The Success of Knowledge Creation in South Africa: Relying on Virtue Alone Will Not Be Enough

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When I think of Harry Zarenda, two characteristics stand out. He was one of the most dedicated teachers of economics I have known, one who deeply influenced many generations of students. He also passionately engaged debate on economic policy. Unusually, he engaged such debate with a generosity of spirit, and a genuine curiosity that turned discussion with him into a source of pleasure, often humour, especially if one disagreed (as he and I almost routinely did). Yet Harry's vocational pursuit was conducted in an institutional environment that incompletely acknowledged his virtues.

It is Harry Zarenda's deep commitment to the pursuit and transmission of knowledge that motivates my contribution to this volume of *Focus*, which seeks to recognise his contribution to South African intellectual life. Specifically, I wish to examine how well South Africa's knowledge creation systems fare in terms of an international comparative perspective.

This is all the more important since South Africa's National Development Plan places knowledge creation and innovation at the heart of its growth strategy:

> "South Africa needs to sharpen its innovative edge and continue contributing to global scientific and technological advancement. This requires greater investment in research and development, better use of existing resources, and more nimble institutions that facilitate innovation and enhanced cooperation between public science and technology institutions and the private sector." [National Development Plan Executive Summary, p.17]

This is a good idea. Unfortunately, as I intend to illustrate, South Africa does not live up to this hype, and underperforms its peers. At the root of this poor performance is a reliance on misaligned incentive systems, which too weakly tie to research excellence. As a result, success in knowledge creation in South Africa relies too heavily on the personal vocational commitment of researchers. Harry's example illustrates that such virtue is too rare to serve as a reliable basis for national policy.

South Africa's Knowledge Creation in International Comparative Perspective

So how does South Africa's capacity to create knowledge compare to international comparators?

To answer this question, we consider two sets of evidence. The first reports results from Confraria and Godhinho (2015) which considers the research output of African nations. The second considers South Africa's performance relative to benchmarks set by high-income and middle-income nations, as well as some specific Latin American countries.

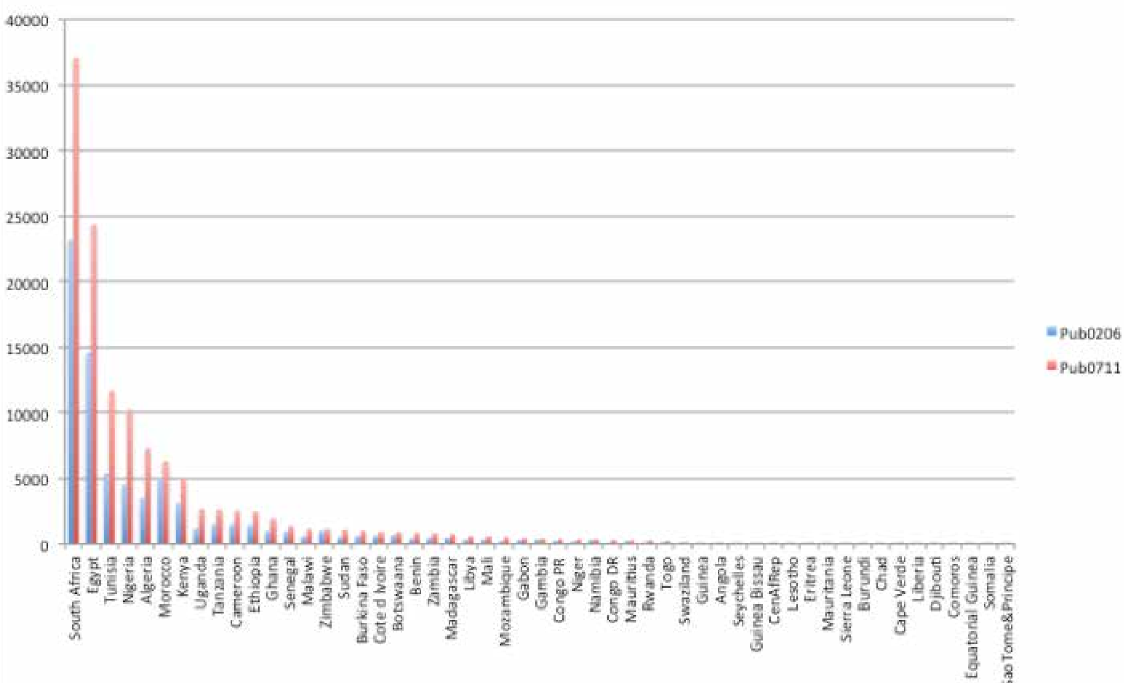
South Africa and Africa Compared

Relative to the rest of the African continent, South Africa's performance appears reassuring in a number of dimensions.

In terms of total research output, defined as peer reviewed published papers as captured by the Thomson World of Science InCites data base, South Africa not only overshadows the rest of the continent, but it has increased research output from the 2002-6 to the 2007-11 time periods. Figure 1 illustrates. Other than Nigeria, the only even approximate competitors are Mediterranean.

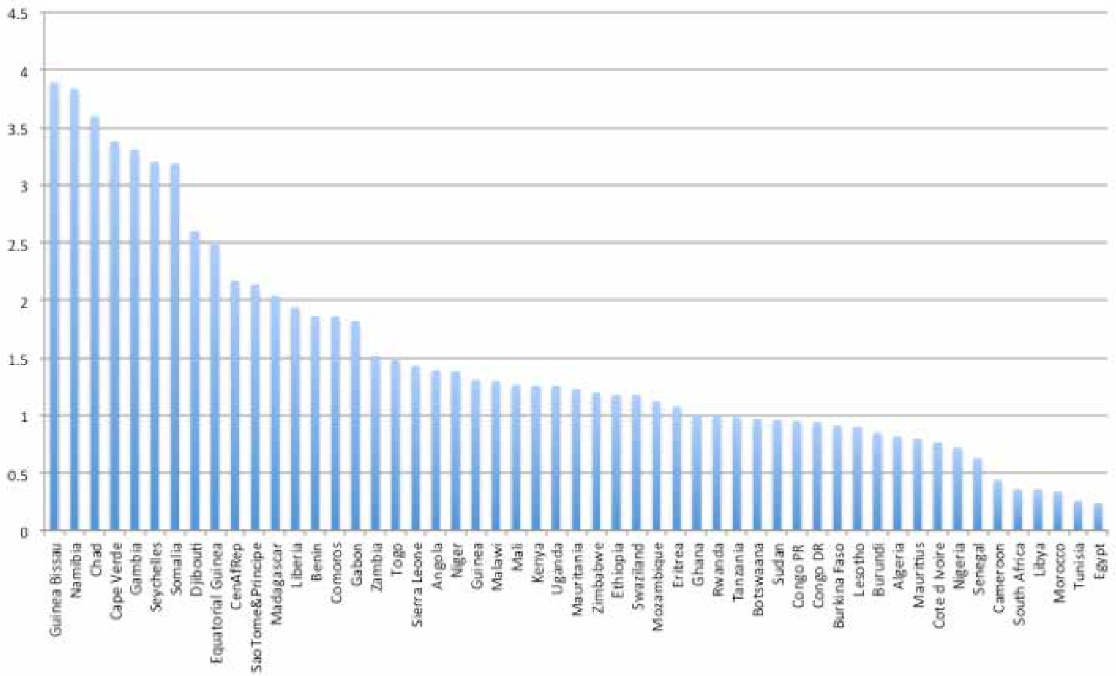
Normalizing the absolute publications output on GDP and population modulates the result. In terms of per unit of GDP South Africa's research output declines to rank 13 in Africa, and to rank 3 when research output is normalized against population. Notable is that the South African publications per unit of population measure of 150 for the 2007-11 period lies below the world average of 170, though it is an improvement on the recorded value of 99 for 2002-6.

Figure 1: Publication Output: 2002-6 vs 2007-11
Source: Confraria and Godinho (2015)



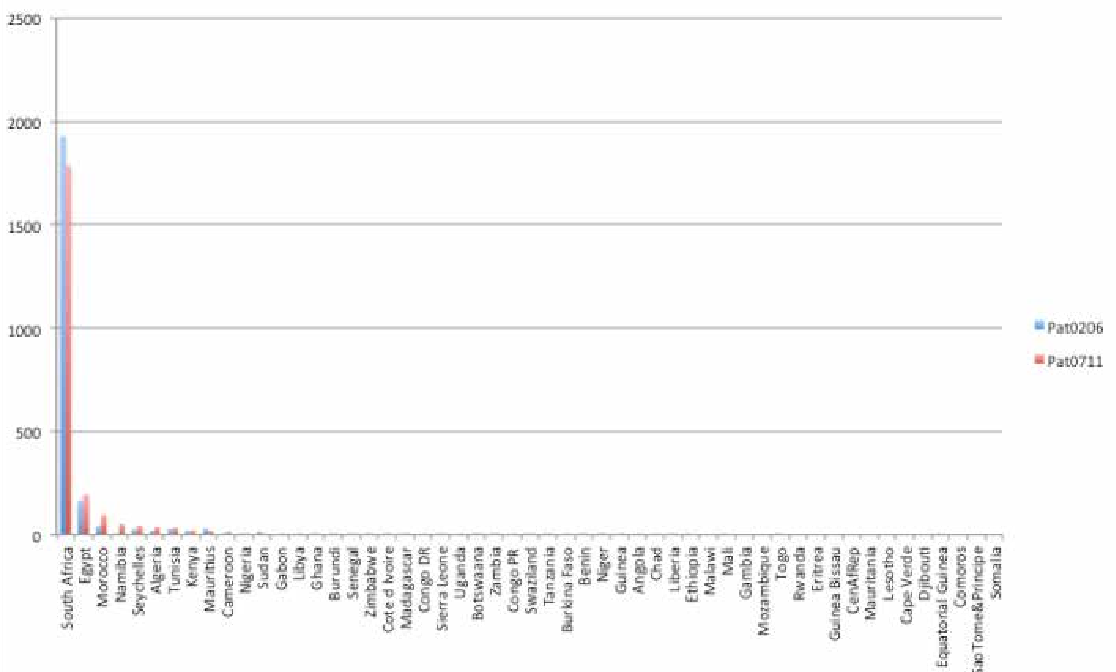
Also reassuring is that South Africa's research output is relatively generalized across disciplinary areas, rather than being narrowly specialized in a small number of niche disciplines.[2] As Figure 2 demonstrates by means of a specialization intensity index (SII), only Egypt, Tunisia, Morocco and Libya are less specialized than South Africa on the African continent for the 2007-11 period.

Figure 2: Specialisation (S11 2007-11)
Source: Confraria and Godinho (2015)



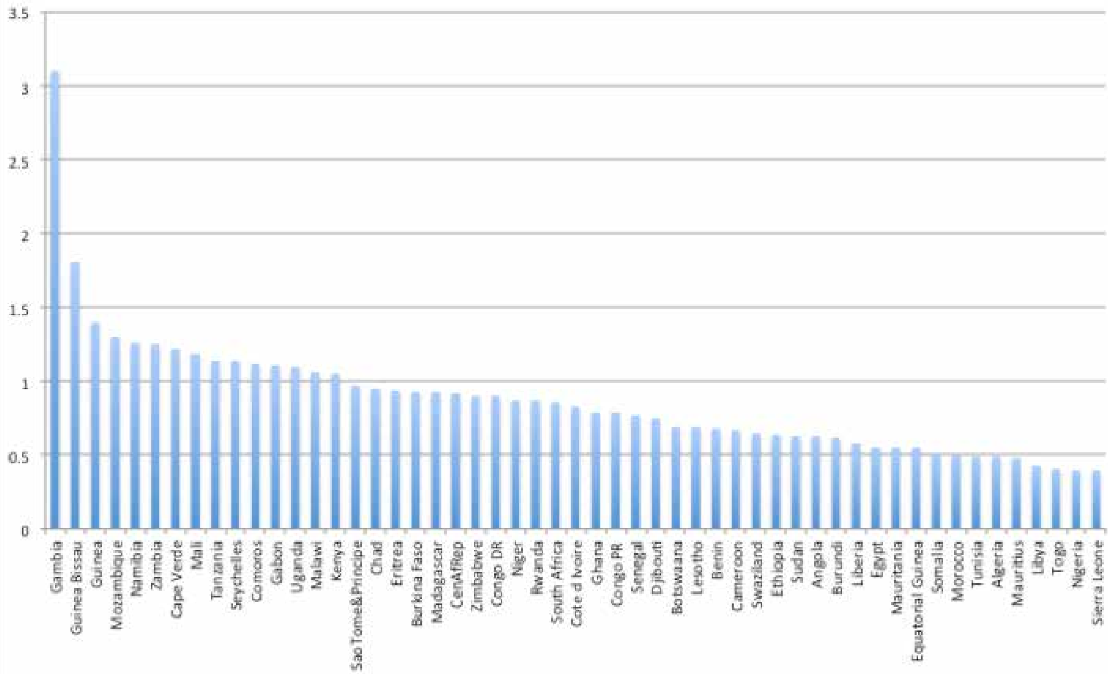
In terms of patent applications, South Africa's dominance on the continent is even more marked – it registers more patents than the rest of the continent combined. But as Figure 3 demonstrates, in this instance the trend over the 2002-6 to 2007-11 period has been downward.

Figure 3: PCT patent applications: 2002-6 vs 2007-11)
Source: Confraria and Godinho (2015)



In the African context there is also cause for concern, however. Consider the impact of research, as measured by the CXC index reported in Figure 4 for the 2007-11 period.[3] What emerges is that the impact of South African research is at best mid-table in the African context. In particular, the specific CXC value for South Africa implies that South African research publications are cited at only 86% of the world average across all research areas. (Any recorded value of the CXC above 1 indicates performance above the average world impact.)

Figure 4: Impact Measure (CXC 2007-11)
Source: Confraria and Godinho (2015)



As to output across disciplines for the 2007-11 period, the greatest absolute output for South Africa occurred in Clinical medicine, Economics and business, Plant and animal sciences, the Social sciences, and Chemistry. These five areas alone account for approximately 57% of total recorded publications output of South Africa. See the evidence of Table 1.

Table 1			
	Publications		RSI
Clinical medicine	5662	Plant and animal science	2.57
Economics and business	5662	Environment ecology	2.29
Plant and animal science	4936	Social sciences (general)	2.05
Social sciences (general)	3564	Immunology	1.95
Chemistry	2896	Mutidisciplinary	1.94
Environment ecology	2328	Space science	1.92
Engineering	1895	Geosciences	1.8
Geosciences	1819	Economics and business	1.52
Biology and biochemistry	1640	Microbiology	1.32
Physics	1581	Agricultural Sciences	1.18
Psychiatry psychology	1026	Psychiatry psychology	1.15
Mathematics	1009	Mathematics	1.01
Agricultural Sciences	961	Biology and biochemistry	0.77
Immunology	794	Clinical medicine	0.76
Microbiology	789	Chemistry	0.71
Materials science	765	Pharmacology and toxicology	0.71
Space science	759	Engineering	0.63
Pharmacology and toxicology	494	Physics	0.5
Molecular biology and genetics	413	Computer science	0.47
Computer science	343	Materials science	0.46
Neuroscience and behavior	322	Molecular biology and genetics	0.43
Mutidisciplinary	160	Neuroscience and behavior	0.32

Since not all disciplines show the same publication rates, one way to control for discipline-specific characteristics is to consider a modification of the Balassa revealed comparative advantage index. This is given by the ratio of the country specific ratio of discipline-specific publications to total publications, to the aggregate world ratio of publications in that discipline to total publications – reported as the RSI in Table 1. Note that any value above 1, indicates a revealed comparative advantage, in the sense that the country specific publication intensity in that discipline lies above the world average. In terms of this measure of performance, Plant and animal sciences, Environmental ecology and the Social sciences report very strong revealed comparative advantage (RSI exceeds 2), and a further 9 disciplinary areas exceed the world average in terms of publication intensity. Note that of the five disciplines that account for 57% of total publications, only three (Plant and animal sciences, Social sciences, Economics and business) also report a revealed comparative advantage (Clinical medicine and Chemistry do not).

In summary, the comparison with the rest of Africa suggests that South Africa reports a creditable performance, particularly in terms of the quantity of its research, though with some concerns regarding the impact of its published research.

But there is an obvious limitation that attaches to any South African comparison to the rest of Africa in terms of research performance. This arises due to the fact that the African region reports the weakest performance of any geographical region in research terms. As such, it does not provide a very demanding standard against which to measure South African performance.

What is more, virtually all countries in Africa lie considerably below South Africa in terms of GDP per capita measures. A more appropriate comparator group of countries for South Africa are middle-income countries and upper middle-income countries that have comparable levels of economic development.

It is to this comparison that we now turn.

South Africa Relative to Countries of Comparable Levels of Development

So how does South Africa compare to countries of comparable levels of development?

To answer this question, we contrast South Africa's performance across a range of metrics against the Upper Middle Income country average, the BRICS grouping (Brazil, Russia, India, China excluding South Africa), as well as Argentina and Chile. In addition, we compare South Africa's performance against the benchmark set by the developed, high-income countries.[4]

All data is from the World Bank Development Indicators.

Consider first the publications of scientific and technical journal articles per capita, as reported in Figures 5 and 6. The first striking feature about the evidence is that South Africa's per capita production of publications has been on a downward trend since the mid-1980s. The increased research output that we noted in section 2.1 above, has not significantly reversed this downward trajectory. As expected South Africa lags the benchmark set by High Income countries. But what is striking is that the gap between South Africa and the High Income average has been growing, and strongly so.[5] What is more, while historically South Africa's publication performance was above that of the Upper Middle Income average, by the close of our sample period the gap has been not only closed, but South Africa now lies below the Upper Middle Income mean.

Figure 5: Scientific and Technical Journal Articles per Capita

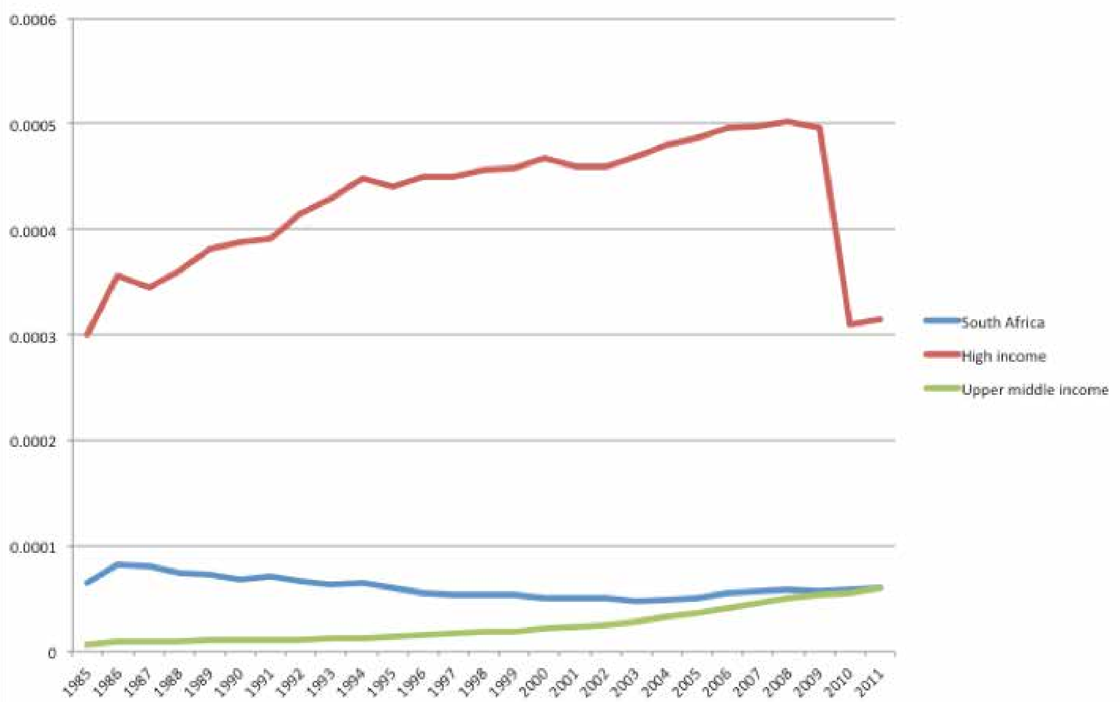
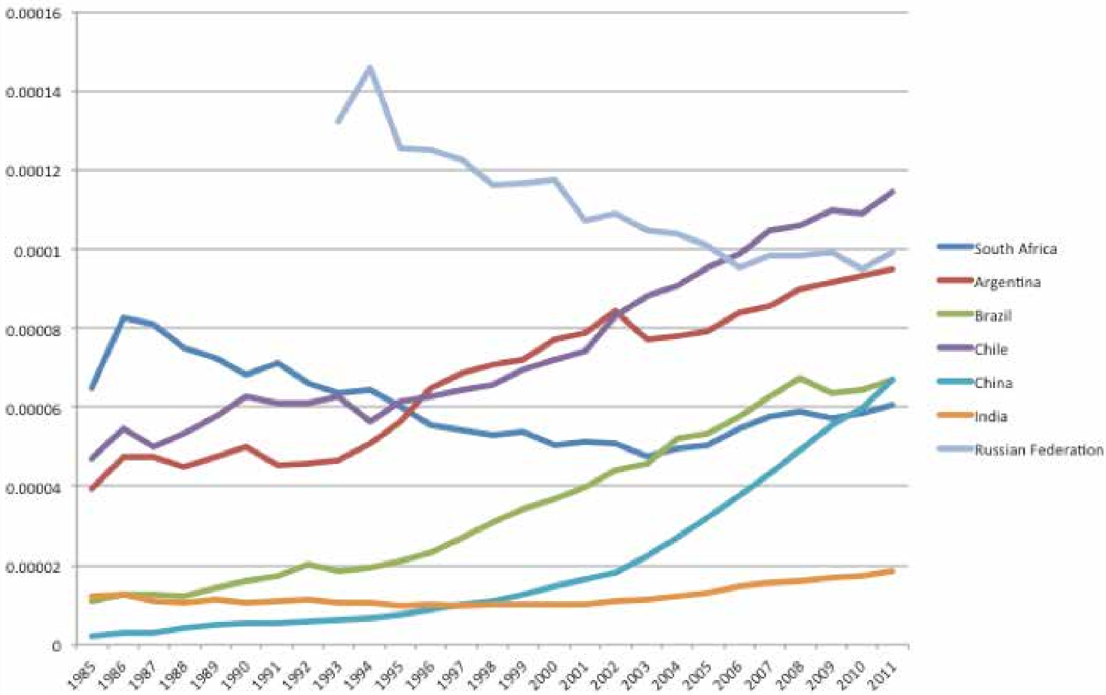


Figure 6: Scientific and Technical Journal Articles per Capita



A symmetrical inference arises from the augmented BRICS grouping (which includes Argentina and Chile). With the exception of Russia (which generates output at a much higher level than South Africa), all of the countries in the augmented BRICS grouping show upward trends and for Argentina, Brazil, Chile and China the trend has been strongly upward since the early 1990s. The result is that all of the augmented BRICS countries now produce more scientific and technical articles per capita than South Africa, with the sole exception of India.

An immediate explanation of this weak South African performance lies in poor research capacity. In Figures 7 and 8 we report the number of researchers engaged in research and development per million of population. Here, while South Africa reports an increasing trend, the trend is not only extremely moderate, but has been overshadowed by the increases reported in both Upper Middle Income and High Income countries.

The augmented BRICS comparison further emphasizes the point. Only India employs fewer R&D researchers per million of population, and Argentina, Brazil and China all report strongly increasing trends in contrast to South Africa's relative flat-lining. Russia's declining trend has to be interpreted in the light of the fact that

Figure 7: R&D researchers per million population

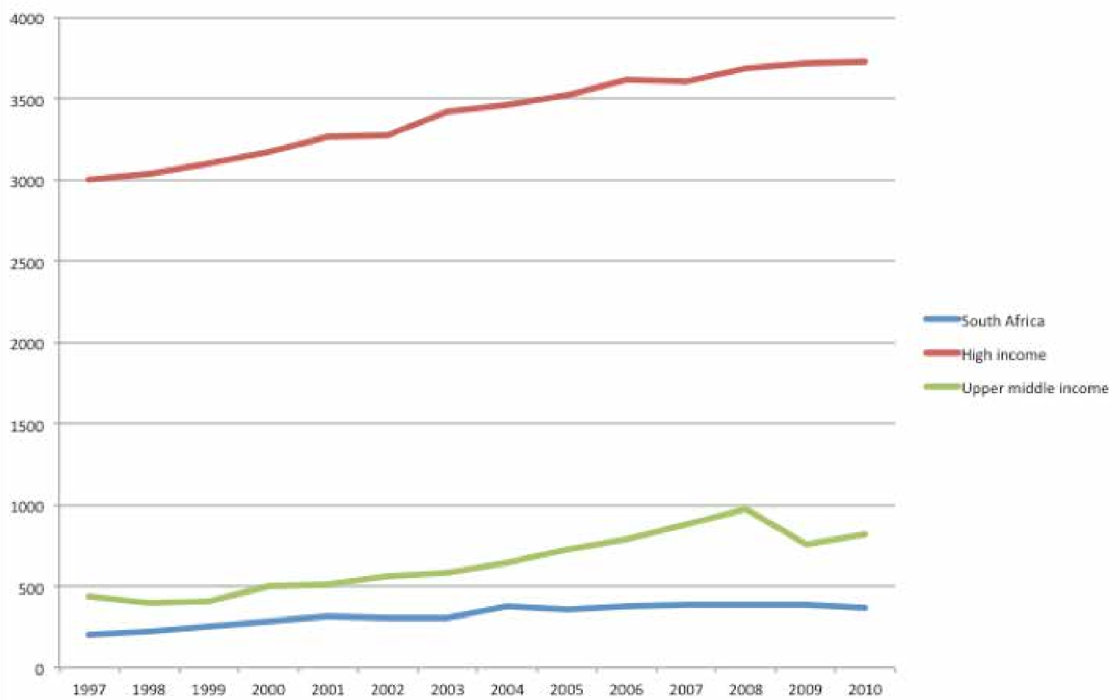
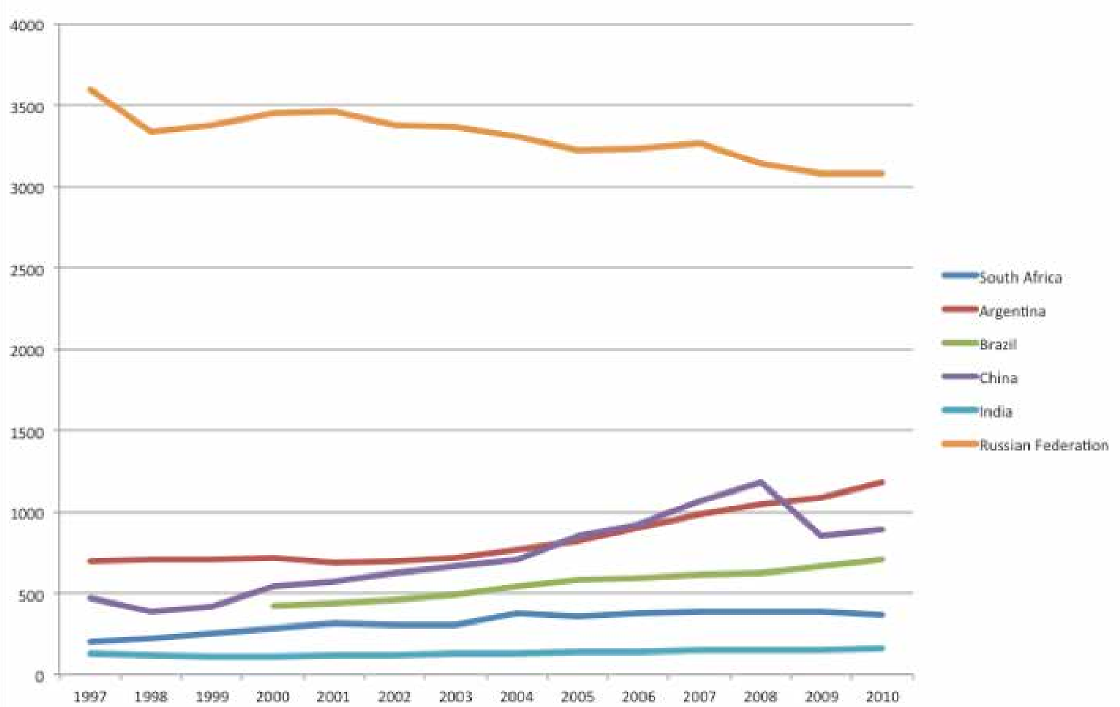


Figure 8: R&D researchers per million population



it began the sample period with more researchers per population unit than High Income countries, and continues to report an intensity of researcher employment that is comparable to developed nations.

So the answer to our question of how South Africa compares to an appropriate comparator grouping of countries defined by their level of economic development is immediate and straightforward: not well.

And this poor performance is both in terms of outputs (scientific publication) and inputs (R&D researchers).

What is more, the dynamics of the comparison imply that South Africa is increasingly falling behind over time, both relative to High Income developed nations, but also relative to the immediate comparator grouping of Upper Middle Income and BRICS countries (augmented).

Insufficient pay for academicians is thus not a feasible explanation for poor South African research performance. But perhaps the reason for this is that pay incentives for researchers are not particularly effective in general?

It is also worth noting that this poor performance in scientific research is mirrored by a changing composition of manufacturing exports. In 1998 approximately 10% of South Africa's manufacturing exports were classified as being of high technology content. Since then the trend has been resolutely downward, and by 2012 was approximately 4%.

The question we must now confront is why South Africa's research performance is so poor?

Some Explanations

There is fault with South Africa's incentive mechanisms: not enough scientists are entering research careers, and when they do enter, they do not produce enough output.

So what incentives are going awry?

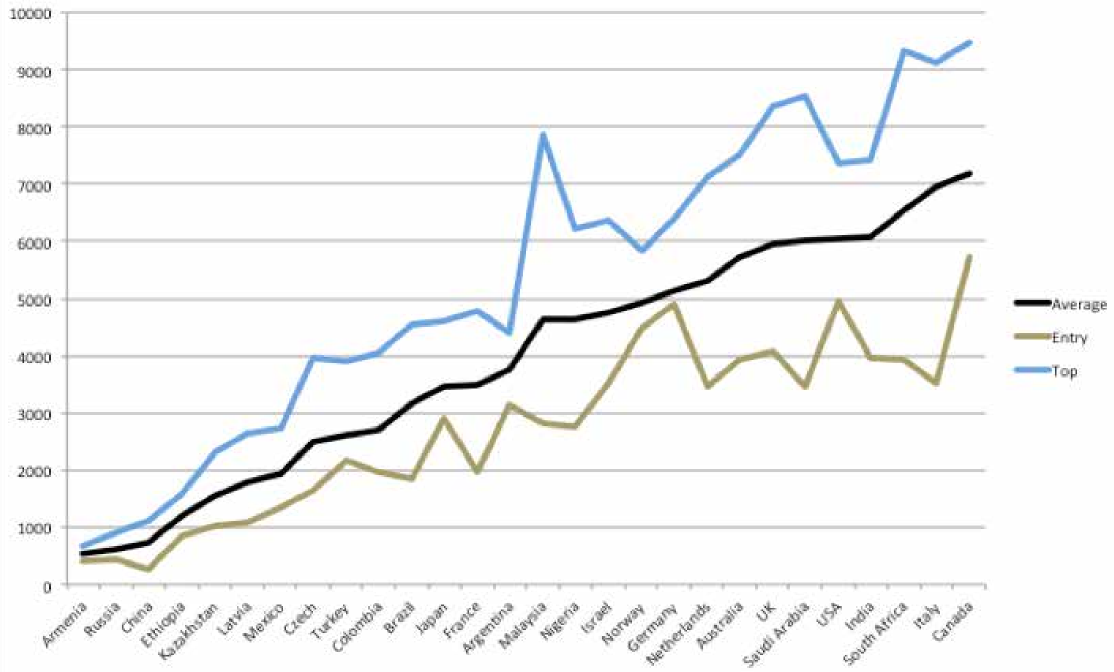
An obvious starting point is the pay that scientists receive. If South African researchers are poorly paid, incentives for attracting productive researchers would be compromised, and morale for producing research would likely be sub-optimal.

But it is difficult to suggest that this is the likely source of the problem. Figure 9 reports the mean, entry and top level pay that academics receive, adjusted for purchasing power parity, as reported for 28 countries by Altbach et al (2012).

Average South African academic salaries in PPP terms are the third highest in the world, outranked by only Canada and Italy, and ahead of the USA and the UK. Certainly academic salaries dwarf Russian levels.

Yet we have seen that South African academic productivity is certainly not amongst the top three in the world, and lags far behind the much more poorly remunerated Russian academy.

Figure 9: Comparitive Pay for Professoriate (US $ PPP)
Source: P. Altbach et al (2012)



Insufficient pay for academicians is thus not a feasible explanation for poor South African research performance. But perhaps the reason for this is that pay incentives for researchers are not particularly effective in general?

Again, the evidence suggests otherwise.

Consider the evidence of Figure 10, which compares average, entry and top-end pay of academicians in PPP terms against research productivity as measured by scientific and technical journal articles per capita. In general, there is a positive association between research publication productivity and academic pay (particularly for developed countries), for all three pay measures. Equally, however, there is a grouping of countries who, despite utilising the pay incentive structure rationally by paying well, do not succeed in realising the full productivity impact the incentive mechanism would predict. These are India, Italy, Malaysia, Nigeria, Saudi Arabia and South Africa. But note also: South Africa together with India and Saudi Arabia fail most spectacularly, paying high salaries in PPP terms, and realising amongst the lowest research productivities in the sample.

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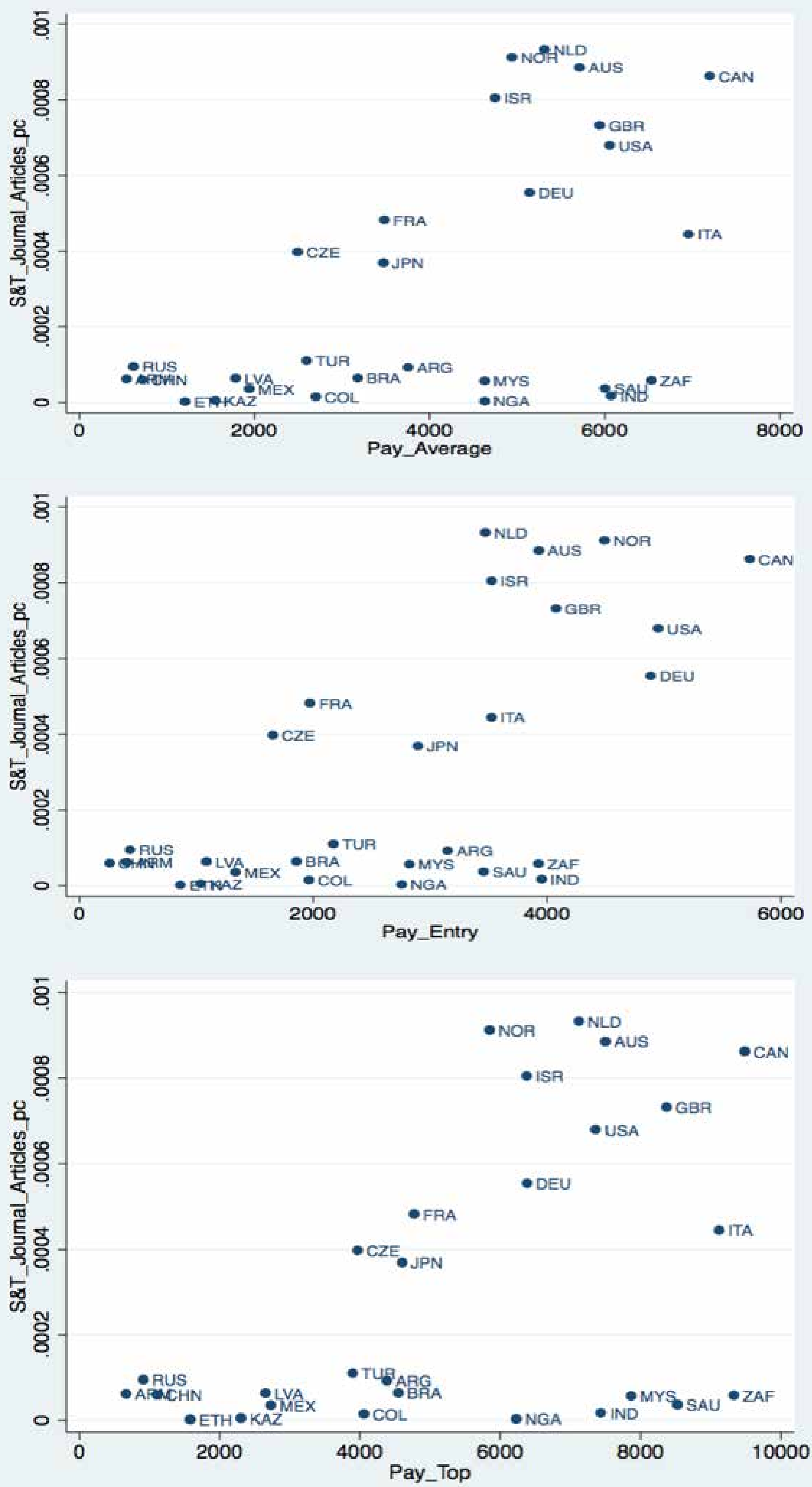
Figure 10


S&T_Journal_Articles_pc
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NLD
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AUS
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KAZ

Something else is the matter.

There is now strong evidence to suggest that at least part of the problem invests in the incentive mechanisms that national science funding bodies provide. This inference follows from the evidence presented in Fedderke (2013) and Fedderke and Goldschmidt (2015) on the functionality of the National Research Foundation (NRF) incentive structures.

There are a number of concerns. NRF rating mechanisms are imperfectly tied to objective research performance. Above all, funding for research is weakly linked to research performance. Consider the single most significant funding that the NRF provides in the form of its research chairs. This funding is very considerable, even by first world standards, at ZAR1.5 million to ZAR3 million per annum. The funding is guaranteed for at least 5 years, possibly 15 years, so is not only substantial but sustained. The official objective is to use the funding to attract "world leading" researchers in their fields.

Figure 11

"low", "med", "high" denotes low, medium, high propensity of being awarded NRF research chair vertical axis reports average performance in relevant metric of the group

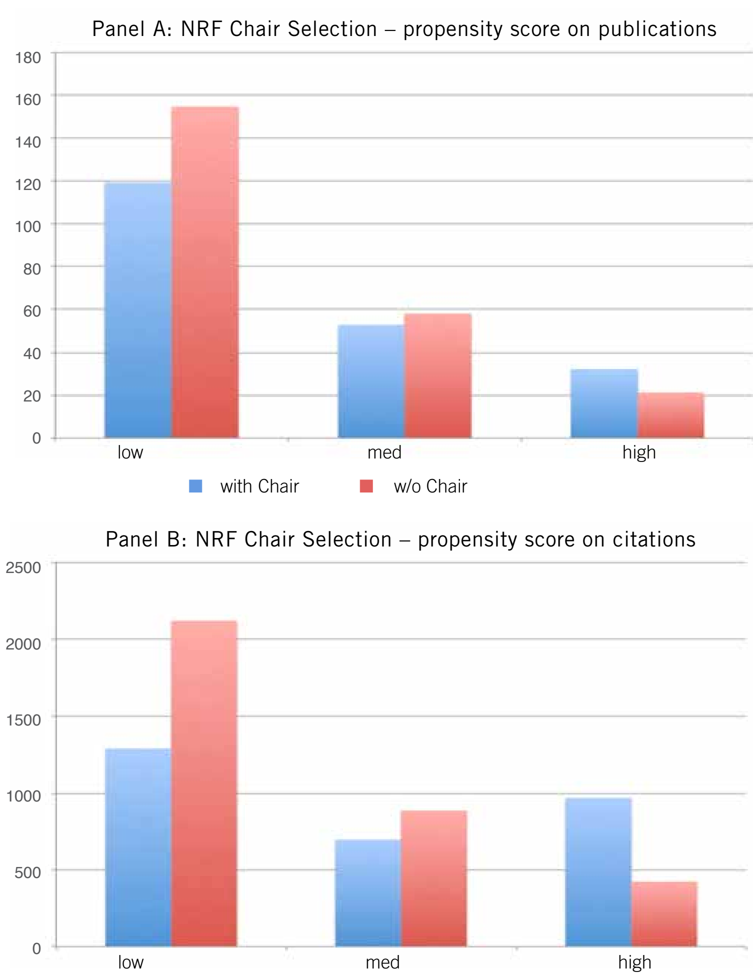
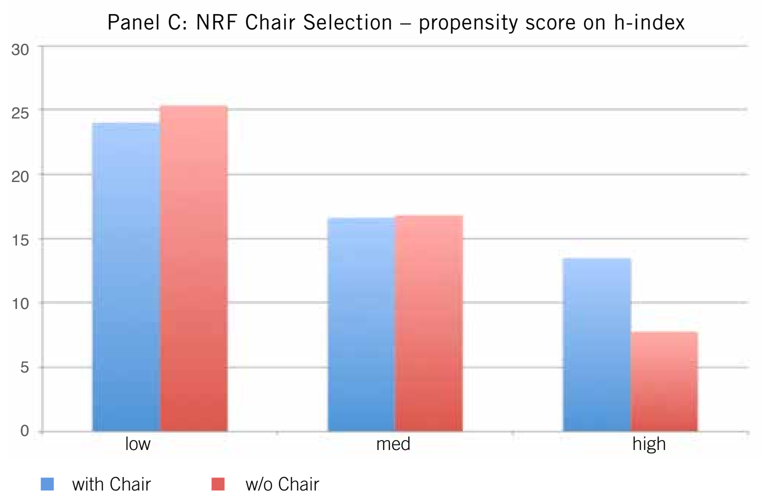


Figure 11



Source: Confraria and Godhinho (2015)

Yet of the initial set of 80 research chairs the NRF awarded, more than 50% did not meet the NRF's own standards for an A or a B rating (which are deemed to reflect world standing). What is more, when considering the likelihood of a research chair being awarded by means of a propensity score, the class of researchers *least* likely to be awarded research chairs were those with the strongest performance in terms of publications, citations or an h-score (a composite index of both absolute output and the impact of output in terms of citations). In fact, researchers that were the *most* likely to be awarded research chairs were those with the weakest performance in the quantity and impact of research produced in terms of these metrics. Figure 11 reports.

> *This rather neatly establishes a central point about how and when incentive structures work: when incentives are used to reward good performance they tend to work. When they are used to reward other characteristics, they do not.*

With predictable consequences. The productivity impact of the NRF research chairs, despite the considerable funding allocated to them, has been weak.

For the 2009-12 period there is no statistical difference between the performance of the NRF chairs on average and A-rated researchers without chair funding, nor between the average NRF chair and researchers without chair funding who under the propensity score matching methodology had the strongest pre-award research performance. In fact, the evidence suggests that both categories of strong researchers without chair funding outperform the NRF research chairs in a number of objective research metrics. Despite a minimum 15:1 funding advantage, there is thus no statistically observable superior research performance on the part of the NRF research chairs.

In fact, what improved research performance there is in the research chairs, is substantially due to the improved performance of those research chairs that were chosen despite the fact that they had strong prior publications and citations records.

This rather neatly establishes a central point about how and when incentive structures work: when incentives are used to reward good performance they tend to work. When they are used to reward other characteristics, they do not.

In the South African science system they are not used to reward excellence, and they do not work.

Conclusion

South Africa's National Development Plan has set economic growth linked to strong knowledge production as one of its key objectives.

South Africa certainly spends money toward that end. It pays its academy well. It allocates substantial funding to education.

But as this discussion indicates, it punches well below the weight class that its level of economic development and level of expenditure would suggest.

Problems invest in the incentive structures that the national science funding bodies provide. Incentives are too weakly tied to research excellence. Funding instead pursues other objectives, leaving the realization of research productivity that is internationally competitive subject to the personal dedication and vocational commitment of individual researchers.

Such commitment is laudable. However, if we follow George Bernard Shaw in recognising that virtue alone is insufficient temptation, it does not constitute a reliable foundation for national policy.

It is time that South Africa got more serious.

FOOTNOTES

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2 The Specialization Intensity Index is measured as a ratio which in the numerator displays the square of the difference between specialization intensity of class s in country i and specialization intensity of that class in the world, while the same denominator displays the sum of the weighting of all subject areas in country i, with this ratio summed up across all subject areas.

3 This is measured as the mean citation rate of a country's set of publications in a specific subject area, in a specific period of time, for the specific document type, divided by the mean citation rate of all publications within the relevant subject area, period and document type.

4 Not all countries have data available in all the dimensions we consider.

5 Note: the apparent decline from 2010 is due to missing data for the US and UK amongst other strong producers.

6 This is confirmed by regression analysis – the pay measures prove to be statistically significant at least for our small sample.

REFERENCES

Altbach, P.G., Reisberg, L., Yudkevich, M., Androushchak, G., and Pacheco, I.F., 2012, Paying the Professoriate: A Global Comparison of Compensation and Contracts, Routledge.

Confraria, H., and Godinho, M.M., 2015, The impact of African science: a bibliometric analysis, Scientometrics, 102, 1241-68.

Fedderke, J.W., 2013, The Objectivity of National Research Foundation peer review in South Africa assessed against bibliometric indexes, Scientometrics, 97(2), 177-206, DOI: 10.1007/s11192-013-0981-0.

Fedderke, J.W., and Goldschmidt, M., 2015, Does Massive Funding Support of Researchers Work?: Evaluating the Impact of the South African Research Chair Funding Initiative, Research Policy, 44, 467-82, http://dx.doi.org/10.1016/j.respol.2014.09.009.