A Framework for Analyzing Science, Technology and Inequalities: Preliminary Observations

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The goals of the ResIST project are to understand the contribution of science & technology to the creation and maintenance of inequality within and between societies; and to develop more inclusive S&T policies that balance growth with reduced inequality and improved accountability to the poor. Inequality is the unequal distribution of something people value, such as income, health, or power. In its dynamic meaning, the word distribution refers to the process of producing and re-producing inequalities. ResIST is concerned with the roles that science and technology play in those processes and how policy can intervene to generate less unequal outcomes.

To understand the dynamics of inequality, ResIST is organized around three types of inequalities: structural, representational, and distributional. These can be briefly characterized as inequalities in individual and institutional capacities, in representation and accountability, and in sharing benefits and costs.

This paper describes the concepts and how they work together, illustrating them with examples drawn from ResIST's first year of work. In 2006-07, the ResIST team consulted with policy audiences in three world regions, heard from them about their local issues and examples,[1] and started work on case studies under three work packages.[2] This framework paper uses the concepts of structural, representational, and distributional inequalities to link the continuing research in the work packages to what we heard from policy audiences about the distributional issues of relevance to them.

Our basic points are these:

1. The three types of inequality (Section I) form conditions for each other. High levels of inequality in one contribute to high levels in another; and conversely, decreasing inequality in one can help to decrease inequality in the others.
2. Attempts to reduce the three inequalities appear in the national science policies of many countries (Section II). While the profile varies across countries, each country has room for significant steps forward in all three areas, and thus for benefits in social cohesion.
3. Applications of the concepts in illustrative stakeholder case studies (Section III) reveal complex tradeoffs and no easy solutions. Yet the analysis of our cases should result in valuable suggestions and proposals for improved policies that reflect greater sensitivity to trade-offs and potential pitfalls.

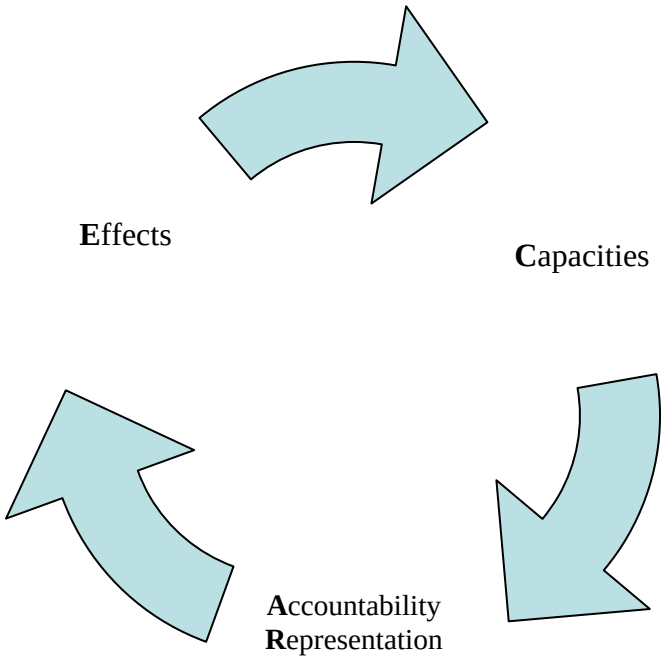
I. THREE INEQUALITIES

We see the three types of inequalities as three moments in a cycle of change. Structural inequalities, that is, the unequal distribution of capacities, are a starting

[1] These meetings took place in Maputo, Mozambique (November, 2006); Rio de Janeiro, Brazil (January, 2007); and Istanbul, Turkey (March, 2007). This paper will refer to the meetings by the name of the city that hosted them. The presentations from the meetings are available on the ResIST web site: http://www.resist-research.net/home.aspx.

[2] Work Package Two, "Policy Tensions in Relation to the Pursuit of Equality: Promoting Scientific Mobility and Balanced Growth," leaders: Louise Ackers (Leeds) and Johann Mouton (Stellenbosch); Work Package Three, "Articulating New Accountability Systems," leaders: João Nunes (CES) and Steve Woolgar (Oxford); Work Package Four, "Distributional Assessment of Emerging Technologies," leaders Susan Cozzens (Georgia Tech) and Mark Knell (NIFU-STEP).

condition for processes of distribution. Representational inequalities in politics and socio-economic and cultural activities contribute to inequalities in levels and forms of accountability – that is, to making visible whose interests are embodied in proposed solutions. Structural and representational factors combine to produce inequalities in effects, that is, in the distribution of benefits and costs for various individuals and households. Together, they form a cycle of CARE, a wheel that can spin for the better or the worse.[3] Inequalities in capacity contribute to inequalities in representation, which in turn perpetuate inequalities in the distribution of benefits and costs. Conversely, greater equality in capacity across groups and communities can contribute to more accountability in decision processes that lead to real improvements in basic needs for a broader range of communities.



Distributional Inequalities (Effects)[4]

We begin this discussion with inequalities in effects because reducing these is the objective of the overall effort, a goal shared between ResIST researchers and the project's stakeholders. We use the word effects in a human-centred and inclusive way, to refer to benefits and costs in everyday life for everyone, from the full population of a country to the full population of the world.

[3] An earlier version of this framework was called CAPE, for capacity, alignment, participation, and effects. It was originally developed by Susan Cozzens, Johann Mouton, and Peter Healey. This simple version of the framework will continue to be developed through the ResIST project.
[4] ResIST Description of Work, p. 6-7, 12, 38-40

The phrase inequality in effects is one way of referring to problems that some people live with and others do not. Our stakeholders provided us with many examples of inequalities in this sense that they wanted to reduce, including health and nutritional inequalities like malaria incidence and blindness from Vitamin A deficiency, environmental inequalities like living in proximity to industrial pollution or without provision for sewers; information inequalities like lack of access to the Internet; and the general pattern of deprivation called poverty. We explore some examples in Section Three.

In science and technology (S&T) policy, a standard approach to challenges like these is to try to solve the problem technologically. The attempt to develop a malaria vaccine, reviewed by stakeholders in Maputo and explored in Work Package Three, is an example. But the technological approach addresses only one of the forms of inequality (effects narrowly conceived), and leaves inequalities in capacity, accountability, and participation in place. Technological solutions are less likely to be sustainable under these circumstances, and the solutions miss the opportunity for broader structural benefits. Work Package Four is taking a broader view of the ways new technologies are embedded in different national contexts and thus explicating relationships between a variety of policies and the broad-based distributional effects of new technologies.

At the same time, S&T policy typically relegates the problem of unequal distribution of costs of such projects to other policy areas, such as regulatory policy. But the outcomes of those processes rest in turn on the capacities of the actors involved and how accountabilty is organized – again reflecting conditions in other phases in the cycle of change. In addition to exploring the benefits of vaccines, Work Package Three explores specific examples of costs in textile life cycles and electronic waste.

In short, our stakeholders want to solve problems, and ResIST aims to provide a deep enough analysis of the processes of problem-solving to help them achieve sustainable and equitable solutions in ways that are inclusive and accountable.

Structural Inequalities (Capacities)[5]

Many concepts that are used to think about science and technology incorporate terms from economics. Thus, the enterprise is seen to involve several types of capital (including physical, intellectual, human, and social) and several types of flows (including funds, knowledge, research materials, and people). The concept of structural inequalities in ResIST refers to unequal capital assets, and our analysis focuses on the processes (flows) that build up or diminish those assets.

Our particular focus is on human capital and more specifically on scientists and engineers. Several dimensions of inequality characterize the distribution of human capital. National-level data on number of scientists and engineers, either in absolute or per capita terms, show great inequalities between countries and groups of countries.[6] Within countries, scientists and engineers and the institutions they work in tend to be

[5] ResIST Description of Work, p. 6, 17, 31-33

[6] See Technology Achievement Index, http://hdr.undp.org/reports/global/2001/en/pdf/techindex.pdf, accessed April 22, 2007.

concentrated in capital cities or a few other urban areas, thus often creating urban/rural differences in capacity.

These differences between geographic regions grow on a substrate of other kinds of inequalities within geographic areas, in particular the interactions of socioeconomic, ethnic, gender, and educational inequalities. Human capital theory predicts the relationship. The process of building science and engineering human capital (that is, providing advanced education in these areas) builds on more general forms of human capital investment (that is, primary and secondary education). Thus groups that are disadvantaged at the lower levels will probably be at least if not more disadvantaged at higher levels, through a process of cumulative (dis)advantage. For example, children from families carrying the health burdens of polluted environments are less likely to do well at school, and thus less likely to move forward into higher education or science and engineering careers.

The process of geographic cumulative advantage also characterizes the flows of people in the system. Places with fewer resources provide less attractive environments for scientists and engineers than those with more resources. So there is generally a flow from rural to urban within countries, and from less affluent to more affluent countries.

This situation sets up a tension that ResIST is exploring. National governments invest heavily in human capital by subsidizing education at all levels, including fellowship programs for scientists and engineers to be trained abroad. But once the investment is made, an individual embodies it and can in principle carry it elsewhere. What is the proper balance between the state's interest in investing in human capital for development at home and the individual's freedom to go where the market and conditions are best for him or her? How can governments in the economically and technologically advanced regions of the world balance the import of highly skilled labour from low income countries with the responsibility to help developing knowledge infrastructures in poor and less developed regions? ResIST Work Package Two is exploring these issues, and they came up in our stakeholder consultations as well.

More and more countries are addressing the loss of scientists and engineers through migration with increased efforts to recruit into science and engineering careers domestically. These efforts are often specifically targeted to groups within the country that are currently under-represented in science and engineering careers, usually women and historically disadvantaged ethnic or religious groups. Thus one cycle of cumulative advantage and disadvantage intersects with the other. Work Package Two is exploring the gender dimension of these issues, and stakeholders also raised the ethnic dimensions.

Representational Inequalities[7]

There are a variety of processes that translate knowledge capacities into effects. S&T-intensive policy areas are characterized by dependence on technical expertise, which is often given deference over other forms of knowledge. This unequal dynamic then contributes to other processes for example, setting the research agenda and taking regulatory action. Knowledge and technologies themselves then come to embody unequal relations. For benefits to be distributed widely and costs to be shared equally, S&T-

[7] ResIST Description of Work 6, 11, 12, 13, 34-37

intensive decision making processes must be broadly and effectively participatory and create real accountability to all groups in society. Work Package Three is explicitly developing these issues, and we have already had glimpses of the practical side of these dynamics from our interactions with stakeholders.

Drawing on our roots in science and technology studies,[8] ResIST respects many forms of knowledge in our analysis, from professional expertise through situated traditional knowledge. The S&T policy literature tends to view traditional situated knowledge as a source of intellectual capital, as our stakeholders at the CSIR in South Africa illustrated in their presentation on a new product and local industry developed from indigenous knowledge.[9] But such situated knowledge is often also the key to solving particular problems in particular places and thus plays a more general role in achieving re-distributional effects. Expert and situated knowledge play different roles in accountability and participation processes, and ResIST researchers are remaining alert to these differences in our work on representational inequalities.

Accountability

Accountability is a pervasive feature of everyday life and social interaction. Institutionalized forms of accountability as we find them in politics, the economy, science, the legal field and in civic society are rooted in and build upon mundane everyday processes in which people hold themselves and others accountable for what we do and how we do it. At the institutional level accountability systems "provide for the explicit stating and framing of distributional issues related to the design, development, and social appropriation of scientific and technological resources," as an interim report from Work Package Three explains (Neyland, Nunes et al. 2007). Yet, as these authors point out, accountability systems normally make some things and processes visible but other aspects invisible. The introduction of supposedly better forms of accountability like 'performance indicators' may also produce 'perverse' effects in which the lofty goals to be achieved are replaced by a focus on producing the right statistics.

Accountability systems attuned to the needs of the disadvantaged are a prerequisite for reorienting scientific governance towards greater social inclusion in building S&T priorities and in distributing its products. They are the means by which the potential distributional consequences of science and policy and practices can be recognised and assessed – and potentially incorporated – by formal elements of the political system. As global interdependencies become stronger and local and national forms of government or 'governance' become intertwined with trans-national governance, systems of accountability also change. Locally situated forms of accountability become linked to trans-national accountability systems and associated issues and this leads to the

[8] Science and technology studies emerged as a distinct field of academic and policy research in the 1970s. It combines deep philosophical and sociological analyses of the role of various forms of knowledge and technology in social life with policy oriented studies on how to harness various forms of knowledge and specifically science and modern technology to enhance economic performance, innovation and sustainable and inclusive social change. For an overview see
Jasanoff, S., T. Pinch, et al. (1995). Handbook of Science and Technology Studies. Thousand Oaks, CA, Sage.

[9] Vinesh Maharaj, "Bioprospecting Research: A Case Study," http://www.resist-research.net/cms/site/docs/Vinesh_Maharaj.pdf, accessed April 14, 2007.

mingling of various forms of accountability. The boundary between alternative accountability systems and those of conventional policy and practice is therefore an important site for the analysis of scientific governance, and one in which any reconfiguring of interests will take place (Neyland, Nunes et al. 2007).

It would be naïve to assume that existing and newly proposed forms of accountability in S&T policy are unambiguously geared towards the needs of the poor and towards addressing the various forms of inequality. Accountability systems embody a whole range of normative assumptions about the purposes and uses of S&T, and to explore such systems and how one may improve them and integrate them into more inclusive forms of representation is a key goal of the ResIST project.

A number of commentators have pointed out that economic liberalisation has made issues of accountability particularly problematic at the global level. Socially inclusive interests and values which may inform a developed nation's internal distributive policies, or its approach to development aid, may not be reflected in the position that country takes in multilateral trade negotiations (Stiglitz 2006). In translating the national policy from a national to an international context, a process of what Work Package Three (Neyland, Nunes et al. 2007) calls 'accountability drift' can take place: a narrowing of the issues and interests represented as a national position is distilled. Work Package One has emphasized the raw power politics of the contemporary global knowledge economy, along with the extent of asymmetry of both power and representation as these conflicting definitions of national interest are played out. Under such a regime developing effective STI policies may involve not just playing by the rules of a established game but challenging and attempting to rewrite them as an essential part of the competitive game (Cozzens, Kallerud et al. 2007).

A number of case studies in Work Package Three explore both traditional and alternative accountability systems, particularly in the context of global transport and trade and of priority-setting processes. In the area of textiles, traditional systems include trade protection by national governments and the donation systems for used clothing in affluent countries. An alternative is Fair Trade labeling, a movement that attempts "to get clear labeling on products giving consumers the opportunity to make choices, and to make ethical statements" about what they buy (Neyland, Nunes et al. 2007). With regard to vaccines, traditional tools include tax breaks and extended patents, while new tools include advance purchase commitments and public-private partnerships. The example of a new accountability system in e-waste is the European Union's directives on recycling, which set up a complex audit trail on the production, consumption, and movement of electronic goods. Each system has its own pattern of identifying "publics" and involving them in determining whether the results of the process are acceptable (Neyland, Nunes et al. 2007).

Representation

The global accountability systems explored in the textile, vaccine, and e-waste cases face the challenge of accountability at a distance: production, consumption, and disposal of the technologies escape accountability in part because they are distributed in different geographic locations. As already indicated, other accountability processes and especially formal political ones continue to operate in one place, through governments at

local, regional, or national levels. These political systems traditionally tend to hear the voices of the rich more clearly than the voices of the poor and the views of technical experts more clearly than knowledge situated in communities. The issue of effective representation for everyone in government priority-setting processes is thus an important item for the ResIST agenda. A number of case studies in Work Package Three focus on the articulation of new accountability systems in capacity building and priority setting that aim to remediate inequalities. These case studies draw on conceptions of accountability that diverge from the typical focus on the relation between those who govern and those who are governed (Neyland, Nunes et al. 2007). In part the case studies focus on experiments in Spain, Portugal and Brazil with participatory budgeting in urban government and knowledge-based policy-making. Other case studies focus on initiatives in public health and environmental justice in Brazil and Portugal.

In all these case studies new processes are being designed to counteract the elitist tendencies of political systems, including health councils and participatory budgeting, a process that gives real control to user communities over certain aspects of resource allocation. ResIST will seek to draw lessons from these experiments for the development of more inclusive, accountable and sustainable S&T policies in other settings and circumstances and explore how this affects the various forms of inequality and the CARE cycle presented above more generally.

II. POLICY CONTEXTS

The central challenge for ResIST is to use these concepts to develop tools that would allow policymakers to assess the distributional effects of their knowledge-intensive programs, either prospectively or retrospectively. Their decision environments are complex. They need to take into account external factors, relevant actors, rationales for action, and the instruments available.

This section draws on a review of national policy documents from several ResIST participant countries and on presentations at the three world regional meetings. These countries serve as examples of the various strata of the world economic system and different levels of S&T capability, as shown below. Mozambique is a low income country; Turkey and South Africa are upper middle income countries and Brazil falls just below the cut-off for this group. The UK and Portugal are both high income countries. This preliminary survey of the policy approaches shows that a wide variety of approaches are currently being taken.

	UK	Portugal	Turkey	Brazil	South Africa	Mozambique
Population[10]	60.2m	10.6m	72.6m	186.4m	45.2m	19.8m
GNI/capita[11]	$37,600	$16,170	$4,710	$3,460	$4,960	$310
Technological Achievement[12]	.606	.419	Not available	.311	.340	.066
Gini index of inequality[13]	35.0	37.1	40.03	59.25	57.7	39.61

[10] World Bank, World Development Indicators, data for 2005
[11] Gross National Income per capita, World Bank, World Development Indicators, data for 2005.
[12] United Nations, Human Development Report 2001.
[13] World Bank, PovCal, accessed April 14, 2007; and WIID2 for UK and Portugal. Most recent years vary.

Pro-growth emphasis

In all the countries we examined, policymakers want to apply science and technology to produce economic growth. This goal is in general their highest priority. So for example in the UK [14], the 'Science and Innovation Ten-year Investment Framework' presented in 2004 is primarily concerned with the impacts of science on economic performance and international competitiveness. With the emphasis on keywords such as 'excellence', 'dynamic research base', 'collaboration', 'confidence', the explicit concern is on the impact of the system on innovation. Likewise in Portugal, [15] the 'Technological Plan' aggregates a variety of measures expected to promote economic growth and social cohesion, based on knowledge, technology and innovation, focusing mostly on the exploitation of S&T for competitiveness. This plan is primarily concerned with contributing for economic growth and is hailed as the central piece in the national growth strategy.

The presentations at the ResIST world regional meetings also all stressed the centrality of science and technology to long-term growth strategies. For example, in Brazil, the Science Advisor to the Brazilian Senate presented a sophisticated analysis of Brazil's current situation and the need to move from use of technology to innovation.[16] In Turkey, a leading industrialist described this transformation in a major manufacturing firm.[17] The Minister for Science and Technology in Mozambique included contributing to economic growth among the goals of his office, as did the presentation on South Africa's S&T strategy.[18]

Another ResIST Working Paper reviews the limitations of focusing entirely on economic growth in S&T policy and articulates the need for a broader view of the benefits of S&T for human development [ref WP1 paper]. In our survey of S&T policies, however, attention to the other benefits appears to be inversely related to the wealth of the country formulating the policy. Brazil, for example, stands at the polar opposite of the above mentioned European countries in its internalization of issues of inclusion in S&T policy.[19] The Strategic Plan for S&T in Brazil identifies as a horizontal axis of action strengthening the national system of research and innovation and identifies three additional vertical axes. These include one on promoting innovation following the

[14] Information on the UK in this section is based on the analysis of HMT (2006), *Science & Innovation Investment Framework 2004-2014: Next Steps*. London: HM Treasury (http://www.hm-treasury.gov.uk/media/D2E/4B/bud06_science_332v1.pdf)

[15] Information on Portugal in this section is based on the analysis of PT (2005), *Plano Tecnológico: Uma estratégia de crescimento com base no Conhecimento, Tecnologia e Inovação. Documento de apresentação*. Lisboa: Conselho Consultivo do Plano Tecnológico do XVII Governo Constitucional Português (http://www.planotecnologico.pt/Docs_PT_DS/OPlanoTecnologico.pdf)

[16] Eduardo Viotti, "S&T Policy and Development: Reflections from a Brazilian Perspective," http://www.resist-research.net/cms/site/docs/resistwrm_programme_ebv.pdf, accessed April 22, 2007

[17] Iffet Iyigün Meydanlı, "Management of R&D in Turkish Industrial Companies: the Case of Arçelik," http://www.resist-research.net/cms/site/docs/Arcelik_R&D_2007_March8_short1.pdf, accessed April 22, 2007.

[18] Michael Kahn, "Science and Technology Policy in South Africa," http://www.resist-research.net/cms/site/docs/Micheal_Khan.pdf, accessed April 22, 2007.

[19] Information on Brazil in this section is based primarily on the analysis of MCT (2004), "*Plano estratégico do Ministério da Ciência e Tecnologia 2005-2007*". Brasília: Ministério da Ciência e Tecnologia do Governo Federal Brasileiro (http://www.mct.gov.br)

Industrial, Technological and Foreign Trade Policy, one on developing strategic programs central to the country's sovereignty and one explicitly dedicated to 'Science, Technology and Innovation for Social Development and Inclusion'.

While the concerns with the economic impact of S&T are naturally central, this strategy does not leave to market and social forces the work of externalizing the impacts on inequality, but rather internalizes these objectives. In addition, this has been reflected at the organizational level of the system, with the implementation of a new Junior Ministry of Science and Technology for Social Inclusion (SECIS), created with the mission of promoting social inclusion through actions that improve the quality of life and stimulate the creation of jobs and income.

Similarly, the challenge for Mozambique's S&T policy is clearly intertwined with inequalities.[20] While it includes actions directed towards the strengthening of the existing research institutions, of the relationship of the research system with civil society and the productive sector, of the advanced education system, or of technological innovations, it also includes explicit actions directed to different forms of inequality. These include:

- promoting the expansion of research institutions throughout the territory;
- promoting the participation of women and youth in research;
- promoting research and the use of local knowledges;
- promoting the integration of local knowledges in the formal system of education;
- promoting innovation in the production and use of local knowledges;
- creating conditions for the diffusion in the media of local knowledges.

By giving such emphasis to the importance of local knowledges the emphasis on distributional issues is made clear. The impacts of S&T can only be appropriated if it is not in competition with other knowledge systems, but rather part of the same ensemble of knowledges.

The South African research system underwent significant changes following the demise of the apartheid era.[21] While specific sectors, such as the nuclear and defense industries, were targeted, there were wider impacts in the research system. After an initial phase when innovation took central ground, recently five key technology missions were identified. These are information technology, biotechnology, manufacturing technology, technologies to add value to natural resources and technologies to impact upon poverty reduction. While these objectives are being highlighted in South Africa, other typical

[20] Information on Mozambique in this section is based on the analysis of Conselho de Ministros da República de Moçambique (2003), "Política de ciência e tecnologia e a sua estratégia de implementação." Resolução nº 23/2003 de 22 de Julho. *Boletim da República*, I Série – nº 31: 349-355; Conselho de Ministros (2006), *Plano de acção para a redução da pobreza absoluta 2006-2009. (PARPA II).* Maputo: Conselho de Ministros da República de Moçambique (https://www.govnet.gov.mz/docs_gov/programa/fo_parpa_2/PARPA_II_aprovado.pdf).

[21] Information on South Africa in this section is based largely on the analysis of DST (2006), *Corporate Strategy 2005/6-2008/9.* Pretoria: Department of Science and Technology of the Republic of South Africa (http://www.dst.gov.za/publications/reports/corp_strategy.pdf); DST (2004), *Indigenous Knowledge System*. Pretoria: Department of Science and Technology of the Republic of South Africa (http://www.dst.gov.za/publications/reports/IKS_Policy%20PDF.pdf)

instruments of S&T policy are also being implemented, focused on scientific excellence and economic impact. Nonetheless, the salience of the social impact initiatives, when compared to other countries is worth highlighting. It raises some difficult questions about the differences in semantics, rethorics and realities of policies and policy documents as they occur in various contexts that should be taken into account in ResIST.

Structural inequalities

All the countries we examined also included programs for building science and technology capacity in their countries in their S&T portfolios. In the higher income countries, these instruments focused on recruiting individuals into science and engineering careers, but in the lower income countries, they also included institution-building activities.

In Portugal, 'human resource policies and programs' are taken as particularly instrumental to the country in catching up with other nations. National policy calls for several activities in this area, and reflects the centrality of reducing structural inequalities by giving particular attention to the impact of these policies on the improvement of the education and advanced qualification levels, rather than on potential sectoral impacts, for example.

In the UK, possibly as a result of the strengthening of the devolution process, the main structural inequalities identified are at the regional level, and a greater role to address these 'gaps' is recognized to the local development agencies. Other forms of inequality explicitly identified are concerned with "women and other low participatory groups." Rather than being explicitly concerned with the potential distributional impact of these asymmetries, the concern is mostly with the functioning of the system, of guaranteeing participation (and in that sense, structural), rather than with the outcomes of such structure.

Turkey is working hard to develop its human resource base, through fellowships, exchange programs, and active participation in European integration.[22] Mozambique is building a higher education system almost from scratch,[23] and South Africa is struggling to transform a previously segregated system into one that serves the whole population. The few strong research universities of South Africa are undergoing transformation, while historically black colleges and universities are being merged with previously white institutions to stimulate learning and development. Although 80% of the population is black, the previous situation of structural inequality was so severe that today's achievement of about a quarter black staff members at universities[24] is a huge step forward, and a fully representative science and engineering cohort is far in the future.

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[22] Ahmet Ademoglu, "Recent Developments in R&D in Turkey: Strategy, Policy, Funding," ; http://www.resist-research.net/cms/site/docs/Resist_07_03_07_ahmet_ademoglu1.pdf, accessed April 22, 2007; Fatih Sahin, "Turkey 's Science and Technology Initiatives Towards South East Europe and the Western Balkans," http://www.resist-research.net/cms/site/docs/ResIST_SEE_WBC_Sahin.pdf, accessed April 22, 2007.

[23] Orlando A. Quilambo, "The importance of ResIST for the Eduardo Mondlane University," http://www.resist-research.net/cms/site/docs/Prop_Quilambo_Roland(a)[1].pdf, accessed April 22, 2007.

[24] Michael Kahn, "Science and Technology Policy in South Africa," http://www.resist-research.net/cms/site/docs/Micheal_Khan.pdf, accessed April 22, 2007.

The most pointed discussion of scientific mobility at the World Regional Meetings took place in Rio, where a staff member from the Ibero-American indicators network presented a review of the deepening crisis in northward migration and the limited options available to countries of the South to stem the tide or reap benefits from it.[25] Brazilian colleagues pointed to the connection between their country's meager, but rapidly increasing, production of Ph.D.s (10,000 per year, but only about a third in science or engineering) and historical ethnic divisions, with both indigenous Brazilians and Brazilians of African descent left almost entirely out of the science and engineering labor force. Capacity-building there has to climb two steep cliffs of inequality, one internal and one external.

Representational inequalities

There are widespread references in both policy documents and stakeholder presentations to the need for processes of consultation in shaping S&T policies. In the U.K., representational inequality is an emerging concern. The lay public is treated increasingly at a par with scientists, with 'public understanding' giving place to 'public engagement', 'participation', and 'public confidence'. Nevertheless, the locus of this concern is somehow tilted towards the protection of those already traditionally represented ("improve the promotion of science in society", "improve public confidence in the Government's use of science"), rather than otherwise (e.g. improving the participation of society in science, or providing new mechanisms of accountability on the Government's use of science).

The ambiguities of this position are illustrated by the Committee on Radioactive Waste Management (CORWM),[26] which has a responsibility under legislation to recommend disposal options to the government. Its terms of reference require it to ensure that the review of options is carried out in an 'open, transparent and inclusive manner…engag[ing] members of the UK public and provid[ing] them with the opportunities to express their views, [along with] other key stakeholder groups'. CORWM itself has also embraced equity as a principle, 'striv[ing] to avoid favouring particular groups, stakeholders, communities or regions' and using deliberative processes. With the exception of its long-term additional objective of trying to achieve intergenerational equity in its proposals, CORWM makes clear that its short-term aim is to make recommendations that are 'both practicable and sustainable.'

In Portugal, a general concern with inclusion in S&T policies is implemented through Public Understanding of Science programs. However, rather than focusing in these programs on issues of representational inequality, there is a focus on a deficit model of public understanding, i.e., public ignorance (a form of structural inequality) and, eventually, on the relevance of greater understanding of science for day-to-day activities

[25] Lucas Luchilo, "Trends, policies and impacts of international mobility of the highly skilled on developing countries," http://www.resist-research.net/cms/site/docs/resistwrm_programme_ll.pdf, accessed April 22, 2007.
[26] www.corwm.org.uk, accessed April 17, 2007.

(some distributional impact). In Turkey, the lead science agency acknowledges the need for participatory and accountable processes,[27] but provided few concrete examples.

The comprehensive Brazilian plan to use S&T for social development and inclusion incorporates some clearly participatory processes, such as "popular cooperative incubators." Specific actions are also directed at specific under privileged groups of the population. For example, there is an action to promote social technologies for traditional communities, recognizing how these have historically been excluded from policies for economic and social improvement, making therefore clear the existence of representational inequalities being addressed.

The Brazilian attempt to link S&T to social inclusion also draws a variety of informal science education efforts into this portfolio. Thus the presentation from the Ministry on this area included efforts to bring the benefits of science museums to more of the country's children through traveling exhibits, and other kinds of activities that fall in Europe under the rubric of "Science in Society." These represent an interesting combination of outreach and capacity building, although the deficit model of science education is still in evidence in the examples given.

The first paragraphs of the 'Science and Technology Policy' document from Mozambique illustrate well that S&T do not have a fully dominant position within knowledge systems as in some of the other countries analyzed here, clearly indicated by the low levels of access to S&T by the majority of the people and by the emerging stage of scientific culture of the country. The identification of science as one among other forms of knowledge, in the national S&T policy, is both recognition of a weaker S&T base in world terms as well as the recognition of the importance of other knowledge systems in local society. At the same time, this document makes clear that, at the global level, S&T has emerged not only as the dominant knowledge system, but also as central to an increasingly interlinked global economic system. The implicit acknowledgement of structural inequalities as well as of representational inequalities is therefore made clear. It is not only the fact that there are less S&T resources in the country, but also that other strong knowledge systems are weakly represented in the global system.

In South Africa as well, there is a strong concern with local knowledges (here framed as 'indigenous knowledges'). The development of an Indigenous Knowledge Systems (IKS) policy was led precisely by the Ministry of Science and Technology and adopted in November 2004. Besides the relevance of an inclusive approach to knowledge from the Ministry of Science and Technology, this policy is also particularly relevant as it links IKS directly with the S&T system. It does not limit itself to stating the need for the recognition of IKS. It includes a broad perspective on IKS in almost full parallel with general S&T policy concerns. For example it includes discussions of the IKS in the National System of Innovation of South Africa, a discussion of the role of research institutions within IKS, IPR issues, as well as an IKS information and research infrastructure. Furthermore, it clearly considers that "IKS development is a unique opportunity to recognise and redress inequities created by past policies in South Africa."

[27] Ahmet Ademoglu, "Recent Developments in R&D in Turkey: Strategy, Policy, Funding," ; http://www.resist-research.net/cms/site/docs/Resist_07_03_07_ahmet_ademoglu1.pdf, accessed April 22, 2007.

Distributional inequalities

The concern with distributional inequalities – uneven distribution of benefits and costs – is also inversely proportional to the wealth of the nations in this group. In Portugal, the S&T plan pays particular attention to issues of inclusion, in particular through *access* to the 'Information Society'. This can be considered a form of distributional inequality as the use of knowledge, which depends on access to it, is likely to have a positive impact on its users. ICTs are given particular importance through their appropriation not only by the economic dimension but also through social actors. Inclusiveness is also considered beyond the 'information society'. In particular through the improvement of education levels, portrayed not only in international comparative terms but also as a form of improving inclusion within society. In the UK, indirect concerns with impacts on inequality are clearer with regard to medical research, and its potential impact in the NHS, where "equality of access to high quality care for the entire population" is a major concern. Issues of distributional inequality appear to be mostly ascribed to the role of science and research across government, rather that to science and research itself. The primacy of the concerns with economic impact is also reflected here.

In the Brazilian inclusion plan, the areas of activity of this strategic objective include actions directly oriented towards addressing inequality (in general terms) through S&T, such as through actions on 'social technologies', 'assistive technologies', 'popular cooperative incubators', or more traditional initiatives on 'local productive arrangements', 'technological vocational centres' or 'digital inclusion'. The concern with distributional impacts is also explicit on including as priorities within this objective 'research on basic sanitation', as well as 'research on health, food nutrition and food safety', or 'S&T in the Northeast and Semi-Arid', reflecting some local primary concerns of the population, and not simply an international research agenda.

With regard to Mozambique, it is also relevant to note that S&T is included as one of the central horizontal issues relevant to the 'Action Plan for the Reduction of Absolute Poverty 2006-2009' (PARPA II). This identification is alongside other elements with a significant technical component, such as HIV/AIDS, Environment or Food and Nutritional Safety, and the particular importance given to ICTs in this respect. The concern of the relationship between S&T and inequality is clear. It is not only driven from within the system, but it is drew upon to address specific social outcomes.

Also in South Africa, distributional inequalities are of central concern within the national S&T policy. In particular, the strategic mission of impact upon poverty reduction has been identified as having "achieved some notable successes, particularly in the area of essential oil production, and new programmes in aquaculture show[ing] great promise" (DST, 2006: 2). Nevertheless, the application of 'social technologies' has had some drawbacks, partly resulting from higher expectations. The objective of developing "technologies to reduce the cost of housing, to enable low cost communication […] or practical sanitation" have not followed plans, and higher levels of funding are expected. And in other areas the concerns with different forms of inequality also emerge. For example, in international partnerships, and following years of political isolation, the focus on themes interesting both parties is considered key. Examples given include the European Developing Countries Clinical Trials Partnership, for drugs targeting locally endemic diseases such as malaria, tuberculosis and HIV and AIDS.

Summary

In sum, both our text analysis and the presentations at the World Regional Meetings confirm that the visibility of inequality as a theme in science and technology policies is higher in countries with lower national wealth, higher income inequality, and deeper poverty. This pattern is not surprising, but it does point to an important observation for ResIST. Inequality is not just one of the problems to be addressed, but also one of the barriers to be overcome in using science and technology for sustainable human development. It will be a major challenge for ResIST to show how in some of the cases and policies we analyze issues of inequality are at play even where they are not made explicit and presented as such, and to follow policy design through to implementation and impact. Another major challenge will be to explore the basis of such inequalities and how they may be addressed more adequately through more encompassing conceptions of S&T policy and innovative forms of organizing inclusion, accountability and representation.

III. CASE STUDY CONTRASTS

As part of our stakeholder consultation, we asked participants in the world regional meetings to give their perspectives on a few examples of issues that ResIST results might illuminate. Along with the cases being explored in Work Packages Two, Three, and Four, these form a site for illustrating the three phases of change and for evaluating the applicability of the general policy approaches presented in Section II.

Toxic Waste

The environmental justice movement's reason for being is to call attention to and take action on the unequal distribution of costs – a distributional inequality problem. Our ResIST stakeholders meetings included only one presentation on the movement, in Rio, but we could have included local activists in other meetings, from Mozambique, South Africa, or Turkey.[28] In Rio, Juliana Malerba briefed us on the principles of the movement and its work of the movement in Brazil with regard to cultivation of soya, transport of wastes from São Paulo to Bahia (a richer state to a poorer one), and disposal of used European tires in Brazil.[29]

This movement addresses all the forms of inequality. Its goal is to reduce distributional inequalities, or as Malerba put it, "the unequal distribution of socio-environmental impacts."[30] Inequalities in capacity are inherent in the area: professional knowledge is generally at the service of polluters and regulatory agencies in these controversies. But the movement over the years has taken on the challenge of building its own knowledge base, and it is aided by public research institutions like Fiocruz, who hosted our Rio meeting,

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[28] For Southern Africa, see http://www.groundwork.org.za/, accessed April 17, 2007. With regard to Turkey, Environment & Society work is being done at Bogazici University, Istanbul – see Göksen, F. / Seippel, O. / O'Brien, M. / Zenginobuz, E.U. / Adaman, F. / Grolin, J. (eds): Integrating and Articulating Environments - A Challenge for Northern and Southern Europe. 2003.

[29] Juliana Malerba, "Environmental Justice Network," http://www.resist-research.net/cms/site/docs/resistwrm_programme_jm.pdf, accessed April 22, 2007.

[30] Malerba, op. cit., p. 2.

Furthermore, the movement is participatory by definition, led by NGOs in the defense of communities. It lifts up situated knowledge and gives it voice in the political process. As Malerba put it,

> … at the origin of the actions promoted or carried out by the network is the understanding that whereas different social groups or communities will endow the environment with different uses and meanings – a river, for instance, has a very different meaning for indigenous communities and for companies which produce electricity – these will be disregarded when the time comes to decide on the implementation of a project, due to current power relations in society. … We believe that environmental conflicts and social struggles involving environmental issues can be very important for changes in the distribution of power in society, for they claim the recognition and valuing of different ways of living, or organizing, or producing and of relating [31]

The movement is aimed precisely at accountability: making patterns visible that affect the lives of disadvantaged ethnic and socioeconomic groups.

But even in the ResIST materials we can see the enormous disconnect between official science and technology policy and the environmental justice movement. Our policy review in Section II did not reveal any acknowledgement of the role such movements might play. The electronic waste case in Work Package Three raises issues that are in principle those of environmental justice, but are framed in terms of sustainability. The mechanisms of accountability are EU regulations and audits, not a social movement. Likewise, outside ResIST, the voices of the movement have scarcely been incorporated into the environmental research agenda.[32] And in Africa, the discussions on science advice for regulatory issues are focusing on professional expertise, not community wisdom (Juma and Yee-Cheong 2005). As work on environmental justice in Work Package Three has put it, grass roots organizations both nationally and trans-nationally appear central to successful coalitions in order to promote accountability as social control of public policies by citizens.

Sweet Potatoes

Several presentations at the ResIST stakeholder meetings illustrated a front-line area for poverty reduction that has also been part of research policy for more than a century: agricultural research. In his presentation in Maputo, Calisto Bias described the participatory priority-setting process for agricultural research in Mozambique.[33] And in Rio, Roger Cortbaoui described the work of his international research center on potatoes, the fastest-growing food crop in the developing world.[34]

Bias's presentation illustrates the blending of pro-growth and pro-poor objectives. The priorities are a mix of subsistence crops, aimed at local food security, and cash crops

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[31] Malerba, op. cit., p. 2.
[32] See the Partnerships for Communication at the National Institute of Environmental Health Sciences, http://www.niehs.nih.gov/translat/envjust/envjust.htm, accessed April 22, 2007.
[33] Calisto Bias, "Priority-Setting for Agricultural Research," http://www.resist-research.net/cms/site/docs/Calisto_Bias.pdf, accessed April 22, 2007.
[34] Roger Cortbaoui,, "Science and Technology for and by the Developing World," http://www.resist-research.net/cms/site/docs/resistwrm_programme_rc.pdf, April 22, 2007.

intended for export. Reducing unemployment is an explicit objective, alongside improving the balance of payments. The national agricultural research institute must devote some attention to building capacity in the whole national system, while producing locally-useful research results. The research objective for the laboratory is the same whether the objective is food security or export crops: find a way to increase yields by 20%, so that projected poverty reduction targets can be met. Yet the capacity issue looms large: there are only 50 people working on these basic crops in the national agricultural research institution. The priority-setting exercise redistributed small numbers of them, and expressed hopes for the resources to hire more.

Cortbaoui's presentation, although made in a different city, intersects with the Mozambiquan story. His International Potato Research Center (CIP) has staff in Maputo, and they are working with Bias's staff on potato projects. Like many efforts in Mozambique, international collaboration is not a luxury but a basic staple. Cortbaoui's center makes capacity-building one of its missions, training dozens of developing country scientists in its main laboratory and helping many others with access to international-standard research. The system of international research centers that CIP is part of a committed to "farmer-embracing" rather than "industry-bound" agricultural research, including "free exchange of germ plasm, fair benefits sharing, recognition of traditional germplasm-related values and knowledge, wide access to genomics data bases, and empowerment of farmers to manage technology and access markets."[35] It thus addresses issues of representation and accountability along with capacity and distribution.

The core of Cortbaoui's story, however, is the battle between the beetle and the baby. The child needs Vitamin A to prevent vitamin-deficiency blindness, which takes sight away from a half million children a year. A new sweet potato strain provides enough to prevent the problem. But when the conventionally-bred version is grown, the beetle eats more than the baby – the infamous "post-harvest loss" to pests. It is the genetically-engineered version that would allow the child to eat more than the beetle. But genetically-engineering crops have not been cleared for planting in any East African country, including Mozambique. The country simply does not have the capacity to develop and enforce complicated bio-safety regulations, especially in a global trade environment with shifting reactions to genetically modified foods – a situation that lets the beetles continue to win over the babies.

How would Bias's participatory priority-setting process deal with this issue? Is the sweet potato high on the agendas of local farmers? When so many challenges are pressing, should Mozambique direct its scarce human resource capacity in biological research to developing bio-safety regulations?

Malaria

Malaria is one of the key health tragedies of the contemporary world. Although the disease is completely treatable with current technologies, millions die annually from malaria infection. Many of these are children, who are particularly vulnerable. Malaria clearly counts as a "health inequity" in the definition shared in a presentation in Rio:

[35] Cortbaoui, op. cit., slide 25.

"health inequalities that in addition to being systematic and relevant are also avoidable, unjust, and unnecessary."[36]

In Mozambique, over 5 million cases of malaria are reported annually and about 3600 people die from the disease each year.[37] Controlling and eventually eliminating malaria infections and death is clearly on the policy agenda in Mozambique, as it is in much of the tropical world. Because so much is at stake in bringing malaria under control, there are dozens of high-profile international campaigns devoted to the same goal.[38]

Clinical trials

These factors form the external context for work against malaria in Mozambique, and an easy justification for concentrating efforts in this area. Key national actors are the Ministry of Health and the National Institute of Health. One instrument of change that the Mozambican government is using with regard to malaria is the Centro de Investigação em Saúde da Manhiça (CISM, the Manhiça Health Research Center).

> Situated 80 km to the north of Maputo, Manhiça is a small rural town where the health research centre was established in 1996 as part of a joint collaborative programme between the Fundació Clinic (Hospital Clínic - University of Barcelona), the Ministry of Health and the Eduardo Mondlane Universtity School of Medicine. Financed by the Spanish Agency for International Co-operation, the CISM forms part of a bilateral co-operation programme established between Spain and Mozambique.[39]

In fact, CISM brings a number of international actors onto the scene in Mozambique. It receives funding from six public and seven private organizations outside Mozambique, including the European Union, several sources in Spain, UNICEF, the Bill and Melinda Gates Foundation, and GSK, a pharmaceutical firm.[40]

In the structural dimension of our framework, CISM represents a new institutional capacity for this part of the Mozambican countryside. It is the result of international collaboration, accompanied by mobility of health professionals between the Clinical Faculty of Barcelona, Eduardo Mondlane University in the capital city of Maputo, and rural Manhiça. The center embraces a three-pronged mission: research into the issues facing the district; "an intense training programme of Mozambican scientists, physicians and technical personnel in order to strengthen capacities within the country"; and providing health care to the surrounding community.[41]

A key to the high level of international interest is the fact that CISM has the capacity to run clinical trials on behalf of international firms. CISM was in fact in the news within the last year as the site of a successful clinical trial for a malaria vaccine

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[36] Alberto Pellegrini, "Research and Health Inequities," taken from Whitehead 1992. http://www.resist-research.net/cms/site/docs/resistwrm_programme_apf.pdf, accessed April 22, 2007.
[37] World Health Organization, Global Health Atlas, http://www.who.int/globalatlas/DataQuery/default.asp, accessed April 13, 2007.
[38] See a partial list at http://www.artemisininproject.org/Malaria/other_initiatives.htm. accessed April 20, 2007.
[39] http://www.manhica.org/pages/ingles/ingles.htm, accessed April 13, 2007.
[40] http://www.manhica.org/pages/ingles/ingles.htm#, accessed April 13, 2007
[41] http://www.manhica.org/pages/ingles/ingles.htm#, accessed April 13, 2007

under development by GSK (formerly Glaxo Smith Kline) in partnership with the Malaria Vaccine Initiative (MVI), a Gates-foundation funded program.[42]

Within the context of Mozambique, CISM is a model program, meeting basic needs by providing health care, building national capacity through international collaboration, and sharing that capacity with other regions through the training program. In terms of representation, CISM described their efforts to maintain good communication links with the local community, stressing the importance of having social scientists on staff to stay in touch with the ways that clinical trial procedures are perceived by the community. While there was no description of a community-based priority-setting process, perhaps the plea from participants -- "When is the vaccine coming?" – is a strong enough voice.

That plea, however, dramatizes the structure of the situation. The people of Manhiça are living with malaria, but GSK and MVI are in control of the anti-malaria solutions. Work Package Three identifies public-private partnerships of the GSK-MVI kind as creating accountability to the partners, but not to developing countries. Perhaps the ultimate form of accountability of a clinical trial to the community participating in the trial would be to assure that when the vaccine is available, it will be available to them. There is no sign of such an assurance for Manhiça. MVI's literature says that in general it supports making medicines available through advance purchase commitments, but no such commitment has been made for the malaria vaccine. Thus Manhiça may get the benefits of a temporary infusion of money to create an environment that is conducive to experimentation, but is not assured of the distributional effects they need so badly: actual access to the vaccine.

Traditional remedies

One pair of stories reported on a different angle on the malaria problem in the form of efforts to produce anti-malarial remedies based on local knowledge. Adelaide Agostinho described a project at the National Institute of Health to develop a tea made from the plant *Artemisia annua*. *Artemisia* is the source of a traditional treatment for the malaria parasite, used for centuries in China. Another Gates-sponsored international effort is applying high technology to the task of making the active ingredient available inexpensively for malaria treatment.[43]

Traditional medicine is being reborn in Africa, and new legal frameworks have encouraged its development, with international agencies, national agencies, associations of traditional healers, and researchers all playing roles. The research on *Artemisia annua* is just part of this effort in Mozambique. The advantages of treatments based on traditional medicine are considerable in the Mozambican context: "no dependence on highly qualified expertise, no dependence on imported medicine, no dependence on

[42] http://www.malariavaccine.org/files/051511-Press_Release-Extended_Efficacy.htm, accessed April 22, 2007.
[43] http://www.artemisininproject.org/, accessed April 22, 2007.

pharmacies (Green Pharmacies), no intellectual property rights related restraints on use, improvement and research."[44] Artemisinin tea is in clinical trials at the Institute.

South Africa is undertaking a similar effort in commercializing a traditional mosquito repellent.[45] But there are a number of contrasts between the stories. The lead organization in South Africa is the Council for Scientific and Industrial Research, CSIR, the largest research institution in Africa. CSIR is still mostly commercially oriented but has added poverty reduction to its missions.[46] The malaria-related project presented in Maputo is part of CSIR's bioprospecting work, an effort to draw on indigenous knowledge to commercialize valuable properties of South Africa's abundant biological diversity. Indigenous knowledge can bypass many steps in the classic, rational approach to drug discovery, and CSIR is trying to mine it for that purpose, focusing in particular on developing technologies to establish community-owned agro-processing businesses, with an emphasis on therapies relevant to South Africa, e.g., malaria, TB, and HIV remedies.[47]

The CSIR colleagues presented the case of BP1, a compound extracted from a local plant. An MOU was signed in 1999 and a benefit sharing agreement was signed in 2003 with the traditional healers who brought the plant to CSIR's attention. High technology then went to work. Scientific research identified the volatile components of the plant; gas chromatography determined the chemical profile of the essential oil; olfactometer tests showed "the efficacy of the samples to repel mosquitoes"; and bioassays and toxicology are underway. These steps led to a patent for a mosquito repellent, which in turn became the basis for community-owned businesses in four provinces. The effects appear to be modest but positive, with jobs at several skills levels created and the potential for growth.

The contrasts between the two stories illustrate the influence of capacity. CSIR capability brings sophisticated techniques to bear on traditional knowledge. Rather than orienting to reducing local costs, the project seeks export markets. In both cases, there is due deference to traditional knowledge, and the local ownership in the South African case provides accountability, representation, and jobs.

IV. POLICY OPTIONS

This survey of national policies and case studies has clearly not provided any recipes for how to turn concepts of inequality into policy options. Indeed, it seems to have led in the opposite direction. The case studies pose situations that clearly have no easy answers, and the three inequalities appear in them as useful sensitizing concepts, but certainly not as policy recommendations.

Likewise, the neat cycle of CARE turns out to need more arrows, in more directions. Poverty does limit capacity (for example, South Africa can not transform

[44] Adelaide Bela Agostinho, "Malaria and herbal therapies: where science and traditional knowledge meet," slide 10, http://www.resist-research.net/cms/site/docs/Adelaide_Agostinho.pdf, accessed April 22, 2007.
[45] Vinesh Maharaj, "Bioprospecting Research: a case study," http://www.resist-research.net/cms/site/docs/Vinesh_Maharaj.pdf, April 22, 2007.
[46] David Walwyn, "The CSIR: A Few Introductory Comments," http://www.resist-research.net/cms/site/docs/Dave_Walwyn.pdf, accessed April 22, 2007.
[47] Vinesh Maharaj, "Bioprospecting Research: a case study," http://www.resist-research.net/cms/site/docs/Vinesh_Maharaj.pdf, accessed April 22, 2007.

township dwellers into researchers overnight). But capacity can be used to address basic needs (an arrow turned backwards), for example, by developing better housing options to improve public health in the township, thus giving its children a better chance to become researchers eventually). Processes of accountability and representation among township dwellers can create the public demand that directs capacity towards the most pressing needs of that community (another arrow running in the opposite direction from the original cycle).

What is clear from our dialogues in national contexts is that any solutions developed using the three concepts will need to be tailored to particular national histories and circumstances. Mozambique's current crying need for capacity creates a different set of tradeoffs on accountability than those that would be made in Portugal, for example. Turkey's relationship to Europe puts the options being explored there front and center in the policy agenda, even when the circumstances are quite different. Brazil's popular government requires explicit labeling of social inclusion efforts, but its large population, modest capacity, and internal inequalities may make real progress on the agenda more difficult than in poorer countries.

ResIST thus has very important questions to ask, using these three concepts of inequalities, as the work packages move forward over the coming year and as the project moves into a second round of stakeholder consultations in its third year. For example, what are the re-distributional consequences of the growth strategies? What are the growth consequences of the re-distributional strategies? What options build capacity in both communities and S&T institutions? What options set genuine local priorities? Questions like these will certainly keep the ResIST team and its partners busy over the coming years.

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