Economic Inequality and Science, Technology and Innovation Policy: the cases of the United Kingdom and South Africa

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'The authors wish it to be known that, in their opinion, the first 2 authors should be regarded as joint First Authors'

Abstract

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There is growing evidence that technology-driven economic growth has a signficant role to play in growing inequality in industrialised countries. Examining innovation policies in South Africa (the G20 Country with the highest levels of inequality) and the UK (inequality at the G20 average), we ask whether the role of innovation in driving inequality is being addressed in STI policy, what measures might be neglected, and why innovation and distribution sensitive policies take the form they do. We find that the distributional consequences of innovation do receive attention in innovation policies in the two countries, albeit in different (and sometimes suprising) ways. However, the approaches taken are limited to a focus on the 'firm' as the model for technology transfer, with little evidence of moves to share assets. These differences and oversights, we argue, are the result of particular sociotechnical imaginaries shaping the role of science and innovation in national life.

1. Introduction

Over the past half-century, science, technology and innovation (STI) have been seen as key drivers of economic growth. This has been reflected in contemporary government policies around the world. The latest United States innovation strategy for example, states that "technological innovation is the key source of economic growth for the United States" (White House 2015: 6); the African Union's long term Agenda 2063 articulates that Africa's growth requires sustained investments in science, technology, and innovation AU 2014); and the European Committee deems

innovation "vital to European competitiveness in the global economy" (EC 2019). Pfotenhauer and Jasanoff (2017) went as far as to say that "it seems as if all governmental functions *must* cater to a discourse of innovation in order to appear economically defensible" (p. 784).

Recently however, there is increasing evidence that economic growth has come hand in hand with growing economic inequality. Since the early 1980s, income inequality has increased rapidly in North America, China, India, and Russia and moderately in Europe (OECD 2008, OECD 2011; Piketty 2015; Alvaredo et al. 2017). The World Inequality Report found that during this time, "the top 1% richest individuals have captured twice as much growth as the bottom 50% individuals" (Alvaredo et al. 2017, p. 11). While the growth in economic inequality varies greatly across regions, very few regions have bucked this trend and the major regions where income inequality has remained relatively stable – the Middle East, sub-Saharan Africa, and Brazil – were already marked by extremely high inequalities at the start of the 1980s (Alvaredo et al. 2017).

If science, technology and innovation are key drivers of economic growth, and if economic growth has been coupled with growing economic inequalities, the question arises of what role science, technology and innovation have in economic inequality? This straightforward question has been curiously underexplored, ostensibly due to the long-held assumption of both neoclassical economics as well as evolutionary economics, that a growing economy benefits everyone (Cozzens et al 2002).

This assumption may not always hold true however. Studies in rather dispersed disciplinary settings provide evidence that science, technology and innovation have had an important role in this rising inequality. For instance, Aghion and colleagues showed that innovation accounts for around 15% of the total increase in the top 1% of income share in the US between 1975 and 2010 (Aghion et al. 2015). This has among others been attributed to the ownership of assets and intellectual property laws that concentrates income and capital at the top, to patterns of diffusion that offer the greatest gains to the earliest adoptions, a market-based research approach that focuses on developing products that benefit the richest the most, and tendency for innovation to increase wage inequality by pulling up the upper end of the distribution through higher demand and wages amongst high-skill, hi-tech workers, at the same time undermining the security of employment, particularly for low skilled workers (Cozzens et al. 2002; Birch 2019; Lazonick and Mazzucato 2013; Acemoglu 2002; Rogers 2003; Wiess and Eikemo 2017; Glied and Lleras-Muney 2008; Wood et al. 2019, Cozzens et al. 2002; Cozzens 2012; Autor 2015; Johnson 1997). Cozzens concludes that "traditional approaches to innovation policy rely on mechanisms that, unless designed specifically to do otherwise, tend to increase inequalities" (Cozzens 2008a, p. 11).

Recently, a handful of studies has identified different ways that innovation policies could include considerations of economic inequality (Planes-Satorra and Paunov 2017; Stanley et al. 2018). These rather isolated instances of distribution sensitive innovation policies include grants to engineering projects led by female researchers (Planes-Satorra and Paunov 2017); platforms for stakeholder participation (Refgaards et al. 2016); micro-loans with favorable conditions for repayment (Planes-Satorra and Paunov 2017); incubator programs that are located in economically disadvantaged regions (Zehavi and Breznitz 2017); and wage subsidies for technology companies

that employ minorities (Zehavi and Breznitz 2017). However, new ideas to develop a more distributional sensitive approach to innovation policy, little is known about how innovation policies *currently* address the potential for economic inequality.

In this article, we contribute to this emerging body of literature by identifying whether and how economic inequality is considered and addressed within national innovation policies of South Africa and the United Kingdom – two countries that consider science, technology and innovation as key drivers of economic growth, that are marked by economic inequalities but one which has the highest level of inequality in the G20 and another which has G20 average levels of inequality, as well as dramatically different histories and political mandates. Specifically, we draw on these similarities and contrasts to ask whether the respective governments address the role of innovation in driving inequality, how inequality is conceived in these context, and what steps they have put in place to address inequality?

The existing literature on inequality and innovation policy focuses on individual policy measures explicitly designed to address inequality (for instance Planes-Satorra and Paunov 2017; Zehavi and Breznitz 2017). However, this provides little information about the position of measures addressing economic inequality within innovation policies at large. Are these measures an integral part of innovation policies' overall objectives or 'add ons' to a wider innovation policy likely to increase inequality overall? Besides contributing to the empirical base on whether and how economic inequality is currently included in innovation policy, in this paper we also aim to improve our understanding of the significance of these policy measures within innovation policies overall. We therefore elucidate measures addressing economic inequality alongside the sociotechnical imaginaries (Jasanoff 2016) underlying these innovation policies, revealing the dominant narratives about the futures the two countries aspire to through science and innovation. In this way, we aim to a more situated understanding of the role of inclusive policy measure within innovation policy as a whole.

2. Understanding how innovation policy accounts for inequality

Analysing innovation policy has traditionally been found within Innovation Studies (IS), the field comprising "economic, management, organisational and policy studies of science, technology and innovation" (Martin 2016, p. 433). Reviewing fifty years of empirical studies within IS, Cohen (2010) describes how the field predominantly focuses on the relationship between firms, innovation and market competitiveness, rather than any wider social impacts. For research into science and technology specifically, Stephan (2010) indicates how such research has concentrated on establishing and quantifying the link between science and economic growth, R&D activity and profitability, again neglecting consideration of wider societal effects.

In Science and Technology Studies (STS), substantial attention has been paid to such wider societal effects. This field studies how societies are shaped by science and technology and conversely how products of science and technology are shaped by various societal factors (Bijker

2001). Inequalities of various kinds have been addressed in this literature - both how they have shaped the products of science and technology, and how science and technology have impacted them. The STS handbook series, for exampe, included chapters on gender, race, postcolonialism, development, and structural inequalities. These studies offer valuable insights into the production of various inequalities, and while inequalities along the lines of gender and race are closely intertwined with economic inequalities, the relationship between science, technology and innovation and *economic* inequality has remained markedly understudied.

While IS studies the relationship between innovation and economic growth but not inequality, and STS studies the relationship between innovation and inequality but not along economic lines, there is now a rather dispersed set of recent studies that squarely focuses on innovation and economic inequality. At the production side of innovation, several authors have highlighted the effects innovation clusters may have on economic inequality on a regional scale (Lee 2011; Lee & Rodriguez-Pose 2013; De Palo et al. 2018), as the growth and increasing wages in innovative regions create inequalities with less innovative regions. Others have demonstrated that the introduction of new production technologies may increase economic inequality by requiring specific skills that are difficult to attain or unevenly distributed, causing wages of highly-skilled workers to rise while less-skilled individuals lose out (Acemoglu, 2002; He and Liu, 2008, Cozzens et al 2002; Birch 2019). Conversely, others have argued that technology has a tendency to undermine the security of employment, particularly for low skilled workers. For instance, Cozzens et al (2002) argued that the focus of 'traditional' innovation policy has been on developing technologies that elimate jobs in manufacturing, a sector where workers could historically earn good wages in steady jobs and where the workforce has been organized to protect such workers rights. By eliminating these jobs, as well as hollowing out middle income jobs, technology also undermines the political base for worker protection. Lazonick and Mazzucato (2013) found that while the risks of the innovation process are largely collective, a disproportionate share of the economic returns is appropriated by small numbers of individuals on strategic positions, hence increasing economic inequality.

At the consumption side, various authors have argued that mainstream technological innovations often ignore the interests and aspirations of lower income people. Studies in inclusive innovation (Heeks 2014), bottom-of-the-pyramid innovation (Prahalad 2004), appropriate technology (Kaplinsky 1990) and reverse innovation (Govindarajan & Trimble 2012) have subsequently identified measures to steer the direction of technological change towards the needs of the poor, for instance by developing cheaper products with slightly lower quality, pursuing innovative distribution channels, focusing on low-tech technologies that can be maintained with locally available materials, or by relocating corporate R&D centers to geographical areas with low-income groups.

These studies are incredibly diverse. They draw upon different methodological approaches, identify diverse mechanisms that generate or mitigate inequality, and build on diverging normative assumptions about what economic inequality is and when it is justified to address this (Cozzens 2007; Levidow and Papaioannou 2018). Some studies for example discuss policy measures that

steer technological change towards the needs of the poor, which can be associated with Rawlsian theories of distributive justice, where policy measures are justified as long as they also bring some benefits to least advantaged groups. Other studies are focused on measures to promote public participation, which have been associated with communitarian approaches aiming to reduce inequalities in an effort to build community (Cozzens 2007).

It is important to emphasize that in this paper we focus on innovation policies for economic *inequality* – defined as a given empirical distribution – and not for *inequity* – defined as a normative judgment about that distribution, often rooted in particular philosophical theories of justice (Cozzens and Wetmore 2010). Moreover, we are interested in providing a *situated* understanding of the role of economic inequality in innovation policies. For our study it was therefore important not to a priori select one theory of distributive justice and identify what policy measures are taken in accordance to that theory, as this risks neglecting policy measures that build on different normative, theoretical or empirical starting points. Instead we cast our nets widely and capture the diverging normative assumptions and associated measures for addressing economic inequality that are put forward locally.

We therefore draw upon a conceptual framework developed by Susan Cozzens and colleagues (2008b; 2010) that deliberately incorporates a wide range of theories of distributive justice. Specifically, Cozzens and colleagues (2008b; 2010) identify three different ways in which science, technology, and innovation policies can address economic inequality, which they label equalising, fair, and pro-poor.

1. Equalising: Does this policy seek to change socioeconomic structures in ways that reduce rather than increase economic inequality?
   Equalising policies attempt to increase income at the middle and bottom of the distribution, thereby reducing vertical inequalities – inequalities along the lines of income or wealth. Cozzens (2008b) describes how investment in innovation tends to hollow out the job market, typically producing high-skilled high wage jobs which communities may or may not be equipped to take up. Equalising policies attempt to mitigate this by emphasising the importance of producing jobs and reducing unemployment, but also on producing mid-wage jobs and considering whether the skills are in place to produce the technologies invented and whether they are creating a contraction in existing industries. This for instance concerns policies that include local employment requirements as conditions for foreign investment, that take into account the possible contractions of old industries, and putting forward models of ownership and intellectual property with equalising effects (Cozzens 2008b).
2. Fair: Does the policy offer help for disadvantaged groups?
   Fair policies attempt to eliminate horizontal inequalities – inequalities along the lines of culturally defined differences, such as gender, ethnicity, or religion (Cozzens and Wetmore 2010). For example “high-technology jobs would be taken up by people from different ethnic groups in proportion to their numbers and educational levels” (Cozzens 2010, p.

444). This includes policies that ensure equality of opportunity, but also includes measures to address historic inequalities often found between culturally defined groups, and as policies ensuring disadvantaged groups are not unfairly impacted by the risks and downsides of innovation (Cozzens 2010).

3. Pro Poor: Does the policy target innovation specifically to the needs of poor households and communities?

   Pro-poor policies aim to reduce poverty or alleviate its conditions. Beyond work and jobs, the availability of consumer goods and services has an important role to play in economic inequality. The processes by which the products available to consumers are determined, what problems they are intended to solve or the benefits they are seen to bring, and how much they cost are important to questions of inequality then (Cozzens 2008b). In particular, for low income communities, innovations that reduce the costs of basic goods and services are key (Cozzens 2010). Pro-poor policies hence focus on creating conditions in which technologies are developed that address the needs of the poor, both by skills of engineers but also by drawing upon the inventiveness of poor communities (Cozzens 2008b).

3. Methodology

To address the questions of whether and how economic inequality is addressed in national innovation policies, we used the equalising/fair/pro-poor framework to analyze recent policy documents from the United Kingdom and the Republic of South Africa. Policy documents are certainly not the only sources for studying the place of inequality in innovation policy, as the various processes prior to the formulation of policies as well as their implementation offer ample room for issues of economic inequality to enter. Yet policy documents are a good source for assessing the role of inequality in innovation policies because they present the official government position, and therefore provide insight into the dominant government thinking about the relation between innovation and inequality.

The United Kingdom and South Africa were considered particularly suitable comparators for three reasons: First, both the United Kingdom and South Africa have dedicated innovation policies. Second, while inequality is a concern in both countries, South Africa has the highest levels of inequality in the G20 (Gini Coefficient of 0.62), while UK has average levels (Gini cooefficient of 0.36, G20 average 0.37), offering an opportunity to compare, contrast and draw wider lessons. Third, inequality has very different histories in each country: Despite being Africa's largest and most technologically advanced economy (OECD 2006) South Africa is still dealing with an historic legacy of inequality that is the result of government policies that favoured one section of the population over others during the Aparthied regime,. In the United Kingdom, wealth concentration is more moderate, yet at the same time, the share of the richest 0,1% of the population in the UK nevertheless doubled between 1984 and 2013, from 4,% to 9% (Alvaredo et al. 2017). If we were looking for contrasting approaches to tackling inequality – or

indeed supporting innovation – it seems reasonable to suppose they may be found here and that comparing and contrasting these approaches offers a broad view on the place of economic inequality in national innovation policies.

The documents included in the analysis reflected the key science innovation policy documents from each country from the early 1990s onwards (see table 1). This time period was chosen because this coincides with the end of the Apartheid regime in South Africa. We therefore opted to select documents following the general election in 1994, the first election that was open to the entire population of South Africa. The first UK policy document in our analysis dates from 1993 and represents what is considered to be the first 'modern' innovation strategy in the UK.

Table 1. List of innovation policy documents in South Africa and United Kingdom

Corpus SA		Corpus UK	
1996	White paper on science and technology	1993	Realising our potential
		1995	Competitiveness white paper
2002	National research and development strategy	2000	Excellence and opportunity
		2002	Investing in innovation
2008	Ten-year innovation plan	2004	Science and innovation investment framework
		2008	Innovation nation
		2010	2010 to 2015 government policy: research and development
		2014	Our plan for growth: science and innovation

To address the questions of whether and how inequality is addressed in national innovation policies and how local priorities are expressed within these, we carried out a two-stage process of analysis. First, we analyzed the policy documents from the Republic of South Africa and the UK, coding them for the three different aspects of economic inequality identified in the framework, using the extended list of questions from appendix 1. The results were subsequently analyzed and interpreted through the lens of the framework, by comparing measures taken in the two countries, and by drawing upon existing work on innovation policies in both countries

In the second step, we analysed the same policy documents from each country to discern the socio-technical imaginaries (Jasanoff and Kim 2009; Jasanoff and Kim 2015), and used these imaginaries to situate measures for addressing economic inequality in the context of overall policy directions.

We began identifying the imaginaries by identifying the underlying discourses within the policy documents using a computer assisted text analysis technique. We used the software IRAMUTEQ (*Interface de R pour les Analyses Multidimensionnelles de Textes et de Questionnaires*) to produce a statistical map of each corpus, which we then interpreted (see

Smallman 2017; Terämä et al. 2016). The statistical map produced by the software reflects the relationship between words and sentences, giving the researchers information such as lists of words that most commonly occur in sentences together, and how they are distributed across the documents. Using this information, along with the original texts, we were able to build up a picture of the key discourses within the texts, which were then negotiated between the researchers, to agree on the most plausible interpretations. On the basis of these discourses, we then identified the sociotechnical imaginaries – or the visions of the role of science and innovation in the world – underpinning these documents, which was subsequently used to interpret and situate the policy measures for addressing economic inequality within the overall policy discourse on innovation.

4. United Kingdom

So are matters of distribution and inequality included in UK science and innovation policy? In the following section we examine in detail the extent that the distributional effects of innovation and its impact on inequality has been consderded in science and innovation policy in the UK.

4.1 Equalizing

4.1.1 Regional development as a proxy for income inequality in the UK

Do the policies seek to change socioeconomic structures in ways that reduce rather than increase income inequality? Throughout the UK documents we were able to find policies to reduce income inequality. However, these were framed specifically in terms of regional development - ensuring innovation and growth is maximised across the UK, rather than in terms of income inequality. Nevertheless, they were relevant because within the UK economic inequality is often identified as having a strong geographical component, typically along the North/South divide (Martin, 1988). We therefore argue that focusing on regional development in the UK is a key way of addressing inequality and targeting jobs for less advantaged communities.

To give a concrete example of this, the 2000 “Excellence and Opportunity” White Paper (page 46) describes how the government will refocus the Regional Selective Assistance (RSA) programme to generate more high skill jobs in areas with low GDP and high unemployment, thereby aiming to reduce income inequality by supporting economic and job growth in these low-income areas.

This commitment to regional development is also evident in the 2004 “Science and Investment Strategy” which, before describing how increased R&D spending in regions will be encouraged, states that:

> “The Government and the RDAs are working towards a practical partnership to ensure that the aim of reducing regional disparities in prosperity is compatible with the pursuit of scientific excellence on a UK wide basis” (Science and Investment Strategy 2004, p. 114).

In relation to supporting regional investment, the 2004 strategy also contains a section looking at the regional distribution of higher education funding, in the context of university innovation as a 'pump' to regional development. Recognising that as long as funding is distributed on the basis of 'excellence' there is the risk that money will be concentrated South East where there is a higher concentration of high-achieving universities (Oxford, Cambridge, London), the strategy puts in place measures to help universities achieve 'excellence' and to have regional capacity in science teaching at university level.

In a similar vein, the 2010-2015 Government Policy on Research and Development launches a series of 'University Enterprise Zones (UEZs)' which were "specific geographical areas where universities and business work together to increase local growth and innovation" (). The pilot phase of these zones, announced in the policy document, were in the cities of Bradford (Leeds City Region), Bristol, Liverpool and Nottingham. All of these cities are outside London and the South East, so arguably targeting areas of higher unemployment. As we will discuss later, what remains to be seen is whether or not these schemes raised incomes for particular individuals or simply attracted high-paid workers from elsewhere.

This commitment to regional development was not evident in policy documents prior to 2000 however and while there were clear actions outlined in documents from 2000-2010, by 2014's "Our Plan for Growth", the focus on targeting job creation in less advantaged communities or areas of high unemployment in particular, appears to have dropped off. An interest in 'place' remains in the 2014 document, but this is discussed in the context of research clusters, and the need to build geographic centres of excellence around top universities – arguably the opposite of targeting disadvantaged communities.

4.1.2 Recognition of that innovation will drive the contraction of old industries

In this context of regional development, also a growing concern can be discerned about the possible contraction of existing industries, whereby the disappearance of traditional industries leads to the displacement of mostly lowly-skilled workers, increasing economic inequalities. 'Innovation Nation'(2008) and 'Our Plan for Growth' (2014) both mention the need to reskill workers in jobs displaced by innovation and technology. However the 'Science and Innovation Investment Strategy' (2004) in particular proposes concrete action to address this. Specifically it sees the new technology-based industries as offering the chance to replace jobs lost through post-industrialisation:

> "Technology-based innovation by business holds out the prospect of contributing significantly to the challenge of narrowing gaps in regional economic performance, by enabling regions to renew their industrial base over time" (Science and Innovation Investment Framework 2004, p. 114).

The Strategy goes on to discuss how the workforce will be provided with the skills to enable this, proposing new 'Foundation Degrees'. These new degrees are work-focused qualifications that combine workplace learning and academic study, to provide an alternative pathway to higher education. This was seen as a way of raising skills levels in the existing workforce:

> "Companies who need high level technical staff and associate professions are already expressing an interest in the potential of the Foundation Degree to enable them to develop their own staff. Working with employees recruited locally, they can use the flexibility and work-based learning offered by Foundation Degrees to enable them to develop internal talent to meet their technical and managerial needs" (Science and Innovation Investment Framework 2004, p. 102).

4.1.3 Taxation policies and models of ownership

One of the key issues of modern patterns of inequality, highlighted by Cozzens (2010) and Brynjolfsson and McAfee (2014), is the way in which technological innovations allow wealth to be concentrated into the hands of the innovators, typically by reducing the number of people involved in the production and distribution of electronic goods. Alvaredo et al (2017) have added to the argument that ownership matters by describing how in the 1970s and 1980s, countries like the UK saw the gradual transfer of assets from public wealth to private wealth, driving inequality further by liminting the government ability to restribute income. Others have since argued that this is being confounded by digital technologies, which have led to the phenomenon of stateless profit (Brynjolfsson and McAfee 2014). Fiscal policy and changes to company ownership are important ways tackling this problem. However we found little evidence in the policy documents of these measures being used in this way in the UK. While there was discussion of taxation and ownership of intellectual property, these discussions were very much in the context of the need to make the UK an appealing place for investment, or as a way to reward those taking the risks in investing in innovation.

Any references to ownership were exclusively focused around a 'company' structure – either a private company limited by shares, or a public limited company that can be quoted on the stock market. There were however some examples of policies to help ensure that employees were able to benefit from ownership of the companies employing them. For example the 2004 "Science and Innovation Investment Strategy" lays out the Enterprise Management Incentive share option, which rewarded employees for investing their time and skills in helping small companies achieve their potential by offering tax and National Insurance discounts on employee share options up to £100,000, with the aim of helping smaller hi-tech companies recruit and retain talented employees. The 2000 'Excellence and Opportunity' policy also mentions changes to the civil service management code that would enable scientists in the civil service to be able to own shares in spin out companies based upon their work. Both these measures are focused around small businesses and start-ups however. We found no instances of such measures being encouraged in larger companies, nor of alternative models of ownership such as cooperatives being discussed.

4.2 Fairness

4.2.1 Helping women and BAME groups enter scientific workforce to fill skills gap

Are opportunities offered for individuals from historically disadvantaged groups to rise out of poverty? While the underlying assumption of all of the policies we looked at is that everyone

benefits from investment in science and innovation, two groups in particular are singled out throughout the timeline as being of particular concern because of historic disadvantages – women and members of minority ethnic groups. Rather than being seen as important because of the need to address historic inequalities and the potential for such groups to bear the burden of the downsides of innovation more heavily, support for such groups was seen as important because of the need to offer equality of opportunity, to have a supply of skilled workers for the innovation-based economy and of utilizing resources sufficiently. Failure to help women and BAME groups join the scientific workforce meant that good workers could be lost from the system, investment in training and education wasted and skilled workers in short supply. The following quotes from policy documents at various time points illustrate these motivations well:

> "Women are the country's biggest single most undervalued and therefore under used human resource. The government believes that there is a massive scope to attract more women into science and engineering and it has set up a working party to address this important issue" (Realising Our Potential 1993, p. 57).

> "A major issue for the UK is the considerable under-representation of women in SET education and the workforce. This contributes directly to the skills shortage and, left unaddressed, would have a considerable negative economic effect on the UK" (Science and Innovation Investment Framework 2004, p. 20).

Actions proposed revolve around government support for culture changes within scientific organisations to make STEM careers more appealing to women, and to help women back into the workforce. For instance, the 2004 Science and Innovation Investment Framework says that government will invest "£2.4 million in the new resource centre for women over the next three years, to help employers make SET a more attractive career for women". While the importance of diversifying the workforce in terms of ethnicity was mentioned (for instance in 'Our Plan For Growth' 2014) we could find no specific policies setting out to address this.

Social mobility in particular was highlighted as a concern in the 2014 "Our Plan For Growth" in the context of ensuring "the brightest and the best from across the country" (p 25) can access training at a vocational and postgraduate level, and in turn to the best paid jobs:

> "These opportunities [for training] cannot be restricted to only those students who can afford to support themselves" (Our Plan For Growth 2014, p. 25).

4.2.2 Everyone's a winner

When considering the role of innovation in inequality, the way in which the benefits and downsides of technologies are distributed is important. While the possible downsides of technologies were mentioned in a number of the policy documents, the way they were distributed was not discussed. Instead downsides were framed very much as risks or matters of safety (particularly in reference to GM foods) or lost opportunities as a result of consumer rejection (with particular reference to nanoscience). Similarly, while social benefits were seen to come from technological solutions (problems such as energy supply, climate change and better healthcare are mentioned), none were

seen to benefits particular groups more than others. For instance, the introduction to the 1993 White Paper 'Realising our Potential' says:

> "The understanding and application of science are fundamental to the fortunes of modern nations. Science, technology and engineering are intimately linked with progress across the whole range of human endeavour: educational, intellectual, medical, environmental, social, economic and cultural. They provide - through tools as diverse as mathematical modelling, biotechnology and earth observation from space - a vital part of humankinds armoury for solving long-standing, world-wide problems, such as poverty and disease, and for addressing new global challenges such as those facing the environment" (Realising Our Potential 1993, p. 1).

Beyond this, as we have described earlier, the potential of science and innovation to create wealth to benefit everyone, was the overriding good that was seen to be delivered in these policy documents. We could find no account of benefits patterning in particular ways, or of concerns relating to the polarisation of wealth that others have argued comes hand in hand with (digital) technologies.

4.3 Pro-poor

4.3.1 Focus on areas where UK shows global competitiveness

Is the development of science, technology, and innovation targeted specifically to the needs of poor households and communities? Throughout the UK policy documents, we could not find any evidence to suggest that the development of research and technology has been targeted specifically to the needs of poor households and communities (i.e. finding solutions to problems that particularly affect low income groups). Instead, the policies encourage research in subject areas in which the UK is globally competitive and which promise to be the most economically successful. For example, Our Plan for Growth (2014) proposes funding focused around eight 'great technologies', which were areas in which the UK believed they had world-leading research. The usefulness or application of these technologies is not discussed beyond that.

4.3.2 Objective set by 'experts' but discussion of the potential to open this up

In terms of how the priorities of research and innovation are set, throughout the documents emphasis is placed on the importance of allowing scientists to decide what research should be funded (adherence to the Haldane Principle) or on bringing science and industry closer together so that applications are more readily available. Typically the policies refer to 'expert groups' or 'advisory groups' which have helped identify the priorities outlined, with these groups usually being made up of representatives from industry and academia.

In keeping with wider moves within science and society thinking, there does however appear to be a growing move towards citizen involvement in priority setting within the innovation policy documents. For example, while the 2000 Excellence and Opportunity paper mentioned the Medical Research Council's Consumer Liaison Group, the 2004 Science and Innovation Investment Strategy sets up a programme of public dialogue to help anticipate and address the

downsides of innovation, but also to consider how public expectations are going to be identified and considered – the implication being that citizens need to have more of a say in the priorities of science and innovation. The document also highlights the need to "widen participation [in such debates] to include people from across the diverse spectrum of social groups in the UK" (). The most recent (Our Plan for Growth 2014) document also highlights the importance of citizen involvement in agenda setting, highlighting work in Citizen Science, stating:

> "Citizen engagement in science brings with it a wider range of influences on what research questions might be tackled in the future and how. It blurs the distinction between the laboratory and the home or the street" (Our Plan for Growth 2014, p. 47)

However, in practice, only the stakeholder workshops that helped shape the 2008 Innovation Nation document appear to have taken this thinking into action and include 'consumers' in their deliberations.

Overall then, the overarching drive for innovation policy in the UK over the past ten or more years appears to be for reasons of economic growth and wealth creation, with the underlying assumption being that everyone will benefit from a growing economy. Within this however we have found instances where tackling inequality has been seen as a key role for innovation policy, particularly in the focus during the early 2000s on regional development and the need to support economic growth in parts of the UK that were arguably being left behind in the post-industrial knowledge economy, as well as in supporting diverse groups to participate in the hi-skilled workforce required by this new economy. However, such measures were largely driven by the desire to see greater economic growth and appear to have tailed off in the most recent documents.

4.4 UK sociotechnical imaginary: A rising tide lifts everyone's boat?

In order to understand the wider policy context of these individual approaches to inequality, we also wanted to understand the underlying socio-technical imaginary underpinning these innovation policies. To do that we carried out a computer assisted text analysis to help us identify four key discourses throughout the UK innovation policy documents: Innovation for growth (UK1 36%); Research Funding (UK2 17%); the role of the government (UK3 27%); and the future supply of scientists (UK4 20%). These are summarised in the table below. As we will discuss further, together, these discourses indicate that UK Science and Innovation policies are broadly framed against a free-market economic policy that sees science and innovation as drivers of growth, productivity and in turn wealth for all – a sociotechnical imaginary that we summarise as "A rising tide lifts everyone's boat".

Table 2. Summary of computer assisted text analysis of UK Innovation Policy documents

Discourse	Interpretive label	10 most significant words	Documents associated
UK1 (36%)	Innovation for growth	Innovation, market, product, company, business, idea, world, create, economy, growth	- Innovation nation (2008) - Excellence and opportunity (2000) - 2010 to 2015 government policy: research and development (2010) - Our plan for growth (2014) - Competitiveness white paper (1995)
UK2 (17%)	Research funding	Fund, research, million, pound, university, stream, charity, cost, council, year	- Investing in innovation (2002) - 2010 to 2015 government policy: research and development (2010) - Innovation nation (2008)
UK3 (27%)	Role of Government	Strategy, department, policy, framework, government, chief, rdas, office, committee	- Realising our potential (1993) - Science and innovation investment framework (2004) - Innovation nation (2008)
UK4 (20%)	Future supply of scientists and engineers	Student, teacher, school, career, employer, subject, train, graduate, engineer, mathematics	- Innovation nation (2008) - Investing in innovation (2002)

The largest of the discourses (UK1 36%) has been labelled "innovation for growth" as it lays out the role of innovation in building economic growth and a competitive economy in the UK. In particular, the discourse lays out the role of innovation in building a competitive economy in the UK. For example, the earliest report *Realising our Potential* (1993) explains that "As knowledge has increasingly become the main component in adding value to goods and services, the wealth of nations has come to depend more and more on the knowledge and skills of their people." Similarly, *Innovation Nation* (2008) states ""Harnessing innovation in Britain is key to improving the Country's future wealth creation prospects". This discourse was drawn from across the documents and timeline examined, even though the timeline covers three different political periods in the UK, chiming with other research claiming that economic growth

and competiveness is the primary motivation for recent government investments in innovation across developed nations (for instance Cozzens et al 2002; Pfotenhauer and Jasanoff 2017).

Beyond this largest discourse, the other discourses develop this initial economic framing of science and innovation further. Discourse UK2 (research funding), again drawn from across the timeline, discusses how the research needed to create these economic gains will be funded. Similarly, discourse UK3 (Role of Government) discusses the role of government in enabling this innovation driven economic growth to take place. In particular, this discourse focuses on the coordinating role that government plays in bringing local, regional and national bodies together, with Regional Development Agencies (RDAs) – the administrative structures put in place to develop innovation on a regional basis in the UK – being a key idea within the discourse. Although this coordinating role includes policies we highlighted earlier as key approaches to tackling inequality, words relating to inequality or redistribution were not significant in this discourse. Furthermore, while the previous two discourses were drawn from across the policy documents in the analysis, the documents most closely associated with this discourse were published between 2000 and 2008, under the UK's Labour Government. Strategies produced by the previous and subsequent Conservative Government do not contribute to this discourse, nor is there an equivalent discourse describing an alternative role for government but drawn from the remaining documents. This suggests a political difference in perceptions of the role of the state in innovation policy, which we will discuss in more detail later.

Finally, discourse UK4 (Future supply of scientists and engineers) discusses how the workforce for the jobs being created by science and innovation will be trained and recruited. We might expect to find any discussions of inequality of equity within this discourse and there are indeed relevant sections about women in science. However this discussion is framed very much as a workforce supply issue, or at best an equality of opportunity issue. Importantly, no words relating to inequality, fairness or equity appear in the list of words most significant to this discourse.

Overall then, the UK policy documents tell a story of UK economic growth and global competitiveness underpinned by investment in science and innovation. Other benefits are likely to accrue from this investment, but the role of the state is to secure that investment, make sure it is translated into applications and to nurture scientific talent to ensure a supply of high skilled workers to fulfil the jobs created by innovation driven growth. Inequality or fairness does not appear to be a dominant or significant discourse in UK Science and Innovation Policy and the assumption appears to be that a growing economy will benefit everyone. The following quote from the 2004 Science and Investment Framework sums up these underlying themes very well:

> "The nations that can thrive in a highly competitive global economy will be those that can compete on high technology and intellectual strength - attracting the highest-skilled people and the companies which have the potential to innovate and to turn innovation into commercial opportunity. These are the sources of the new prosperity. This is the opportunity" (Science and innovation investment framework 2004-2014, p. I).

5. South Africa

5.1 Equalizing

Do the policies seek to change socioeconomic structures in ways that reduce rather than increase income inequality? The South African policy documents seek to change socioeconomic structures in several different ways, which are markedly different to the UK efforts. For example the policy documents repeatedly state the objective for innovation to contribute to the overall government strategy to reduce unemployment amongst historically disadvantaged groups. The 1996 white papers aims to create "employment on a large scale" (p. 38) and the 2008 ten-year plan aims to contribute to government ambitions for halving poverty and unemployment by 2014" (p. 2).

These measures are not coupled to more specific policies, however, in contrast to the regional development efforts we saw in the UK. Instead it is seemingly assumed that innovation will automatically result in the creation of jobs amongst all layers of society. The 2002 R&D strategy simply states that "innovation is the key process by which (…) businesses generate jobs and wealth" (p. 5), only then to consider no further measures through which these jobs can be distributed. It was surprising to find no accompanying targeted support that was equivalent to the UK's regional innovation focus, especially considering the recent concerns over the potential of innovation in automation to replace jobs (Cozzens et al. 2002; Autor 2015).

What is more, while UK innovation policies only briefly touched upon ownership structures, the South African policies leave this entirely unaddressed. For example when it comes to intellectual property rights, the 1996 white paper takes the approach to "align our intellectual property regulations with international norms, rather than opt for a regional or purely national system" (p. 42). The historical legacy of Apartheid that sees ownership over intellectual property concentrated in the hands of a few is hence not taken into account as meriting special attention.

And when it comes to tax incentives, South Africa also abstains from taking any measures. The South African documents gives a nod to the practice in most Western countries of using tax incentives to support innovation in private companies, concluding that these measures would be too difficult to administer by tax officials lacking sufficient expertise. This highlights a double-bind that low income but high-inequality countries face – that the infrastructure necessary to make the state interventions to ensure less inequality through innovation may simply not be in place.

The South African documents do seek to change socioeconomic structures in other ways, however, and substantially so. The two main ways through which socioeconomic structures are targeted are through the distribution of funding and the creation of a national system of innovation.

5.1.1 Funding distribution

The distribution of funding was explicitly couched in terms of undoing historical inequality. Resources need to be distributed, so the policy documents highlight, in ways that adequately reflect government priorities "rather than being the product of 'historical incrementalism'" (DACST 1996, p. 55). This included both objectives to provide funding for historically disadvantaged institutes (HDIs) and to funnel funds towards innovative fields that offer solutions specifically

targeted towards the poor, such as the development of solar cells and medication for diseases that are particularly prone amongst the poor.

This was addressed in several ways. Firstly, rather than providing funding to universities and institutes in lump sum, the government created a new structure of competitive funding in specific thematic areas such as biotechnology and nanotechnology. Whereas the specific priorities changed over time, the structure of funding research and innovation through thematic and competitive calls remained more or less the same, thereby offering more government control over the allocation of resources on the basis of particular government priorities. Tackling economic inequality was an important motivation for these structural changes. The 1996 white paper makes this most explicit, noting that at least 50% of the funding allocated through the newly created innovation fund "will be allocated to projects directly dealing with the needs of disadvantaged populations" (p. 44). For example in the field of nanotechnology, measures were taken to ensure that not only projects were funded that benefit mining and petroleum corporations but also projects on water filters and tuberculosis medication (Beumer 2015; Harsch et al. 2018).

Secondly, funds for scientific equipment were distributed in ways that considered historical inequalities. Several scientific fields required costly items of research equipment that could only be funded at the national level. In making decisions about funding such equipment, the government explicitly instructed the funding agencies to take into account "access by all researchers in the region, particularly those from HDIs" (DACST 1996, p. 83). Also attempts were made to make funding allocation more inclusive. Whereas basic research applications would be peer reviewed by researchers of international statues where possible, the policy notes that "peers for applied activities will include representative users of the potential outputs" (DACST 1996, p. 46).

5.1.2 National system of innovation

Another major change in the socio-economic structures for science and innovation was the introduction of the concept of a national system of innovation (NSI) (Lundvall 1992; Freeman 1995). This concept, championed by the OECD in a review of the South African innovation system (OECD 2007), highlights that innovation is not merely the product of individual organizations but requires strong connections between different actors involved in innovation. The concept first entered South Africa in the 1996 white paper and became the central concept guiding the governance of science and innovation.

Although in OECD countries the national system of innovation concept is not usually associated with economic inequality, in South Africa it is explicitly put forward as a way to address economic inequality. First, in South Africa the success of a system of innovation is not measured only in terms of the number of publications, patents, and collaborations, as is conventional in many OECD countries. Instead, the South African policy documents note that:

> "A national system of innovation can only be judged as healthy if the knowledge, technologies, products and processes produced by the national system of science, engineering and technology have been converted into increased wealth, by industry and

business, and into an improved quality of life for all members of society" (DACST 1996, p. 19).

Second, the emphasis on collaboration and linkages between different actors had rather specific implications for South Africa, whose institutes were still largely stratified along racial lines by the time the first policy document was published. During the Apartheid era, black and coloured people were not allowed access to most research and innovation institutes and were designated towards so-called historically disadvantaged institutes that only received scant resources and were barred from doing research (Cherry 2010). In this context, the NSI concept provided a theoretical basis for bringing advantaged and disadvantaged institutions closer together, affording "an opportunity to think of means for the promotion of coherence and integration among national activities, two factors which have been sorely neglected in the South African S&T system of the past" (p. 20). The policy documents subsequently propose numerous measures to strengthen the connection between historically disadvantages institutes and historically advantaged institutes.

5.2 Fairness

5.2.1 Equity through redress

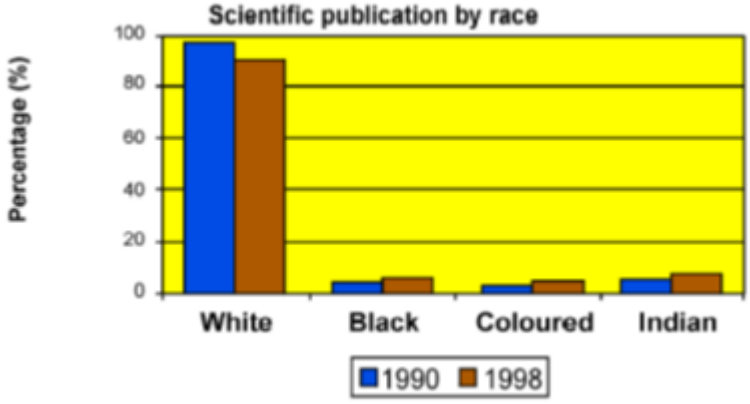
Are opportunities offered for individuals from historically disadvantaged groups to rise out of poverty? As was just mentioned, a direct legacy from the Apartheid era was that universities and research institutes were almost exclusively white, and predominantly male (Cherry 2010). The policy documents explicitly mention this: "Women and people from previously disadvantaged communities have not benefited sufficiently in terms of access to, and participation in, science, engineering and technology in South Africa as yet" (GRSA 2002, p. 7). It is hence not surprising that fairness is a prominent theme throughout the South African policy documents. Whereas in the UK the main emphasis was on gender, in South Africa the emphasis was on both gender and race. The 1996 white paper leaves no room for doubt when stating that the disparities in race and gender in science and technology were 'unacceptably high' and that "we need to address this imbalance pro-actively" (p. 5). Twelve years later the ten-year plan asserts with similar certitude "the crucial need to expand the numbers of black and women scientists, engineers and technology experts" (p. 5).

The policy documents set out a policy of equity by redress. The documents refer to fairness principles in support of affirmative action, noting that redress is required simply "because it is right to do so" (DACST 1996, p. 5). But also more instrumental arguments were put forward, much like in the UK, pointing to the importance of including the entire population to optimize South African productivity and economic performance. If the new South Africa is to succeed in the global marketplace that it was now exposed to, so it is noted, "South Africa will have to maximise the utilisation of ideas, creativity, ingenuity and innovation from the entire population" (DACST 1996, p. 72). This justification for redress moves beyond arguments of historical injustice and instead is rooted in "the belief that sustainable human development will occur faster where equity exists" (DACST 1996, p. 72).

The approach to achieving redress within the innovation system changed over time. The 1996 white paper predominantly sought to transform historically disadvantaged institutes into institutes also performing research and to promote access to education. Also lifelong learning was promoted, as this could enable older generations of previously excluded groups to be included in the innovation system. "Aggressive promotion of the principle of lifelong learning gives South Africa the best chance, in the long term, of redressing SET-related skills, where the imbalances were most pronounced" (DACST 1996, p. 72).

The later policy documents, however, took rather different measures. By 2002 it was clear that despite measures taken in 1996, "black and women scientists, technologists and engineers are not entering the academic ranks" (GRSA 2002, p. 21). The share of scientific publications authored by black scientists merely rose from 3,5% in 1990 to only 8% in 1998, while the percentage of publications produced by women did not improve at all (GRSA 2002). The national system of innovation suffered from a 'frozen demographics': "an overwhelmingly white, male and aging scientific population is not being replaced by younger groupings more representative of our demographics" (p. 21).

Figure 1. Figure from the 2002 National Research and Development strategy captioned "limited progress with the representativity of the research and development community" (p. 53).



The 2002 R&D strategy therefore instigated additional measures to offer opportunities to historically disadvantaged individuals. These measures particularly focused on scientific careers, for example through interventions in the school system and by putting extra effort in making science attractive through the media. The step to redirect funding towards particular 'missions', introduced in the 2002 strategy, was also presented as a measure to achieve equity. By focusing on areas where South Africa could achieve international excellence, attractive career paths that would draw in individuals from historically disadvantaged groups could be created. Attracting young people to careers in science and technology, so the 2002 R&D strategy notes, "will depend on our adoption of new technology missions that are designed for a democratic, inclusive South Africa" (p. 56). Whereas in 1996 the presupposition was that improving access would result in

redress, in 2002 the government presumed that creating attractive career prospects would warm up the frozen demographics.

5.3 Pro-poor

5.3.1 Two-pronged approach to societal need

Is the development of science, technology, and innovation targeted specifically to the needs of poor households and communities? Key to the South African policies is the idea that the innovation system needs to be responsive to societal needs in the new South Africa. This also included efforts to provide specific support to the development of technologies and innovations that would particularly benefit historically disadvantaged groups. In practice, this meant the system had to move away from the priorities of the former minority regime. Whereas science and innovation policies during the Apartheid era were focused on objectives like energy self-sufficiency, defense, and national food security – objectives that were key to maintain the Apartheid regime in the face of international isolation – these objectives were now deemed "inappropriate in the context of the new democracy" (GRSA 2002, p. 35).

The major challenge in addressing societal needs in the rainbow nation was "to integrate successfully into global systems and communities while addressing the local needs and aspirations of South Africans" (DACST 1996, p. 9). The policy documents resolve this tension by articulating two different types of needs that the innovation system would have to become responsive to: global competitiveness and pro-poor innovations. This two-pronged approach runs throughout the policy documents, from the minute details of policy measures to the broad vision statements. The foreword of the first post-Apartheid policy document began by stating that:

> "This vision is one where, on the one hand, South Africa uses S&T to become economically competitive on a global scale, and on the other hand to provide essential services, infrastructure and effective health care for all South Africans" (p. 4).

Similarly, the 2002 R&D strategy notes that "good systems of innovation have two significant high-level goals, namely: quality of life; growth and wealth creation" (p. 25). And the 2008 ten-year plan highlights that "scientific and technological innovation are crucial to developing a more competitive foothold in the global economy, and to addressing pressing developmental needs" (p. 22).

The policy documents frame both global competitiveness and pro-poor innovation in relation to economic inequality. The focus on global competitiveness was for instance justified by highlighting the importance of industries and services for creating jobs and opportunities for historically disadvantaged groups, as was mentioned before. Yet it is the other part of the two-pronged approach that is specifically pro-poor: the government explicitly aspired to "addressing the urgent needs of those of our citizens who are less able to assert themselves in the market" (DACST 1996, p. 12). This focus on pro-poor innovations was informed by the idea that science and innovation can provide innovative solutions that can directly help to redress inequities of the past. For disadvantaged communities to climb the economic ladder, they "should have access to

innovations that accelerate development and provide new and more effective solutions than those utilised previously. (…) New innovations are not readily used to address poverty" (GRSA 2002, p. 42).

The emphasis on pro-poor innovation was perhaps most prominent in the choice of strategic priorities. Whereas these priorities shifted over time, a key criteria in selecting priorities was that they had the potential to both help South Africa gain global competitiveness *and* to address the needs of poor households and communities. For instance the 2002 R&D strategy decided to focus efforts on several thematic missions, like ICT, biotechnology, and advanced manufacturing, which were chosen based on their potential to benefit both competitiveness and the needs of the poor. For instance investing in ICT innovations could help to kick-start a new sector while also producing innovative solutions to the provision of electricity to the townships, and innovative developments in biotechnology could both be used to develop agricultural crops that would benefit smallholder farmers while simultaneously offering a promising business model for local enterprises. In each of these cases, the strategic choice was informed by the potential for pro-poor applications.

The mission-specific policies that were drafted, like the 2001 biotechnology strategy and the 2006 nanotechnology strategy, subsequently specified policies to ensure these technologies were steered towards both industrial benefits and poverty-related applications (Beumer 2015; Beumer 2016). Policies to make the two-pronged approach operational further included measures to designate a significant part of funding for projects that were specifically targeted towards the poor, as was mentioned before. And also the performance assessment of science and innovation institutions was set to include criteria broader than those used in the United Kingdom. Besides the scientific quality of the scientific output, also the "contribution of the output (…) to the realisation of national goals" (DACST 1996, p. 58) was part of institutional assessments, even if this remains challenging in practice (Saidi and Douglas 2017).

5.4 South African socio-technical imaginary

What is the role of the policy measures within the overall socio-technical imaginary on innovation in South Africa? The computer assisted text analysis of the South African innovation policy documents identified five distinct discourses: innovation for industry and security (SA1 20%); innovation for a fairer South Africa (SA2 18%); building a knowledge economy (SA3 18%); innovation governance (SA4 24%); and document architecture (SA5 20%). Besides highlighting the challenges of a new regime in setting up a new system of governance, these discourses reflect the two-pronged approach whereby innovation is harnessed both for competitiveness in a global market place and for undoing historical inequalities by providing benefits to the poor – a sociotechnical imaginary we summarize as "innovation for equality and redress in a globalizing world".

Table 3. Summary analysis of South African Innovation Policy documents

Discourse	Interpretive label	10 most significant words	Documents associated
SA1 (24%)	Innovation governance	Department, budget, line, DACST, fund, council, institution, minister, dti, government	- White paper on science and technology (1996)
SA2 (20%)	Governance principles	Paper, white, policy, green, implementation, national, section, function, system, facility	- White paper on science and technology (1996)
SA3 (20%)	Innovation for industry and security	Manufacture, biotechnology, ICT, industry, military, off, local, platform, reduce, security	- South African national R&D strategy (2002)
SA4 (18%)	Innovation for a fairer South Africa	Society, social, life, quality, economic, change, redress, innovative, demand, Africans	
SA5 (18%)	Capacity building	Capital, plan, grand, ten, knowledge, challenge, economy, generation, human, transformation	- South Africa 10 year plan (2008)

The two largest discourses (SA1 24% and SA2 20%) focus on creating institutional structures for governing innovation. For example discourse SA1 (innovation governance) refers to various institutions and their relations to other government agencies, like the department of trade and industry (dti). Discourse SA2 (governance principles) – similarly refers to various measures to reform the institutional landscape and redirect it towards the newly defined national needs. The concept of the national system of innovation was put forward in the 1996 white paper as the core principle around which innovation policies should revolve. This in turn required white papers, green papers, and policies to be drafted to implement this concept and optimize the various functions of the innovation system. A third discourse (SA5 capacity building) further specifies the various transformations required to make knowledge work for South Africa.

These discourses reflect the efforts of the post-Apartheid regime to gain control over the innovation system and it is no coincidence that these discourses were mostly drawn from the 1996 white paper on science and technology: this was the first policy document after the end of Apartheid and hence laid the foundations for a new innovation policy, along with a new institutional structure and decision-making processes.

The two other discourses reflect the two-pronged approach discussed in the previous section, aiming to direct innovation both towards competitiveness in a global world on the one hand, and towards equality and redress on the other hand. SA3 (innovation for industry and security) reflects the support to innovation in specific industrial sectors. This was deemed important considering the sudden exposure of South African markets to increased foreign competition after the isolation during the Apartheid era was ended (Carmody 2002). Although we earlier saw that global competitiveness was partly justified by highlighting the importance of competitive industries for job creation, words related to inequality or redistribution were not significant in this discourse.

SA4 (innovation for a fairer South Africa), finally, directly addresses issues of economic inequality. This discourse refers to the need to redirect the South African science and innovation policies towards the needs of previously excluded communities, particularly along racial and gendered lines. Innovation is hence not perceived to contribute to a more equitable society merely by generated economic growth, however, as we saw in the UK. The historic legacy of Apartheid clearly plays a strong role here. It is widely acknowledged that Apartheid innovation policies contributed to sustaining racial segregation by focusing on fields that benefited the white minority rule, like military security and energy self-sufficiency (Mouton 2003; Sooryamoorthy 2010; Dubow 2006; Edwards and Hecht 2010). The South African science and innovation policies explicitly acknowledge this, noting that "the system was built for 5–8 million people and now has to grow and develop to serve all South Africans" (GRSA 2002, p. 73). The various policy documents therefore include numerous measures for making the South African innovation system more responsive to the needs of economically and socially disadvantaged groups. This discourse captures this, highlighting different ways in which the policy documents aim to contribute to redress by promoting innovations that are produced by a more diverse workforce, and that would explicitly address the demands of historically disadvantaged groups.

Overall, addressing issues of economic inequality is one of the main justifications for pursuing science and innovation in the South African policy documents. This is illustrated by the finding in the table 2 above, that the discourse relating to inequality (SA4) was not associated with any particular policy documents, but found throughout all of the South African documents. When the 1996 white paper describes the aim of drafting a science and innovation policy, it notes that "South Africa has begun, for the first time in its history, to undertake the task of the equitable development of the life opportunities of all its citizens" (DACST 1996, p. 6). The science and innovation policies subsequently put forward a view in which also science and innovation could potentially contribute to this new, more equitable South Africa.

Overall then, the South African policy documents are explicitly devoted to turn the innovation system around, and make it responsive to the needs of economically and socially disadvantaged groups. Even the efforts of the post-Apartheid government to create new institutional structures that increase government control can hence be seen in the light of this effort to undo inequality. Yet nowhere is this more clear than in the usage of the phrase 'all' South Africans that runs throughout the policy documents (Beumer 2017; Beumer 2016). The very first sentence of the 1996 white paper already notes that the policy is "based on a view of the future where *all South Africans* will enjoy an improved and sustainable quality of life" (DACST 1996, p. 73 [italics ours]) and the 2008 ten-year plan similarly notes that the policy document is aimed to create "a prosperous South Africa, one in which *all citizens* benefit from the fruits of our investment in knowledge and its exploitation" (DST 2008, p. v). The recurrent emphasis on 'all' South Africans signaled the departure from an exclusionary innovation system that perpetuated economic inequalities, to an innovation system that could contribute to a more equal South Africa.

6. Conclusions and discussion

In this paper we aimed to contribute to the growing body of literature looking at the role of science, technology, and innovation in growing economic inequality by asking how innovation policies currently address the potential for growing economic inequality in two countires with contrasting contexts and approaches to innovation and inequality – the UK and South Africa. Specifically, by identifying the sociotechnical imaginaries underlying and driving innovation policy, we have set out to understand such measures in the light of the overall direction of those policies. To do so, we further developed the equalising-fairness-pro-poor framework to assess whether and how innovation policies take into account economic inequalities, which we have tested by applying it to the innovation policies of the United Kingdom and South Africa.

Our analysis has shown, first, that the distributional consequences of innovation do receive attention in innovation policies in both the United Kingdom and South Africa, albeit in different ways, and to different degrees. We argue that these differences can be explained by the sociotechnical imaginaries underpinning wider innovation policies in these countries.

In the UK, we found an imaginary of "A rising tide lifts everyone's boat" which takes the view that the economic growth that comes from innovation policy will eventually benefit everyone. As a consequence, the measures we found for addressing the distributional consequences related firstly to regional development, which can be understood as an equalising approach but which aimed to make all areas of the UK economically active and therefore maximizing the potential 'rise' in tide; and secondly to equality of opportunity, which could be seen as a fairness approach, but was again framed within the 'rising tide lifts everyone's boat' imaginary, as a productivity and workforce availablity matter.

In South Africa, in contrast, we found a socio-technical imaginary of "innovation for equality and redress in a global world" that takes the view that the South African system of

innovation has to become more responsive to the needs of economically and socially disadvantaged groups. As a consequences, South African policies for science, technology, and innovation had a very strong focus on addressing economic inequality. We found measures under each of the categories of our framework – equalising-fairness-pro-poor – all taking rather different directions than UK's. Under equalising measures, for example, we did not find efforts at regional development, but instead found a strong focus on creating a national system of innovation in order to increase government control, to include previously disadvantaged parts of the system. Under fairness a wide variety of measures were taken to promote the inclusion of disadvantaged populations, while perhaps most measures were found under the pro-poor approach to inequality. Not only were strategic choices for technological fields informed by the need to deliver innovations beneficial to the poor, also significant parts of the budget specifically reserved for innovations that specifically target the poor.

The equalising-fairness-pro-poor framework of Cozzens, further developed in this paper, also proved to be key in enabling us to identify distribution sensitive measures, even when the policies were not framed as such, for instance the UK's regional development policies discussed earlier. Furthermore, the framework can be used to elicit specific concepts of inequality at play, particularly through comparing measures taken in one country with those in others and those known from the literature. For example, the framework helps to understand that the UK favours equalisation and fairness measures for addressing inequality while neglecting pro-poor measures to developing technology for poorer groups. This raises questions on the rationale for this (possibly implicit) choice. Conversely, while South Africa's policy documents included measures related to all three inequality approaches, the comparison with the United Kingdom revealed notable omissions in terms of equalisation measures, particularly in relation to job creation and regional development. By situating these individual policy measures in a comprehensive framework, and thereby visualizing what approaches and measures are – and are not – taken, the framework opens up space for discussion about the way innovation policies address economic inequality.

Furthermore, the framework helped us find that policies in both countries tended to focus on the privately owned firm as the only model of ownership, with little incentive in place to encourage alternative models and moves to share assets (with workers, states or communities). This is coupled with little activity around fiscal policy and taxation regimes focusing upon incentivising investment in innovation rather than rewarding workers or redistributing benefits – themes that have become prominent in both STS and innovation studies literature as means to address innovation-related economic inequality (Birch 2019; Lazonick and Mazzucato 2013).

It is important to note that we have not considered the impact of these policies. For example, do regional development policies in the United Kingdom create jobs for unemployed residents of those areas or attract high skilled workers to low income areas? Do the technologies and innovation supported by pro-poor policies in South Africa actually reach poor communities? How successful have fairness policies in both countries been in attracting minorities to careers in science, technology, and innovation? And do pro-poor policies also encourage redistribution of wealth? These are, in our views, important areas to consider in further research, particulary if we

wish to make recommendations about the appropiate balance of different policy approaches for tackling inequality.

Using both the framework to identify distribution-sensistive innovation measures, along with the concept of sociotechnical imaginaries to help us understand the wider innovation policy context within which these measures sit, we have gained insight into whether or not the role of innovation in driving inequality is being addressed in innovation policy and what measures might be being neglected, but also why this might be the case – why innovation and distribution sensitive policies take the form they do. Significantly, we argue that the framework could provide valuable inspiration and guidance for policymakers wanting to address the distributional consequence of innovation – helping them understand and pinpoint more precisely the types of measures that are or could be in place. However, equally valuable will be measures to engage with the underlying imaginary of innovation – helping policymakers understand that without deliberate action, innovation has the potential to reinforce existing inequalities further. This represents an important resource in dealing with one of the most important challenges of our time – to combine the benefits of science, technology, and innovation while curtailing excessive economic inequalities that may follow from this.

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Appendix 1

Framework

1. Equalizing: Does the policy seek to change socioeconomic structures in ways that reduce rather than increase income inequality? (Cozzens 2010)
    - Does the policy prioritise reducing unemployment (rather than simply creating jobs)?
    - Does the policy prioritise creating jobs for less advantaged communities?
    - Does the policy produce mid wage jobs?
    - Does the policy consider whether the skills are in place to produce the technologies invented?
    - Are possible contractions of old industries as a result of innovation considered?
    - Do conditions for foreign investment include local employment requirements
    - What economic models are evoked? Are they mentioned explicitly or simply implied?
    - What models of ownership are conceived in the policy? Are the any measures to share assets?
    - How is IP dealt with? Any ideas relating to open source or 'copy left'?
    - Is the policy describing/connected to any other redistributive measure, such as fiscal policy?
    - Does the policy conceive of an active or passive role for government?

2. Fairness: What opportunities does it offer for individuals from historically disadvantaged groups to rise out of poverty? (Cozzens 2010)
    - Who does the policy see as the main beneficiaries of science and innovation?
    - Is anyone acknowledged as possibly losing from innovation?
    - Are the downsides of innovation acknowledged? If so, how? How are they described? How does this policy indicate the downsides should be dealt with?
    - Are measures put forward to share the risks and downsides of technological innovation equally?
    - Is inequality/equality/fairness mentioned in the policy? If so, how is it conceived? Are any measures proposed to address any imbalance?
    - Does the policy set out to reduce inequalities between culturally defined categories such as gender and racial groups?

3. Pro-poor: Targeting research and technology development specifically to the needs of poor households and communities. (cozzens 2010)
    - What is the purpose of funding science and innovation?
    - How are the benefits of science and innovation conceived? Are they named or mentioned explicitly?

- How have the objectives/understanding of benefits been developed? Were citizens involved in any way?
- Who are seen as the beneficiaries of the products of science and innovation?
- Is there any discussion of improving living standards/health in disadvantaged communities/creating conditions for education and employment to take hold?