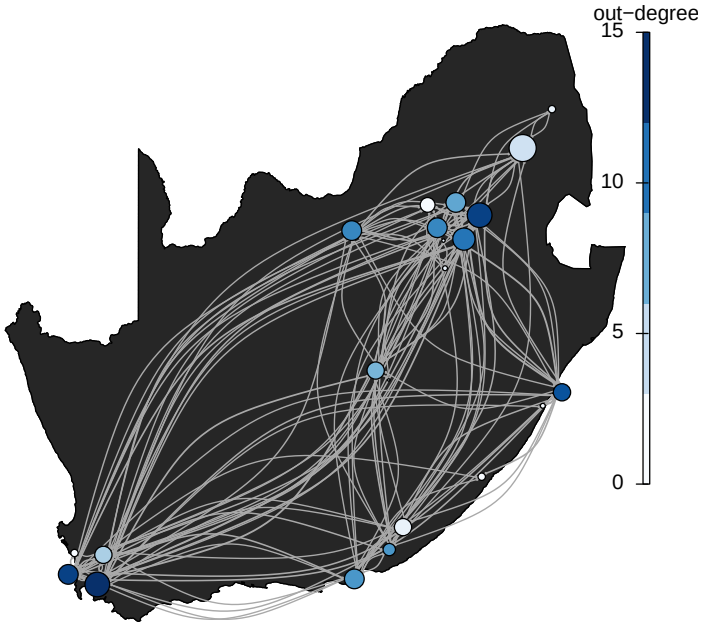

Figure 1: Hiring networks 1970-2004 SET. The vertex are the South African Universities, plotted according to their geographical coordinates (for the institutions located in the same area we separated manually). Vertex size in-degree, vertex colour out-degree. Where the correlation between in-degree and out-degree is 0.72.

versities,[2] where each entry m_{ij} represents the number of scholars with a PhD from university i and a subsequent first job in university j. Tables 8 and 9 show summary statistics of the hiring network for all, male, female, white and black[3] scholars for SET and SSH. Both fields show a common pattern for females and blacks, their networks are sparser than those of white males (figure 9). That is, they have fewer edges and so lower density, but also higher average path length, and a lower clustering coefficient. The networks of SET and SSH (shown geographically in figures 1 and 2) show common hiring corridors, where universities with high production of PhDs tend to hire more (nodes with high/low in-degree tend to have high/low out-degree); indeed, the correlation (excluding self-hiring) between in-degree and out-degree is 0.72 for SET and 0.53 in SSH. The exceptions to this strong correlation are for SET: Tshwane University of Technology, University of Fort Hare, and University of Limpopo that have a high hiring (in-degree) and a low placement (out-degree); while University of KwaZulu-Natal, and University of Cape Town

[2] In 2004 the university system was reformed: some universities were merged and changed names. The reform does not affect the big universities, excepting University of Johannesburg and KwaZulu-Natal, but does have some effects on the slower ranked ones. We use the post-merger names because the data are more complete. We discuss this in Appendix A.

[3] In this section we consider with "black" all ethnic groups offended by the Apartheid regime

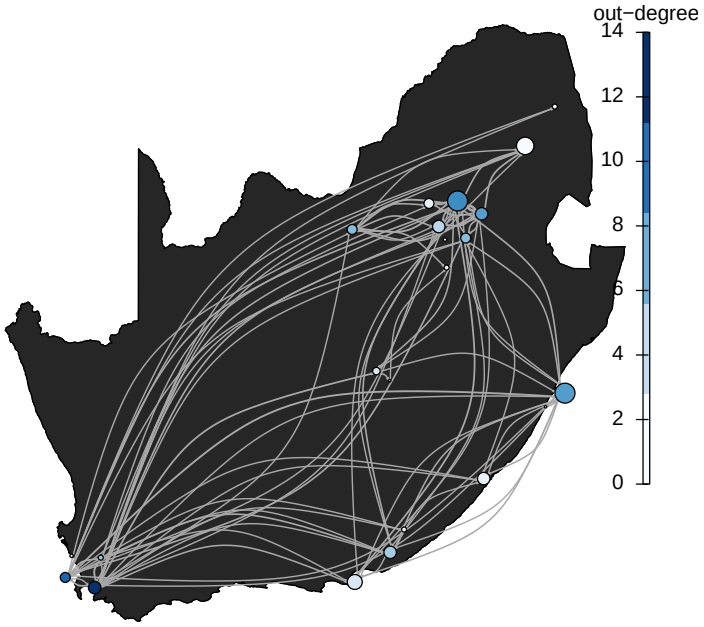

Figure 2: Hiring network 1970-2004 SSH. The vertex are the South African Universities, plotted according to their geographical coordinates (for the institutions located in the same area we separated manually). Vertex size in-degree, vertex colour out-degree. Where the correlation between in-degree and out-degree 0.53.

instead show a high placement (out-degree) and a low hiring (in-degree) (shown in table 10). For SSH we find the following exceptions: Walter-Sisulu University, Nelson Mandela Metropolitan University, and University of Limpopo with a high hiring (in-degree) and a low placement (out-degree); and University of Stellenbosch, and University of Cape Town with a high placement (out-degree) and a low hiring (in-degree) (shown in table 11). We observe that the universities with a high hiring and low placement are historical black universities, while those with an high placement and a low hiring are historical white universities with the exception of KwaZulu-Natal.[4] This suggests that formerly black universities have been upgrading by Apartheid.

3.2 Prestige ranking

We consider university prestige as a social assessment, emerging from the interaction among institutions. Authoritative university rankings can proxy prestige, but they put interaction out of the picture and have questionable reliability. Prestige is not an individual attribute but it is part of a social process (Burris, 2004; Clauset

[4]KwaZulu-Natal was formed in 2004 after the merger between the University of Natal (white) and the University of Durban-Westville (indian)

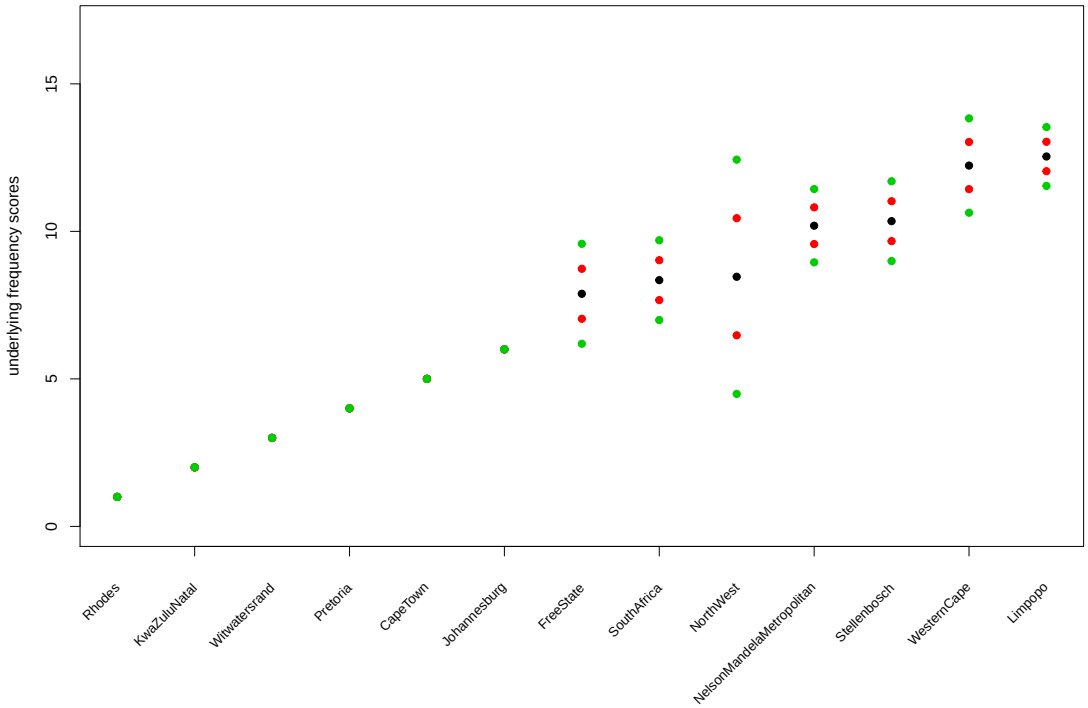

Figure 3: Prestige Ranking for SET 1970-2004. The frequency scores are in ascending order from the highest prestige which correspond to one. The black dots is the average of the orders with the maximum scores under 10.000 repetition, red dots and green dots are respectively one and two standard deviation from the average. Our algorithm runs on the adjacency matrix of the hiring network. Universities with fewer than 5 PhDs are excluded.

et al., 2015). Consequently, following Clauset et al. (2015), we develop our new measure of prestige ranking where the institutional status arises from the patterns observed in the faculty hiring network. We start from two hypothesis:

1. *Universities want to improve the quality of research and teaching. A colloray is that they want to hire from universities that are "better" then themselves;*

2. *Scholars want to be hired by the best universities.*

When the desires expressed in these two hypothesis are perfectly satisfied, we can order universities (the rows and column of the adjacency matrix M) so people only move down the ordering, implying that the adjacency matrix has only zeros below the diagonal. Since actual hiring often departs from this "ideal" we search for an ordering that most closely approximates "zero weight below the diagonal". We apply to the adjacency matrix M the algorithm inspired by Vries (1998) and Clauset et al. (2015). The algorithm starts with a random ordering of rows (columns always having the same ordering as rows) of the matrix o_0 and we compute the score s_o of this order, where:

Definition 1. An order o_k is an ordered n-tuple of universities names, and its score

s_k is $\sum_j (\sum_{i<j} m_{ij} - \sum_{i>j} m_{ij})$

The algorithm tries to improve the score of the current order o_0 100 times, swapping each time 2 nodes (one row and one column). If the swap improves (or not decreases) the score we keep the swap, otherwise we revert it. We repeat this procedure 10000 times to get a set O of 10000 orders and 10000 related scores S

Definition 2. The set of orders O is $O = \{o_1, o_2, ..., o_{10000}\}$;
The set of scores S is $S = \{s_1, s_2, ..., s_{10000}\}$.

Then we create the set Q of the orders $o \in O$ with the maximum scores:

Definition 3. Let Q be the set of orders with maximum scores $Q = \{o \in O | s_o = max(s_k)\}$, where o is a set of orders and $k = 1, 2, ..., 10000$

Then for each university we compute the mean of its ranks in the orderings in Q, obtaining our prestige ranking. To note is that our prestige ranking is not a rank of natural numbers, it is an average value. This is important because gives a better picture of university prestige where the distances in prestige among institutions are not of a fix amount: some universities has similar averages so they are closer in prestige then those with distant average values.

Moreover, to have a reliable measure we remove universities with fewer than 5 PhDs in the period. Figures 3 and 4 show the results of our prestige rankings for SET and SSH. The frequency scores are in ascending order from the highest prestige (which corresponds to a score of one) to the lowest.

3.2.1 Prestige ranking and other measures

For a robustness check we look at the correlations between our prestige ranking and measures of research output. The correlation between prestige and number of papers per person is statistically significant and is 0.6 in SET. When we look at number of citations per paper of SET and its correlation with prestige ranking we find a non statistically significant correlation of 0.2. In this respect we find an outlier: Stellenbosch university. This can be due to the fact that Stellenbosch was specialized in the period. When we remove this outlier the correlation between prestige and number of citations per paper is statistically significant and equal to 0.6. So, our measure of prestige correlates with measures of research performance.[5] This is in line with past contributions (Burris, 2004).

3.2.2 Institutional Stratification

Tables 13 and 14 witness the institutional stratification hypothesis, respectively for SET and SSH. They show the number of PhDs from the top 5 prestige universities

[5]Repeating this for SSH we find non statistically significant results. As discussed previously our methodology is less suited for SSH

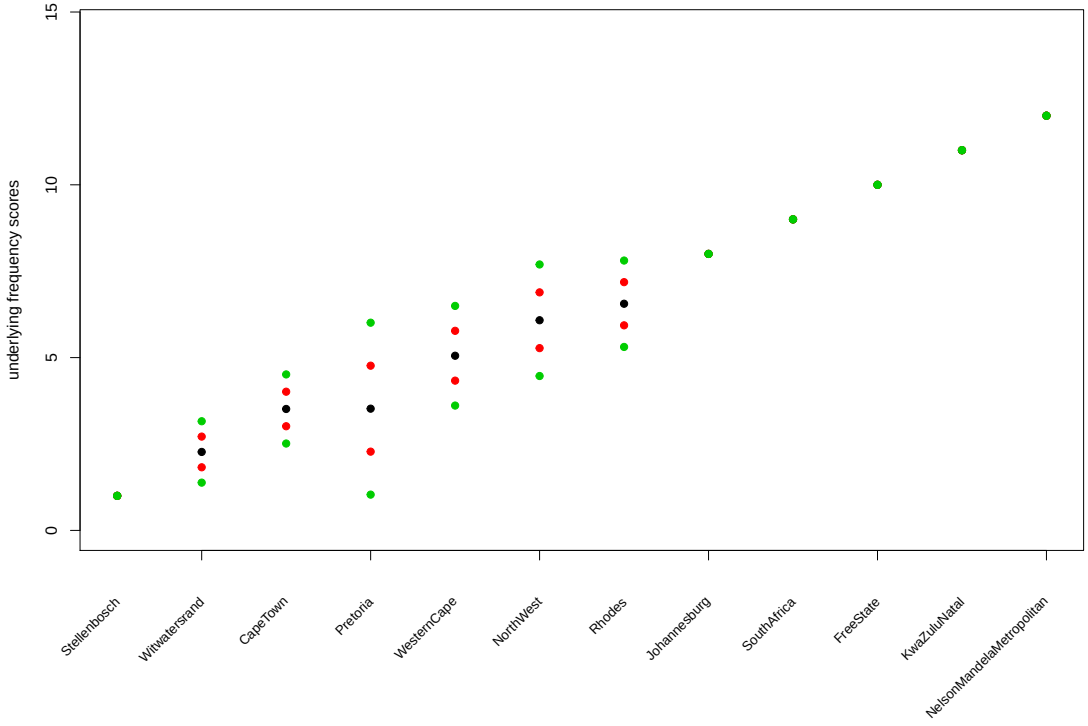

Figure 4: Prestige Ranking for SSH 1970-2004. The frequency scores are in ascending order from the highest prestige which correspond to one. The black dots is the average of the orders with the maximum scores under 10000 repetition, red dots and green dots are respectively one and two standard deviation from the average. Our algorithm runs on the adjacency matrix of the hiring network. Universities with fewer than 5 PhDs are excluded.

hired within the other top 5 institutions, and those hired in others. The results are striking. In SET the top 5 prestige universities produce the 58% of all scholars in the country, while for SSH the percentage is 48. Among those, in the field of hard sciences, the 77% find a first job within these 5 institutions and 74% in SSH. This underlines the crucial role of prestige hierarchies in academia. We find deep inequalities among universities in terms of first job placement, endorsing previous US based work (Burris, 2004; Clauset et al., 2015). So, South Africa shows a pattern of stratification similar to those found in more mature knowledge systems. Moreover, the lower percentage of the first job placement of the top universities in SSH with respect to SET highlights the diverse hiring processes of the two fields. SSH are often govern by schools of thought and in South Africa language and culture also play important roles. This makes hiring processes more complex and less predictable.

3.3 Prestige rank-change

Prestige rank-change measures the movements in prestige of individuals from the PhD to the first job. The measure is simply the difference between the prestige

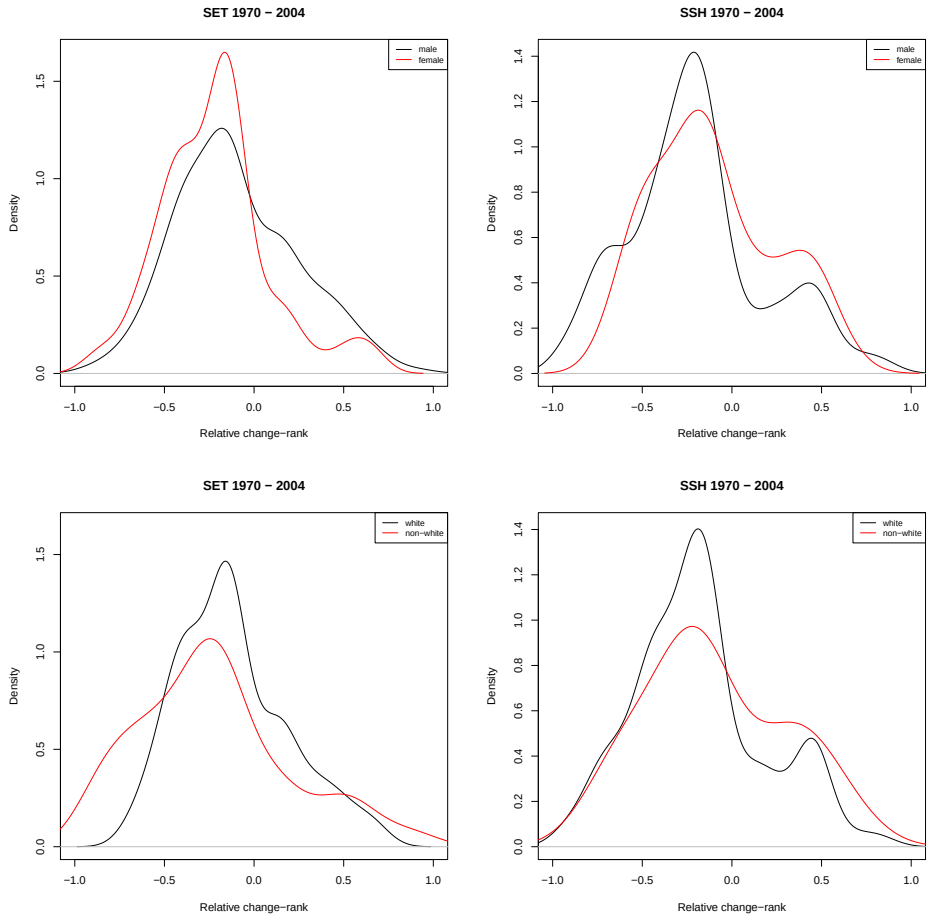

Figure 5: Relative prestige rank-change distributions for SET (left) and SSH (right). We included only rank-change different than zero. For male vs. female, white vs. black (bottom). The p-value of 2-sided Ks test for male vs. female is 0.038 in SET and 0.366 in SSH, while for white vs. black is 0.033 in SET and 0.926 in SSH

ranking of the university where a person obtained his PhD and the one of his first job.[6] So each young scholar can move in the hierarchy in three ways:

1. UP: if his prestige rank-change is positive. He gets his first job in an institution more prestigious then his PhD;

2. DOWN: if his prestige rank-change is negative. He gets his first job in an institution less prestigious then his PhD;

3. STAY: if his prestige rank-change is zero. In practice, that means he is hired by the institution granting his PhD.

[6]To note is that our prestige ranking is in ascending order: the lower the number the higher the prestige.

Figure 5 shows the distributions of rank-change in relative terms for SET and SSH where we compare female vs. male and white vs. black. We find that people tend to move down the hierarchy the distributions peak toward negative numbers, as is consistent with our basic assumptions. In SET, both females and blacks are more likely to move down in prestige than white males (P-values of 2-sided Kolmogorov-Smirnov (KS) tests $< 5\%$). In SSH, by contrast, the movements of the groups are not statistically different from each other. Though this is not our major concern, we included a simple regression as a check on the strength of this observation. We obtain consistent results (Tables 15 and 16) performing a multiple regression analysis, using rank-change as a continuous dependent variable, controlling for possible confounding factors such as individual productivity, interaction effects between productivity race and gender, and cohort effects in time decades. In SET blacks and women are likely to have smaller increases in prestige than white men. In SSH, race has no (significant) effect, whereas women have larger increases than man, but there is a poor goodness of fit overall.

4 Matched pair analysis

Given the structural hierarchies in faculty hiring, people moving up the hierarchy are rare. So we test whether they have something special. We ask, in particular, whether *uncommon* prestige transitions from PhD to first job are correlated with future research performance and whether the relationship changes over time. We perform a matched pair analysis following a re-sampling technique. We compare scholars' NRF ratings at different points in time (5, 10, 15 and 20 years after they were granted their PhD), looking whether people with different prestige transitions (Up, Down, or Stay) but same individual characteristics differ in rating. For each time span, we do a matched pair analysis comparing the transitions: Up vs. Stay, Down vs. Stay, and Up vs. Down. We match people according to gender, ethnic group, PhD obtained year, and either receiving or sending university. So, for each of the three comparisons we look at pairs of scholars from the same receiving or sending institution. When we match people with the same receiving university we compare people with same characteristics hired into the same institution. The match using the same sending institution, instead, compares individuals with a PhD granted by the same university. To differentiate between sending and receiving institutions is important also because it is a control for possible Matthew effects on performance driven by university prestige. That is: the more prestigious a university is, the greater its ability to attract resources and this can result in higher productivity of the scholars and therefore higher NRF ratings. We solve this possible source of endogeneity by matching people with same receiving institution, while the match for same sending university looks at the effects of mobility. For the reason explained above, we focus our analysis on SET. As testified by the heavy diagonal of the SET hiring network (table 2) individuals who move (Up or Down) in prestige rankings are less numerous than those who stay (roughly two-thirds of

PhDs do not change institutions for their first job). Movements in prestige ranking are rare events, so for each scholar who moves there are many potential matched individuals who stay.

We use a re-sampling technique as follow. To do the Up vs. Stay comparison, we start with the set U of people who move Up, of size N_u and a set S of people who Stay, of size N_s. Then we sample with replacement, N_u people from the set U getting U'. For each member in U' we find his matches in S, and we pick one of his potential matches at random. In this way we create matched pairs Up-Stay. Then we calculate and store the proportion of those pairs in which the Up person had a higher NRF rating (r) than the Stay person $r_{up} > r_{stay}$ and vice versa $r_{stay} > r_{up}$. We then repeat this 10000 times obtaining distributions of those proportions, $F(p|r_{up} > r_{stay})$ and $F(p|r_{stay} > r_{up})$.

Under the null Hypothesis that prestige movements are unrelated to individual performance, for each comparison, the distributions of the proportions should be exactly the same, that is **H0:** $F(p|r_{up} > r_{stay}) = F(p|r_{stay} > r_{up})$. So when the null Hypothesis **H0** is rejected the distributions are different, and then, we look whether one distribution stochastically dominates the other. According to the definition of First-Order Stochastic Dominance:

Definition 4. a CDF $F(x)$ First-Order Stochastic Dominates $G(x)$ iff $F(x) \leq G(x)$ for all x (Mas-Colell et al., 1995).

If for example $F(p|r_{up} > r_{stay}) \leq F(p|r_{stay} > r_{up})$ we have that $F(p|r_{up} > r_{stay})$ stays below the other distribution $F(p|r_{stay} > r_{up})$ which means that the expected NRF rating is higher for those who went up the hierarchy in comparison to those who stays.

5 Results

The major concern of this paper is whether prestige movements from PhD to first job correlate with the future research performance of the scholars. We compare, for different points in time, the NRF rating of individuals with the same characteristics but different prestige rank-change movements: Up vs. Stay, Down vs. Stay, and Up vs. Down. Since prestige could influence individual careers differently as time passes; we look at people's ratings 5, 10, 15 and 20 years after their PhD. For each group comparison we study separately people hired by the same (receiving) university and those with a PhD granted by the same (sending) institutions. Moreover, our matching technique accounts also for additional confounding factors: gender, ethnic group, and PhD obtained year. The null hypothesis **H0** of our matched pair procedure is that prestige movements are unrelated to research performance: the distribution are equal:

$$\textbf{H0: } F(p|r_{up(or\ down)} > r_{stay}) = F(p|r_{stay} > r_{up(or\ down)}). \quad (1)$$

Performing two-sided and one-sided KS tests, we find that this is not the case, in each comparison the distributions are different and one always stochastically dominates the other.

Figure 6 shows the results of Up vs. Stay. Looking at people hired by the same institutions (left column) and those with the same PhD institution (right column) we find consistent results. After 5 years $F(p|r_{up} > r_{stay})$ (black curve) stochastically dominates the other $F(p|r_{stay} > r_{up})$ (grey curve); while 15 and 20 years later we have the reverse: $F(p|r_{stay} > r_{up})$ dominates $F(p|r_{up} > r_{stay})$. This tells us a consistent story. In the short term, those persons who are promoted, move up in prestige, have higher ratings then those who stay; while in the long term we have the opposite result: those who do not move (stay) have higher ratings. So in the long term, looking at people with the same first job, we find that those with "better" PhDs (stay) do better; while looking at people with same PhD institution, those with "worse" jobs (stay) perform better.

Figure 7 shows the results for the Down vs. Stay comparison. With two exceptions (first job match 20 years, and PhD match 5 years) we find that $F(p|r_{stay} > r_{down})$ stochastically dominates $F(p|r_{down} > r_{stay})$, which is: those who stay have higher ratings than those who move down in prestige. In particular looking at those with the same first job (left column) we have that those with "worse" PhDs (stay) do better; while when we look at people with same PhD institution (right column), those with "better" jobs (stay) perform better. Again we find that those who do not move after their PhD have higher ratings.

The results for the Up vs. Down comparison are consistent (Figure 8) and they capture the link between of university prestige and performance. But, because of the small sample size of both groups this comparison is less reliable, and needs cautions interpretation. To have a reasonable number of matches we relax the matching for the characteristics of PhD obtained year, where we consider an interval of six years. That is, two agents match on PhD year if they are within ± 3 of each other. Figure 8 shows, looking researchers hired by the same institution (left column), that $F(p|r_{down} > r_{up})$ dominates $F(p|r_{up} > r_{down})$. That is those coming from a higher prestige (down) institutions perform better in NRF rating than those coming from a less prestigious universities (up) and the gap increases across time, the distance between the two cumulative distributions increases. While looking people with the same PhD institution (right column) we find that $F(p|r_{up} > r_{down})$ dominates $F(p|r_{down} > r_{up})$. That is, those who move up the prestige (hired by a more prestigious institution) perform better in ratings than those hired in a less prestigious universities. So comparing people who experience mobility in the transition from PhD to first job we have that, holding job constant, coming from "better" PhD (down) is good; while holding PhD constant, going to "better" job (up) is good.

We can then summarise the results in a more intuitive way. When we compare

people who experience transitions from the PhD to first job with those who do not (that stay) we find a beneficial inertia effect. Those who stay in the same university after the PhD have higher rating. This positive effect of inertia can be due to various factors: universities keep the best scholars for them; mobility has a negative effect because it disrupts knowledge networks; or personal incentives. But it can also simply relate to the way the PhD job market works: A university has better information about its own graduates, and so it can make better judgements with respect to their intrinsic quality; moreover since it also has strong incentives to keep its best students it will hire them. The comparison of Up vs. Down instead tells us the role of university prestige; when people experience PhD to first job mobility their movements in prestige are crucial: holding PhD constant, moving to a more prestigious first job is better; and holding first job constant, having a more prestigious PhD is better

5.0.1 Cohort effects

Cohort effects could drive our results for the observed differences in time spans (short, medium and long-run). This because the cohort composition is different in each time sample. Specifically, 5 years rating include PhDs from 1970 to 2004; whereas 20 years ratings include only PhDs from 1970 to 1992. To test for this cohort effect hypothesis we repeat the analysis restricting the sample to only older scholars, with a PhD granted before 1992. Figures 12, 13, and 14 show the results for the restricted sample. This results are consistent with the ones discuss above, therefore we can exclude this hypothesis. Our results are not driven by changes in the cohort composition.

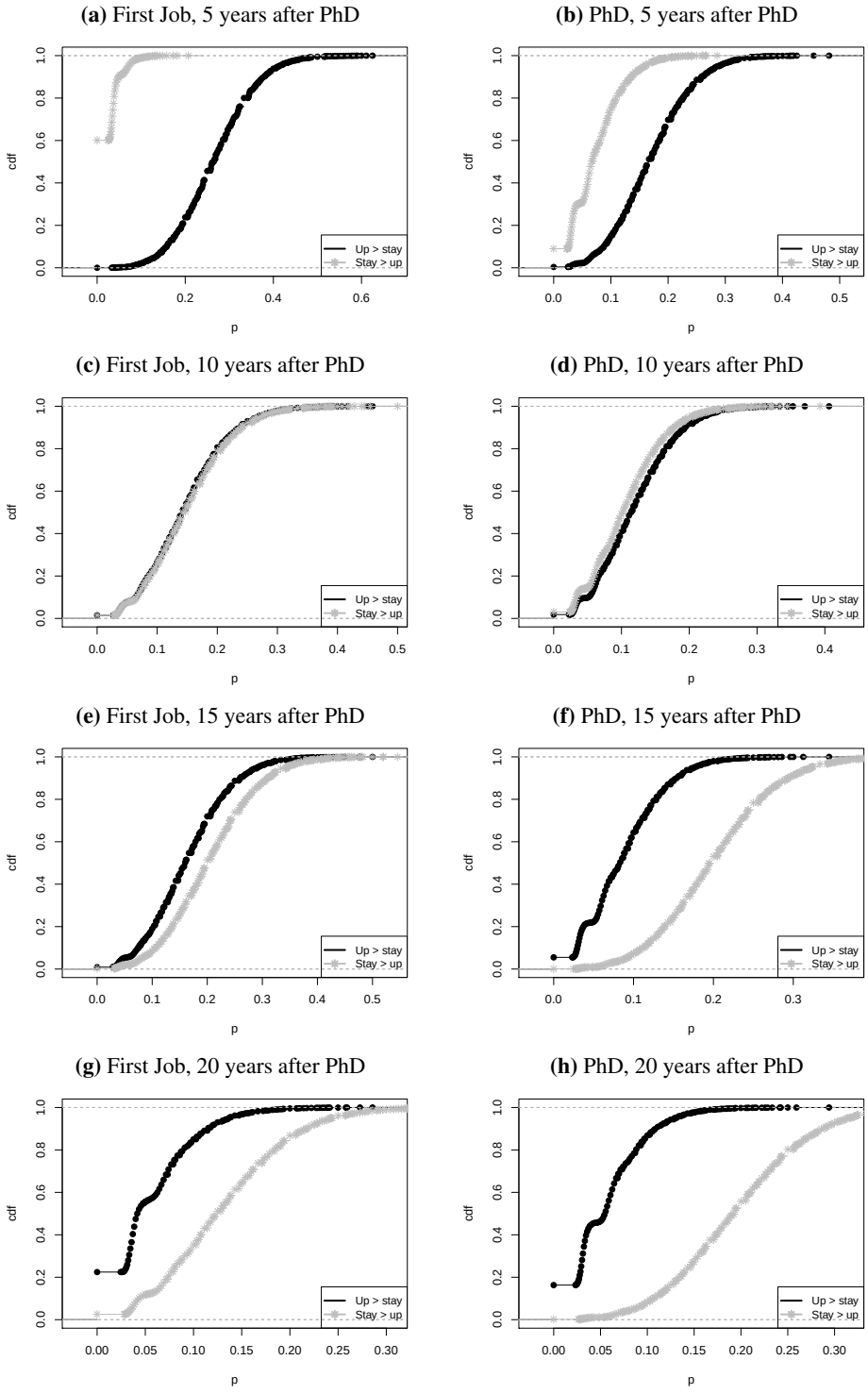

Figure 6: Up-stay comparison. Cumulative distribution function of proportions NRF rating up>stay (black) and stay>up (grey), from top to bottom 5,10,15, and 20 years after PhD. Pairs matched using gender, race, PhD obtained years and first job university (left) or PhD institution (right).

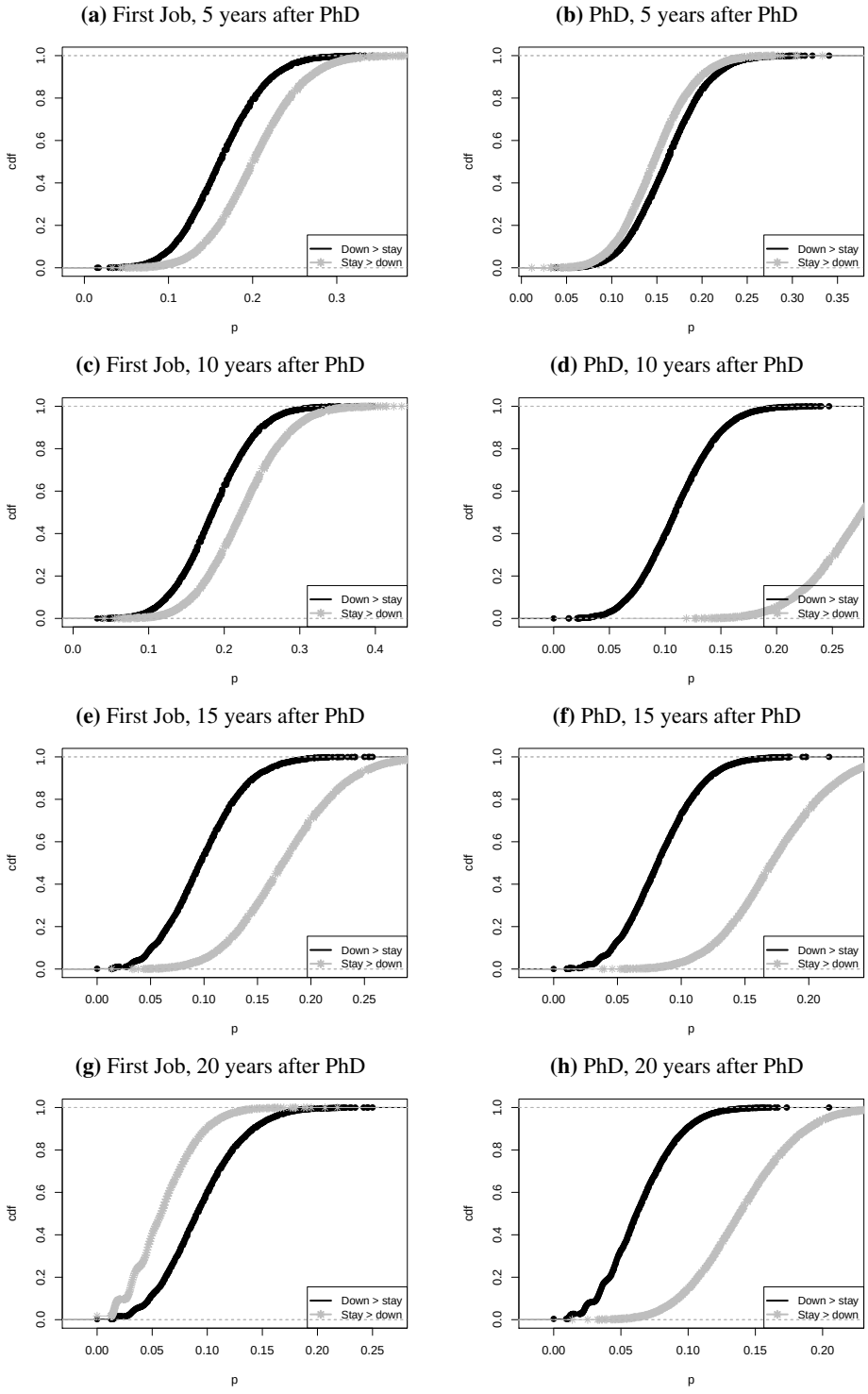

Figure 7: Down-stay comparison. Cumulative distribution function of proportions NRF rating down>stay (black) and stay>down (grey), from top to bottom 5,10,15, and 20 years after PhD. Pairs matched using gender, race, PhD obtained years and first job university (left) or PhD institution (right).

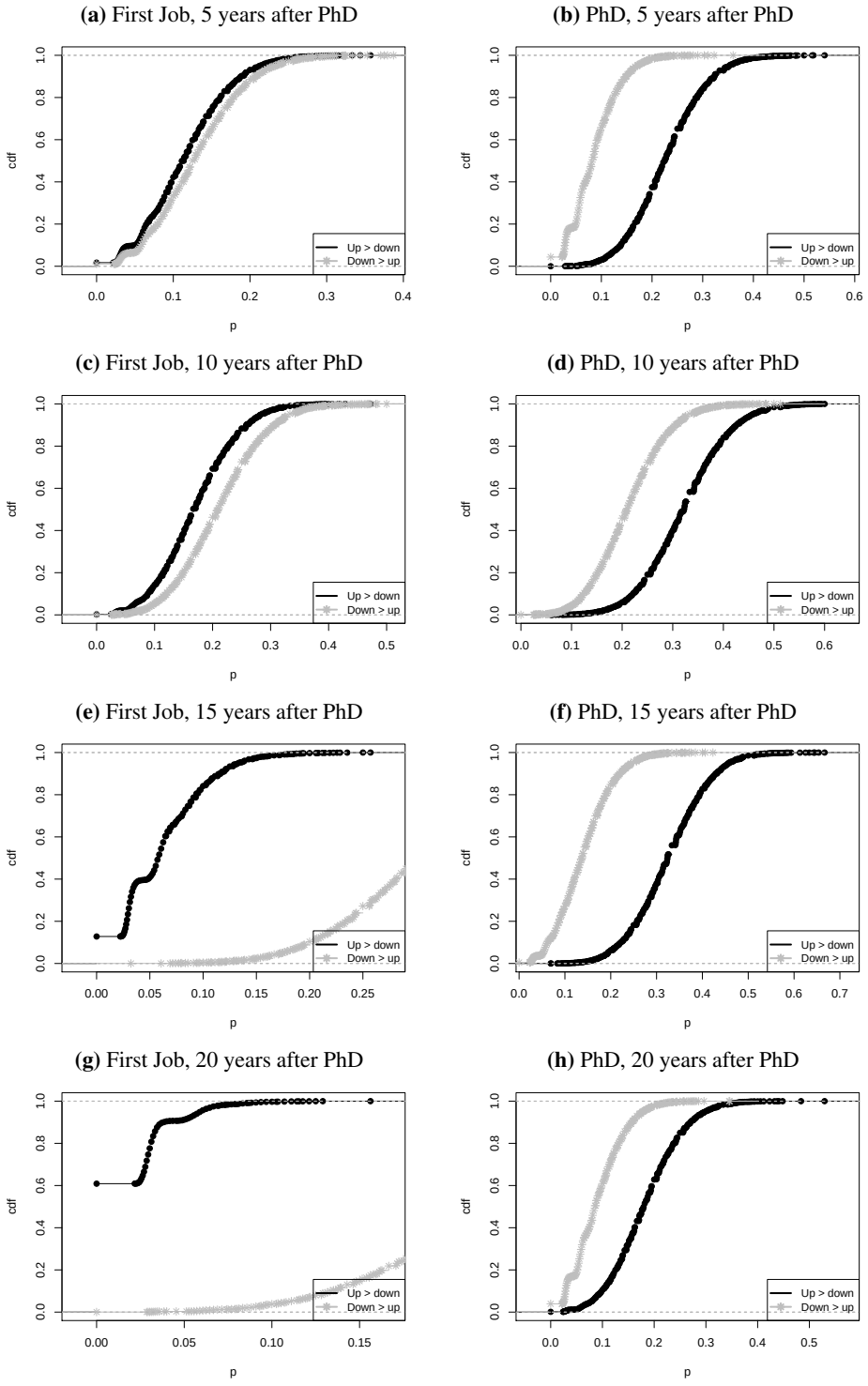

Figure 8: Up-down comparison. Cumulative distribution function of proportions NRF rating up>down (black) and down>up (grey), from top to bottom 5,10,15, and 20 years after PhD. Pairs matched using gender, race, PhD obtained years and first job university (left) or PhD institution (right).

6 Discussion and Conclusion

The paper reveals important aspects of how the PhD job market works in South Africa and our results tend to be in line with previous work. As is often observed in other settings, we find that institutional stratification hypothesis of higher education holds in the South African context. The 5 most prestigious universities produce between the 48 and 58% of all PhD graduates in the country and they tend to hire graduates from this elite group. Occupational segregation is also present in South Africa as elsewhere: under-represented groups are more likely to get a job in a lower prestige university than are white males.

Looking at the relation between prestige transitions from PhD to first job and individual research performance we find two main results. On the one hand, comparing people who experience a prestige transition with those who do not, we find a positive inertia effect. Those who stay in the same institution after the PhD have higher performance than those who move. At first glance, what appears to matter is not moving up or down the prestige hierarchy, but rather resting in an established environment. However, when we compare explicitly those how make upward and downward transitions, we find that university prestige is deeply related with academic performance, consistent with previous literature (Burris, 2004; Clauset et al., 2015). Holding PhD prestige constant, those with a more prestigious first job have better long run performance then those with a less prestigious first job. But similarly, holding first job constant, those having a PhD from a more prestigious institution have better long run performance than those with a less prestigious PhD. This suggests that prestige is at the very least a signal of quality, but possibly also has causal effects. More prestigious PhD programmes may attract better students and or give better training. More prestigious universities may attract better junior faculty and or may provide better resources. Extracting these causal relationships is certainly worth doing, though beyond the scope of this work.

Our results underline the big role played by inertia in the South African PhD job market. In our data, of the rated researchers in South Africa, roughly two thirds of those going into the professoriate do not change institutions at the completion of the PhD. We observe in the data that those who do not change institutions after the PhD tend to have higher NRF ratings later in their career. This suggests that imperfect information is fairly severe in PhD hiring: universities have good information about their own graduates, and can successfully "pick the winners". Of their own students, they have better information on candidates' intrinsic qualities, and so can make better judgements. Further, they have strong incentives to encourage their best students to stay, rather than let them drift off to strengthen competing institutions.

To understand why those internally selected perform better over a long period of time our research suggests to further look at the deep causes of the positive role

played by inertia. The role of inertia might be related not only to the general dynamics of the university system and the PhD job market, but might also be linked to the behaviour of the scholars in terms of co-authorship and specialization. In particular, the young researchers who do not experience mobility may have different collaboration patterns in comparison to their counterparts. They can have more stable co-authorship linkages able to sustain their careers especially in the early stages. Furthermore, their research orientation may be different in terms of specialization. Those internally selected could be more specialized in a particular area of research than the others, and this specialization could drive their long-run performance. This type of further research at micro level could shed new light on the university system not only of South Africa but also of other countries with low first job mobility.

It is important to realize that this is an historical analysis. The most recent PhD in our data is from 2002, and the most recent ranking from 2012. Nonetheless, university reputations change slowly, so even given the major re-organizations of 2004, we expect that the patterns of prestige ranking will not have had significant changes in the past decade. That said, we should observe that particularly among the formerly black universities there have been several notable changes in research output (University of Fort Hare or the University of the Western Cape for example), suggesting that some of these universities may be entering a different era and playing a different role in the system. However, there is little reason to believe that information asymmetries surrounding PhD hiring will disappear any time soon, in South Africa or elsewhere, so the results regarding effects of mobility on career success are likely to be robust.

Because in principle universities have as their raison d'être the creation and diffusion of knowledge, and because by its nature knowledge changes relatively slowly (that is to say, what is true does not change quickly) universities tend to evolve relatively slowly, and so do their standings relative to each other. Seen from this perspective stratification, and to a lesser extent inertia, in hiring is a natural outcome. These two forces are a source of the Matthew effect at the university level, and tend to create stasis, or possibly even reinforce the gaps in university hierarchies. Whether or not in general a hierarchical or even two-tier university system is good or bad, in the South African context, where the current hierarchy is born of the apartheid period, one can argue that the existing hierarchy is not ideal. The top universities in the current structure tend to be the historically white universities, and there, even 20 years after apartheid ended, the professoriate remains dominantly white, and for structural reasons is likely to remain so for many years. (Barnard et al 2017). In this case the hierarchy of the universities is socially problematic. In this respect a policy devoted to increasing the in-house capabilities of the latter and the exchange of expertise between universities could help to reverse this trend, and to create a more equal and productive system.

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A University reform in 2004

The South African university system saw a major reform in 2004. The reform merged and split university departments in the spirit of a geographical rationalization and racial integration. In our analysis we use post-merger names mostly because the data are more complete. More precisely, it is possible to make an accurate translation from pre- to post-merger names, but not from post- to pre-merger names, so by using pre-merger names we would lose a significant number of observations. Moreover, the use of post-merger names represents a value added of the work. It is a way to produce the prestige ranking of the South African universities that can be compared to the actual system. From the point of view of the analysis the we note the following. The University of Johannesburg came into existence as the result of a merger between Rand Afrikaans University, Technikon Witwatersrand, and Vista University, where the latter two have almost no PhDs (3 in total) in the period. So using University of Johannesburg instead of its disaggregation pre-merger would not make much difference. Similarly, Nelson Mandela Metropolitan University was created by the merger of Port Elizabeth Technikon, University of Port Elizabeth, and Vista University where the sample is dominated by PhDs from Port Elizabeth. NorthWest University is a merger of University of the North West and Potchefstroom University, and the latter dominates PhD production, particularly if we restrict attention to SET where 32 Phds are from Potchefstroom versus 6 from the University of the North West. The only possible problem could arise for the case of University of KwaZulu Natal which is the merger of University of Durban West Ville and University of Natal. Though, restricting to SET, Natal dominates with 32 PhDs versus 6 in Durban West Ville.

To make a robustness check we redo the prestige ranking in SET with those observations for which we have full data using pre-merger names. Table 1 shows the results which are quite consistent to those of the full sample. We must also be cognizant of the fact that in the period there was to some extent a language divide which appears mitigated using post-merger names. Indeed, looking separately English and Afrikaans language in Table 1 we can observe a more informative pattern. English universities have the same rankings here as in the main analysis. The exception being KZN: University of Natal is ranked 4th in the analysis using old names whereas KZN was ranked second among english universities in the main analysis. Afrikaans language universities have almost the same ranking here as they do in the main analysis; and if UNW (NWO and Potchefstroom) are excluded.

We have also repeated the matched pairs analysis with pre-merger names, and notwithstanding the reduced sample size, results are in line with our main findings.

Prestige Ranking with pre-merger names

University	Prestige Ranking	Language
NorthWestUniversity	1.873418	Afr
RhodesUniversity	2.721519	Eng
UniversityOfWitwatersrand	4.417722	Eng
UniversityOfCapeTown	4.506329	Eng
UniversityOfTheOrangeFreeState	4.658228	Afr
UniversityOfNatal	5.78481	Eng
UniversityOfPretoria	7.088608	Afr
PotchefstroomUniversity	7.721519	Afr
UniversityOfDurbanWestVille	8.35443	Eng
RandAfrikaansUniversity	10.658228	Afr
UniversityOfTheFreeState	11.139241	Afr
UniversityOfStellenbosch	12.101266	Afr
UniversityOfSouthAfrica	12.367089	Afr/Eng
MedicalUniversityOfSouthAfrica	13.139241	Afr/Eng
UniversityOfPortElizabeth	14.683544	Afr/Eng
UniversityOfTheWesternCape	14.78481	Eng

Table 1: Prestige Ranking for SET 1970-2004 using pre-merger names. The prestige ranking is in ascending order from the highest prestige which correspond to one. The number is the average of the orders with the maximum scores under 10.000 repetition. Our algorithm run on the adjacency matrix of the hiring network with pre-merger names. Universities with fewer than 5 PhDs are excluded.

B Faculty hiring network

	UniversityOfCapeTown	NelsonMandelaMetropolitanUniversity	UniversityOfWitwatersrand	UniversityOfPretoria	UniversityOfJohannesburg	UniversityOfTheFreeState	UniversityOfSouthAfrica	UniversityOfStellenbosch	UniversityOfKwaZuluNatal	UniversityOfTheNorthWest	UniversityOfLimpopo	RhodesUniversity	UniversityOfTheWesternCape	UniversityOfFortHare	WalterSisuluUniversity	UniversityOfVenda	CentralUniversityOfTechnology	TshwaneUniversityOfTechnology	VaalUniversityOfTechnology	MonashSAUniversity	DurbanInstituteOfTechnology	CapePeninsulaUniversityOfTechnology
UniversityOfCapeTown	107	4	5	0	2	0	2	19	1	2	1	3	4	1	1	0	0	1	0	0	0	5
NelsonMandelaMetropolitanUniversity	1	33	0	1	1	0	0	1	0	0	1	1	1	1	1	0	0	0	0	0	0	0
UniversityOfWitwatersrand	4	2	83	6	2	1	2	1	8	0	1	1	0	0	0	0	0	2	0	0	0	0
UniversityOfPretoria	2	1	1	116	7	3	7	6	1	6	2	0	3	3	0	1	0	6	0	0	0	0
UniversityOfJohannesburg	0	2	2	5	30	4	7	1	0	4	4	0	1	0	0	0	0	0	1	0	0	0
UniversityOfTheFreeState	0	1	0	1	1	55	0	8	0	2	3	0	0	0	0	0	6	0	0	0	0	0
UniversityOfSouthAfrica	0	1	1	1	0	0	15	2	1	0	0	0	1	1	0	1	0	0	0	0	0	0
UniversityOfStellenbosch	2	1	2	4	1	6	1	73	3	2	1	0	6	1	0	0	0	1	0	0	1	2
UniversityOfKwaZuluNatal	4	0	10	5	0	1	2	4	65	1	2	1	1	2	5	0	0	0	0	0	12	0
UniversityOfTheNorthWest	0	0	2	3	1	2	1	2	1	52	3	0	0	0	0	0	0	1	2	0	0	0
UniversityOfLimpopo	0	0	0	2	0	0	0	0	0	0	7	1	0	0	0	1	0	0	0	0	0	0
RhodesUniversity	2	2	4	3	0	1	0	0	3	1	2	19	0	1	0	0	0	0	0	0	0	0
UniversityOfTheWesternCape	2	0	1	0	0	0	0	1	0	1	0	0	8	0	0	0	0	0	0	0	0	1
UniversityOfFortHare	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
WalterSisuluUniversity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
UniversityOfVenda	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
CentralUniversityOfTechnology	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
TshwaneUniversityOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
VaalUniversityOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
MonashSAUniversity	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DurbanInstituteOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CapePeninsulaUniversityOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 2: Adjacency matrix of the hiring network for the years 1970-2004 in SET, rows are PhD institutions and columns are first job institutions. Each entry represents the number for people with a PhD in university *i* hired as first job in university *j*.

	UniversityOfCapeTown	NelsonMandelaMetropolitanUniversity	UniversityOfWitwatersrand	UniversityOfPretoria	UniversityOfJohannesburg	UniversityOfTheFreeState	UniversityOfSouthAfrica	UniversityOfStellenbosch	UniversityOfKwaZuluNatal	UniversityOfTheNorthWest	UniversityOfLimpopo	RhodesUniversity	UniversityOfTheWesternCape	UniversityOfFortHare	WalterSisuluUniversity	UniversityOfVenda	CentralUniversityOfTechnology	TshwaneUniversityOfTechnology	VaalUniversityOfTechnology	MonashSAUniversity	DurbanInstituteOfTechnology	CapePeninsulaUniversityOfTechnology
UniversityOfCapeTown	35	0	0	0	0	0	1	8	0	0	0	0	1	0	0	0	0	0	0	0	0	1
NelsonMandelaMetropolitanUniversity	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UniversityOfWitwatersrand	1	0	26	5	0	0	1	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0
UniversityOfPretoria	2	0	0	44	4	0	3	5	1	0	1	0	3	1	0	0	0	0	0	0	0	0
UniversityOfJohannesburg	0	0	1	0	12	1	4	1	0	2	2	0	1	0	0	0	0	0	0	0	0	0
UniversityOfTheFreeState	0	0	0	1	0	10	0	4	0	1	1	0	0	0	0	0	3	0	0	0	0	0
UniversityOfSouthAfrica	0	0	0	0	0	0	6	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0
UniversityOfStellenbosch	0	0	1	0	0	1	1	15	1	0	1	0	2	0	0	0	0	0	0	0	0	0
UniversityOfKwaZuluNatal	2	0	2	2	0	0	0	2	19	1	1	0	1	0	1	0	0	0	0	0	3	0
UniversityOfTheNorthWest	0	0	1	0	0	0	1	0	0	14	3	0	0	0	0	0	0	0	1	0	0	0
UniversityOfLimpopo	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
RhodesUniversity	0	0	1	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0
UniversityOfTheWesternCape	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1
UniversityOfFortHare	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WalterSisuluUniversity	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
UniversityOfVenda	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
CentralUniversityOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TshwaneUniversityOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
VaalUniversityOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MonashSAUniversity	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DurbanInstituteOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CapePeninsulaUniversityOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 3: Adjacency matrix of the hiring network of females for the years 1970-2004 in SET, rows are PhD institutions and columns are first job institutions. Each entry represents the number for people with a PhD in university *i* hired as first job in university *j*.

	UniversityOfCapeTown	NelsonMandelaMetropolitanUniversity	UniversityOfWitwatersrand	UniversityOfPretoria	UniversityOfJohannesburg	UniversityOfTheFreeState	UniversityOfSouthAfrica	UniversityOfStellenbosch	UniversityOfKwaZuluNatal	UniversityOfTheNorthWest	UniversityOfLimpopo	RhodesUniversity	UniversityOfTheWesternCape	UniversityOfFortHare	WalterSisuluUniversity	UniversityOfVenda	CentralUniversityOfTechnology	TshwaneUniversityOfTechnology	VaalUniversityOfTechnology	MonashSAUniversity	DurbanInstituteOfTechnology	CapePeninsulaUniversityOfTechnology
UniversityOfCapeTown	18	0	1	0	0	0	1	2	0	1	1	0	2	0	1	0	0	0	0	0	0	1
NelsonMandelaMetropolitanUniversity	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
UniversityOfWitwatersrand	1	0	11	0	2	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
UniversityOfPretoria	0	0	0	7	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0	0	0	0
UniversityOfJohannesburg	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
UniversityOfTheFreeState	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
UniversityOfSouthAfrica	0	0	1	0	0	0	2	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0
UniversityOfStellenbosch	0	0	0	0	0	0	0	8	0	1	0	0	2	0	0	0	0	0	0	0	0	0
UniversityOfKwaZuluNatal	2	0	3	0	0	0	1	2	26	0	2	0	1	0	4	0	0	0	0	0	10	0
UniversityOfTheNorthWest	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0
UniversityOfLimpopo	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0
RhodesUniversity	0	1	0	1	0	0	0	0	0	1	2	1	0	1	0	0	0	0	0	0	0	0
UniversityOfTheWesternCape	2	0	1	0	0	0	0	1	0	1	0	0	5	0	0	0	0	0	0	0	0	1
UniversityOfFortHare	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WalterSisuluUniversity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
UniversityOfVenda	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
CentralUniversityOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TshwaneUniversityOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
VaalUniversityOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MonashSAUniversity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DurbanInstituteOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CapePeninsulaUniversityOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 4: Adjacency matrix of the hiring network of blacks for the years 1970-2004 in SET, rows are PhD institutions and columns are first job institutions. Each entry represents the number for people with a PhD in university *i* hired as first job in university *j*.

	UniversityOfCapeTown	NelsonMandelaMetropolitanUniversity	UniversityOfWitwatersrand	UniversityOfPretoria	UniversityOfJohannesburg	UniversityOfTheFreeState	UniversityOfSouthAfrica	UniversityOfStellenbosch	UniversityOfKwaZuluNatal	UniversityOfTheNorthWest	UniversityOfLimpopo	RhodesUniversity	UniversityOfTheWesternCape	UniversityOfFortHare	WalterSisuluUniversity	UniversityOfVenda	CentralUniversityOfTechnology	TshwaneUniversityOfTechnology	VaalUniversityOfTechnology	MonashSAUniversity	DurbanInstituteOfTechnology	CapePeninsulaUniversityOfTechnology
UniversityOfCapeTown	30	0	1	0	0	0	3	1	5	1	1	3	4	1	1	1	0	0	0	0	0	0
NelsonMandelaMetropolitanUniversity	0	11	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
UniversityOfWitwatersrand	3	0	27	3	0	0	2	0	2	0	0	1	0	0	1	0	0	0	0	0	0	0
UniversityOfPretoria	0	1	3	48	5	1	10	0	0	4	4	0	0	0	0	0	0	3	0	0	0	0
UniversityOfJohannesburg	0	0	0	1	16	0	4	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
UniversityOfTheFreeState	0	0	0	0	0	24	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0
UniversityOfSouthAfrica	1	4	0	11	1	2	69	0	3	5	3	0	0	0	0	0	0	1	0	0	0	0
UniversityOfStellenbosch	4	2	1	3	1	4	2	42	1	0	1	1	5	1	1	1	0	0	0	0	0	0
UniversityOfKwaZuluNatal	1	2	1	0	0	0	1	1	36	0	0	1	0	0	2	0	0	0	0	0	2	0
UniversityOfTheNorthWest	0	0	0	0	3	0	5	1	0	36	1	0	0	0	0	0	0	2	2	0	0	0
UniversityOfLimpopo	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
RhodesUniversity	0	1	0	0	1	0	3	0	2	0	0	7	0	0	1	0	0	0	0	0	0	0
UniversityOfTheWesternCape	0	1	0	0	0	0	0	2	0	0	1	1	14	0	0	0	0	1	0	0	0	0
UniversityOfFortHare	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WalterSisuluUniversity	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0
UniversityOfVenda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CentralUniversityOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
TshwaneUniversityOfTechnology	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
VaalUniversityOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MonashSAUniversity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DurbanInstituteOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CapePeninsulaUniversityOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 5: Adjacency matrix of the hiring network for the years 1970-2004 in SSH, rows are PhD institutions and columns are first job institutions. Each entry represents the number for people with a PhD in university *i* hired as first job in university *j*.

	UniversityOfCapeTown	NelsonMandelaMetropolitanUniversity	UniversityOfWitwatersrand	UniversityOfPretoria	UniversityOfJohannesburg	UniversityOfTheFreeState	UniversityOfSouthAfrica	UniversityOfStellenbosch	UniversityOfKwaZuluNatal	UniversityOfTheNorthWest	UniversityOfLimpopo	RhodesUniversity	UniversityOfTheWesternCape	UniversityOfFortHare	WalterSisuluUniversity	UniversityOfVenda	CentralUniversityOfTechnology	TshwaneUniversityOfTechnology	VaalUniversityOfTechnology	MonashSAUniversity	DurbanInstituteOfTechnology	CapePeninsulaUniversityOfTechnology
UniversityOfCapeTown	13	0	1	0	0	0	2	0	2	0	0	1	4	1	0	0	0	0	0	0	0	0
NelsonMandelaMetropolitanUniversity	0	7	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
UniversityOfWitwatersrand	1	0	14	1	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
UniversityOfPretoria	0	0	1	24	0	0	4	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0
UniversityOfJohannesburg	0	0	0	1	11	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
UniversityOfTheFreeState	0	0	0	0	0	5	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
UniversityOfSouthAfrica	0	0	0	5	0	0	35	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0
UniversityOfStellenbosch	1	0	0	2	0	0	0	11	0	0	0	1	0	0	0	0	0	0	0	0	0	0
UniversityOfKwaZuluNatal	1	0	0	0	0	0	1	0	13	0	0	1	0	0	1	0	0	0	0	0	0	0
UniversityOfTheNorthWest	0	0	0	0	1	0	3	1	0	10	1	0	0	0	0	0	0	1	1	0	0	0
UniversityOfLimpopo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RhodesUniversity	0	1	0	0	0	0	0	0	1	0	0	3	0	0	0	0	0	0	0	0	0	0
UniversityOfTheWesternCape	0	1	0	0	0	0	0	0	0	0	0	1	8	0	0	0	0	0	0	0	0	0
UniversityOfFortHare	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WalterSisuluUniversity	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
UniversityOfVenda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CentralUniversityOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TshwaneUniversityOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
VaalUniversityOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MonashSAUniversity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DurbanInstituteOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CapePeninsulaUniversityOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 6: Adjacency matrix of the hiring network of females for the years 1970-2004 in SSH, rows are PhD institutions and columns are first job institutions. Each entry represents the number for people with a PhD in university *i* hired as first job in university *j*.

	UniversityOfCapeTown	NelsonMandelaMetropolitanUniversity	UniversityOfWitwatersrand	UniversityOfPretoria	UniversityOfJohannesburg	UniversityOfTheFreeState	UniversityOfSouthAfrica	UniversityOfStellenbosch	UniversityOfKwaZuluNatal	UniversityOfTheNorthWest	UniversityOfLimpopo	RhodesUniversity	UniversityOfTheWesternCape	UniversityOfFortHare	WalterSisuluUniversity	UniversityOfVenda	CentralUniversityOfTechnology	TshwaneUniversityOfTechnology	VaalUniversityOfTechnology	MonashSAUniversity	DurbanInstituteOfTechnology	CapePeninsulaUniversityOfTechnology
UniversityOfCapeTown	4	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0
NelsonMandelaMetropolitanUniversity	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UniversityOfWitwatersrand	0	0	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UniversityOfPretoria	0	0	0	3	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
UniversityOfJohannesburg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UniversityOfTheFreeState	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UniversityOfSouthAfrica	0	1	0	1	0	0	3	0	1	1	2	0	0	0	0	0	0	1	0	0	0	0
UniversityOfStellenbosch	1	0	0	1	0	0	1	5	0	0	1	0	0	0	0	0	0	0	0	0	0	0
UniversityOfKwaZuluNatal	1	1	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	1	0
UniversityOfTheNorthWest	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
UniversityOfLimpopo	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
RhodesUniversity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UniversityOfTheWesternCape	0	0	0	0	0	0	0	2	0	0	1	0	8	0	0	0	0	1	0	0	0	0
UniversityOfFortHare	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WalterSisuluUniversity	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0
UniversityOfVenda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CentralUniversityOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TshwaneUniversityOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VaalUniversityOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MonashSAUniversity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DurbanInstituteOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CapePeninsulaUniversityOfTechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 7: Adjacency matrix of the hiring network of blacks for the years 1970-2004 in SSH, rows are PhD institutions and columns are first job institutions. Each entry represents the number for people with a PhD in university *i* hired as first job in university *j*.

Summary Statistics SET hiring network

	All	Male	Female	White	Black
Number of Nodes	22	22	22	22	22
Number of Components	1	2	3	1	2
Number of isolated Nodes	0	1	2	0	1
	Statistics on the Giant Component				
Number of Nodes	22	21	20	22	21
Number of Edges	133	115	57	107	52
Edge Density	0.288	0.274	0.15	0.232	0.124
Average Path Length	1.795	1.764	2.498	1.748	3.087
Diameter	9	6	12	9	15
Global Clustering Coefficient	0.648	0.588	0.511	0.578	0.41

Table 8: Summary Statistics SET hiring network for the years 1970-2004. Network statistics are compute without considering self-loops

Summary Statistics SSH hiring network

	All	Male	Female	White	Black
Number of Nodes	22	22	22	22	22
Number of Components	3	3	5	3	7
Number of isolated Nodes	2	2	4	2	6
	Statistics on the Giant Component				
Number of Nodes	20	20	18	20	16
Number of Edges	83	63	43	74	26
Edge Density	0.218	0.166	0.141	0.195	0.108
Average Path Length	1.959	1.976	2.386	2.02	2.037
Diameter	8	11	7	9	5
Global Clustering Coefficient	0.525	0.429	0.35	0.51	0.308

Table 9: Summary Statistics SSH hiring network for the years 1970-2004. Network statistics are compute without considering self-loops

SET Indegree and Outdegree

	Indegree	Outdegree
UniversityOfCapeTown	8	14
NelsonMandelaMetropolitanUniversity	8	9
UniversityOfWitwatersrand	9	11
UniversityOfPretoria	10	14
UniversityOfJohannesburg	8	10
UniversityOfTheFreeState	7	7
UniversityOfSouthAfrica	8	8
UniversityOfStellenbosch	10	15
UniversityOfKwaZuluNatal	7	13
UniversityOfTheNorthWest	8	10
UniversityOfLimpopo	11	3
RhodesUniversity	5	9
UniversityOfTheWesternCape	7	5
UniversityOfFortHare	7	1
WalterSisuluUniversity	3	0
UniversityOfVenda	3	1
CentralUniversityOfTechnology	1	1
TshwaneUniversityOfTechnology	6	0
VaalUniversityOfTechnology	2	1
MonashSAUniversity	0	1
DurbanInstituteOfTechnology	2	0
CapePeninsulaUniversityOfTechnology	3	0

Table 10: Indegree and Outdegree SET hiring network for the years 1970-2004. Network statistics are compute without considering self-loops

SSH Indegree and Outdegree

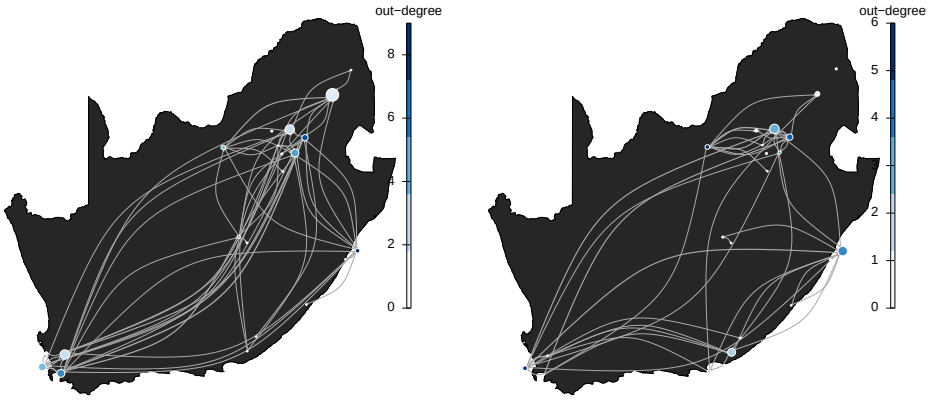
	Indegree	Outdegree
UniversityOfCapeTown	4	11
NelsonMandelaMetropolitanUniversity	6	2
UniversityOfWitwatersrand	4	6
UniversityOfPretoria	5	8
UniversityOfJohannesburg	5	4
UniversityOfTheFreeState	3	2
UniversityOfSouthAfrica	8	9
UniversityOfStellenbosch	5	14
UniversityOfKwaZuluNatal	8	8
UniversityOfTheNorthWest	4	6
UniversityOfLimpopo	7	0
RhodesUniversity	5	5
UniversityOfTheWesternCape	2	5
UniversityOfFortHare	2	0
WalterSisuluUniversity	5	1
UniversityOfVenda	2	0
CentralUniversityOfTechnology	1	1
TshwaneUniversityOfTechnology	4	1
VaalUniversityOfTechnology	2	0
MonashSAUniversity	0	0
DurbanInstituteOfTechnology	1	0
CapePeninsulaUniversityOfTechnology	0	0

Table 11: Indegree and Outdegree SSH hiring network for the years 1970-2004. Network statistics are compute without considering self-loops

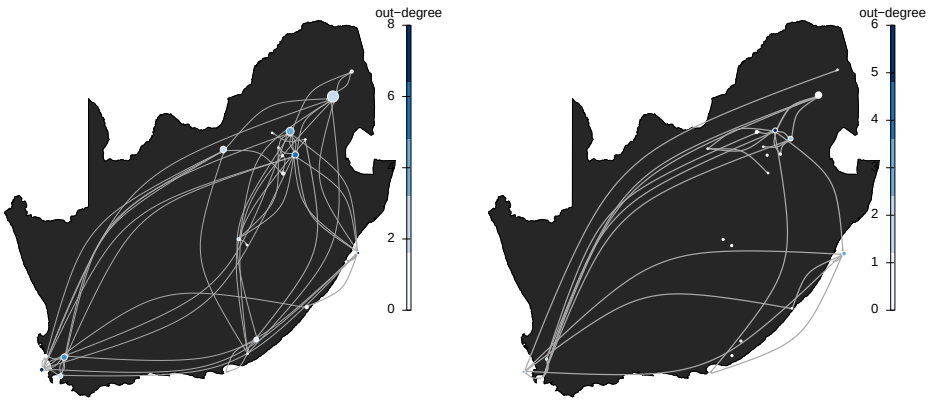
PhDs hired in South African Universities within 5 years after PhD

	All	Male	Female	White	Black
		SET			
1970-1979	99	92	7	98	1
1980-1989	231	179	52	220	11
1990-1999	390	264	126	334	56
2000-2004	291	174	115	191	98
tot SET	1011	709	300	843	166
		SSH			
1970-1979	31	28	3	31	0
1980-1989	121	88	33	118	3
1990-1999	225	132	93	202	23
2000-2004	165	78	87	121	44
tot SSH	542	326	216	472	70
tot SET+SSH	1553	1035	516	1315	236
Ratio SSH/SET	0.536	0.46	0.72	0.56	0.422

Table 12: Number of Doctorates hired in South African Universities within 5 years after PhD. Summary statistics in decades

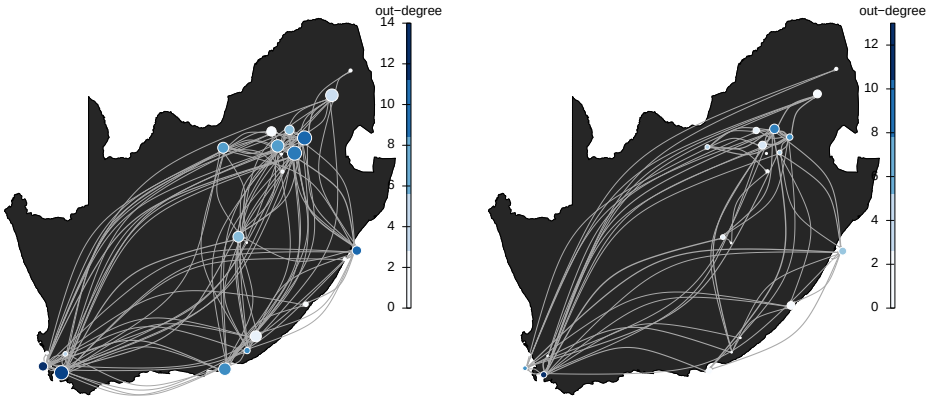


(a) SET Females **(b)** SSH Females

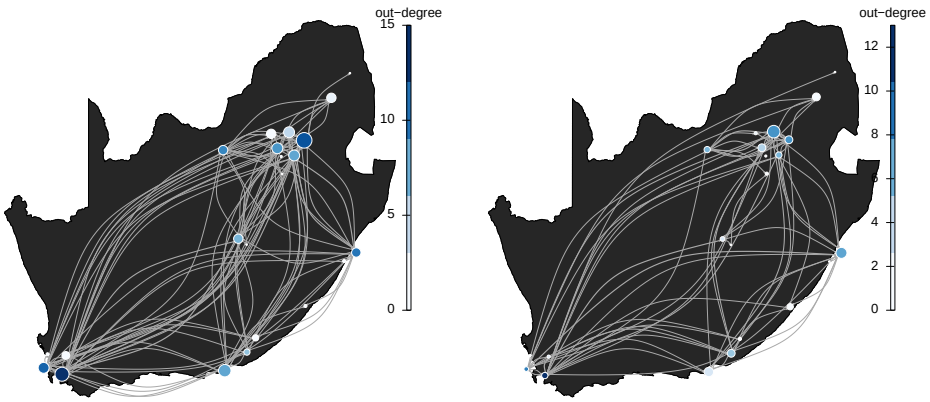


(c) SET Blacks **(d)** SSH Blacks

Figure 9: Hiring networks 1970-2004 left SET, right SSH. From top to bottom: Females, Blacks. The vertex are the South African Universities, plotted according to their geographical coordinates (for institutions located in the same area we separated manually). Vertex size represent in-degree and vertex colour is out-degree.



(a) SET Males **(b)** SSH Males



(c) SET Whites **(d)** SSH Whites

Figure 10: Hiring networks 1970-2004 left SET, right SSH. From top to bottom: Male, White. The vertex are the South African Universities, plotted according to their geographical coordinates (for institutions located in the same area we separated manually). Vertex size represent in-degree and vertex colour is out-degree.

C Prestige Ranking

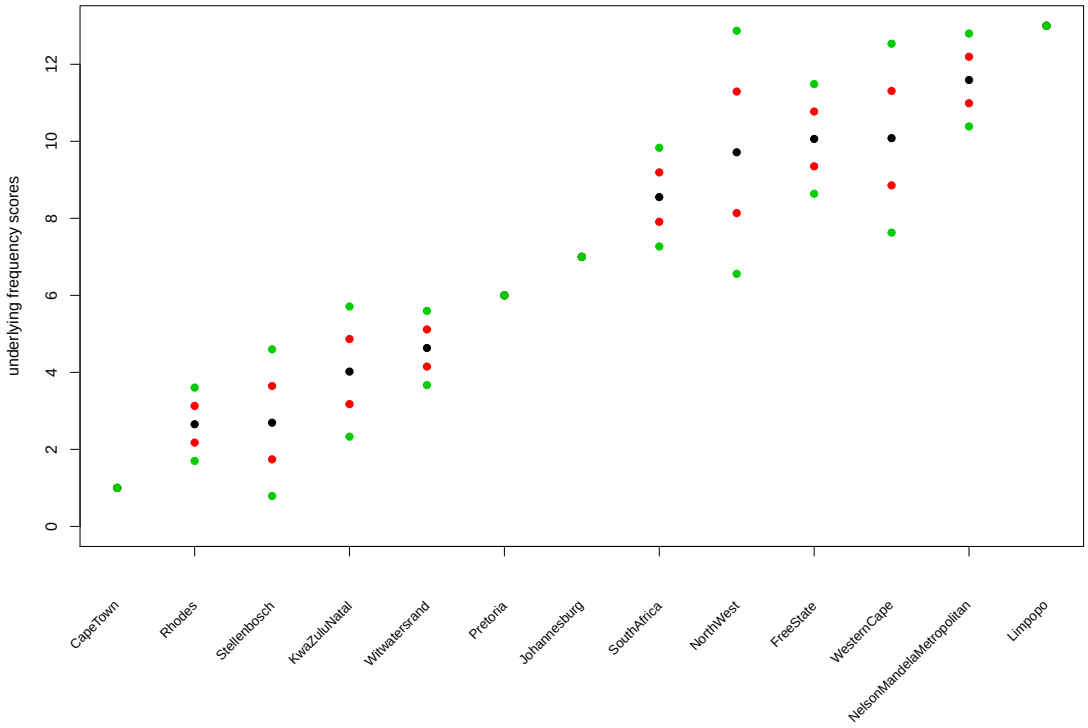


Figure 11: Prestige Ranking 1970-2004. The frequency scores are in ascending order from the highest prestige which correspond to one. The Black dots is the average of the orders with the maximum scores under 10000 repetition, red dots and green dots are respectively one and two standard deviation from the average. Our algorithm runs on the adjacency matrix of the hiring network. Universities with fewer than 5 PhDs are excluded.

SET PhDs hired from the top 5 universities

Rank	PhD University	Hired from: All 22 (total hired)	prop.	Top 5 (total in Top 5)	prop. Top 5
1	RhodesUniversity	38	0.038	31	0.816
2	UniversityOfKwaZuluNatal	115	0.114	85	0.739
3	UniversityOfWitwatersrand	113	0.112	102	0.903
4	UniversityOfPretoria	165	0.163	120	0.727
5	UniversityOfCapeTown	158	0.156	116	0.734
	All in Top 5	589	0.583	454	0.771

Table 13: PhDs hired from the top 5 prestigious universities in SET, according to our prestige ranking

SSH PhDs hired from the top 5 universities

Rank	PhD University	Hired from: All 22 (total hired)	prop.	Top 5 (total in Top 5)	prop. Top 5
1	UniversityOfStellenbosch	70	0.129	55	0.786
2	UniversityOfWitwatersrand	39	0.072	33	0.846
3	UniversityOfCapeTown	52	0.096	36	0.692
4	UniversityOfPretoria	79	0.146	51	0.646
5	UniversityOfTheWesternCape	20	0.037	16	0.8
	All Hired in Top 5	260	0.479	191	0.735

Table 14: PhDs hired from the top 5 prestigious universities in SSH, according to our prestige ranking

D Prestige rank-change

SET multiple regression

	Dependent variable:					
	Prestige rank-change					
	(1)	(2)	(3)	(4)	(5)	(6)
female	−0.457**	−0.448**	−0.548**	−0.553**	−0.176	−0.705**
	(0.193)	(0.193)	(0.241)	(0.246)	(0.279)	(0.275)
black	−0.745***	−0.764***	−0.573*	−0.541	−1.161**	−0.748**
	(0.258)	(0.258)	(0.317)	(0.330)	(0.583)	(0.314)
paperyearratio		0.036	0.039	0.039	0.066	0.027
		(0.023)	(0.027)	(0.027)	(0.049)	(0.027)
dummy8089				0.131		
				(0.337)		
dummy9099				0.161		
				(0.323)		
dummy0004				0.003		
				(0.347)		
female:paperyearratio			0.042	0.045		
			(0.057)	(0.057)		
black:paperyearratio			−0.066	−0.065		
			(0.061)	(0.061)		
Constant	−0.396***	−0.492***	−0.499***	−0.599**	−0.667***	−0.311
	(0.114)	(0.129)	(0.136)	(0.287)	(0.180)	(0.207)
Observations	762	762	762	762	381	381
R^2	0.017	0.021	0.023	0.023	0.015	0.032
Adjusted R^2	0.015	0.017	0.016	0.013	0.007	0.025
Residual Std. Error	2.466	2.463	2.464	2.468	2.333	2.590
	(df = 759)	(df = 758)	(df = 756)	(df = 753)	(df = 377)	(df = 377)
F Statistic	6.750***	5.333***	3.490***	2.253**	1.881	4.214***
	(df = 2; 759)	(df = 3; 758)	(df = 5; 756)	(df = 8; 753)	(df = 3; 377)	(df = 3; 377)

Note: OLS estimates. Standard errors are in parenthesis *p<0.1; **p<0.05; ***p<0.01

Table 15: Multiple regression analysis for SET. The dependent variable is prestige rank-change from PhD to first job, which is the difference between the prestige ranking of scholars' PhD and the one of first job, according to our prestige measure. The variable *paperyearratio* measures scholars' productivity; it is the ration between the number of paper published according to Web of Science and number of years. Dummies of times decades, *dummy*8089, *dummy*9099, and *dummy*0004, capture possible cohort effects. Interactions terms, $female : paperyearratio$ and $black : paperyearratio$, control for possible non linearities between demographic characteristics and productivity. Model 1-4 consider the whole period of analysis 1970-2004; Model 5 includes only scholars with a PhD granted between 1970 & 1994; Model 6 includes only scholars with a PhD granted between 1995 & 2004.

SSH multiple regression

	Dependent variable:					
	Prestige rank-change					
	(1)	(2)	(3)	(4)	(5)	(6)
female	0.533**	0.509*	0.509*	0.511*	0.272	0.812**
	(0.261)	(0.264)	(0.276)	(0.287)	(0.430)	(0.359)
black	0.414	0.380	0.433	0.448	0.864	0.532
	(0.425)	(0.428)	(0.450)	(0.471)	(1.538)	(0.466)
paperyearratio		0.028	0.054	0.056	0.170	0.021
		(0.045)	(0.127)	(0.128)	(0.213)	(0.045)
dummy8089				−0.092		
				(0.601)		
dummy9099				−0.024		
				(0.584)		
dummy0004				−0.099		
				(0.614)		
female:paperyearratio			−0.014	−0.014		
			(0.124)	(0.125)		
black:paperyearratio			−0.043	−0.044		
			(0.118)	(0.119)		
Constant	−0.999***	−1.011***	−1.023***	−0.966*	−0.908***	−1.286***
	(0.175)	(0.176)	(0.185)	(0.541)	(0.242)	(0.284)
Observations	404	404	404	404	191	213
R^2	0.012	0.013	0.013	0.013	0.007	0.029
Adjusted R^2	0.007	0.005	0.001	−0.007	−0.009	0.015
Residual Std. Error	2.566	2.568	2.574	2.583	2.634	2.518
	(df = 401)	(df = 400)	(df = 398)	(df = 395)	(df = 187)	(df = 209)
F Statistic	2.393*	1.729	1.063	0.670	0.437	2.079
	(df = 2; 401)	(df = 3; 400)	(df = 5; 398)	(df = 8; 395)	(df = 3; 187)	(df = 3; 209)

Note: OLS estimates. Standard errors are in parenthesis *p<0.1; **p<0.05; ***p<0.01

Table 16: Multiple regression analysis for SSH. The dependent variable is prestige rank-change from PhD to first job, which is the difference between the prestige ranking of scholars' PhD and the one of first job, according to our prestige measure. The variable *paperyearratio* measures scholars' productivity; it is the ration between the number of paper published according to Web of Science and number of years. Dummies of time decades, *dummy*8089, *dummy*9099, and *dummy*0004, capture possible cohort effects. Interactions terms, $female : paperyearratio$ and $black : paperyearratio$, control for possible non linearities between demographic characteristics and productivity. Model 1-4 consider the whole period of analysis 1970-2004; Model 5 includes only scholars with a PhD granted between 1970 & 1994; Model 6 includes only scholars with a PhD granted between 1995 & 2004.

E Additional Results

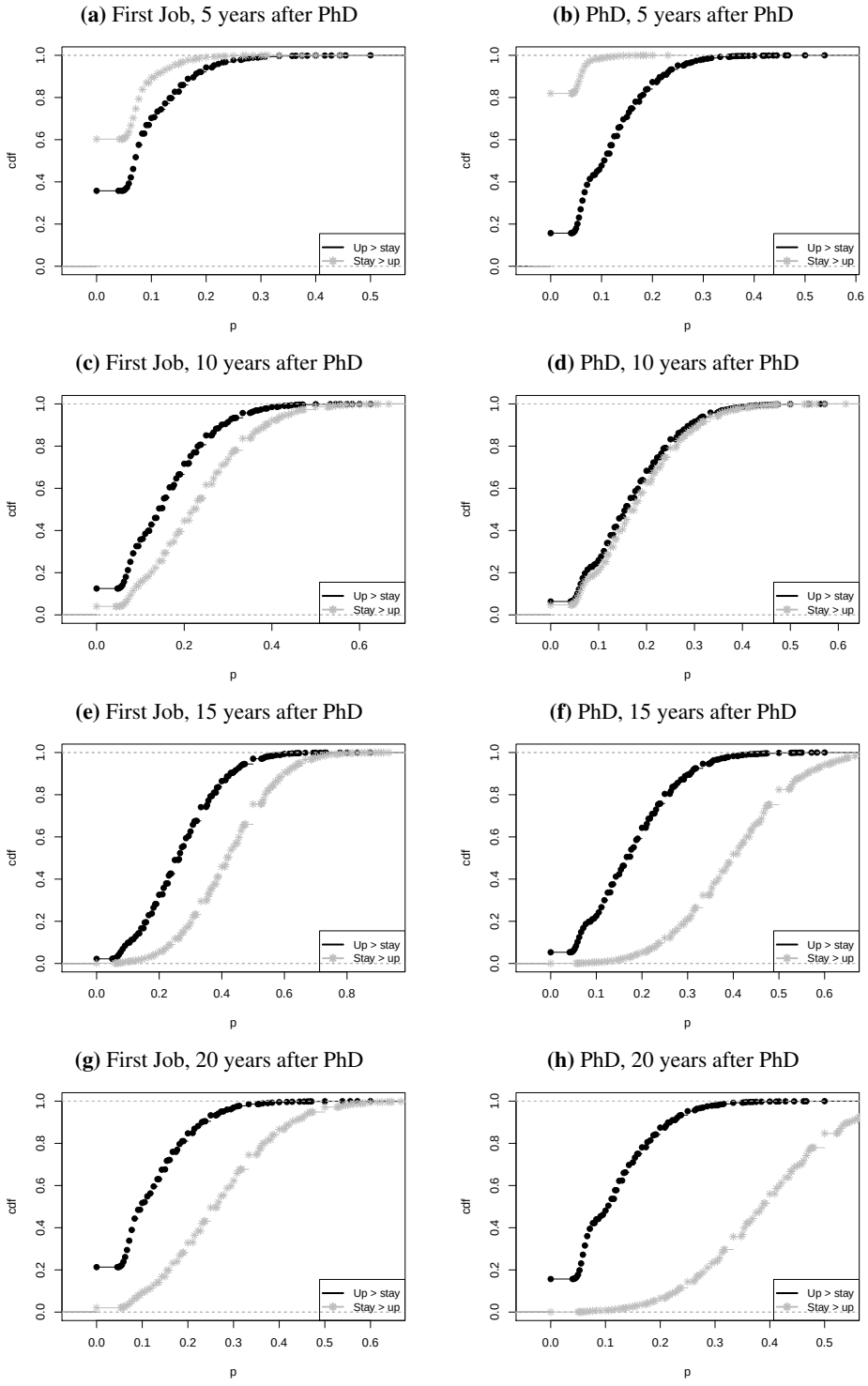


Figure 12: Up-stay comparison with PhD obtained years pre-1992. Cumulative distribution function of proportions NRF rating up>stay (black) and stay>up (grey), from top to bottom 5,10,15, and 20 years after PhD. Pairs matched using gender, race, PhD obtained years and first job university (left) or PhD institution (right).

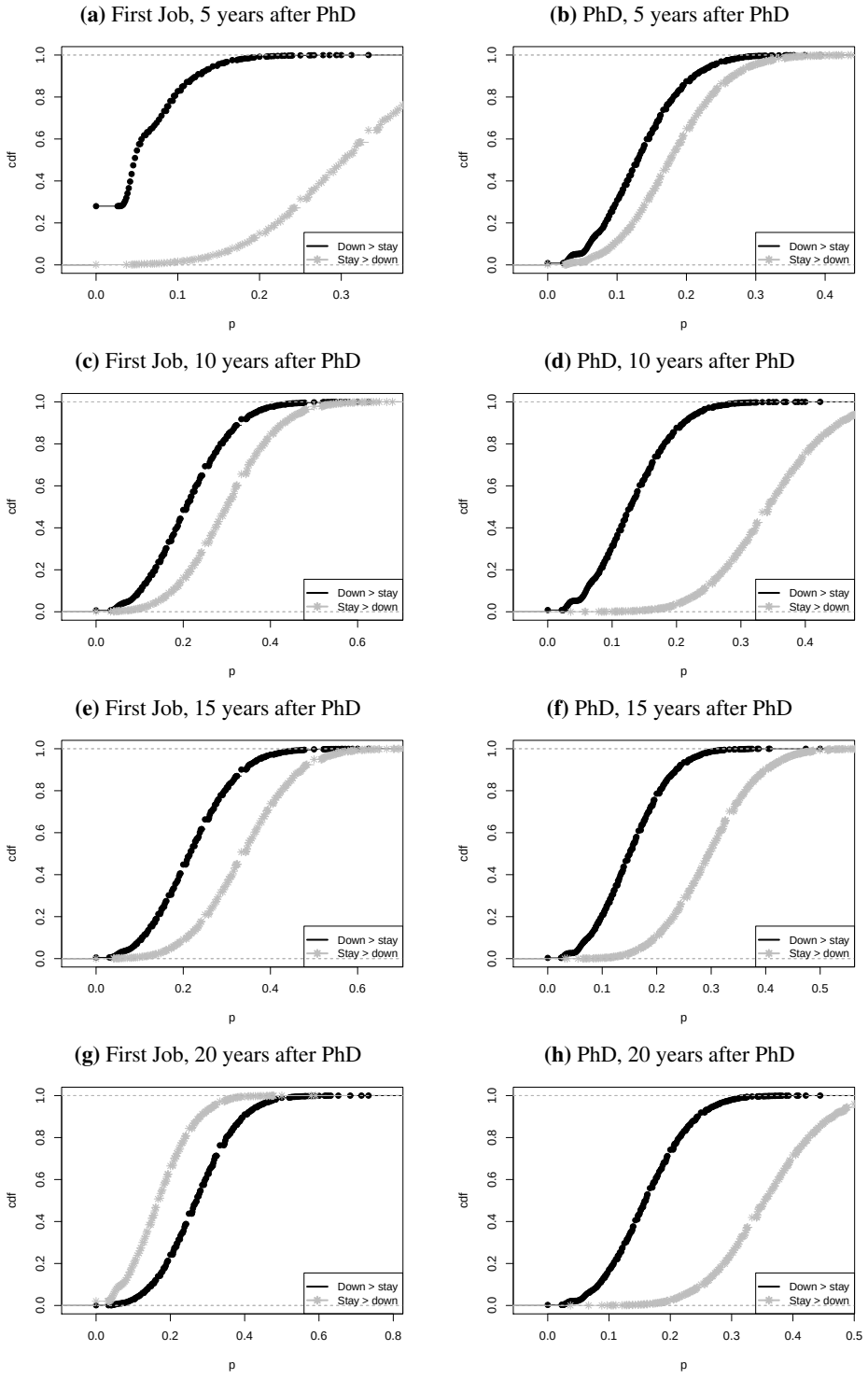


Figure 13: Down-stay comparison with PhD obtained years pre-1992. Cumulative distribution function of proportions NRF rating down>stay (black) and stay>down (grey), from top to bottom 5,10,15, and 20 years after PhD. Pairs matched using gender, race, PhD obtained years and first job university (left) or PhD institution (right).

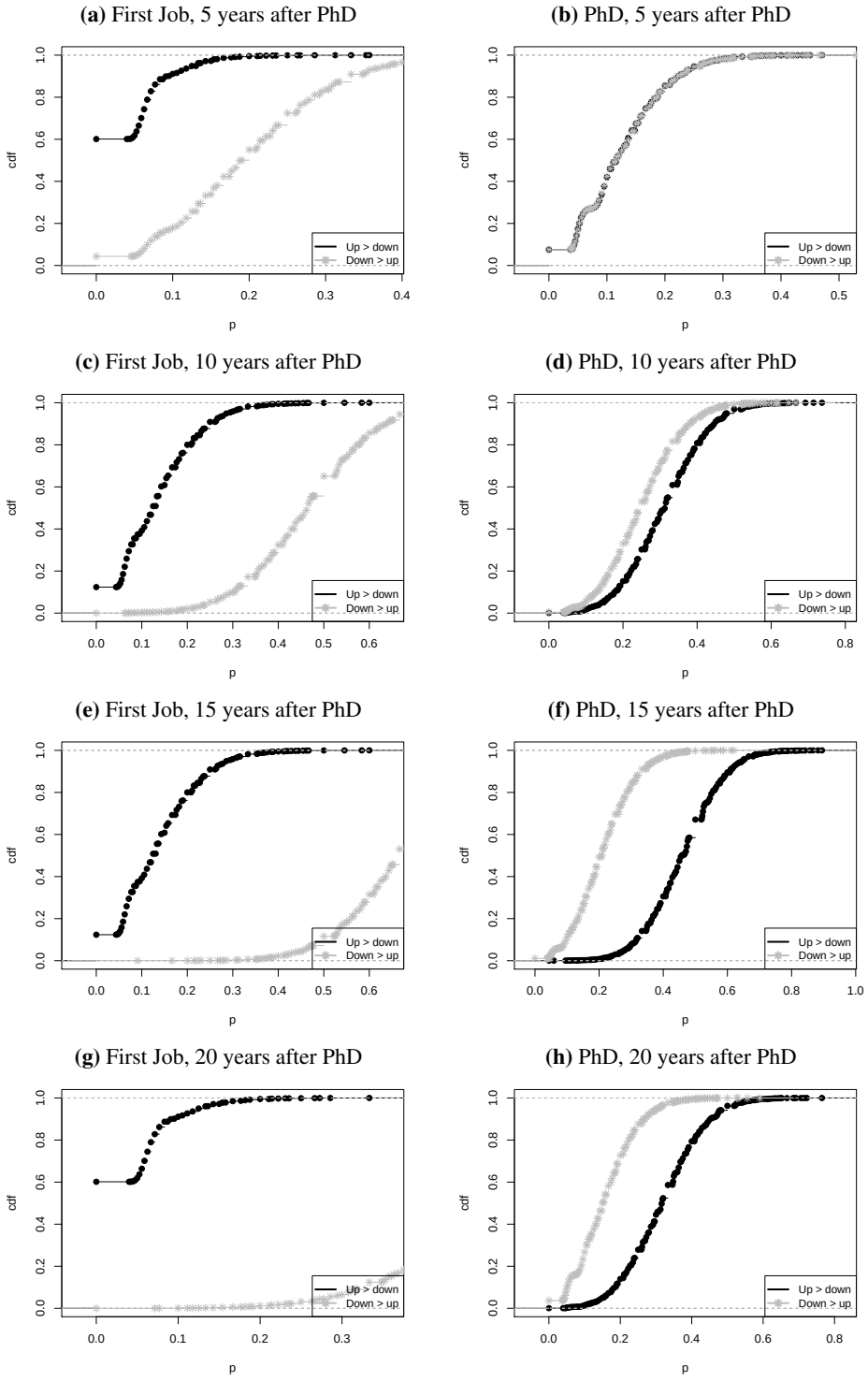


Figure 14: Up-down comparison with PhD obtained years pre-1992. Cumulative distribution function of proportions NRF rating up>down (black) and down>up (grey), from top to bottom 5,10,15, and 20 years after PhD. Pairs matched using gender, race, PhD obtained years and first job university (left) or PhD institution (right).

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