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Lock-in situations in the global debates on climate change, biotechnology and international trade: Evidence from a global stakeholder survey

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The problem of man-made global climate change is strongly related to land-use practices and the global dependence on fossil fuels. Biotechnology is a platform technology that may help reduce greenhouse gas emissions in agriculture, improve adaptation to climate change, offer new sources of renewable energy and transform the current petrochemical industry into a less energy intensive biological industry. Yet, this potential is hardly ever discussed in the public debate on climate change because it is currently not associated with the term 'cleantech' that is used to describe climate-friendly technology. In our study we investigate the perceptions and interests of the main stakeholders involved in the global debate on biotechnology and climate change in order to better understand why 'cleantech' is currently not linked to 'biotech'. For that purpose, we designed a global stakeholder survey which was completed online by 59 respondents representing 40 core institutions in the global sustainability debate. The response rate was above 90%. The survey results reveal that most stakeholders even in the climate change debate regard the potential of biotechnology to be significant. Yet, the results also show that one of the stakeholders that is assessed to be key in the biotechnology as well as the climate change debate and of central importance in the formation of global public opinion is also firmly opposed to the use of modern biotechnology to address climate change problems. The survey findings also indicate that the perception of biotechnology depends to a large extent on the educational background and the institutional affiliation of the respective respondent. Despite the generally favourable view of modern biotechnology as a tool to address climate change problems it is unlikely that it will be considered as being part of 'cleantech' any time soon unless influential opponents would change their attitudes. This is however not going to happen since the political and psychological costs to change its mind would be too high. It amounts to a typical lock-in situation.

A. Introduction

The 16th Conference of the Parties (COP16) of the United Nations Framework Convention on Climate Change (UNFCCC) in Cancun in December 2010 ended with a legally non-binding commitment by all nations to take steps to reduce their greenhouse gas emissions by mobilizing the necessary financial and technological means. In accordance with the Bali Action Plan, the preamble of the Cancun decision recognizes that the Parties would have to reduce emissions at least in a range of 25-40 percent below 1990 levels by 2020 in order to keep track with the ambitious goal of avoiding an increase of global temperatures above 2 degrees Celsius by 2050. For that purpose, a Green Climate Fund (GCF) of US$100 billion per year is to help financing appropriate measures in the developing world. Furthermore a Technology Mechanism is designed to spur deployment of clean technologies, and an Adaptation Framework is to facilitate international cooperation to developing countries in their efforts to protect themselves from the impacts of climate change. In addition to the GCF, many Climate-specific funds already exist both within and outside the UNFCCC including the Global Environment Facility (GEF) that also manages the Least Developed Country (LDC) and the Special Climate Change Fund, the World Bank's Forest Carbon Partnership Facility (FCPF), and the Multilateral Development Bank (MDB)–administered Climate Investment Funds (CIFs), among many other public and private funds. Even though many questions related to governance, transparency, funding priorities and future sourcing of the funding remain open, there seems to be broad consensus that the GEF and its co-financing approach should be given a central role in the future GCF (Bird et al. 2011, Van Kerkoff et al. 2011).

In order to ensure the FCCC-entrenched Principle of Common but Differentiated Responsibilities, recipient countries are to access financial resources directly from a fund, or can assign an implementing entity of its own choosing. Furthermore, country-based 'Technology Needs Assessments' (TNA) are funded by the GEF to learn more about the priorities in the allocation of funds. The assessments are done by the national ministries of environment[1] - often with the assistance of the United Nations Environment Program (UNEP) as well as environment and aid agencies from developed countries. In addition, these ministries are strongly supported by Western donors and NGOs who are primarily focused on environmental conservation in developing countries. Most of these generous foreign donors represent the dominating view in affluent countries that the use of new technologies represents an environmental risk rather than a potential contribution to global sustainability (Tobin 1996, Paarlberg 2008, Aerni & Bernauer 2006). In many occasions the adoption of the views of co-funding donor agencies by their local partners in developing countries may have become an informal conditionality to secure access to funding (Aerni 2005, Van Kerkoff et al. 2011).

National environment ministries in developing countries are not just in charge of implementing the ratified Multi-lateral Environment Agreements (MEAs) but also likely to be the entities authorized to direct access to the GCF. In view of all the strong ties and funding dependence from Western stakeholders concerned with environmental conservation, they are likely to focus primarily on risk management measures rather than transfer of new technologies – even though it also falls into their jurisdiction if related to the environment. They may however consider transfer of technology to be outside their expertise because it might involve issues such as Intellectual Property Rights (IPRs) and broader social and economic aspects related to the sustainable integration of a new technology into the local economy (UNCTAD 2003a, Juma 2011).

The dominance of environmental ministries in the priority-setting process of environment-related technology transfer and the marginal involvement of business and technology experts may lead to 'information cocoons' of like-minded stakeholders, a phenomenon that has become even more pronounced with the rise of social networks in the digital age (Liebowitz 2002, Sunstein 2007). This trend may have led to a path-dependence that essentially discards views that favour the use of modern biotechnology to address climate change as being ignorant about the 'system-oriented' approach in environmental management or driven by vested interests (IAASTD 2008, Shiva 2008). As a consequence, calls for a radical re-think of how to address global climate change more effectively by relying less on subsidies and regulation and more on incentives to facilitate sustainable technological change, did not have a significant impact on Post-Kyoto negotiations (Nordhaus and Shellenberger 2007, Victor 2010). This may help explain why the potential of modern biotechnology to contribute to mitigation and adaptation measures of climate change are hardly discussed in the global sustainability debate.

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[1] See list http://ncsp.undp.org/tna-country-list

Previous experience with the implementation of technology transfer schemes in response to MEA commitments show that the preferences of donor countries may cause undue interference with the development priorities in the recipient countries and run counter to the FCCC-stated Ideal of Common but Differentiated Responsibilities as stated in Article 3 of the Convention[2]. For instance, an independent high-level panel on biotechnology established by the African Union and NEPAD concluded recently that Africa will be unable to cope with its future sustainability challenges unless it makes its institutions more friendly to learning and innovation (Juma and Serageldin 2008). This NEPAD/AU report further argues that home-grown solutions can emerge through the successful combination local traditions and practices with new technologies, such as biotechnology. Only such an approach would facilitate sustainable change that is able to cope with the doubly challenge of adapting to climate change and ensuring future food security. Yet, this report was apparently not interpreted as a Technology Needs Assessment (TNA) by funding agencies concerned with agriculture and the environment and consequently ignored in any subsequent reports.

In our study, we aim to better understand the dominant dualist framing of modern biotechnology versus the environment in the global debate on climate change. For that purpose, we investigate how the composition of stakeholders as well as their respective perceptions and interests shape the global debates on biotechnology and climate change and thus influence the general perception of sustainable development.

For that purpose we identified the most important stakeholders in both debates by means of key informants. The selected stakeholders were subsequently contacted and invited to complete an online survey about their perception of the topic as well the influence of each of the stakeholders listed in the attached policy network table. We assume that many of the selected stakeholders are active in both debates. Most of them are concerned with issues related to agriculture, energy and the environment. Yet, whereas the public experts tend to be trained primarily in risk assessment and management, the private sector experts may be more focused on technological innovation. Therefore not just institutional affiliation but also the educational and professional background may matter when explaining the perception and influence of the stakeholders. Scholars with a background in geography, agronomy, environmental science or social science may be little familiar with the potential uses of modern biotechnology but are highly exposed to messages that frame modern biotechnology merely as another reductionist solution that only serves industry at the expense of the poor and the environment (Shiva 2008, Jeffrey Smith etc). In return, those with a background in business, engineering or biotechnology may focus too much on profitability and technological feasibility and ignore the wider social and environmental implicationst. A sustainable approach must be a combination of the strengths developed on both sides. Yet, educational path-dependence may lead to the above-mentioned academic/professional information cocoons causing a lock-in situation that makes it more difficult than usual to overcome political partisanship in favour of a joint and effective solution to sustainable development (Sunstein 2007).

The following paper first discusses the potential of modern biotechnology to address problems related to climate change mitigation and adaptation and the reasons why biotechnology is hardly ever part of MEA-related technology transfer programs. Secondly, it will give an overview of the methodology and the implementation of the stakeholder survey

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[2] See http://www.climaticoanalysis.org/wp-content/uploads/2009/12/kmcmanus_common-responsibilities.pdf

followed by a presentation of the main results. The conclusions will focus on the political implications of the research findings.

B. Transfer of Technology and the Environment

The idea to facilitate technology transfer in order to help developing countries cope with future environmental challenges is an essential pillar of the Rio Declaration and Agenda 21 adopted by more than 178 Governments at the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil in 1992. It is also entrenched in the subsequent multilateral environmental agreements (MEAs). The Convention on Biological Diversity even becomes explicit about the type of technology transfer it envisions for developing countries to make better use of their genetic resources and improve biodiversity conservation: in Article 19 of the CBD, Contracting Parties are asked….'to provide for the effective participation in biotechnological research activities'. For that purpose, the same article contains a call for a protocol setting out appropriate procedures to ensure the safe transfer of the technology. In other words, modern biotechnology was considered to be part of 'Environmentally Sound Technologies' (EST) as defined in Chapter 34 of Agenda 21. The resulting Cartagena Protocol on Biosafety that was adopted on 29 January 2000 and entered into force on 11 September 2003 does however no more refer to any possible benefit of modern biotechnology in its main objective (Article 1) but frames its use as a potential risk with '…adverse effects on the conservation and sustainable use of biological diversity, taking also into account risks to human health'. As a consequence, technology transfer within CBD was no more related to the actual transfer of the technology itself but to the transfer of precautionary measures to prevent possible technological risks (Paarlberg 2008). Many of the same government delegates and NGOs that were involved in the negotiations of the Cartagena Protocol on Biosafety also took part in the negotiations of the Kyoto Protocol. They are mostly concerned with environmental issues and, as such, tend to support well-established and accepted technological solutions rather than make the case for new but less tested technologies (Shellenberger and Nordhaus 2007). In the most recent report (SBSTA 2010), the Subsidiary Body for Scientific and Technological Advice (SBSTA) of the FCCC briefly mentions in one paragraph the potential of mid- and long-term research and development to contribute to mitigation and adaptation of climate change. In this context, they also mention 'breeding technologies and crop production' technologies (the use of the word 'biotechnology' may already be too controversial) yet reminding the reader that one characteristic of such long-term R&D is that it is risky.

I. Conservation projects as technology transfer

It is therefore not surprising that the Global Environment Facility (GEF), the fund with the mandate from the MEAs to co-fund technology transfer, primarily supports projects that deal with capacity building, conservation and risk management. As for the issue of biodiversity it '…recognizes the potential risks posed by modified living organisms and the urgent need to build systemic and institutional capacity to address biosafety issues' (GEF 2005). Since its inception in 1991, it has provided more than 6,000 small grants directly to community-based organizations (CBOs) and NGOs mostly in areas related to biodiversity and climate change. As a consequence, NGO interest in the GEF has grown exponentially (GEF 2005). In November 2008, the GEF Council and the Council of the Least Developed Countries Fund (LDCF)/ Special Climate Change Fund (SCCF) approved the Poznan Strategic Program on Technology Transfer to move beyond the previous conservation focus and move towards scaling up the level of investment in the actual transfer of environmentally sound technologies (ESTs). Yet, none of the ongoing projects involves the use of modern biotechnology (GEF 2010).

II. Environmental Goods and Services

Finally, in accordance with the Doha Declaration, WTO members are working to eliminate trade barriers in environmental goods and services (EGS). The aim is to provide improved access to products and services that help improve energy efficiency and reduce greenhouse gas emissions in order to ensure a more harmonious co-existence between WTO rules and specific trade obligations in various MEAs. However, there remains considerable uncertainty about the exact definition of environmental goods. Generally, environmental goods are expected to follow the end-of-use criteria and not processes and production methods (UNCTAD 2003b). Environmental goods may nevertheless cover a number of key technologies that positively contribute to the fight against climate change. In this context, the application of modern biotechnology could result in environmentally friendlier or preferable goods meaning that they are produced, used or disposed of in a way that has a reduced or minimal impact on the environment. The OECD definition of EGS does however not include environmentally friendly goods because they are associated with certain production processes. Since modern biotechnology would fall in this group, it is not mentioned (OECD 2005, EAU 2011). The Environmental Area Initiative (EAI) to negotiating EGS in the WTO may be more promising (Cottier and Baracol-Pinhão 2009). It would replace the 'list' approach by an EAI approach that focuses on the negotiations of the specific targets and goals. Goods and services as well as particular technologies will be covered if they are relevant for the achievement of the environmental goals. But with all previous initiatives, there may be pressure to leave out any reference to modern biotechnology once again.

III. How to apply the Precautionary Principle

Despite all the deliberate and accidental attempts to frame both modern biotechnology and climate change as risks to mankind that need to be prevented by means of the use of the precautionary principle as defined in Principle 15 of the Rio Declaration[3], some recent reports would rather conclude that the attempt to ignore the potential of modern biotechnology, especially in the area of climate change adaptation and mitigation in agriculture, may increase the probability that the ambitious target of avoiding an increase in global temperature by more than 2 degrees Celsius will not be met by 2050 (World Bank 2010, ICTSD 2010, UK Government Office for Science 2011). In other words, if the precautionary principle applied in the climate change context calls for urgent action even in the absence of full evidence and would duly include risk-trade offs (Zander 2010), then this would imply that all possible technologies must be considered in the global effort to combat climate change. As a consequence, the use of modern biotechnology would have to be included, especially in consideration of the ongoing global food crisis.

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[3] Principle 15 of the Rio Declaration: "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation"

IV. Why modern biotechnology may matter to climate change

Agriculture, Industry, Electricity and Transportation make up the 90% of the greenhouse gas emissions in the United States and other developed countries (EPA 2010). In each of these areas, modern biotechnology has a great potential or is already actively contributing to energy-saving production and process methods. In the chemical and feedstock industry, the substitution of fossil-based with bio-based products and processes through the use of genetically modified enzymes has already greatly reduced the amount of energy and waste and is likely to further convert the energy-intensive petro-chemical industry into a cleaner biological industry in future (NRC 2009, Danish Agriculture and Food Council 2009). As for electricity production, hydrogen may once be produced as a by-product from specially engineered photosynthetic process (Geiver 2010) and Microbial Fuel Cells (MFCs) already generate electricity directly from bacteria as they consume biodegradable materials such as sugars and sewage (Pant et al. 2011). Furthermore, certain types of biofuels from the first-, second- and third generation may contribute to a decrease in dependence on fossil fuels without being the cause of significant land-use change (Murphy et al. 2011). Finally, genetically modified crops in combination with a systems-oriented approach in agriculture may have the potential to mitigate climate change in agriculture (e.g. nutrient efficient plants) and help farmers better adapt to the effects of climate change (e.g. drought tolerant varieties) (Varshney et al. 2011). As a whole, a bio-based economy promises to make better use of the single most important renewable energy on this planet, which is sunlight. The biomass reaped from sunlight can be enhanced and employed for various purposes without encroaching further on pristine ecosystems. In this sense, biotechnology may also indirectly contribute to biodiversity conservation through sustainable intensification of existing cultivated land, as well as to agro-biodiversity by saving endangered local varieties (e.g. threatened by a virus) by inserting the resistance trait directly into the preferred local traditional crop (Aerni 2006).

V. The importance of agriculture and agricultural biotechnology

Agriculture is a major contributor to greenhouse gas emissions. The IPCC assesses its direct impact to be around 10-12% of global emissions (Smith et al. 2007). The figure increases to around 30% if pre-farm emissions such as fertilizer production and post-farm gate emissions (processing, transport and retailing) are considered (Garnett 2011). Finally land use change alone accounts for another 6-17% (Bellarby et al. 2008). Since 34% of the global land area is used for food production, agriculture ties up a vast amount of carbon: changes in agricultural practices that affect this carbon storage could have a considerable effect on global warming (Godfray 2011). These numbers stand in strong contrast to the fact that agriculture's share of the global gross domestic product (GDP) makes up only about 4 percent (ICTSD 2010).

Despite being responsible for a significant share of GHG emissions (including CH4 and N2O), agriculture has so far been exempted from any greenhouse gas reduction commitments. Even though a dedicated work programme on agriculture at COP 16 in Cancún managed to come up with a 'Roadmap for Action: Agriculture, Food Security and Climate Change' that emphasizes the need for sustainable intensification, the decision to include agriculture in the climate change negotiations was postponed to next year's round in Durban.

Depending on the price of carbon, it is estimated that in the context of climate change mitigation in agriculture, 89% can be achieved through soil carbon sequestration in the form of restoring degraded lands, afforestation, no or minimum tillage and the incorporation of organic matter (Smith et al. 2007). However, the large-scale conversion of arable land into grassland and forests for carbon sequestration purposes may have a negative impact on global agricultural production and thus conflict with concerns about global food security. Moreover, because of the complex interactions between the carbon and the nitrogen cycles, applications of organic and inorganic fertilizers to enhance carbon capture is likely to lead to an increase in N_20 emissions, a much more aggressive greenhouse gas (Garnett 2011).

VI. Sustainable intensification

In view of these trade-offs, many institutions conclude that sustainable intensification in agriculture is inevitable if the challenge of climate change mitigation and future food security are to be met simultaneously in future without further damage to ecosystems (ICTSD 2010, World Bank 2009, UK Government 2011)

The use of modern agricultural biotechnology may play a crucial role in this. Its various new tools could help address emission problems in all the different stages of the food value chain (ICTSD 2010, Juma 2011). At the same time, it would also make agriculture more productive on land already under cultivation, decrease its dependence on the use of fossil fuels and become a better source for carbon capture (Harvey & Pilgrim 2011). This would greatly help achieve the other ambitious goal that the Parties of the Conference in Cancun have agreed upon, namely to slow, halt, and reverse forest loss and the related emissions in developing countries through the UN Program “Reducing Emissions from Deforestation and Degradation” (REDD+). This can only happen through sustainable intensification and not extensification of agriculture.

Despite the fact that no-tilling practices associated with the cultivation of herbicide-tolerant soybean already resulted in significant global reductions in greenhouse gas emissions and increases in carbon storage in industrial agriculture (through soil and water conservation) as well as less machine use (Brookes and Barfoot 2010), this success is nowhere mentioned in climate change reports. This may be related to the controversy regarding the negative social and environmental impact of large-scale plantations of herbicide-tolerant soybean in Brazil and Argentina. However results of a recent in-depth report, that is based on long-term empirical research rather than anectotal evidence, shows that Herbicide-tolerant GM crops are not responsible for the denounced agrarian structures that existed already long before the adoption of the new technology (Franke et al. 2011).

At any rate, the potential of genetic engineering in agriculture is not discussed in the IPCC report (Smith et al. 2007). Moreover, all the subsequent reports by well-known international organizations (e.g. FAO 2009, IAASTD 2008, OECD 2009) on climate change mitigation or adaptation hardly mention the word biotechnology, or even discard its potential as in the case of the IAASTD report.

Furthermore, the new tools of modern biotechnology do not appear in the so-called ‘cleantech’-portfolios of the multinational corporations that engage in Corporate Social Responsibility (CSR) activities and vow to participate in the fight against climate change. The reason for that is that they are mainly concerned about their image with environmental NGOs (not to be confused with the environment itself) and these NGOs tend to disapprove of biotechnology.

Since biotech products and processes are not included in cleantech portfolios, the use of biotechnology in projects to reduce greenhouse gas emissions in agriculture in developing countries does not yet benefit from "Certified Emission Reductions" under the Clean Development Mechanism (CDM) of the Kyoto Protocol. Modern agricultural biotechnology is also not mentioned in the context of the Bali Action Plan adopted in Bali in 2007 (COP13) on transfer of technology.

VII. The role of Europe in the climate change and the biotechnology debate

The omission of the potential of modern biotechnology in the global debate on climate change may be related to the fact that Europe is widely considered to be the main advocate for strong action against climate change but also the main global opponent of the use of genetic engineering in food and agriculture. The refusal of EU countries to lift the de-facto ban on GMOs in agriculture that was put in place in 1998 eventually led to a dispute at the WTO in which the United States, Canada and Argentina sued the European Union for causing undue delay. In its Final Report in fall 2006 the WTO Dispute Settlement Panel on the 'EC-Measures Affecting the Approval and Marketing of Biotech Products' ruled that the EU ban on the import of GMOs from 1998 to 2003 was inconsistent with Annex C(1)(a) and Article 8 of the WTO Sanitary and Phytosanitary (SPS) Agreement because it caused undue delay in the approval process. Moreover, it was also considered to be in breach with SPS Articles 5.2 and 2.2 that outline the conditions for safeguard measures; the EU safeguard measures applied to GMOs were not found to be based on risk assessment that satisfies the conditions set out by the SPS Agreement (Bernauer & Aerni 2009). Even though the EU would have had the opportunity to appeal the decision, it decided not to do so. It was convinced to have designed a workable regulatory framework that would allow for the safe approval of GM crops and thus make the de-facto ban redundant (Bernauer and Aerni 2008). However, up to 2011, many European countries continue to uphold a ban on GMOs and the EU is now considering to leave decisions on GMOs entirely to member states, which would make the SPS requirement for science-based risk assessment obsolete and legitimize bans on GMOs based on the single objection that it allegedly lacks consumer and social acceptance (EU 2010).

The fear of the European public towards GMOs has been confirmed in European-wide Surveys (Eurobarometer 2005) but stands in strong contrast with the results of the EU's own publicly funded risk research projects related to GM crops and GM food since the mid-1990s. The European Commission just published a report called 'A Decade of EU-funded GMO research (2001-2010)' (EC 2010). The report does not just cover a decade but actually includes the past 25 years of EU research funding (in total EUR 300 billion) involving more than 500 independent research groups. The overall conclusion of this large-scale assessment is that biotechnology, and GMOs in particular, are not per se more risky than e.g. conventional plant breeding technologies. Another very important conclusion is that modern biotechnology will help address the main challenges for industry to increase resource efficiency, replace the use of finite resources by renewable ones, and develop more eco-efficient products and life cycles. By invoking the 'Europe 2020' strategy, adopted by the European Council on 17 June 2010, and its intention to build a European-wide bioeconomy by 2020, the authors of the report point out that economic pressure in a globalised world, as well as experience with biotechnology in Europe, should encourage the different stakeholders to pursue the development and application of all available technologies without prejudice, while respecting fundamental safety and ethical principles. Yet, this report was released by the EU's DG Research which may have no impact on the views of DG Environment, which is representing the EU in international issues related to climate change and biodiversity. This illustrates another case of the lock-in phenomenon with its corresponding path-dependence in the framing of the relationship between biotechnology and climate change.

C. Stakeholder perception and lock-in Situations

It was the economic historian Paul David who used the typewriter keyboard 'QWERTY' as an example to illustrate how path-dependence can lead to lock-in situation where people prefer the old product to the new one even though the new one would represent a substantial improvement. He argued that the QWERTY arrangement of letters on the keyboard was originally designed to prevent jamming of the mechanical keys. Today we would still use this allegedly less efficient keyboard even though the problem of mechanical jamming has gone a long time ago (David 1985). Even though it may be contested whether the subsequent attempts to improve keyboards did really represent a truly superior solution, there is no doubt that the lock-in phenomenon exists in business as well as politics - especially in the modern network economy (Liebowitz 2002). It is related to the costs of switching from one product or political view to another. What has one to lose when being embedded in a like-minded community and suddenly being confronted with the new research findings that challenge one's cherished views or products? The costs of changing one's mind are significant. A whole chain of argumentation that was repeated over and over again in the like-minded community may suddenly have to be questioned. But replacing it with a new line of argumentation is not simple because it may be based on a different philosophical foundation. Even if the old view is not incompatible with the new view it is still costly and time-intensive to become familiar with the new perspective and understanding it.

Moreover there are also psychological costs of abandoning a cherished view that has become part of one's identity (Akerlof and Kranton 2000). The threat of losing the respective like-minded community that not just formed part of one's collective identity but also facilitated access to shared sources of knowledge and funding is real. Even if one is willing to abandon all in order to better serve the common purpose of solving future sustainability problems, finding a new network in a polarized environment may not be easy. In the case of the polarized debate on agricultural biotechnology, desertion from the opponent camp may cause enthusiasm on the supporter side. Yet, despite sharing the same views on agricultural biotechnology, the exclusive concern for the environment may not be shared in the proponent network because it has to be reconciled with competitiveness and return on investment. In turn, an industry person that abandons the supporter side because of its narrow focus on economic rather than environmental criteria may eventually realise that the environmental community is governed by its own rules of self-interest that are often not conducive to finding effective solutions to environmental problems (Aerni 2002, Luhmann 1993).

The lock-in problem may already start in school and in the subsequent choice of university subjects. The educational path and cultural background shapes a particular world view and identity and abandoning this identity may come along with increasing costs (Akerlof & Kranton 2002). The subliminal evaluative conditioning through the social environment of teachers, family and friends (Jones et al. 2009) as well as the influence of the student milieu and the professors at the university (Fleischhauer 2009). For most people, the mere thought that they may also be a product of educational path dependence and locked in a milieu that is costly to leave, strikes fear because it implies that they are not guided by free will (Aerni & Grün 2011). Therefore, most people prefer to stick to certain lines of argumentation and political views they developed early on in their lives but may no more be applicable to the contemporary context. Instead of trying to defend their point through argumentation they would simply argue that this is what they feel, disguising fear of being perceived as ignorant.

The costs of abandoning a particular view in public is even bigger for stakeholders who are to represent and defend the views of a particular constituency. The official attitude of an institutional representative may well be predictable, depending on the position in the global network on environmental issues, the area of expertise as well as educational background.

D. Methodology

In our global stakeholder survey, we investigate the lock-in phenomenon that may have led to the exclusion of modern biotechnology in climate change adaptation and mitigation funding schemes by looking at the dominating perception clusters as well as the political weights attributed to the respective stakeholders within the clusters. Moreover, we test to what extent self-assessed expertise and educational background correlate with the perception towards modern biotechnology in the context of climate change.

The first objective was to identify the major stakeholders in the global debates on biotechnology and climate change. For that purpose, we contacted key informants in both debates and asked them to review a list of around 50 selected stakeholders[4]. Depending on their personal experience, they had the possibility to add new institutions or remove already listed ones. Finally 48 stakeholders were selected consisting of 14 academic institutions, 9 different industries and global business associations, 10 international bodies, 6 governmental institutions of global importance and 9 international non-governmental organisations (NGO). Most international institutions are active in both debates whereas certain specialised academic institutions and industries are primarily concerned with one of the two debates. They are all considered to be actors involved in the global debate on sustainable development.

The selection of 48 stakeholders is far from complete and many institutions that are relevant in either the biotechnology or the climate change debate may be missing. We therefore wanted to know from our respondents during the survey if they felt an important institution is missing in the policy network table. At the time we closed the survey, 19 names of stakeholders were added by the respondents. However, none of the names was mentioned twice, which indicates that the selection is quite comprehensive.

This method of stakeholder selection was adopted from policy network approach as developed by Laumann and Knoke (1987). The survey design and methodology to investigate the attitudes and political influence of stakeholders follows the approach designed by Aerni (2002).

In a first step, a questionnaire was designed for the stakeholders. It consisted of four parts that comprised

(a) a general assessment of the potential of the different approaches, tools and products of biotechnology to address climate change problems (especially with regard to mitigation and adaption in agriculture)[5], plus a self-assessment of the competence in the field of biotechnology and climate change.

(b) an evaluation of different statements in favour or against using biotechnology in climate

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[4] A list of 50 relevant stakeholders cover two global debates may be far too small, yet, there is a trade-off: if the list is large it may cover a larger share of views in the global debate, but a large list would not be welcomed by the respondents who have a limited amount of time to complete the survey and might get frustrated with a long list of stakeholders.

[5] The listed approaches were either already widely applied or then at least in a stage when they passed proof-of-efficacy.

change,

(c) a policy network table where respondents were asked to assess the influence of each of the listed stakeholders and to indicate whether they are cooperating with each of them in terms of information or financial exchange. An finally

(d) a general information sheet about the educational background and institutional affiliation.

The questionnaire was sent out to the selected stakeholders in July 2010 in form of a printed and an online version (www.surveymonkey.com). If the selected stakeholder belonged to one of the core players, we asked for one or more respondents to complete the questionnaire, preferably from different divisions (in the case of an international body) or different research department (in case of an academic institution). The follow-up process subsequently took place via phone calls and e-mails. By November 2010, 59 respondents representing 44 different institutions returned the survey. Yet, since four of them did not complete the last part about the respondent's name and institutional affiliation only 55 could properly be identified. Nevertheless, even counting only the 55 complete questionnaires, the response rate still amounts to more than 90%. Most respondents have senior positions in their respective institutions (40 out of 55 have a PhD). Their academic backgrounds can be divided in Physical Sciences, Molecular Sciences, Environmental Sciences and Social Sciences)

Figure 1 shows the participation of respondents grouped by institutional category and type of Organization. The relatively small share of For-Profit Firms (19%) compared to the share of respondents affiliated with Business (27%) is due to the fact that organizations such as the World Business Council for Sustainable Development, the World Economic Forum and Europabio are registered as non-profit but still represent business. Each institutional group consisted of a number of organisations, agencies and institutes affiliated with the particular category (NGOs, Government, Academia, International Bodies). The exception was the category 'business' where we did not single out representatives of particular companies but focused industry representatives. This included not just the biotechnology industry but also industries related to wind power and solar as well as the insurance industry, the retail industry and the chemical/petroleum industry. Whereas the participation rate of representatives from the biotechnology industry was large, we received no response from the petroleum, the solar energy and the wind energy industry. Moreover, the Global Compact of the UN, a strategic policy initiative for businesses that are committed to sustainable development, preferred not to participate. The invited participants from the institutional group of NGOs were selected from organizations that are core in both debates, the one on climate change and biotechnology, as well as influential think tanks and large foundations. It turned out that the large foundations such as the Bill Gates Foundation and the Clinton Foundation did not feel comfortable to reveal their views in such a survey. From the group of NGOs, six respondents represented well-known and globally active environmental organisations that do multisectoral advocacy work related to the potential risks of modern agricultural biotechnology and climate change. Moreover, one respondent represented a smaller NGOs that is known for its expertise in the climate change and biotechnology debate but represents an environmentalism that does not reject the use of modern biotechnology. In academia, 12 institutes represented primarily climate change research whereas 5 institutes represented primarily biotechnology research. The institutes were based in the US, the UK, Switzerland, Germany, India and China. Government respondents represented core agencies in Brazil, the United States and Germany. We also try to find a respondent from the Alliance of Small Island States but were unsuccessful. Finally, most of the respondents that represented international organisations associated with climate change (7 in total) deal only marginally with biotechnology. Only the respondents from the Consultative Group of CGIARs, UNECA and the World Trade Organisation (WTO) may be active in both debates.

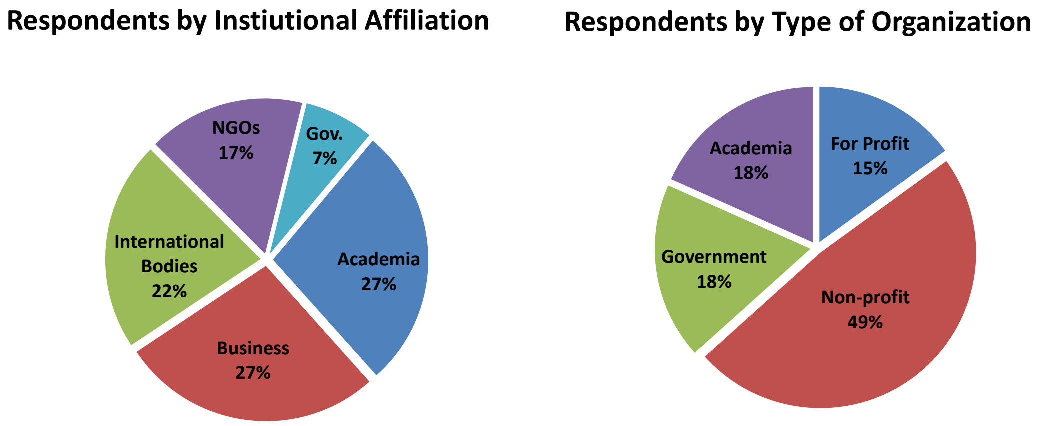

Figure 1: Share of Respondents by Institutional Affiliation and Type of Organization

E. Results

I. Results of the Descriptive Analysis

(a) A general assessment of biotechnology and climate change

In the first part of the questionnaire, we wanted to know from the respondents how they assessed the potential of different applications of modern biotechnology with regard to (a) climate change adaptation, (b) climate change mitigation, (c) renewable energy and (d) low-energy bio-based products. Subsequently, we asked them to assess the overall potential of modern biotechnology with regard to the above-mentioned four different challenges (a,b,c,d) as well as the potential different types of modern biotechnology. Finally, we wanted to know if they feel more familiar with the science and techniques of biotechnology or more familiar with the science of climate change. All their assessments had to be done in a scale from 1 (not important) to 4 (very important).

Figure 2 shows the average assessment of the potential of modern biotechnology (see Figure 2). Everything above the average rating of 2.5 can be considered a positive assessment of the potential.

The high importance attributed to modern biotechnology with regard to climate change adaptation is especially due to the need for drought-tolerant plants (3.61) and salt-tolerant plants (3.48). Further potential is seen with flood-tolerance (3.04) and herbicide-tolerance (soil conservation/reduced water use). Interestingly, the potential of herbicide-tolerant GM plants is considered to be higher (3.0) than herbicide-tolerant plants derived from mutagenesis (2.8).

The second highest rating (Industry) is related to the potential of modern biotechnology to replace industrially produced chemicals by means of less polluting and less energy-intensive bio-based products thanks to the use of genetically modified enzymes. The potential of GM enzymes is assessed to be very high in the production of paper (3.10), starch (biodegradables) (3.07), animal feed (3.02) and detergents (2.95),

The potential of biofuels (Renewables) is also assessed to be high, but mainly with regard to second generation (3.4), and to some extent third generation biofuels (2.98) where food production is largely decoupled from biofuels production.

Finally, modern biotechnology is also considered to have a potential with regard to climate change mitigation, especially with regard to no tilling practices (e.g. herbicide tolerant plants (3.12) and nutrient efficient plants (3.10). The more uncertain approaches (where there is only proof of efficacy) such as reduction of photo-respiration in plants (2.63) and reduction of methane emissions in animals with GM grass (2.57) were assessed to have less potential.

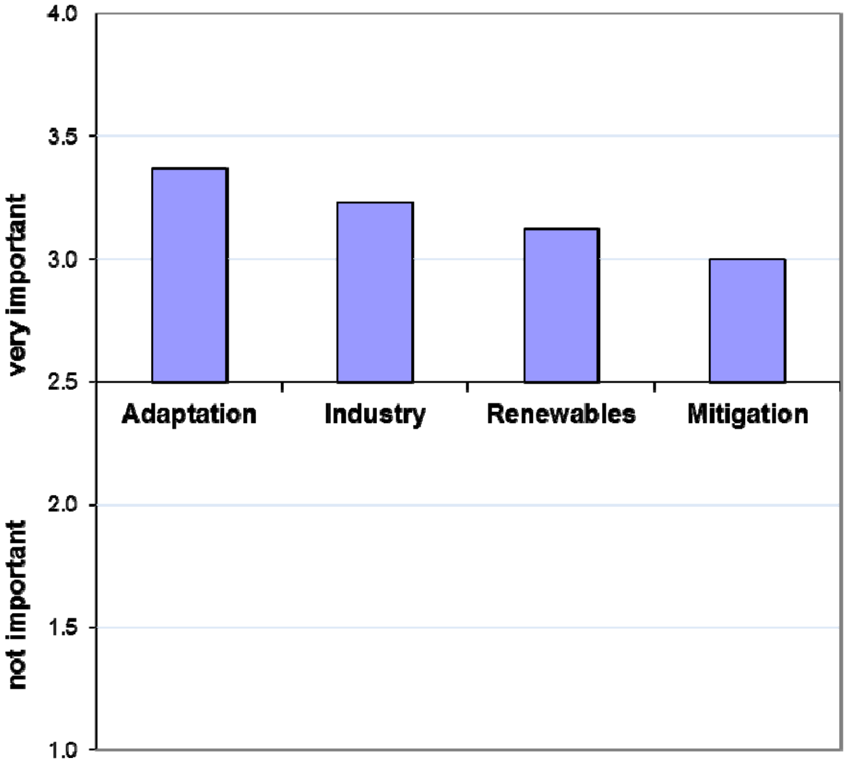

Figure 2: Overall Assessment of Biotechnology for Climate Change

The overall assessment of the general instruments applied in modern biotechnology (see Figure 3) shows that GM enzymes enjoy the highest approval, followed by gene silencing (iRNA), synthetic biology, genetic engineering and, finally mutagenesis. Even though the view is overall positive for all the different techniques, it is nevertheless surprising that mutagenesis gets less approval than genetic engineering. New plant varieties created by means of mutagenesis are not considered to be substantially different from conventionally bred varieties in Europe. Therefore they do not face regulatory burdens or outright bans such as in the case with GM crops.

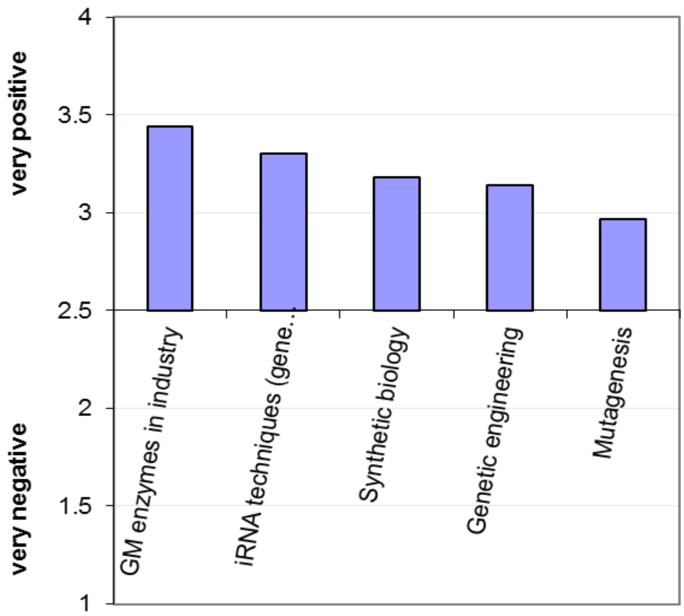

Figure 3: Average view of the respondents toward the different techniques of modern biotechnology

When asking the respondents how familiar they felt with the new tools of biotechnology and the science of climate change in a scale from 1 to 4, it becomes obvious that a greater share of respondents had a background in climate change (see Figure 4).

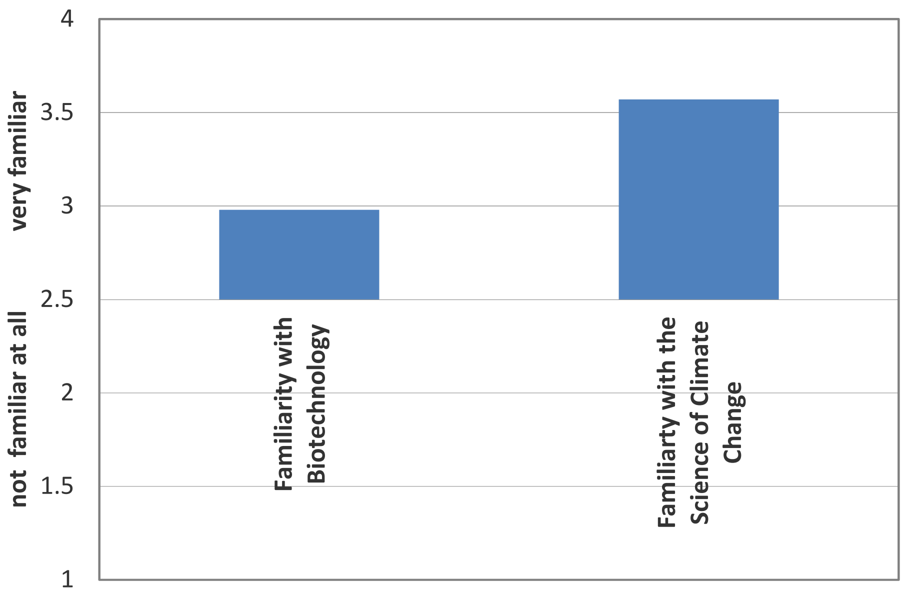

Figure 4: Overall Familiarity with Biotechnology and Climate Change issues

(b) Evaluation of statements in favor or against considering biotechnology as a tool in the struggle against climate change

In part 2 of the questionnaire 14 statements were listed that were directly or indirectly in favor or against using biotechnology to address climate change problems. The favorable and unfavorable arguments were alternating in most cases so that respondents would not perceive a bias. The statements had to be judged in a scale from 1 (I completely agree) to 4 (I completely disagree). Figure 5 shows the average of agreement or disagreement with the various statements (8 statements represented the critical view and 6 the favorable view toward using biotechnology to address climate change problems).

The highest score of approval received the statement 'We need *all available technologies* that could help us move away from fossil fuels', followed by the statement 'Genetic engineering in agriculture is *just a new tool* that enables breeders to solve problems that currently cannot be solved by traditional breeding methods'. These two rather positive statements toward the use of modern biotechnology are followed by the four remaining positively worded statements towards modern biotechnology: respondents generally think that *European fear* towards GM crops is not justified and that *biotech*nology *and organic* production would go well together in agriculture if the ultimate goal is to preserve the environment. Furthermore the climate-change friendly practice of *no-tilling and reduced machine-use* in the cultivation of herbicide-tolerant GM soybean should be acknowledged as a contribution to climate change mitigation and GM plants should also *be included the Clean Development Mechanism* (CDM) if they really reduce greenhouse gas emissions, according to a majority of the respondents. In return, the two negatively worded statements that *there are cheaper and better solutions* to cope with climate change and that especially *solar and wind power are more promising* also received majority approval. The most disapproved statement is that 'genetic engineering lacks *public acceptance* and is therefore not an option'. Most respondents also think that '*organic* agriculture alone cannot be the solution', that 'the potential risks of genetic engineering might be a bigger danger than climate change' (*GM bigger risk than climate change*) and that 'the climate change challenge will be solved by persuading people to change their life styles' *(Better change life styles).* Even the statement that 'genetic engineering is a problem for developing countries because they would not be able to cope with the *biosafety risks*' did not receive widespread agreement.

The rather positive view is surprising since profit-oriented organisations and biotechnology experts represent a comparatively small share in this survey. This may indicate that many climate change experts prefer to be silent in public about the potential of modern biotechnology out of concern to fall prey to radical opponents who would brand them subsequently as irresponsible and indifferent towards human health and the environment. But the internal discussions may look different. There seems to be a growing awareness that it will become increasingly difficult to ignore a platform technology like biotechnology in the climate change discussion. There was however also considerable uncertainty among respondents that were not very familiar with biotechnology. This is reflected in the fact that many of the respondents representing the climate change debate tended to click on the 'don't know' box when facing a statement that was too specific. The maximum number of 'don't knows' was 7 for each of the two statements 'Herbicide-Tolerance Mitigation' and 'GM plants considered in CDM'. The controversy over herbicide-tolerant crops as a cash cow for industry may make it more difficult to judge its actual positive environmental aspects.

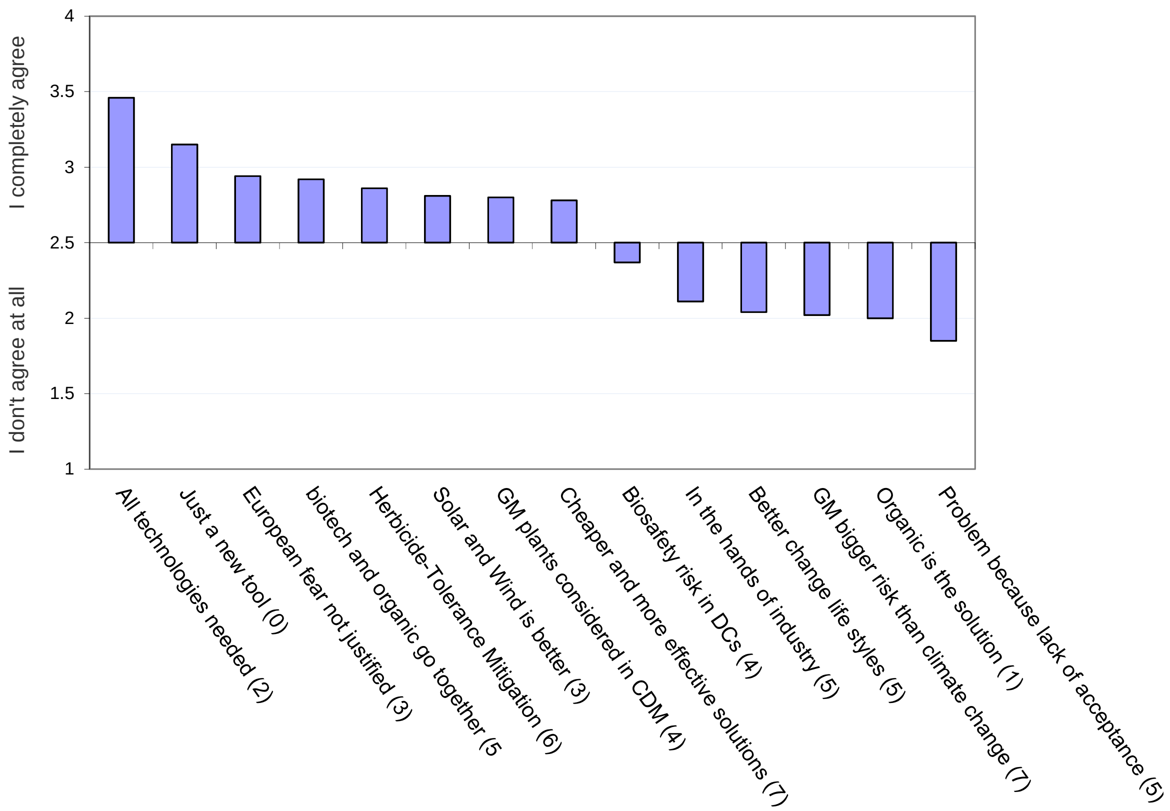

Figure 5: Positive and negative views about the use of biotechnology in climate change

II. Results of the Perception Pattern Analysis

After discussing the stakeholder perceptions on an aggregate level, this part focuses on individual perceptions and the identification of perception patterns among the stakeholders involved.

For that purpose we created the following variables from the statements in part 1 and 2 of the questionnaire:

Variables formed from statements and evaluations in Part 1 of the questionnaire

ADAPTATION: comprises the assessment of the different instruments, techniques and products of modern biotechnology that could help farmers adapt to climate change. In addition, it includes the overall score given to the potential of biotechnology in climate change adaptation.

MITIGATION: comprises the assessment of the different instruments, techniques and products of modern biotechnology that could help mitigate climate change in agriculture. In addition, it includes the overall score given to the potential of biotechnology in climate change adaptation.

RENEWABLES: includes the assessment of the first, second and third generation biofuels as well as the overall assessment of modern biotechnology with regard to renewable energy.

BIODEGRADABLES: represents the potential of genetically modified enzymes to replace chemicals and energy intensive production systems with bio-based and biodegradable products. In addition, it includes the overall score given to the potential of biodegradables.

OTH_TOOLS: includes the view toward the different techniques related to modern biotechnology such as genetic engineering, iRNA (gene silencing), synthetic biology and mutagenesis

Variables formed from statements Part 2 of the questionnaire:

BIOTECH_NEG: comprises the eight negatively worded statements

BIOTECH_POS: comprises the six positively worded statements

Most statements in part 2 of the questionnaire were not directly negative or positive toward the use of biotechnology but represented arguments that are often heard in the narrative of opponents and proponents of the use of modern biotechnology to address climate change.

A factor analysis confirmed that the evaluation of the statements followed indeed a certain line of argumentation and thus justified the creation of two variables, one tending to be positive and the other one negative (see Table 1).

Rotated Factor Pattern 2.5 (Midrank) Imputation			
		Factor1	Factor2
INCLUDE_CDM	Positive	0.79754	-0.33298
FEAR NOT JUSTIFIED	Positive	0.77553	-0.3374
HERB_SOYBEAN	Positive	0.79143	-0.22944
JUST A NEWTOOL	Positive	0.71475	-0.26787
All TECHNOLOGIES	Positive	0.53127	-0.27616
BIOTECH_ORGANIC	Positive	0.43144	0.10757
BIG RISK	Negative	-0.62128	0.43693
GEN_ENG_BIOSAFETY	Negative	-0.24755	0.75999
IN HANDS OF INDUSTRY	Negative	-0.10439	0.67468
ORGANIC_BETTER	Negative	-0.32591	0.65131
LIFESTYLE_CHANGE	Negative	0.0062	0.49017
SOLAR_WIND BETTER	Negative	-0.18038	0.51986
LACKS ACCEPT	Negative	-0.37155	0.60727
OTH MORE EFFECTIVE	Negative	-0.40369	0.53742

Table 1: Factor Analysis to create the variables BIOTECH_POS and BIOTECH_NEG

The Cluster Analysis

The cluster analysis is designed to identify perception patterns among the survey participants based on their overall assessment of the variable vectors. For that purpose, we used the WARD Ward's Minimum Variance Method and the canonical discriminant analysis. In search of the optimal number of clusters, there was no clear cut result. On a cumulative level, 3 clusters would explain 86%, 4 clusters 91% and 5 clusters 95% percent[6]. We decided to work with four clusters since an additional cluster would have just explained 4 additional percentages (see Illustration 1 in Annex).

Based on Mahalanobis Distance, the distances between the four clusters are significant different at 1% level (see Illustration 2 in Annex).

Moreover, all averages or means of the variables are statistically different among clusters at a 1% level of significance (see Illustration 3 in Annex).

Table 2 shows the distribution of stakeholders over the different clusters. Cluster 1 contains 21 respondents. It consists of representatives from all the institutional groups. The great majority are representatives from business and academia. Cluster 2 is of similar size and again comprises stakeholders from all institutional groups. The share of representatives of academia, business and international bodies is about equal in size in this cluster. Cluster 3 is only about half of size of cluster 1 and 2. It does no more contain business and government representatives. Instead it is dominated by stakeholders representing NGOs, international bodies and a few academics. Finally cluster 4, merely contains only three observations, all of them representatives from NGOs.

Cluster	Stakeholder Category					Total
	Academic Institutions	Global Business	Government Agencies	International Bodies	NGOs	
1	6	10	2	2	1	21
2	6	6	1	5	1	19
3	3	0	0	4	3	10
4	0	0	0	0	3	3
Total	15	16	3	11	8	53

Table 2: Clusters formed by means of the WARD clustering method

The Canonical Discriminant Analysis

The rule of the discriminant function requires that the number of canonical variates is equal to the number of clusters minus 1 (CAN=k - 1, for k = 4 clusters > CAN=3).

The linear function of the clustering/discriminating variables is as follows:

CAN1 = b1 ADAPTATION + b2 OTH_TOOLS + b3 RENEWABLES + b4 BIOTECH_POS + b5 BIODEGRADABLES + b6 MITIGATION – b7 BIOTECH_NEG[7]

The analysis revealed that about 95% of the variation in clusters is explained by CAN1. Its Eigenvalue is 17.55 accounting for 98%. This means that CAN 1 contributes significantly to the separation of clusters whereas CAN 2 and CAN 3 are no longer significant (see Illustration 4 in Annex). The standardized canonical coefficients and pooled-within canonical coefficients show the negative and positive correlations between the variables (see Illustration

[6] Based on a general rule, the max number of cluster is 5 for a sample (n=53). It is computed as (=√53/2=√26.5□5)

[7] b1, b2,…,b7 are standardised canonical coefficients. The discriminating variables are ADAPTATION, RENEWABLES, BIOTECH_POS, BIODEGRADABLES, MITIGATION and BIOTECH_NEG

5 in Annex). It indicates that the variables ADAPTATION, MITIGATION, RENEWABLES, BIODEGRADABLES and OTH_TOOLS are positively correlated with BIOTECH_POS and negatively correlated with BIOTECH_NEG. It shows that those respondents who see a potential in biotechnology to address the different problems of climate change also reveal a positive attitude towards modern biotechnology in general.

Illustration 6 in the Annex reveals that there is a significant relationship between the canonical variates and the clusters. All four tests produced high significance at 1% level. Illustration 7 in the Annex proves that all values of the different variables differ significantly between the clusters.

Table 3 reveals the dominating perceptions within these clusters by showing the average values of the different variables obtained in each of the clusters (statement categories rated in a scale from 1 to 4).

The 21 respondents in Cluster 1 tend to regard the potential of biotechnology to be very high when it comes to addressing climate change problems (ADAPTATION, MITIGATION, RENEWABLES, BIODEGRADABLES) and then generally regard all new tools of modern biotechnology (OTH_TOOLS) to be very promising. Their positive attitude toward the potential of biotechnology is also reflected in the fact that they endorse all the positively worded statements (BIOTECH_POS) and reject all the negatively worded statements (BIOTECH_NEG). In short, this cluster reveals the most positive attitude towards the use of modern biotechnology in climate change. The 19 respondents in Cluster 2 also regard the potential of biotechnology to be significant. However their assessment is more moderate. When it comes to OTH_TOOLS, they also tend to approve of all of them but may be a little bit more skeptical towards Mutagenesis. In turn, they seem to highly believe in the potential of biotechnology to contribute to renewable energy (RENEWABLES) and endorse the positively worded statements towards biotechnology to a great extent. Yet, they also give the negatively worded ones some consideration. The 10 respondents in Cluster 3 are more ambiguous about biotechnology. If they see a potential then it is in the area of adaptation and with regard to renewables (especially second generation biofuels). On average, they give a slightly higher score to the negatively worded statements than to the positively worded ones. Their attitude towards the different tools of biotechnology ranks much lower, mainly because they are skeptical towards genetic engineering. Finally, there are the 3 respondents in Cluster 4 which deny any potential of biotechnology. Their hostility is also reflected in the fact, that they endorse all the negatively worded statements and reject all the positively worded ones.

The last two variables in Table 3 refer to the self-assessed familiarity with the tools of modern biotechnology (BIOTECH_TOOLS) and the Science of Climate Change (SCIENCE_CLIMATE). Even though these two variables were not included in the cluster analysis they are nevertheless revealing interesting trends. The results show that most respondents feel highly familiar with the science of climate change. However, only respondents in Cluster 1 and 4 felt very familiar with the new tools of modern biotechnology. Overall, it can be said that the more familiar respondents felt in the area of biotechnology, the more likely they consider its potential in climate change to be significant – except for the three respondents in the last cluster which believed themselves to be highly competent on biotechnology but felt very negative about its use.

Variable	Cluster				Overall
	1	2	3	4	
ADAPTATION	3.77	3.31	2.42	1.28	3.21
MITIGATION	3.45	2.93	2.12	1.52	2.90
RENEWABLES	3.36	2.73	2.43	1.25	2.84
BIODEGRADABLES	3.60	2.97	2.26	1.73	3.01
OTH_TOOLS	3.79	3.03	2.22	1.33	3.08
BIOTECH_NEG	1.66	2.42	2.86	3.36	2.26
BIOTECH_POS	3.67	3.05	2.58	1.12	3.10
BIOTECH_TOOLS	3.67	2.68	1.95	3.67	2.99
SCIENCE_CLIMATE	3.31	3.53	3.90	4.00	3.54

Table 3: Mean values of the different variables in the four clusters

In order to visualize the perception patterns and identify the institutional category of respondents, a Biplot was created with the vector variables discussed in Table 3 except BIOTECH_TOOLS and SCIENCE_CLIMATE since they don't refer to the perception of biotechnology in the climate change debate. The Biplot is a visualization technique of the principal component analysis that allows to identify each single perceptions in a two-dimensional space. The biplot macro portrays the perception variables as vectors. The length of a vector represents its particular Eigenvalue. The different observations represent the respondents and their respective perception (Gabriel 1981).

Figure 6 shows the distribution of the different clusters within the two-dimensional perception space of the Biplot. In order to ensure that all the 53 respondents are represented in the graph, we assigned the 'don't know' answers in the questionnaire the value 2.5, which amounts to a neutral response[8]. Altogether 11 respondents crossed at least once 'don't know', but only one respondents crossed the 'don't know'-box in each of the different sections.

The vector variables with the largest Eigenvalues are BIOTECH_NEG, OTH_TOOLS, and RENEWABLES. Apart from these three variables. which seem to express the largest differences between the clusters, all remaining variables are strongly correlated (indicated by the small angle between the vectors). This means that those respondents who express a positive attitude toward biotechnology (BIOTECH_POS) also see a great potential of the technology with regard to climate change adaptation (ADAPTATION), mitigation (MITIGATION), and the use of genetically modified enzymes (BIODEGRADABLES).

Generally, the great majority of the respondents is found in the central right part of the graph (clusters 1 and 2), indicating that they tend to be in favor of biotechnology and also see quite a potential with regard to climate change. Respondents in cluster 3 and 4 are then mostly found more scattered on the left and upper left part, indicating that they tend to endorse the negatively worded statements and see little potential in biotechnology.

[8] A comparison between the Biplot with the 2.5 values and the Biplot with the missing values showed that apart from the two missing observations there were no significant distortions.

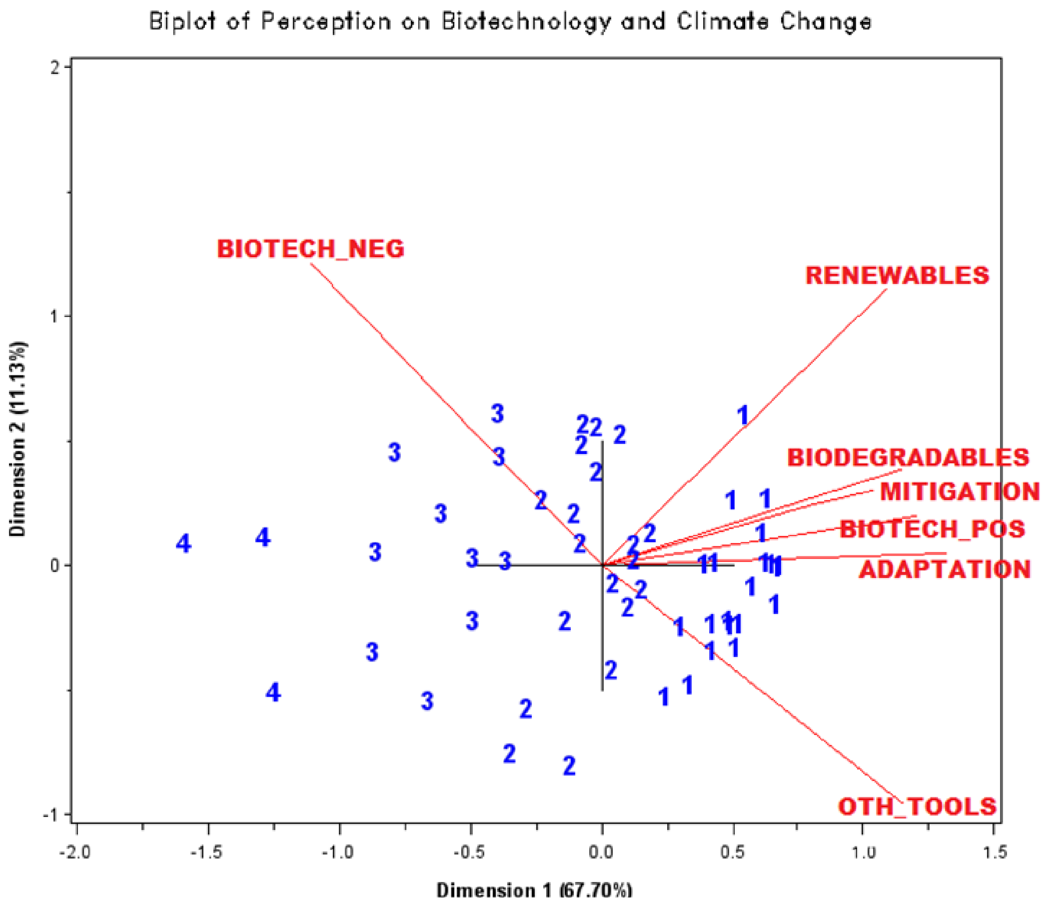

Figure 6: Biplot with the four perception clusters

Figure 7 shows the same Biplot but this time it is not the cluster number but the institutional affiliation of the respondents that can be identified. Whereas NGOs (N) and International Bodies (I) seem to be rather critical and see little potential in biotechnology, Academia (A), Business (B) and the very few Government Institutions (G) tend to be more in favor using biotechnology to address global climate change. Non-parametric tests also confirm these significant differences among the different institutions, except for the variable 'RENEWABLES' (see Illustration 8 in Annex). However, there are also some business institutions that are either close to the BIOTECH_NEG vector or very remote from the 'potential' vectors. They therefore are either critical towards the use of biotechnology or consider its potential to be rather low. They represent the retail and the chemical industry. In return, there is one NGOs that is found in the very right part. This NGO is one of the few that advocates the use of modern technology to address environmental problems. The most skeptical representatives among the international organizations are representatives of the Earth System Science Partnership (IHDP, DIVERSITAS) whereas the most positive ones represent institutions that deal with agriculture and development (CGIAR, UNECA). Certain important institutions in the area of international organizations (IEA), NGOs (Greenpeace) and Academia (Oeschger Centre, ETH Zurich, TERI, Chinese Academy of Sciences) were represented by two representatives. It turns out that these respondents within the same institution tend to have quite different views of the topic, expect for the respondents of Greenpeace (International/CH); they share very similar, strongly negative views (Cluster 4).

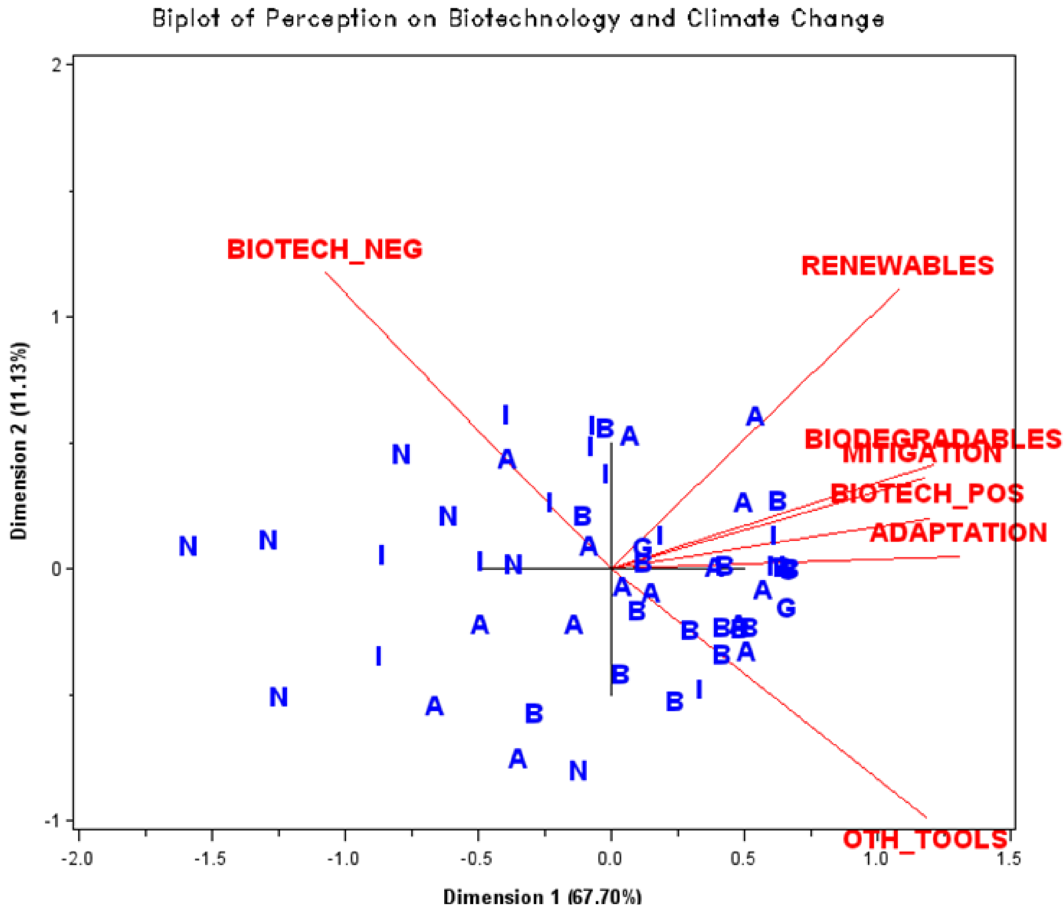

Figure 7: Biplot with the institutional affiliation of each respondent

Finally, we used the Biplot again to see if there is any link between educational background and attitude toward biotechnology in climate change. Figure 8 shows that in fact there is. The educational background in the Figure is broadly categorized in MS (Molecular Sciences), PS (Physical Sciences), ES (Ecological Sciences) and SS (Social Sciences). In turns out that there is just one representative with a background in MS (lower left part) that tends to have a negative attitude and sees little potential in biotechnology. Not surprisingly, he represents a producer of chemicals (that might be substituted by bio-based products). All the MS respondents tend to be found in the right and upper right area. Whereas they could generally be considered as being strongly in favor of using biotechnology to address climate change problems, those with a degree in the physical sciences tend to be in more skeptical but many of them are still found in the right side. In return, most stakeholders with a degree in Ecological Sciences and Social Sciences are found in the left part. The significance of the educational background has been validated in non-parametric tests, except for the variables MITIGATION and RENEWABLES (see Illustration 9 in Annex).

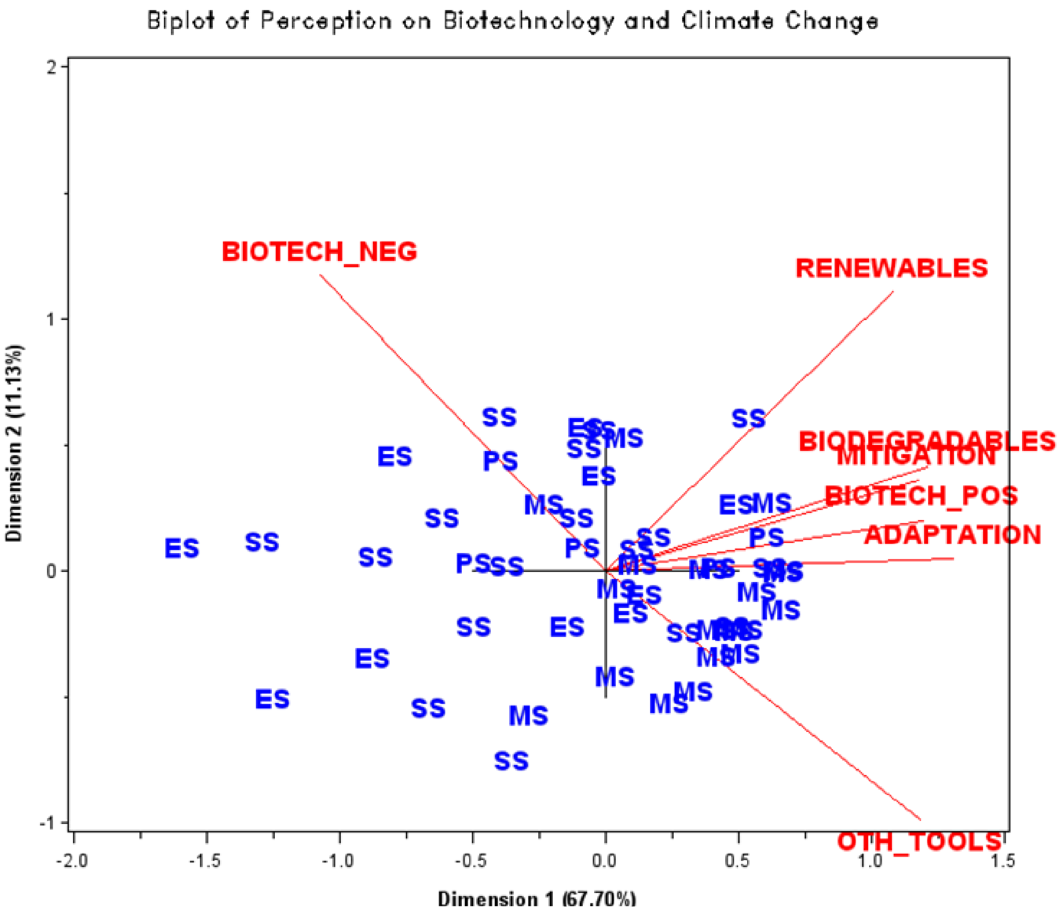

Figure 8: Biplot with the educational background of each respondent

III. Results from the Policy Network Analysis

1. Stakeholder influence

In Part III of the questionnaire, respondents were presented with a policy network table that listed 48 stakeholders. Each of them had to be assessed with regard to

(a) familiarity with the stakeholder,

(b) influence on global public opinion,

(c) influence on the climate change debate and

(d) influence on the biotechnology debate.

Table 4 shows the ranking of the top five and the bottom five in each sphere of familiarity and influence. The table shows organizations such as Greenpeace and WWF are in the top five in each sphere meaning that most respondents are familiar with them and consider them to be most influential in terms of public opinion formation, the debate on climate change as well as the debate on biotechnology. IPCC is considered to be most influential in the climate change debate whereas the biotechnology industry is considered to be the actor with most influence in the biotechnology debate. This shows that biotechnology is associated with industry interests and not perceived to have public good character in the sense that it could help address global problems. The CGIAR system, which deals with the global challenges of climate change and food security is found in the top five as a non-corporate stakeholder.

Another important observation is that only two academic stakeholders are found in the top five: MIT in global public opinion, and the Potsdam Institute in the Climate Change Debate. The high ranking of the Potsdam Institute may also be related to the fact that many respondents in the survey came from Germany and Switzerland.

There are also interesting trends when looking at the bottom five stakeholders in the different spheres. The Break Through Institute for example is always found on the bottom. This institute represents an important US-based think tank that undertook a great effort to create a more positive relationship between technological change and the environment. In their milestone publication 'Break Through' (Shellenberger & Nordhaus 2007) they argue that the climate change problem must be primarily addressed by investing in new technologies and promoting public-private partnerships. Yet, the low ranking once again confirms that this type of environmental NGOs are no match against the established ones such as Greenpeace and WWF that dominate all the debates. These two NGOs were the first movers in the 60s and 70s on issues related to the environment and today they are automatically associated with efforts to save the planet in the mass media as well as in the education system. Their political clout and the trust they enjoy in public may have produced a true lock-in situation since collaborating with less trusted stakeholders or seeking a political compromise might upset their constituencies. Critical questions about their approaches to address environmental problems would not have much resonance thanks to the positive branding of these organizations and the emotional attachment of their constituency.

Finally, when looking at the average score in Table 4 (the amount of crosses given to each organization on average in each sphere) there seems to be evidence that the respondents were much more familiar with the actors in the climate change debate (average score 10.067) than with the actors in the biotechnology debate (average score 3.889)

Familiarity	Score	Public Opinion	Score
38) WWF	46	21) IPCC	33
37) Greenpeace	45	38) WWF	29
21) IPCC (Intergovernmental Panel on Climate Change)	43	37) Greenpeace	23
22) UNEP (United Nations Environmental Program)	40	19) World Economic Forum	16
12) Biotechnology industry	39	5) MIT, Cambridge	14
18) Global Compact	14	31) WGBU (German Advisory Council on Global Change)	3
31) WGBU (German Advisory Council on Global Change)	12	35) Nat'l Development & Reform Commission, China	3
4) Sciences du Climat et de L'Environment, Gif-sur-Yvette	11	43) Bill Clinton Foundation	3
35) Nat'l Development & Reform Commission, China	10	4) Laboratoire des Sciences du Climat et de L'Environme	2
41) Break Through Institute	5	41) Break Through Institute	1
Total Average Score (assessed by the respondents)	26.15556		8.488889

Climate Change	Score	Biotech	Score
21) IPCC (Intergovernmental Panel on Climate Change)	39	12) Biotechnology industry	27
38) WWF	24	37) Greenpeace	25
3) Potsdam Institute for Climate Impact Research	23	25) CGIAR Consultative Group on International Agricultu	16
37) Greenpeace	20	33) US Department of Agriculture	15
22) UNEP (United Nations Environmental Program)	19	38) WWF	11
16) Retailing industry	2	31) WGBU (German Advisory Council on Global Change)	0
18) Global Compact	2	36) Alliance of Small Island States (AOSIS)	0
27) World Trade Organization (WTO)	2	41) Break Through Institute	0
8) Donald Danforth Plant Science Center, St. Louis	1	43) Bill Clinton Foundation	0
41) Break Through Institute	1	45) Club of Rome	0
Total Average Score (assessed by the respondents)	10.06667		3.888889

Table 4: The most and least familiar stakeholders and their assessed influence on global public opinion, the climate change debate and the biotechnology debate

Since most social networks are mostly dominated by personalities that are associated with multiple institutions, we wanted to know from the respondent whether they have a particular person in mind when reading the name of the organization in the policy network table. Unsurprisingly, Rachendra Pachauri was frequently mentioned. He is associated with the Indian research institute TERI as well as IPCC. Joachim Schellenhuber is another personality that is especially well-known in the german-speaking regions of Europe. He is affiliated with the Potsdam Institute as well as the WGBU (Wissenschaftlicher Beirat für Umweltfragen der Deutschen Regierung).

2. Network position

Apart from assessing the influence of the listed stakeholders, respondents were also asked to indicate if they collaborate with each of the respective stakeholders, and if so, in what sense (financial collaboration, information exchange). The software programs UCINET and Krackplot were used to create the respective social networks of information exchange and funding. Figure 9 shows the social network of information exchange. The numbers assigned to the different nodes represent the respective stakeholders in the table of the questionnaire. The more arrows that point at them the more central they are in the network. The arrows are marked with a small number: 1 means the organizations gives information, 2 means the organization receives information and 3 means that the organizations gives and receives information. An asymmetric relationship may in many cases not indicate cooperation but actually antagonism (e.g. an environmental NGO write a position paper to a government or a protest note to a company).

The numbers 21 (IPCC), 24 (GEF) and 42 (World Resources Institute) represent a central position in the information network. All three are mostly connected to the stakeholders in the climate change debate.

In the second inner circle of central positions are 23 (World Bank), 31 (WGBU), 3 (Potsdam Institute), 7 (ETH Zürich), 1 (Oeschger Institute), 12 (Biotechnology Industry), 26 (IEA), 38 (WWF) and 37 (Greenpeace). In this second circle only the biotechnology industry and certain institutes at ETH Zürich could be clearly attributed to the biotechnology debate. The strong presence of the WGBU, the Potsdam Institute, ETH Zurich and the Oeschger Institute at the University of Bern may also be related to the frequency of respondents from Switzerland and Germany.

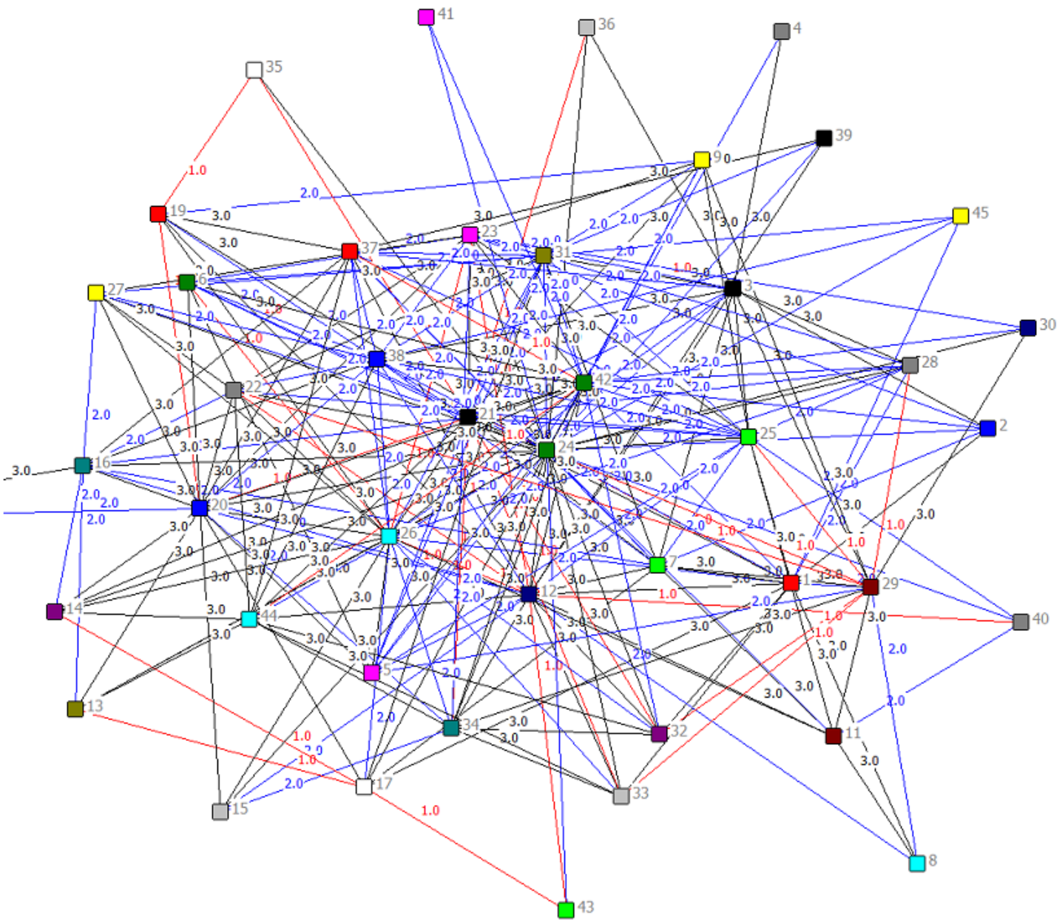

Figure 9: The network of information exchange

Figure 10 shows the financial network. At the core there are three major receiver institutions: The Earth Science Partnership (IHDP, IGBP, WCRP, DIVERSITAS) >29, MIT>5, CGIAR>25 and ETH Zurich>7. They get most of their support from International Organisations such as UNEP>22, Breton Woods (IMF/World Bank)>23 and the Global Environmental Facility (GEF)>24. The Solar energy industry >12 as well as the biotechnology industry>11 are also well embedded in the network. Finally, an important source of funding are the US Departments of Agriculture >33 and of Energy >34 as well as the US Environmental Protection Agency >32. Interestingly, Greenpeace>37, Friends of

Earth>39 and the Break Through Institute>41 are not part of the network. The network reveals that the major donors are international organisations involved in the climate change debate. The biotechnology industry and the CGIARs are the only stakeholders from the biotechnology debate that show up in the network. But generally the network indicates that their role is quite limited and if they are involved it has hardly anything to with the development of genetically modified crops.

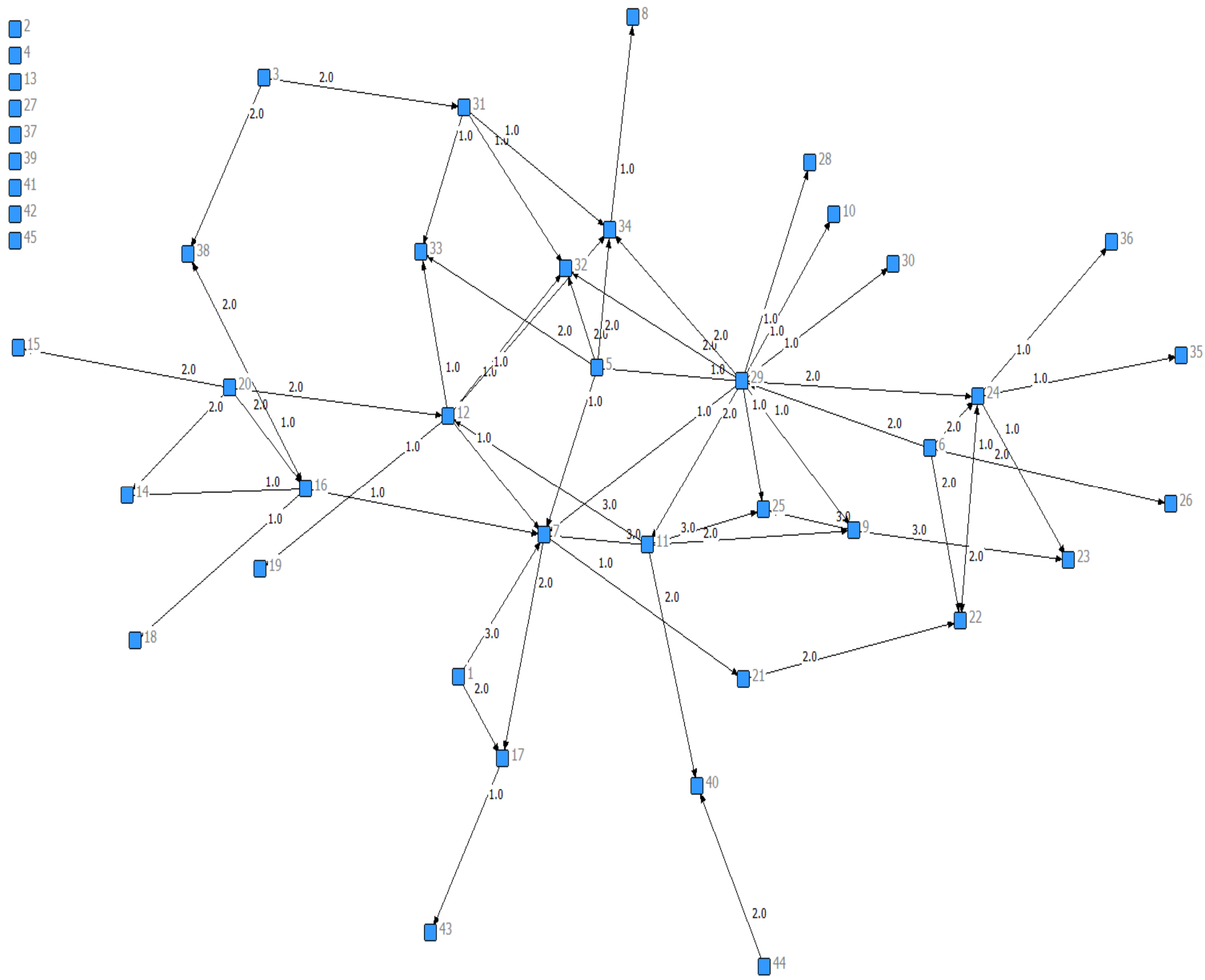

Figure 10: The Network of Financial Exchange

F. Conclusions

Biotechnology will be one of the crucial platform technologies of the 21st century. It is already transforming industry and agriculture in unprecedented ways. Yet, most of the product-related R&D in biotechnology is conducted in the private sector while public sector research, especially in Europe, had to face serious budget cuts and field trials with GM crops have become virtually impossible.

In view of the current food crisis and the long-term threat of global climate change there is a general call for sustainable intensification in agriculture. Modern biotechnology may make a crucial contribution to achieve this goal. Yet, international organizations that deal with climate change, agricultural development and international trade hardly ever mention the potential of biotechnology, and even corporate social responsibility strategies tend to avoid the term biotechnology. The main reason is that the public does not associate biotechnology with sustainable environmental change. Therefore it is not considered to be part of 'cleantech' in the context of climate change. Over the past decade, modern biotechnology has also ceased to be linked to terms such as 'Environmentally Friendly Technologies' and 'Environmental Goods and Services' that could benefit from technology transfer programs, despite the fact that it was considered to be part of 'Environmentally Sound Technologies' in Agenda 21 and the Rio Declaration in 1992. Moreover the Conventional on Biological Diversity explicitly points at its importance in Article 19 where it calls for a Protocol to facilitate the safe transfer of biotechnology. It resulted in the Cartagena Protocol on Biosafety that has so far not been perceived as a facilitator of technology transfer.

The change of perception of biotechnology in the course of time may be related to shifting patterns of stakeholder perceptions, interests and influence over time. This does however not explain why political polarization has increased to an extent that made people in affluent countries perceive that GM crops to be a bigger threat to mankind than climate change.

15 years of experience with the cultivation GM crops and consumption of GM foods have not revealed any risks that are not known already from conventional agriculture. This should make stakeholders involved in the climate change debate feel more confident about the potential of biotechnology to help address the future challenges. Yet, this has not happened and it cannot be because of the science but because of politics.

The investigation of the perception, influence and interests of the central global debate on climate change and biotechnology may therefore be crucial in helping to understand why biotechnology has been bracked out of any strategy to combat climate change, despite overwhelming evidence that it is already contributing to significant reductions in greenhouse gas emissions.

In our study, we investigated how the composition of stakeholders as well as their respective perceptions, interests and influence shape the global debates on biotechnology and climate change and thus the general perception of sustainable development.

Our survey on the perception as well as the political influence of the stakeholders was completed by 59 leading global stakeholders representing academic, business, international organisations, government agencies and NGOs. The majority of stakeholders represented non-profit organisations and were generally more familiar with the science of climate change compared to the science of biotechnology. Almost 80% of the respondents had a PhD.

The descriptive analysis of the survey shows that respondents generally considered the potential of modern biotechnology to be high with regard to climate change adaptation and mitigation, renewable energy and biodegradables (GM enyzmes in industry). This insight is surprising and stands in strong contrast to the exclusion of modern biotechnology in the global climate change debate.

As for the overall attitude towards modern biotechnology and technological change in particular, most stakeholders agreed that all available technologies should be used to address climate change and they consider genetic engineering to be just a new tool that helps solving problems that cannot be solved with the currently available technology. Most stakeholders also believe that European fear is not justified. This seems to be in line with EU's own conclusion, based on the findings of 10 years of EU-sponsored risk research, that genetically modified crops are not inherently more risky than conventional crops (EU 2010).

The cluster analysis of the survey data produced four main perception groups. The two largest perception groups comprising almost 4/5 of the respondents reveal moderately positive to very positive attitudes towards modern biotechnology and its potential in the fight against climate change. The respondents in these two clusters represent stakeholders from all the different institutional categories. Cluster 3 contains only 10 respondents. They tend to be more concerned about the possible negative aspects of modern biotechnology but still endorse the potential of biotechnology in many problem areas of climate change. Finally, cluster 4 only consists of 3 respondents that represent anti-GMO NGOs that are radically opposed to the use of biotechnology and reject any possibility of biotechnology to contribute to solve the climate change problems.

The policy network analysis subsequently revealed that one of these radical stakeholders in cluster 4 is felt to belong to the most influential stakeholders in the climate change as well as the biotechnology debate. It also turns out to be among the five best known stakeholders and as well as the five most influential public opinion leaders.

This leads to the very puzzling situation that an overwhelming majority of the stakeholders involved in the climate change debate considers the potential of biotechnology to be considerable. However, one of the most powerful and influential stakeholders opposes it. It plays a crucial role in both debates and therefore can ensure that the climate change and the biotechnology debate do not mix.

The firm opposition of the influential opponent to any sort of agricultural biotechnology despite the absence of evidence of harm and growing calls for sustainable intensification may indicate that the organization is unable to move away from its initial position out of fear of losing its globally growing constituency. Fear of GM food is too popular to be abandoned as a protest topic. Moreover, the cost for this powerful advocacy group to even admit that agricultural biotechnology may also have benefits compared to conventional agriculture would be too high. It would amount to a great loss of members. Members may then instead search for another NGO that still abides to the old cherished views. Moreover, most employees of the influential GMO-opposing advocacy group may have an educational background and personal views that have made them regard the fight against modern biotechnology as part of who they are. A change of mind would amount to a personal loss of identity and a great loss of friendships and social networks. In other words there might represent an unresolvable lock-in situation from a political and psychological point of view.

Environmental sciences in schools and at universities have been framed over the past two decades as a research area that deals with the avoidance of environmental risks. In this context, new technologies were considered to be a potential risk to the environment rather than part of the solution to environmental problems. This is also reflected in the survey since those with a background in social and environmental science revealed a more critical attitude compared to those with a background in molecular biology and the physical sciences. Moreover stakeholders in academia and business tended to be more positive about the role of modern biotechnology than the stakeholders representing international organizations and

NGOs. All these observations might indicate that accountability to a particular constituency as well as educational and professional background may indeed have a significant influence on a stakeholder's attitude towards the role of biotechnology in climate change. Yet, the big gap between the very positive assessment of modern biotechnology as a tool to combat climate change and the silence in global environmental negotiations about the potential of biotechnology may be an indication that educational alone cannot account for the fact that biotechnology is not mentioned in the context of environmental goods and services as well as environmentally friendly technologies. It rather reveals that many stakeholders may think differently in public than in private and this would be again a confirmation of a lock-in situation. Biotechnology might indeed have a great potential but the social costs of being denounced by a popular and trusted actor such as Greenpeace as being bought by industry or indifferent to the potential environmental risks may be considerable. It would represent a loss of social capital and thus less access to material and immaterial resources in business and politics.

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ANNEX

Number of Clusters	Eigenvalue	Difference	Proportion (%)	Cumulative (%)
1	2.81	2.36	68%	68%
2	0.45	0.17	11%	79%
3	0.28	0.06	7%	86%
4	0.22	0.05	5%	91%
5	0.17	0.06	4%	95%
6	0.12	0.03	3%	98%
7	0.08	0.00	2%	100%

Illustration 1: Number of clusters based on Eigenvalue and Variance Contribution

From Cluster	To Cluster 1	2	3	4
1	0.00***	18.53***	69.63***	215.15***
2	18.53***	0.00***	18.05***	111.01***
3	69.63***	18.05***	0.00***	43.87***
4	215.15***	111.01***	43.87***	0.00***

**** P <= 0.01; ** P <= 0.05; * P <= 0.10; NS not significant, Mahalanobis Distance*

Illustration 2: Cluster Distances

Variable	Standard Deviation			R-Square	F Value	Significance
	Total	Pooled	Between			
ADAPTATION	0.76	0.33	0.78	0.82	73.71	***
MITIGATION	0.79	0.55	0.68	0.55	20.14	***
RENEWABLES	0.75	0.54	0.62	0.52	17.64	***
BIODEGRADABLES	0.74	0.46	0.67	0.63	27.71	***
OTH_TOOLS	0.85	0.46	0.83	0.73	43.13	***
BIOTECH_NEG	0.68	0.43	0.62	0.62	26.96	***
BIOTECH_POS	0.79	0.48	0.73	0.65	30.73	***

**** P <= 0.01; ** P <= 0.05; * P <= 0.10; NS Not significant*

Illustration 3: Univariate Test on Cluster Means

Canonical Variate[1]	Canonical Correlation	Approximate Standard Error	Squared Canonical Correlation	Eigenvalue	Proportion	Likelihood-ratio[2]	F Value	Significance[3]
CAN1	0.97	0.01	0.95	17.55	0.98	0.04	12.68	***
CAN2	0.42	0.11	0.17	0.21	0.01	0.69	1.50	NS
CAN3	0.41	0.12	0.17	0.20	0.01	0.83	1.80	NS

[1] *Linear combination of discriminating variables*
[2] *Testing the canonical correlations in the current row and all that follow are zero*
[3] **** P <= 0.01; ** P <= 0.05; * P <= 0.10; NS not significant*

Illustration 4: Test of Significance of Canonical Variables

Variable	Standardised Total			Standardised Pooled Within		
	CAN1	CAN2	CAN3	CAN1	CAN2	CAN3
ADAPTATION	1.12	-0.88	-1.45	0.49	-0.39	-0.64
MITIGATION	0.13	0.69	-0.43	0.09	0.47	-0.30
RENEWABLES	0.81	-0.61	0.84	0.58	-0.43	0.60
BIODEGRADABLES	0.28	1.06	-0.18	0.18	0.66	-0.11
OTH_TOOLS	1.11	0.05	-0.01	0.60	0.02	0.00
BIOTECH_NEG	-0.90	-0.57	-0.78	-0.57	-0.36	-0.49
BIOTECH_POS	0.68	-0.74	0.70	0.42	-0.45	0.43

Illustration 5: Canonical Structure

Statistic	Value	F Value	Significance[2]
Wilks' Lambda[1a]	0.04	12.68	***
Pillai's Trace[1b]	1.29	4.82	***
Hotelling-Lawley Trace[1c]	17.96	35.92	***
Roy's Greatest Root[1d]	17.55	112.83	***

[1] *Statistics to test the null hypothesis that the canonical correlations are zero, no relationship between the canonical variables and clusters*

[2] **** P <= 0.01; ** P <= 0.05; * P <= 0.10*

[a] *$(1-r_1^2) X (1-r_2^2)$, equal to the Likelihood-ratio*

[b] *$r_1^2 + r_2^2$*

[c] *$r_1^2/(1-r_1^2) + r_2^2 (1-r_2^2)$*

[d] *$r_1^2/(1-r_1^2)$, r used is the larger between r_1 and r_2*

Illustration 6: Relationship of Canonical Variates and Clusters

Varaible	1	2	3	4	Kruskal-Wallis Test	
	n=21	n=19	n=10	n=3	Chi-Square Value	Pr > Chi-Square
ADAPTATION***	3.77 a	3.31 b	2.42 c	1.28 d	37.33	<.0001
	40.48	*25.24*	*9.50*	*2.17*		
MITIGATION**	3.45 a	2.93 b	2.12 c	1.52 c	28.90	<.0001
	38.29	*26.58*	*10.70*	*5.00*		
RENEWABLES***	3.36 a	2.73 b	2.43 bc	1.25 d	24.24	<.0001
	38.36	*23.42*	*17.25*	*2.67*		
BIODEGRADABLES***	3.60 a	2.97 b	2.26 c	1.73 cd	32.75	<.0001
	40.00	*24.50*	*11.15*	*4.67*		
OTH_TOOLS***	3.79 a	3.03 b	2.22 c	1.33 cd	36.38	<.0001
	40.86	*23.92*	*10.80*	*3.50*		
BIOTECH_NEG***	1.66 a	2.42 b	2.86 bc	3.36 bc	33.57	<.0001
	12.88	*31.76*	*41.30*	*48.00*		
BIOTECH_POS***	3.67 a	3.05 b	2.58 bc	1.12 d	27.97	<.0001
	39.50	*22.71*	*16.40*	*2.00*		
BIOTECH_TOOLS***	3.67 a	2.68 b	1.95 bc	3.67 abd	19.25	0.0002
	35.71	*23.58*	*12.70*	*35.33*		
SCIENCE_CLIMATE**	3.31 a	3.53 ac	3.90 bc	4.00 abd	8.11	0.04
	21.90	*27.05*	*34.60*	*37.00*		

Means with different letters are statistically different

Values in italics (below the means) are Wilcoxon Scores

**** Mean scores are significantly different at 1%*

*** Mean scores are significantly different at 5%*

** Mean scores are significantly different at 10%*

Illustration 7: Nonparametric Test of mean differences (cluster)

Varaible	A n=15	B n=16	G n=3	I n=11	N n=8	Kruskal-Wallis Test Chi-Square Value	Pr > Chi-Square
ADAPTATION**	3.41 a *30.87*	3.44 a *29.75*	3.81 ab *12.75*	3.13 ab *24.18*	2.25 b *41.33*	11.36	0.02
MITIGATION**	2.90 a *26.73*	3.29 ab *34.53*	3.40 ab *16.25*	2.70 b *21.32*	2.22 ab *37.67*	10.77	0.03
RENEWABLES	2.78 a *25.97*	3.02 a *29.56*	3.33 a *16.75*	2.94 a *29.14*	2.25 a *38.00*	5.87	0.21
BIODEGRADABLES***	3.06 a *27.47*	3.36 a *34.34*	4.00 ad *13.13*	2.70 ab *19.91*	2.29 ac *48.50*	18.54	0.00
OTH_TOOLS**	3.27 a *28.97*	3.49 a *33.72*	3.67 ab *16.69*	2.63 a *18.82*	2.31 a *38.83*	11.94	0.02
BIOTECH_NEG***	2.31 a *28.03*	1.82 a *17.06*	1.72 a *36.69*	2.59 ab *36.64*	2.77 ac *13.67*	16.40	0.00
BIOTECH_POS***	3.38 a *32.73*	3.44 a *32.84*	3.22 ac *9.19*	3.00 ac *23.77*	1.98 bc *26.50*	15.58	0.00
BIOTECH_TOOLS**	2.97 a *26.13*	3.56 a *35.09*	3.00 a *24.06*	2.27 ab *17.91*	2.88 a *29.33*	9.72	0.0455
SCIENCE_CLIMATE***	3.50 a *27.07*	3.13 a *17.69*	4.00 a *31.00*	3.91 ab *34.82*	3.75 a *37.00*	14.18	0.01

Means with different letters are statistically different
Values in italics (below the means) are Wilcoxon Scores
**** Mean scores are significantly different at 1%*
*** Mean scores are significantly different at 5%*
** Mean scores are significantly different at 10%*

Illustration 8: Nonparametric Test of mean differences (institutional affiliation)

Varaible	ES n=10	MS n=19	PS n=5	SS n=17	Kruskal-Wallis Test Chi-Square Value	Pr > Chi-Square
ADAPTATION**	2.60 a *24.50*	3.56 b *25.40*	3.28 ab *16.05*	3.10 ab *32.74*	8.67	0.03
MITIGATION	2.38 a *22.62*	3.18 a *32.40*	3.26 a *19.20*	2.70 a *30.92*	6.08	0.11
RENEWABLES	2.53 a *24.76*	3.12 a *21.50*	2.65 a *19.75*	2.81 a *31.58*	5.11	0.16
BIODEGRADABLES**	2.66 a *22.15*	3.37 b *24.40*	3.06 ab *19.00*	2.80 ab *33.55*	8.46	0.04
OTH_TOOLS***	2.55 a *19.09*	3.67 b *25.50*	3.00 ab *17.35*	2.65 ac *36.87*	17.52	0.00
BIOTECH_NEG***	2.69 a *29.62*	1.82 b *34.00*	2.67 ab *35.50*	2.41 ac *15.66*	15.77	0.00
BIOTECH_POS**	2.70 ab *19.79*	3.47 a *32.00*	3.43 ab *21.75*	2.81 b *32.21*	7.96	0.05
BIOTECH_TOOLS***	3.00 a *14.41*	3.95 b *17.70*	2.30 a *25.00*	2.06 ac *39.08*	29.98	<.0001
SCIENCE_CLIMATE***	3.90 a *25.91*	3.18 b *36.00*	4.00 ab *33.70*	3.53 ab *19.39*	11.60	0.01

Means with different letters are statistically different
Values in italics (below the means) are Wilcoxon Scores
**** Mean scores are significantly different at 1%*
*** Mean scores are significantly different at 5%*
** Mean scores are significantly different at 10%*

Illustration 9: Nonparametric Test of mean differences (institutional affiliation)