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MECHANISMS FOR INTERNATIONAL COOPERATION IN RESEARCH AND DEVELOPMENT: LESSONS FOR THE CONTEXT OF CLIMATE CHANGE

Carlos M. Correa

RESEARCH PAPERS

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MECHANISMS FOR INTERNATIONAL COOPERATION IN RESEARCH AND DEVELOPMENT: LESSONS FOR THE CONTEXT OF CLIMATE CHANGE

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I. INTRODUCTION

Technology is central to address climate change; the development, transfer and timely diffusion of the technologies required for adaptation and mitigation constitute one of the major challenges faced by the international community. As noted by the UNFCCC Executive Secretary at the first meeting of the Technology Executive Committee (TEC) under the United Nations Framework Convention on Climate Change (UNFCCC) (Bonn, 1st September 2011), there is a need for 'the development, diffusion and transfer of climate technologies on a massive scale'. [1] Technology is so essential to a global response to climate change that other efforts would be fruitless in the absence of a comprehensive and large-scale action to make technologies available and effectively deployed globally.

The 16th Conference of the Parties of the UNFCCC created a 'Technology Mechanism' and defined a number of priority areas for enhanced action on technology development and transfer.[2] Paragraph 10 of the Decisions adopted on the Outcome of the work of the Ad Hoc Working Group on Long-term Cooperative Action defined as one of such actions:

> (a) [the] [D]evelopment and enhancement of endogenous capacities and technologies of developing country Parties, *including cooperative research, development and demonstration programmes*; (emphasis added).

In addition, one of the functions of the established 'Climate Technology Network' is to

> (b) Stimulate and encourage, through collaboration with the private sector, public institutions, academia and research institutions, the development and transfer of existing and emerging environmentally sound technologies, as well as opportunities for North/South, South/South and triangular technology cooperation;

These elements in the Cancun negotiated text reflect the importance attributed by the Parties to the UNFCCC, particularly by developing countries, to the implementation of effective cooperative mechanisms to develop and transfer environmentally sound technologies (ESTs).

In fact, article 4.1(c) of the UNFCCC stipulated the Parties' commitment to

> '[P]romote and cooperate in the development, application and diffusion, including transfer, of technologies, practices and processes… in all relevant sectors, including the energy, transport, industry, agriculture, forestry and waste management sectors'.

Although the issue of technological cooperation in the area of ESTs was raised on several occasions by developing countries[3], little has been achieved so far. A report by

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[1] Third World Network (TWN), "Technology committee tussles over issue of chair", *TWN Info Service on Climate Change,* Sept11/01., Available from www.twnside.org.sg (2 September 2011).

[2] Decisions adopted by the Conference of the Parties on the Outcome of the work of the Ad Hoc Working Group on Long-term Cooperative Action, FCCC/CP/2010/7/Add.1. Available from http://unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf#page=2.

[3] See, e.g., Decision 4/CP.7, 2001, paragraph 14(c), which urged all the Parties 'to promote joint research and development programmes, as appropriate, both bilaterally and multilaterally".

the Expert Group on Technology Transfer (EGTT) established in the context of the UNFCCC in 2001[4], observed in this regard:

> While there are a large number of climate-related international collaborative activities, a preliminary survey of the landscape indicates a number of large gaps. First, most existing initiatives are focused on enabling frameworks and facilitating deployment. Second, mitigation technologies (and within that, energy technologies) dominate; there is relatively limited focus on adaptation. Third, most of the collaborations between developed and developing countries are targeted at or take place with the major developing economies…
>
> One particular observation relating to technologies for both mitigation and adaptation is that, while there are many international collaborative initiatives around technologies to address climate change, many of these involve processes for identifying needs and facilitating the sharing of knowledge and experiences rather than actually undertaking collaborative R&D[5].

Other relevant finding of the EGTT is the limited number of collaborative R&D initiatives in which least developed countries participate; not surprisingly, they are concentrated in the most advanced developing countries (notably India and China).[6]

This paper examines possible modalities of collaboration for *research and development* (R&D), understood as comprehensive of scientific studies and of activities for the generation of new processes and products and the improvement of existing ones[7]. It briefly discusses, first, the various sources of technology for adaptation to and mitigation of climate change. Second, the paper examines different elements relevant for fostering cooperation in R&D and the modalities that such cooperation may adopt, having in view experiences made in other areas of science and technology. Finally, an analysis of the cooperative model used to promote the development and diffusion of seeds in the 'green revolution' is presented, with the aim of exploring its possible applicability to the case of environmentally sound technologies.

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[4] The Conference of the Parties (COP) decided to terminate the mandate of the Expert Group on Technology Transfer (EGTT) at the conclusion of its sixteenth session.

[5] Report on Options to Facilitate Collaborative Technology Research and Development, Note by the Chair of the Expert Group on Technology Transfer, United Nations Framework Convention on Climate Change (FCCC/SBSTA/2010/INF.11). Available from http://unfccc.int/resource/docs/2010/sbsta/eng/inf11.pdf, pp. 4-5 and 26.

[6] Ibid, p. 27.

[7] This definition encompasses adaptive and incremental innovation as well as original developments.

II. SOURCES OF TECHNOLOGY FOR ADAPTATION TO AND MITIGATION OF CLIMATE CHANGE

Countries may ensure the diffusion of technologies needed for adaptation to and mitigation of climate change through a combination of various sources: the application of technologies in the public domain (including by reverse engineering[8]), access - under licensing or other agreements - to foreign-owned technologies, and research and development (R&D) leading to the implementation of new technologies. Differences in technological capacities and the range of technologies needed in different sectors are so wide that the utilization of multiple sources of technologies seems unavoidable. Indeed, no individual country is likely to be self-sufficient in the generation of the technologies needed to address the effects of climate change.

Developing countries, in particular, may face three types of barriers in their efforts to incorporate technologies for the *production and goods and services*[9] suitable for adaptation to and mitigation of climate change:

Lack of skills and/or financial resources to utilize freely available technologies

Significant reductions in greenhouse gas emissions may be obtained without major technological breakthroughs, by diffusing technologies in the public domain, for instance, known techniques to improve carbon efficiency.

The public domain comprises of technologies that have not been subject to intellectual property rights (IPRs), and those for which protection has expired; their use does not require any permission or compensation[10].

However, the effective use of production technologies, even if freely available, requires technical capabilities (which may often be supplied by consultancy and engineering firms) and investment. The fact that a technology is in the 'public domain' does not mean that it will be applied widely or without difficulty. Technological learning is neither automatic nor free of cost. In many cases, incorporating new technologies require plant lay-out changes, purchase of equipment, adaptation to local raw materials and conditions, and training of personnel. Many developing countries lack a broad pool of skilled personnel or the financial resources necessary to ensure the utilization of ESTs even if in the public domain. This problem may be addressed through national measures and through international cooperation.

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[8] 'Reverse engineering' consists of the evaluation of the technological features, function and operation of a device, object, or system in order to replicate it. Often the outcome of this process entails improvements on the evaluated matter.

[9] The adoption/consumption by final users of such products and services also face a series of problems (e.g. higher cost vis-à-vis conventional solutions, reliability, etc.) that may be addressed with various policies (e.g. tax exemptions, subsidies). This paper does not address this set of issues.

[10] Secret know-how is not part of the public domain, since it is protected as 'undisclosed information', one of the categories of IPRs in accordance with articles 2 and 39 of the TRIPS Agreement.

Reluctance to or onerous conditions for the transfer of technologies

Despite the role played by the public sector in the development of technologies relevant to address climate change, a large portion of environmentally sound technologies is covered by intellectual property rights (IPRs)[11]. Patenting has significantly grown in the last decade, particularly in solar photovoltaic (PV) and wind technologies; six countries – Japan, USA, Germany, Korea, France and the UK – are the source of almost 80% of all patented innovations in the field of 'clean energy technologies' (CETs), including solar PV, geothermal, wind, and carbon capture.[12] In accordance with a recent survey, large conglomerates are starting to play an increasing role in the clean technology landscape, including smart grid / energy efficiency, lighting, electric transport, solar, energy storage, wind and water.[13]

In some cases, technology owners exploit their technologies by licensing them to third parties, against payment of royalties or other forms of remuneration; in other cases, however, technology owners are reluctant to part with their technologies, particularly if potential recipients may become competitors in the local or global markets. As shown by the experience of some developing countries that were successful in catching-up processes (such as South-East Asian countries), recipients may not only absorb received technologies but improve on them and eventually enter the innovation race in competition with the original transferors of technology. This risk, which has become higher for technology owners with the growing market globalization, may lead to the outright refusal to transfer, to the transfer of only outdated or less efficient technologies, or to the demand of high prices that put a barrier to potential acquirers. Restrictive conditions (such as tying clauses, grant-back provisions, export and field of use prohibitions) may also hamper technology transfer.

Thus, in a case where an Indian company demanded the transfer of technology from a transnational corporation producer of HFC 134A, an ozone-depleting substances (ODS) substitute, the required price was more than 10 times what was deemed reasonable by the Indian company. Other options suggested by the supplier were a joint venture with majority stake or export restrictions on HFC 134a produced in India[14]. Similarly, Indian firms found difficulties in their attempts to acquire fire-extinguishing technology: the owners of the patent

[11] This reflects both the importance of the private sector in the development of such technologies and the growing trend by public institutions to claim IPRs on their research outputs.

[12] European Patent Office (EPO), the United Nations Environment Programme (UNEP) and the International Centre for Trade and Sustainable Development (ICTSD), *Patents and Clean Energy: Bridging the Gap Between Evidence and Policy-making* (2010). Available from http://www.unep.ch/etb/events/pdf/UNEP%20ICTSD%20EPO%20Geneva%20Trade%20&%20Development%20Symposium%201st%20December%202009.pdf. China also ranks high by the number of patent applications filed in a several fields of CETs (except carbon capture) but many patent filings are possibly made by the Chinese subsidiaries of multinational enterprises (Lee, B., Iliev, I. and Preston, F., *Who Owns Our Low-Carbon Future? Intellectual Property and Energy Technologies*, London, Chatham House, 2009, pp. 14-15).

[13] JEFFERIES Group, *Jefferies Survey Finds Investor Focus on Clean Technology is Becoming More Diversified*, 20.4.11. Available from http://www.4-traders.com/JEFFERIES-GRP-COM-13161/news/JEFFERIES-GRP-COM-Jefferies-Survey-Finds-Investor-Focus-on-Clean-Technology-is-Becoming-More-Diversi-13606192/.

[14] Jayashree Watal, "The issue of technology transfer in the context of the Montreal Protocol: Case study of India", in *Achieving objectives of multilateral environmental agreements: a package of trade measures and positive measures, Elucidated by results of developing country case studies* Veena Jha and Ulrich Hoffmann, eds., UNCTAD/ITCD/TED/6, Geneva, 1998, p. 50.

did not accept licensing of the technology to wholly domestically owned companies, but only to joint ventures with a majority shareholding[15].

Recent studies reported similar situations:

> In a study of wind power industry development strategies in India, China and Spain, Lewis (2006) found that developing country manufacturers often have to obtain technology from second- or third-tier wind power companies. This is because leading manufacturers are less inclined to license to would-be competitors. Lewis notes that the technologies obtained from the smaller companies may not necessarily be inferior to those provided by the larger manufacturers, but such smaller companies have substantially less operational experience. The Energy and Resources Institute (2009)… cites examples [in India, China, Indonesia, Malaysia and Thailand] in which local companies have terminated negotiations with licensors due to high royalty fees for licences or have incurred additional costs buying non-related equipment before accessing the desired technology[16].

The need for developing countries to get access to foreign-owned technologies (overwhelmingly held by private and public entities in developed countries) was already recognized by the UNFCCC, which in article 4.5 included, among the commitments of the developed country Parties and other developed Parties listed in Annex II, the obligation to 'take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention'. Little has actually been done so far to effectively implement this provision.

Asymmetries in R&D capabilities

Domestic R&D capacity is not only necessary to develop new technologies and provide local solutions to local problems, but also to scrutinize scientific and technological developments that take place elsewhere and to generate capacity to absorb and adapt foreign technologies. This dual role is critical for technologies relevant to climate change, largely held by entities from developed countries. An R&D capacity permits institutions and companies to screen how the scientific and technological frontier evolves. They may, through 'gatekeeping' activities, benefit from technology spillovers and choose possible partners for cooperation. "Gatekeeping" refers to a permanent search for new sources of innovation, either within or outside the firm. It requires special skills in order to identify new sources of core information, interpret and assimilate it.[17]

Developing countries account for a growing but still minor proportion of global R&D.[18] North America accounts for more than one-third (35 per cent), Europe for more than one-fourth (27.2 per cent) and Japan for 13.2 per cent (total 75.4 per cent) of global R&D

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[15] Ibid, p. 51.

[16] UNEP, EPO, ICTSD, *Patents and clean energy: bridging the gap between evidence and policy. Final report*, 2010. Available from http://ictsd.org/downloads/2010/09/study-patents-and-clean-energy_159101.pdf, p. 21.

[17] W. Faulkner, *Understanding industry-academic research linkages: towards an appropriate conceptualisation and methodology*, Edinburgh, University of Edinburgh, 1992..

[18] Defined in accordance with the OECD's *Frascati Manual* (OECD, *The Measurement of Scientific and Technological Activities. Frascati Manual. Proposed Standard Practice for Surveys on Research and Experimental Development*, Paris , 2002 ,).

expenditures[19]. The Organisation of Economic Co-operation and Development (OECD) countries account for 78 per cent[20]. Asia (without Japan) accounted for 19 per cent[21], while Latin America (2.4 per cent)[22], the Near and Middle East (1.2 per cent) and Africa (0.7 per cent).[23]

Thus, developing countries excluding China only account for around 10% of global R&D expenditures[24]. Although this share is much higher than the estimated share (4 per cent) for such countries twenty years ago[25], the world distribution of R&D is indicative of one the most dramatic North-South asymmetries[26].

This is despite the fact that developing countries as a whole have performed well in the last decade in terms of consolidation of an R&D basis (see Box 1).

Box 1
Expansion of R&D capacities in developing countries

The number of researchers in developing countries jumped from 1.8 million to 2.7 million over 2000-2007. The surge in researcher numbers means that the developing world employed 30 per cent of researchers in 2002 but 38 per cent by 2007. However, China accounts for over half (53 per cent) of researchers in developing countries. In the 50 least developed countries (defined according to the standard UN classification) there was an average 20 per cent increase in researchers.

While spending on research and development (R&D) by developed countries grew by about one third (32 per cent) during 2000-2007, developing countries more than doubled their expenditures (103 per cent), from US$135 to US$274 billion. This figure falls, however, to a less than three quarters increase (73 per cent) if China and India are removed from the calculation.

Total spending on R&D by developing countries accounted for one per cent of their gross domestic product (GDP) in 2007, up from 0.8 per cent in 2002. This compares with 2.3 per cent for the developed world.

Source: Ochieng' Ogodo, ‘Poor countries spending more on science’, *Scidev Net*. Available from http://www.scidev.net/en/news/poor-countries-spending-more-on-science-.html.

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[19] JACQUES GAILLARD, “Measuring Research and Development in Developing Countries: Main Characteristics and Implications for the Frascati Manual”, *Science, Technology & Society* 15:1 (2010): 77–111, p. 95.
[20] Ibid, p. 96.
[21] 11.8 per cent corresponds to China alone.
[22] 1.3 per cent corresponds to Brazil alone.
[23] 0.5 per cent corresponds to South Africa alone.
[24] While R&D investments in USA, Europe and Japan countries are generally between 1.5 per cent and 3 per cent of the gross domestic product (GDP), most developing countries invest much less than 1 per cent of GDP in R&D. See GAILLARD, op. cit. p. 96.
[25] Jean-Jacques Salomon, Francisco R. Sagasti and C. Sachs-Jeantet (eds.), *The uncertain quest: science, technology, and development* , United Nations University Press, The United Nations University, 1994. Available from http://archive.unu.edu/unupress/unupbooks/uu09ue/uu09ue0d.htm.
[26] In comparison, developing countries account for around 45 per cent of world exports.

A number of features characterize R&D in developing countries, namely:

-Governments have traditionally provided the principal funding for R&D; however, new sources of funds are emerging, such as foundations, non-governmental organizations (NGOs) and foreign organizations.[27]

-The business sector performs much less R&D than the government and higher education (public) sectors, particularly in the agricultural sector[28].

-In most developing countries R&D is focused on basic and applied research, and much less in 'development': 'this likely means that more 'R' than 'D' occurs'[29].

-Minor or incremental changes, including adaptations and improvements on existing technologies, constitute the main source of innovation in developing countries.[30]

- Although the number of R&D institutions has increased rapidly during the last decades, in the majority of the developing countries the research is largely concentrated in one or very few institutions.[31]

-The scientific agenda in many developing countries concentrates around the issues of interest for developed countries.[32]

However, there are growing differences among the developing countries in terms of R&D capacity. Some (notably China, Brazil and India) that are more scientifically advanced than others, are starting to reap benefits from decades of investments in education, research infrastructure, and manufacturing capacity. These countries - which have been called in recent literature as 'innovative developing countries' (IDCs) - invest in R&D relatively more than other developing countries, there is a greater involvement of the private sector, and the interactions between public institutions and private companies and with innovation agents in developed countries are more frequent .

These differences are evident in the area of ESTs. As noted by a recent report,

> [I]n actual fact, developing countries themselves now constitute quite a diverse group, embracing a wide range of technological capabilities. Countries such as China, India and Brazil are already playing a leading role in developing, manufacturing, deploying and exporting (including to developed countries) various green technologies (such as solar panels, wind turbines and biofuel technologies). Moreover, global value chains, which extend across developed and developing countries and represent a new global division of labour, cannot be subsumed under the traditional technology transfer paradigm based on the "provider-receiver" relationship. Instead, many developing

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[27] United Nations Educational, Scientific and Cultural Organization (UNESCO), *Measuring R&D: Challenges Faced by Developing Countries*, Paris, 2010. Available from http://www.uis.unesco.org/Library/Documents/tech%205-eng.pdf, p. 7.
[28] Ibid, p.12.
[29] Ibid.
[30] Expenditures on this type of innovations, as well as on reverse engineering, are not captured by the data on R&D, as defined by the Frascati Manual.
[31] Gaillard, op. cit., p. 89.
[32] Foreign support to local research, collaboration with foreign institutions and the possibility of publishing in international journals are often crucial in determining the areas of research.

countries are already partners in the innovation, production and deployment of green technologies. This role will likely become increasingly important and its impact more widespread in the future[33].

The range of technologies susceptible of being applied for adaptation to or mitigation of climate change is so vast (including in the fields of transportation, mining, agriculture, building, energy and manufacturing), and the potential for 'migration' from conventional technologies so wide, that calculating the investment in relevant R&D is a difficult task. The Expert Group on Technology Transfer (EGTT) under the Convention estimated (as of 2009) that the global resources available for R&D, deployment, diffusion and transfer for *mitigation technologies*[34] were between U$S 77.3 and 164 billion per year[35]. The largest part of this investment, however, is accounted for by deployment and diffusion, while the private sector is the main source of financing for R&D[36].

Partial estimates for financial resources available within developing countries are shown in Table 1.

Table 1

Estimates of current financing for development and diffusion of climate mitigation technologies, by stage of technological maturity and source (billions of US dollars per year)

	R&D (total spending)	Demonstration (total spending)	Deployment (additional cost of climate technologies)		Diffusion (additional cost of climate technologies)		Total
	Global	Global	Global	Developing countries	Global	Developing countries	Global
Public	6 10	Included with R&D	33 45 30	NA	19.5–27.0	8.0–15.5	55.5–82.0
Private	9.8–60	Included with R&D	NA	NA	12–22	3.3	21.8–82.0
Total	15.8–70		30–45	NA	31.5–49	11.3–18.8	77.3–164.0

Abbreviations: NA = not available, R&D = research and development.
Source: UNFCCC, 2009a

[33] United Nations, World Economic and Social Survey 2011, *The Great Green Technological Transformation*, E/2011/50/Rev. 1-ST/ESA/333, New York, 2011, p. 24.
[34] It was not possible to make similar estimates on technologies for adaptation, due to the absence of reliable data.
[35] UNFCCC, *Recommendations on future financing options for enhancing the development, deployment, diffusion and transfer of technologies under the Convention. Report by the Chair of the Expert Group on Technology Transfer*, Document FCCC/SB/2009/2, UNFCCC, Bonn, 2009 (summary available at http://unfccc.int/resource/docs/2009/sb/eng/02sum.pdf), p. 2.
[36] Ibid, p. 3.

In accordance with the EGTT report, despite the uncertain figures, the following broad patterns of financing are clear:

(a) The financing resources for technologies for mitigation and adaptation make up only a small share (probably less than 3.5 per cent) of the resources devoted globally to all technology development and transfer;
(b) Most of the financing resources (probably over 60 per cent) for the development and transfer of climate technologies are provided by businesses;
(c) Most of the remaining resources (about 35 per cent of the total) are provided by national governments;
(d) Technology development is concentrated in a few countries/regions (about 90 per cent): the United States of America, the European Union, Japan and China;
(e) Although R&D is becoming more international, there is no international funding mechanism and there is limited coordination for such activities;
(f) Only about 10.20 per cent of financing resources are used for the development and transfer of technologies to developing countries;
(g) Current financing resources need to be increased significantly[37].

Other imbalances in R&D portfolios have been observed. For instance, a study found that current investments in energy R&D by the public sector, in all industrialized countries, are heavily biased in favor of nuclear energy, to the detriment of energy efficiency research.[38] Such investment has typically been less than 10 per cent of the overall public sector R&D budget in the countries of the International Energy Agency (IEA), despite the fact that energy efficiency is deemed to be the most important option for achieving significant and long-term reductions in green house gas emissions (up to 50 per cent of the potential reduction under different scenarios).[39]

There is a wide range of policy measures that developing countries may adopt to promote domestic R&D relating to climate change. In fact, a large variety of such measures, including subsidies, are used in developed countries. It has been noted in this regard that

> research and development subsidies (some of which take the form of investment incentives) seem to be increasing. In the European Union, it was the third largest horizontal aid in 2005 at € 5.7 billion. Many Canadian provincial officials have come to favour it as a relatively non-specific subsidy that is less likely than other types of support to attract countervailing duty complaints from the United States... Numerous U.S. states have tax incentives for R&D. Its popularity notwithstanding, it is likely that R&D aid exacerbates regional inequality…if we compare industrialized and developing countries, the disparity is undoubtedly wider.[40]

In addition to the observed inequality, developing countries may face legal challenges when the progress they achieve in certain areas may alter the competitive landscape. Thus, the

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[37] UNFCCC (2009), p. 4-5.
[38] A. Grubler and K. Riahi, 'Do Governments have the right mix in their energy R&D portfolios?', *Carbon Management* 2010 1(1):79-87.
[39] Ibid.
[40] Kenneth Thomas, *Investment Incentives. Growing use, uncertain benefits, uneven controls. An exploration of government measures to attract investment*, The Global Subsidies Initiative (GSI) of the International Institute for Sustainable Development (IISD), Geneva, Switzerland, 2007. Available from http://www.globalsubsidies.org/files/assets/GSI_Investment_Incentives.pdf, p. 28.

USA challenged the World Trade Organzation (WTO) compatibility of China's Special Fund for Wind Power Equipment Manufacturing in 2010, on the argument that subsidies were granted conditional on the use of local inputs in violation of Article 3.1(b) of the Subsidies and Countervailing Measures (SCM) Agreement and that China had failed to notify the WTO of these measures[41]. In accordance with the United States Trade Representative (USTR), the fund 'provided grants to those Chinese wind turbine manufacturers that used locally-produced input rather than foreign imports… Individual grants had ranged from US $6 to 22 million, with several hundred million dollars being spent since the inception of the programme in 2008'[42].In June 2011, China notified that it had decided to formally revoke the legal measure that had created that programme[43].

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[41] See US Proclaims Victory in Wind Power Case; China Ends Challenged Subsidies, Bridges Weekly Trade News Digest , Volume 15, Number 21, 8th June 2011.
[42] Ibid.
[43] Ibid.

III. COOPERATION IN R&D

As noted above, despite the commitment originally contained in article 4.1(c) of the UNFCCC and the perceived need of massive investments in R&D, deployment and diffusion of technologies[44], it is little what has been achieved in the area of technological cooperation, particularly in relation to the development of adaptation technologies. As noted in a recent report, '[A] sustained scaling up and reform in international cooperation and finance are required to achieve the global technological revolution' [45]. Given the limitations of technology transfer from developed countries, and the need for a global effort to generate new technologies, developing countries must participate in the creation, transfer and diffusion of new technologies suitable to their conditions and development objectives. The UN report quoted above has noted that

> The required greater international cooperation… must encompass greater cooperation between developed and developing countries. During previous technological revolutions, beginning with the first industrial revolution, the role of developing countries was a limited one. Mainly, they were relegated to the status of colonies supplying material resources and providing captive markets. Based on their historical role, these countries continue, generally, to be viewed primarily as receivers of the technologies produced in developed countries. However, if the technology revolution for a green economy is to be successful, developing countries will need to be true partners in developing, utilizing and generally sharing the new technologies.

Despite the weaknesses and asymmetries in R&D capabilities in developing countries mentioned above, there is great potential for cooperation among developing countries and between them and developed countries. Several possible models for such cooperation exist. They can be categorized in accordance with a number of features, such as:

-whether they are 'pull' or 'push' mechanisms, based on incentives that operate on the demand (e.g. advance purchase contracts) or on the supply (e.g. subsidies for research);

-the type of R&D to be conducted (such as basic or applied research, development of pre-competitive or competitive technologies);

-the thematic fields selected for R&D;

-the type of cooperating parties (public, private, mixed);

-the policies regarding the generation and availability of R&D results for utilization or further research (intellectual property issues); and

-the organizational structure of the R&D activities.

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[44] The EGTT report mentioned above estimated that 'current financing for mitigation technologies needs to increase by USD 262.670 billion annually until 2030 (to a total of USD 332.835 billion annually)' (UNFCCC, 2009, p. 3).
[45] United Nations (2011), op. cit., p. xix.

These aspects are briefly explored in more detail below.

Push-pull mechanisms

The use of *push* and *pull* mechanisms to promote technological development critically depends on the kind of outputs sought (scientific knowledge, prototypes, etc.) and on the prospective market for new products. Pull mechanisms are particularly suited to overcome insufficient markets, which they may help to create or secure. Push mechanisms, such as subsidies, essentially aim at reducing the cost or risk of R&D[46].

An example of a 'pull' mechanism is the offer of a prize that may be awarded for reaching specified results (e.g. a product with certain characteristics) or some defined milestones in the R&D process. One advantage of this mechanism vis-à-vis 'push' conventional incentives, is that the prize is only paid when success has been achieved. So far, prizes have been successful in encouraging mechanical inventions, electronic systems, and engineering; they have also been proposed to encourage the development of health products needed to address diseases prevailing in developing countries. This is the case, for instance, of the Health Impact Fund (HIF).[47] Some non-profit and for-profit organizations have experimented in recent years with this approach.[48]

Another 'pull' mechanism is the 'advance market commitment' (AMC), which has also been broadly discussed to overcome market failures in health. For instance, in 2009 a pilot project was launched

> to supply 2 billion doses of pneumococcal vaccine by 2030, potentially averting 7 million childhood deaths. The pilot is useful for this vaccine in particular because versions of the vaccine effective against the virus form circulating in the developing world will soon be ready and may attract more than one supplier. The funding for this pilot project is a cooperative effort among many international stakeholders, including the governments of Canada, Italy, Norway, Russia, and the UK. Other parties are the Bill & Melinda Gates Foundation, the World Bank, the GAVI Alliance, and UNICEF[49].

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[46] It is worth noting that there has been considerable scholarly debate on whether innovation is primary driven by market demand (i.e. market needs) or by technological shifts (e.g. changes in technology). See, e.g., Chidamber, Shyam R., and Kon, Henry (1994) , 'A research retrospective of innovation inception and success: the technology-push, demand-pull question', *International Journal of Technology Management*, Volume 9, Number 1 , pp. 94-112.

[47] See Aidan Hollis and Thomas Pogge (lead authors) (2008), *The Health Impact Fund: Making New Medicines Accessible to All*, available at http://www.yale.edu/macmillan/igh/hif_book.pdf.

[48] For instance, the X PRIZE Foundation is an educational nonprofit organization 'whose mission is to bring about radical breakthroughs for the benefit of humanity, thereby inspiring the formation of new industries and the revitalization of markets that are currently stuck due to existing failures or a commonly held belief that a solution is not possible' (see http://www.xprize.org/about/who-we-are); Innocentive is a private company that organizes prize competition for clients to find technological solutions; currently, for instance, a prize of U$S 100.000 is offered to find 'solutions for a transformative and sophisticated insulin drug for patients with diabetes, to improve glucose control, decrease or eliminate the need to test or monitor blood glucose levels, and reduce their chances of short- and long-term diabetic complications' (https://www.innocentive.com/ar/challenge/9932818).

[49] See http://ghtcoalition.org/incentives-pull.php.

Type of R&D

Regarding the *type* of R&D, there is potential for cooperation in basic research and in different forms of applied research and technological development. The funding and organizational structure of such cooperation will significantly vary, however, depending on what their specific object is.

While there is a considerable tradition in *scientific cooperation* between North-North, North-South and South-South, there is much less in the technological arena. Unlike in the case of technologies, non-appropriable, public goods are typically created through scientific research, thus avoiding tensions and possible rivalry[50]. In addition, as noted, many developing countries have emphasized scientific rather than technological research, often under the assumption that there is a linearity between science and technology, that is, that investment in science will naturally lead to progress in the field of technology. This assumption has proven, however, to lead to an incorrect understanding of the dynamics of the innovation process[51].

Scientific cooperation in climate change-related areas is not only desirable but needed to avoid unnecessary duplication, and to share skills and resources to address difficult issues, especially those demanding an interdisciplinary approach.

Technological cooperation generally requires a more complex governance structure than that centered on science. Since the main *locus* of technological innovation is the firm, such cooperation is generally sought to enhance the competitive advantages of the cooperating parties. However, public sector entities also play an important role in the development of ESTs.

A key determinant of the modalities of cooperation is whether the technology to be developed is such that would create a *pre-competitive platform* for the further development of more specific technologies, or whether the latter is the case. The way in which the relationship between the cooperating parties is organized is crucial for technological cooperation. Four aspects are crucial:

1. The orientation or common predisposition to work together, whether this may involve taking advantage of or sharing an asset (generating economies of scale) or taking advantage of complementarity.
2. Dependence, deriving from the fact of different organizations working together.
3. The link which, in some way, is a measure of connection (albeit unspecified) between the parties which interact.
4. The investments made by the parties, which will determine the future obligation of the relation, and which normally materialize in the form of people and time.[52]

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[50] This does not mean, however, that rivalry and conflicts do not exist; in many cases, there is tough competition among scientific research teams to be the first to arrive at a discovery leading to prestige and eventually more funding for further research. See, e.g. Paula Stephan (1996), "The Economics of Science", *Journal of Economic Literature*, vol. XXXIV.

[51] See, e.g. Benoît Godin (2006), 'The Linear Model of Innovation. The Historical Construction of an Analytical Framework', *Science Technology Human Values*, vol. 31 no. 6, p. 639-667.

[52] See Nieves Arranz and Juan C. Fdez. de Arroyabe (2009), 'Technological Cooperation: a New Type of Relations in the Progress of National Innovation Systems', *The Innovation Journal: The Public Sector Innovation Journal*, Volume 14(2), p. 5., who quote Johanson, J. and Mattson, L.G. (1987), "Interorganisational Relations in Industrial Systems: A Network Approach Compared with a Transaction Cost Approach",

Such cooperation may be crucial for developing countries in the area of climate change-related technologies. Development is generally more costly than research, except when it focus on incremental changes or adaptations; the pooling of funds and human resources may be the only option for developing countries to undertake large-scale or complex technological projects.

Typical objectives of technological collaborations are sharing limited resources, minimizing costs, reducing risks and achieving economies of scale and/or rationalization. However, they may be more *strategic* in nature and seek a number of indirect effects, such as strengthening the partners' capacity to undertake R&D, as well as keep open *options* that may be foreclosed in the absence of the cooperation. For this reason, the mere cost-benefit analysis of a strategic alliance based on inputs-ouputs may be inadequate.[53]

Technological cooperation may, among other advantages, shorten research duration, reduce transaction costs, make it possible to reach the critical threshold necessary for undertaking large-scale projects, and spread a new technology more rapidly.[54]

Finally, cooperation schemes between R&D entities may differ depending on the resources that each of the partners bring thereto. They may be classified as:

- 'symmetrical' when partners bring together similar resources to generate economies of scope, rationalize capacity, transfer knowledge, or share risk; and

- 'complementary' where partners contribute different assets and build on their respective strengths and advantages.

Thematic fields

Establishing the *themes* for scientific and technological cooperation is one of the greatest challenges from a technical, economic and political point of view. R&D is subject to different levels of risks (the highest for basic science, the lowest for incremental technological developments) and, in view of limited resources, choosing the targets to be achieved is a challenging task. The rationale for such choices in the private and public sectors would normally differ substantially. As noted above, the private sector accounts for a great portion of investment in R&D; as a consequence, a large part of resources will be oriented by the expectation of profit gains. The extent to which the public sector may influence (through incentives of different type) the patterns of private R&D is an open question.

In accordance with the UNFCCC Secretariat,

> further research on carbon capture and storage, hydrogen and fuel cells, biofuels, power storage systems and micro-generation, clean energy technologies, early warning

International Studies of Management Organisation, 17(1), 34-48.

[53] See, e.g., Doz, Yves and Hamel, Gary (1998), Alliance Advantage. The art of creating value through partnering, Harvard Business School Press, Boston, p. 9-10 and 12.

[54] Arranz and Fdez. de Arroyabe, op. cit., p. 8 (references ommitted).

> systems for extreme weather events and biotechnology will also be required – which will in turn require a range of government support packages[55].

The UNFCCC Secretariat also noted that

> Many developing countries have undertaken detailed assessments of their technology needs. A synthesis of technology needs in 69 developing countries was prepared in 2009…The most commonly identified technology needs for mitigation were renewable energy technologies, technologies for improved crop management, energy-efficient appliances, waste management technologies, forestry-related technologies and more clean and efficient vehicles. The most commonly identified technology needs for adaptation were related to crop management, efficient water use, improving irrigation systems, technologies for afforestation and reforestation, and technologies to protect against and accommodate rises in sea level[56].

On the other hand, the EGTT report mentioned above found a 'weak coverage on technologies for adaptation' and that

> the portfolio of existing R&D programmes are strongly focused on energy technologies, in particular on renewable energy. There are far fewer collaborative R&D activities in industry, transport and energy efficiency in buildings, and forestry, agriculture and waste are covered only within more general programmes[57].

Type of cooperating parties

Technological cooperation may involve different *parties* both from the public and private sectors. There are abundant examples of public-private cooperation in various fields for the development of technologies and in scientific research. Governments in developed and many developing countries have made significant efforts to promote such cooperation through direct incentives and by giving private partners the right to assert intellectual property rights emerging from cooperative activities[58]. A large number of public-private-partnerships (PPPs) have been established, for instance, with the objective of developing drugs and vaccines. One example is the *TB Alliance* financed by public agencies and private foundations which, in association with research institutes and private pharmaceutical companies, aims at developing novel treatments for tuberculosis that are affordable and accessible to the developing world[59]. PPPs commonly use some private sector approaches to address R&D challenges; their primary objective is public health rather than a commercial goal; and their principal funders

[55] UNFCCC, Second synthesis report on technology needs identified by Parties not included in Annex I to the Convention. Note by the secretariat, Document FCCC/SBSTA/2009/INF.1, Bonn, UNFCCC, 2009. Available from http://unfccc.int/resource/docs/2009/sbsta/eng/inf01.pdf (references ommitted).
[56] Ibid. (references ommitted).
[57] UNFCCC (2009), p. 26.
[58] The model adopted by the US Bayh-Dole Act has influenced policy making in many developing countries, such as South Africa, Malaysia and India. See, e.g., Anthony D. So, Bhaven N. Sampat, Arti K. Rai, Robert Cook-Deegan, Jerome H. Reichman, Robert Weissman and Amy Kapczynski, 'Is Bayh-Dole Good for Developing Countries? Lessons from the US Experience', *Plos Biology*, 6(10): e262, available at http://www.plosbiology.org/article/info:doi/10.1371/journal.pbio.0060262.
[59] See www.tballiance.org/.

are foundations rather than governments[60]. This latter feature raises concerns about the long term viability of these initiatives.

The Asia-Pacific Partnership on Clean Development & Climate, established in 2005 by Australia, Canada, India, Japan, the People's Republic of China, South Korea, and the United States, is an example of governmental cooperation to accelerate the development and deployment of clean energy technologies. The objectives of the Partnership are to:

- Create a voluntary, non-legally binding framework for international cooperation to facilitate the development, diffusion, deployment, and transfer of existing, emerging and longer term cost-effective, cleaner, more efficient technologies and practices among the Partners through concrete and substantial cooperation so as to achieve practical results.
- Promote and create enabling environments to assist in such efforts.
- Facilitate attainment of our respective national pollution reduction, energy security and climate change objectives; and
- Provide a forum for exploring the Partners' respective policy approaches relevant to addressing interlinked development, energy, environment, and climate change issues within the context of clean development goals, and for sharing experiences in developing and implementing respective national development and energy strategies[61].

The areas identified for cooperative work include cleaner fossil energy, renewable energy and distributed generation, power generation and transmission, steel, aluminum cement, coal mining, buildings and appliances.[62]

Policies regarding availability of R&D results and IPRs

R&D creates intangibles that, by their very nature, are public goods, that is, goods that are non-rival and non-excludable[63]. Non-rival goods have the property that they can be available for public use[64]. Knowledge may become excludable by action of its possessor (limitations to access, secrecy) or by legal means (e.g. patent protection).

Technological cooperation may be based on different models regarding the appropriability of the results obtained. They may include the generation of results for which IPRs are not claimed or asserted, that is, they remain freely available without prior authorization or compensation. Such results, however, may be protected by IPRs, such as patents, and its utilization by third parties subject to different conditions such as:

- licensing agreements with payment of a compensation;

- licensing agreements without compensation or with special conditions for utilization by certain categories of parties, in certain countries or for specific purposes.

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[60] See Report of The Commission on Intellectual Property Rights, Innovation and Public Health (CIPIH) (2006), WHO, Geneva, p. 72.
[61] See http://www.asiapacificpartnership.org/english/about.aspx.
[62] Ibid.
[63] See, e.g., Joseph Stiglitz (1999), "Knowledge as a global public good", Kaul, Inged, Grunberg, Isabelle and Stern, Marc, (Eds.), *Global public Goods. International Cooperation in the 21 ST Century*, New York, p. 309.
[64] Once knowledge has been created, its use by one agent does not reduce the amount or quality of the knowledge available for use by others.

An example of a cooperative R&D arrangement designed to produce freely available R&D results is the case of the Consultative Group on International Agricultural Research (CGIAR) which will be reviewed in more detail below.

The negotiation of licensing agreements with payment of a compensation could be necessary to recover R&D costs and to finance further R&D, and to avoid 'free riding' by others. Many public R&D institutions have adopted this approach in the last two decades. In the area of agricultural research, for instance, some institutions in developing countries started to request plant variety protection to be able to obtain compensation from private companies that utilized their improved varieties.

An example of the model based on licensing agreements without compensation or with special conditions for utilization by certain categories of parties, in certain countries or for specific purposes, is provided by the 'humanitarian license reservation' (or 'equitable access license') proposed by a number of institutions and universities[65], whereby title-holders leave open the possibility of sharing their technology with third parties for the benefit of people in need. For instance, the policy statement of a US university part of the 'Universities Allied for Essential Medicines' notes that

> Equitable Access Licensing works by segmenting the world market—any drug developed using an upstream university innovation can remain under patent protection in countries where the pharmaceutical industry earns the vast majority of its revenue. Generic competition is allowed only in markets where there is little access—and therefore little revenue—in the first place. For any given product, then, a pharmaceutical company's bottom line remains relatively intact, and, by extension, any decrease in revenue from licensing at Penn [University of Pensylvannia) would be vanishingly small.[66]

Another example is the case of the 'golden rice', a genetically engineered rice rich in Vitamin A, where certain 'humanitarian uses' are allowed, as shown in Box 2.

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[65] See, e.g., Brewster, Amanda L., Chapman, Audrey R., Hansen Stephen (2005), 'Facilitating Humanitarian Access to Pharmaceutical and Agricultural Innovation', *Innovation Strategy Today*, Vol. 1, 3 (2005), available at http://www.biodevelopments.org/innovation/ist3.pdf.

[66] Available from http://www.med.upenn.edu/uaem/issues.shtml.

Box 2
Golden rice sub-licensing agreements

1. The inventors[67] have assigned their exclusive rights to the *Golden Rice* technology to Syngenta.
2. Syngenta added some further technologies, and arranged licences with other companies for some additional technologies to be included in the original *Golden Rice*.
3. Syngenta, in turn, has given the inventors a humanitarian licence with the right to sublicense public research institutions and low-income farmers in developing countries, to the full set of necessary technologies.
4. Syngenta retains commercial rights, although it has no plans to commercialize *Golden Rice*.
5. 'Humanitarian Use' means (and includes research leading to):
Use in developing countries (low-income, food-deficit countries as defined by FAO)
Resource-poor farmer use (earning less than US$10,000 per year from farming)
The technology must be introduced into public germplasm (= seed) only (see below).
No surcharge may be charged for the technology (i.e. the seed may cost only as much as a seed without the trait)
National sales are allowed by such farmers (in this way urban needs can also be covered)
Reusing the harvested seed in the following planting season is allowed (the farmer is the owner of his seeds)
6. Regulatory imperative and national sovereignty, i.e. *Golden Rice* may not be released in a country lacking biosafety regulations, and the decision to adopt the technology is a national matter.
7. No export allowed (except for research to other licensees): this is a humanitarian project, i.e. the seeds are meant to cover the daily requirements of the poor populations that are deficient in vitamin A.
8. Improvements to licensed technology:
Commercial rights of improvements to the technology go to Syngenta, but Humanitarian Use of such improvements is guaranteed under the same terms of the original agreement
9. No warranties are given by licensor/s.

[67] Prof emeritus Ingo Potrykus, of ETH-Zurich and Prof Peter Beyer, of the Univ of Freiburg.

Organization of the R&D activities

One of the most critical issues for cooperation in R&D is its organization and governance, including funding, coordination, relationship between partners and third parties, sharing of costs and benefits, and the management[68] of the agreed upon activities.

There is a variety of models that may be applied, ranging from the conventional schemes of inter-institutional relations governed by agreements where the participants, objectives, fund allocation, tasks, etc. are defined, to the creation of a an institutionalized network of research institutions, resorting to a common pool of resources and services[69].

An interesting example of an innovative cooperative organization for R&D is the Open Source Drug Discovery (OSDD), inspired in the Open Source model for software development and the Human Genome Project.[70] OSDD was launched by the Council of Scientific and Industrial Research (CSIR) of India,

> with a vision to provide affordable healthcare to the developing world by providing a global platform where the best minds can collaborate & collectively endeavor to solve the complex problems associated with discovering novel therapies for neglected tropical diseases like Malaria, Tuberculosis, Leshmaniasis, etc. It is a concept to collaboratively aggregate the biological and genetic information available to scientists in order to use it to hasten the discovery of drugs…The OSDD consortium launched in September 2008 has more than 4500 registered users from more than 130 countries around the world, and has emerged as the largest collaborative effort in drug discovery. Launched on the three cardinal principals of Collaborate, Discover & Share, it is a community driven open innovation platform to address the unmet need of research and development of drugs for diseases that affect the developing world. Its objective is affordable health care.[71]

OSDD aims at accelerating research and reducing its cost; all the projects and the research results are reported on the web based platform http//sysborg2.osdd.net. [72]. In addition, 'to ensure affordability, the drugs that come out of the OSDD platform will be made available like a generic drug, without Intellectual Property encumbrances'. [73]

OSDD is supported by direct funding from the Government of India of Rs. 46 Crores (about US$12 Million), with an overall project outlay of about US$46 Million[74]. Although this scheme seems essentially suitable for the discovery phase of new products, the aim of the

[68] Although most literature on technological cooperation focuses on issues related to cooperation formation, adequate management is essential to achieve a satisfactory performance. See, e.g., Chen, Hung-hsin (2003), *Cooperative Performance. Factors Affecting the Performance of International Technological Cooperation*, University of Manchester, Manchester.
[69] The example of the CGIAR is considered in a separate section below.
[70] See http://www.osdd.net/about-us.
[71] Ibid.
[72] Ibid.
[73] Ibid.
[74] Ibid.

OSDD is to also undertake clinical trials if potential candidate molecules are identified, eventually in partnership with the private sector.

IV. THE CGIAR MODEL[75]

Several proposals have been made to foster climate change R&D and ensure a broad availability of their results. They include the establishment of specialized international funds, such as a 'multilateral technology fund'[76], and the setting up of 'regional R&D networks of existing indigenous research institutions in developing countries for climate change technology development and commercialization that permit sharing of resources and cost for innovation infrastructure and expensive equipment'.[77]

At the Delhi High Level Conference on 'Climate Change: Technology Development and Transfer', held on 23rd October 2009, a proposal was made to create a network of international research institutes inspired by the CGIAR. In accordance with the Chair's summary of the Conference:

> The second lesson we will take away from here is what President Nasheed called a Green Power Revolution, learning from the lessons of the Green Revolution in which India led the way, with international cooperation, in the 1960s and 1970s, to address what was then the most formidable threat faced by developing countries, the threat of famine and food insecurity. Several speakers alluded to the CGIAR network as a model for addressing the challenge of climate change as well as energy poverty. As you are aware, the Green Revolution relied on an elaborate mosaic of interlocking institutions for research, education, credit, marketing, inputs provision, and most importantly, extension—getting the knowledge into the hands of those who needed it. Within 10 years we had transferred knowledge from a few hundred scientists to millions of farmers, the vast majority of whom were illiterate. The CGIAR network provided international support and cooperation in research and education (paragraph 9) [78].

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[75] This section is partially based on Carlos Correa (2009), 'Fostering the Development and Diffusion of Technologies for Climate Change: Lessons from the CGIAR Model', ICTSD, Geneva, available at http://ictsd.org/downloads/2009/12/climate_change_technology_an_-the-_cgiar.pdf.

[76] *World Economic and Social Survey* 2009, p. 147, Available from http://www.un.org/esa/policy/wess/wess2009files/wess09/chapter5.pdf. It has also been proposed to create an international fund to match developing country commitments to targeted climate change R&D undertaken at developing country universities and other research institutions. See Cynthia Cannady (2009), *Access to Climate Change Technology by Developing Countries: A Practical Strategy*, ICTSD ,Issue Paper, Geneva, available at http://ictsd.org/i/publications/58385/. See also a proposal to negotiate a binding agreement to enhance access to basic science and technology by developing countries at reasonable cost, in John Barton and Keith E. Maskus (2006), 'Economic perspectives on a multilateral agreement on open access to basic science and technology', in Simon J. Evenett and Bernard M. Hoekman, eds, *Economic Development and Multilateral Trade Cooperation*, Basingstoke, World Bank and Palgrave MacMillan, United Kingdom.

[77] See also Cynthia Cannady (2009). *Access to Climate Change Technology by Developing Countries: A Practical Strategy*, ICTSD Programme on IPRs and Sustainable Development, Issue Paper 25, Geneva, available at http://ictsd.org/i/publications/58385/.

[78] Chair's Summary of the Delhi High Level Conference on 'Climate Change: Technology Development and Transfer', 23rd October 2009. Available from http://moef.nic.in/downloads/public-information/Chair%27s%20summary-FINAL.pdf

> A CGIAR type of global network could provide international support for research and cooperation and ensure that they become centers of excellence (paragraph 10).

The 2010 World Development Report - Development and Climate Change- has also raised the question about the CGIAR as a model for climate change[79], while a report by the Clean Energy Group and the Meridian Institute has suggested that the CGIAR's 'Challenge Programs'[80] may provide a good model for technology sharing and cooperative research to foster open and distributed innovation. [81] Similarly, the already mentioned World Economic and Social Survey 2011 also suggested the CGIAR as an example of a successful mechanism to achieve the rapid worldwide diffusion of new technologies.[82]

History

The CGIAR was born in 1971 as a result of the joint initiative of a number of international and bilateral agencies, supported by the Ford and Rockefeller Foundations. The CGIAR emerged as a loose network of international agricultural research centres that, although independently managed, worked together to create and disseminate improved plant varieties[83] in the context of what has been termed the 'Green Revolution', with the goal of alleviating hunger and poverty. Various factors decisively contributed to the establishment of the CGIAR:

a) During the 1960's there was significant public and scientific concern about a 'Malthusian' threat of a world food crisis, that is, the risk 'that rapidly rising population in developing countries would soon outstrip the world's capacity to provide food.'[84] This was associated with a sense of urgency to address the widespread problem of hunger in developing countries.

b) Successful experiences with the development of and diffusion of high-yielding varieties, initially in Mexico, India and Pakistan, created the perception that, given the available scientific and technological tools, targeted research could be undertaken to significantly increase food production in developing countries. In particular, work by Norman Borlaug on semi-dwarf, high-yield, disease-resistant wheat varieties created the basis for a revolutionary transformation of agriculture, by putting improved varieties and other agricultural technologies within the reach of small farmers in those countries.

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[79] *The 2010 World Development Report - Development and Climate Change*. Available from http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTRESEARCH/EXTWDRS/EXTWDR2010/0,,menuPK:5287748~pagePK:64167702~piPK:64167676~theSitePK:5287741,00.html, p.306.

[80] See below.

[81] See Clean Energy Group and the Meridian Institute (2009), *Accelerated Climate Technology Innovation Initiative (ACT II):A New Distributed Strategy to Reform the U.S. Energy Innovation System*, available at http://www.cleanegroup.org/Reports/ACTII_Report_Final_November2009.pdf.

[82] United Nations (2011), p. xx.

[83] As mentioned below, the CGIAR later adopted a more holistic view of agriculture and expanded its activities to other areas of biodiversity.

[84] Warren Baum, *CGIAR-How it all began*, A 1985 Report Reprint, 1988. Available from www.worldbank.org/html/cgiar/publications/cgbaum.pdf.

c) The constitution of the CGIAR built on the previous creation, with the support of the Ford and Rockefeller Foundations, of four international research centres specialized in particular crops: the International Rice Research Institute (IRRI) in the Philippines (rice), the Centro Internacional de Mejoramiento de Maiz y Trigo (CYMMIT) in Mexico (wheat and maize), the International Institute of Tropical Agriculture (IITA) (crops for low, humid tropics) and the Centro Internacional de Agricultura Tropical (CIAT) (tropical crops).

d) The heads of FAO, UNDP, the World Bank, of British, Canadian, Swedish and U.S. aid organizations, were personally involved in the process leading to the creation of the CGIAR. The Asian Development Bank, the Inter-American Development Bank, Japan's Ministry of Foreign Affairs also participated. The Ford and Rockefeller Foundations had a decisive role in this process. The World Bank offered technical advice and financial assistance and provided the secretariat to the new institution.

e) An independent Technical Advisory Committee (TAC), composed of scientists and research administrators, was created in order to define priorities and assess CGIAR's activities. TAC - replaced in 2004 by the 'Science Council'- was effective in defining the overall CGIAR research strategies. It subjected the Centres to periodic and thorough evaluations, conducted by external teams of scientists and other experts. Despite the Centres' independence, the extent to which they contributed to the CGIAR general mission was permanently scrutinized by a centralized unit.

f) While the main focus of the CGIAR Centres has been biological research in various fields, social science played a significant role in determining their objectives and modes of operation. Gender, malnutrition, poverty, international norm setting[85], *inter alia*, became issues of system-wide relevance. In particular, the International Food Policy Research Institute (IFPRI), which was associated to the CGIAR in 1980, provided economic analysis for the system's operation.[86]

The CGIAR is a strategic partnership with 64 Members that include 21 developing and 26 developed countries, four co-sponsors as well as 13 other international organizations. Most of the funding is provided by development assistance agencies of developed countries. The World Bank covers the Secretariat costs in Washington D.C. The CGIAR operates a center-driven coalition of 15 research Centres.[87] The Centres are *international* legal entities established on the basis of specific agreements with the host countries.

The CGIAR was conceived as 'a loose federation of independent centres' and not as 'an organization at all, but an arrangement for consultation'.[88] Each Centre is managed by its own

[85] The CGIAR has been actively involved, through the International Plant Genetic Resources Institute (IPGRI), recently renamed as Bioversity, in the design and implementation of international agreements and rules in the area of plants genetic resources for food and agriculture.
[86] Centres' staff included economists nearly since the beginning of the CGIAR. See Dana G. Dalrymple (2006), 'International Agricultural Research as a Global Public Good: Concepts, the CGIAR Experience, and Policy Issues', *Journal of International Development*, Volume 20 Issue 3, pp. 347 – 379.
[87] The number of Centres reached 17 in the 1990's, later reduced to 15 as a result of mergers.
[88] Baum, op. cit. p. 10.

board, has an independent budget, and can seek funding for its own activities. While the core operations of the Centres has been supported by 'unrestricted' funding (that is, not linked to specific tasks or projects), the relative weight of 'restricted' (that is, targeted) funding grew over time, possibly to the detriment of activities of global interest as opposed to those of national or regional relevance.[89] Since contributions to the CGIAR are entirely voluntary, the level of funding is one of the constant challenges faced by CGIAR's management and the Centres themselves. The system, however, has been successful in securing funding for their activities, subject to the limitations found in all types of public research activities.[90]

The existence of the CGIAR has permitted the Centers to share resources and coordinate policies at the system level, and thereby generate economies of scale and of scope that enhance the Centres's capacity to perform their missions. The Centres rely on more than 8,000 scientists and staff, with activities in over 100 countries.[91] Although at its inception the CGIAR research focused on the diffusion of the Green Revolution (essentially through increases in the productivity of foodgrains), as economic and social changes took place in developing countries, its work expanded into areas of natural resources management, problems of the poor (including enhancing the micronutrient content of food staples) and analysis of policy and institutional issues.[92] Currently, the CGIAR mission is:

> to achieve sustainable food security and reduce poverty in developing countries through scientific research and research-related activities in the fields of agriculture, forestry, fisheries, policy, and environment'. The priorities of CGIAR research are defined as follows[93]:

- Reducing hunger and malnutrition by producing more and better food through genetic improvement
- Sustaining agriculture biodiversity both *in situ* and *ex situ*
- Promoting opportunities for economic development and through agricultural diversification and high-value commodities and products
- Ensuring sustainable management and conservation of water, land and forests
- Improving policies and facilitating institutional innovation.[94]

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[89] In accordance with Dalrymple, this may have contributed to the CGIAR's shift from a 'science-driven' to a 'donors-driven' model leading to under-emphasis on *global* public goods. See Dana G. Dalrymple (2006), op. cit.

[90] The total CGIAR revenues in 2008 were $553 million. They doubled the revenues obtained in 1994 (See http://www.cgiar.org/who/members/funding.html). However, in constant terms total funding 'increased by only $21million (in 2007 dollar terms) from 1995 to 2007, a rise of less than half a per cent in 12 years. Furthermore, 36 percent of funding in 2007 was unrestricted as compared with 63 percent in 1995 and 100 percent in 1972. In addition, a lack of coordination among investors results in sub-optimal resource use' (CGIAR Change Steering Team, 2008,, *A Revitalized CGIAR — A New Way Forward: The Integrated Reform Proposal*, , Washington, DC, p. 2, available at http://www.cgiar.org/pdf/agm08/agm08_reform_proposal.pdf).

[91] See http://www.cgiar.org/who/index.html.

[92] See Science Council, *An Assessment of the Impact of Agricultural Research in South Asia since the Green Revolution* (2008), which reviews and assesses the large body of evidence on the impacts of agricultural research by the CGIAR and its partners in South Asia, p. xi, available at http://impact.cgiar.org/eims_search/1_dett.asp?pub_id=249792

[93] See http://www.cgiar.org/who/index.html.

[94] Idem.

The CGIAR system produces a number of global public goods[95], such as the maintenance of the world's largest collection of germplasm of various crops. However, the extent to which the Centres operate globally vary significantly. Although most of them function with a global reach, 'there is a tendency to emphasize one or two regions, particularly Africa'.[96]

In addition, the expansion of IPRs in different areas of biodiversity, and the growing role of the private sector in agricultural research, required the adaptation of the Centres' *modus operandi* to a new reality. In accordance with the Science Council,

> the Centers have found, increasingly and particularly in the molecular biology area, that they need to be able to use proprietary technologies; the need for and the implementation of humanitarian licences have become much debated; biotech crops, with varying levels of statutory protection but still under the control of an increasingly consolidated international plant breeding industry, are now being grown widely in a number of developing countries; and, the System has had its first experiences of third party IP in its own biotech crops.[97]

Despite the proposal of a system wide IPRs policy elaborated in 2000[98] and the establishment of a Central Advisory Service for Intellectual Property (CAS-IP), defining a common approach to IPRs has posed a complex challenge to the CGIAR Centres. The Genetics Resources Policy Committee (GRPC) elaborated a new proposal on the subject. In accordance with this proposal, the Centres might only exceptionally seek or assert intellectual property rights, such as when it is indispensable to ensure further development of a research

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[95] The concept of 'global public goods' was first used by TAC in 1997 and defined by the Science Council in 2005 as 'as data, information, and value-added information and services based on data and information that are :

- Searchable and located in repositories (electronic)

- Globally available

- Open and easily accessible to all

- Demonstrably sustainable

- Contributing substantially to the CGIAR mission'. See Science Council (2005), Consultative Group on International Agricultural Research, *CGIAR Research Priorities 2005-2015. Draft*, Science Council Secretariat, FAO, Rome. See also Katell LE GOULVEN and Selim LOUAFI (2008), 'Biens publics mondiaux : de la théorie à la pratique', *Techniques financieres et developpement*, No. 91, p. 20.

[96] Dana G. Dalrymple (2006), op. cit.

[97] Science Council Secretariat, *CGIAR research strategies for IPG in a context of IPR. Report and Recommendations Based on Three Studies*, 2006, p. 1. Available from *www.sciencecouncil.cgiar.org/fileadmin/.../Reports/IPR_Report_Web.pdf.*

[98] See GRPC (2002), *Guiding Principles for the Consultative Group on International Agricultural Research Centers on Intellectual Property Relating to Genetic Resources*, Report of the 11th Meeting of the GRPC for ICW2000, Appendix 3, available at http://www.cgiar.org/corecollection/docs/icw0009.pdf.

result, or to get access to technologies under the control of private companies that are needed to fulfill the CGIAR mission.[99]

A distinct feature of CGIAR's operation is the constant efforts made to identify and evaluate the impact of the Centres' activities. According to an independent review conducted in 2008 of CGIAR's governance, scientific work and partnerships, 'its research has produced high returns since its inception, with overall benefits far exceeding costs… Even under the most conservative assumptions, they far outweigh total research expenditures of $7.1 billion since 1960 (expressed in 1990 dollars)'.[100] The impact of policy-oriented research has also been positively evaluated in 2007-2008 by the CGIAR's Standing Panel on Impact Assessment.[101]

The CGIAR's Organization

The Chair of the CGIAR, usually a Vice President of the World Bank, is nominated by the World Bank's President and endorsed by CGIAR members. As mentioned, the World Bank facilitates the services of a professional secretariat to the CGIAR. The Director of the CGIAR, act as Chief Executive Officer and heads the CGIAR Secretariat.[102] In addition, a 'virtual' System Office was created to integrate services provided to the Centres by the CGIAR Secretariat and other office units[103], including strategic planning and development, monitoring and evaluation, communication and resource mobilization and management.

Annual General Meetings (AGMs) provided CGIAR members and stakeholders a forum for discussion about needs to be addressed, strategies and programmes. The Genetic Resources Policy Committee and the Private Sector Committee were established to deal with particular issues and ensure the participation of civil society and other stakeholders in CGIAR debates and activities.

The CGIAR's organization and programming approach has changed over time in order to adapt to changing realities and perceived needs. Two significant changes were undertaken in the last ten years. In 2001, a 21-member Executive Council was established in order to act on behalf of the CGIAR on matters delegated to it by the Group, facilitate decision-making, provide oversight during the implementation of the Group's decisions, and ensure continuity between the AGMs. In addition, the Alliance Executive (AE) of the CGIAR Centers provides support and perspective on system wide issues and on technical and management concerns of the Centers, while the Alliance Board (AB) makes recommendations to the individual Boards

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[99] See the proposal by the CGIAR Genetics Resources Policy Committee for a 'Policy of the Alliance of CGIAR Centres on Intellectual Assets', available at http://cgiar.org/pdf/grpc_25th_meeting_minutes.pdf.

[100] See http://www.cgiar.org/pdf/pub_cg_corp_folder_inserts_IMPACT_10_09.pdf. Based on the development of a counterfactual scenario of world food production without CGIAR contributions, it was found that 'world food production would be 4-5% lower, and developing countries would produce 7-8% less' and 'world grain prices would be 18-21% higher' (Idem).

[101] See http://impact.cgiar.org/eims_search/briefs.asp#Impact%20Assessment%20of%20Policy-Oriented%20Research%20in%20the%20CGIAR:%20Evidence%20and%20Insights%20from%20Case%20Studies.

[102] See http://www.cgiar.org/who/structure/executive/index.html.

[103] These units are: Central Advisory Service on Intellectual Property, Alliance Office, Gender & Diversity Program, Media Unit, Science Council Secretariat, Internal Audit and Human Resources Unit.

about policies, methodologies and practices. In addition, a set of 'Challenge Programs' was established. A 'Challenge Program' is 'a time-bound, independently-governed program of high-impact research, that targets the CGIAR goals in relation to complex issues of overwhelming global and/or regional significance, and requires partnerships among a wide range of institutions in order to deliver its products'.[104] While for some CGIAR members these programs should have reinforced the CGIAR's role as producer of public goods (by allowing, *inter alia*, broader cooperation with different partners), the new CGIAR vision and strategy, as adopted in 2000, rather gave preference to a *regional* focus in research in order to complement and supplement the national approach.[105]

In December 2008, the CGIAR decided to significantly change its governance structure in order to establish a results-oriented research agenda, clarify accountability across the system, and streamline governance and programs for greater efficiency.[106] The AGMs has been replaced by a biennial Global Conference on Agricultural Research for Development, which is intended to provide a consultation forum for stakeholders to provide input into the formulation of the CGIAR strategy. Under the new organizational model, a 'more programmatic approach than in the past' will be taken through "mega-programs" that would 'bring CGIAR scientists and partners together to address critical issues and deliver international public goods that advance global development objectives'.[107] A 'Consortium of the CGIAR Centers' and a 'CGIAR Fund' was established. The Consortium will provide a single entry point for the Fund to contract research products from the Centers and partners.

The new governance structure entails significant changes for Centres' operations. The new 'Consortium of the CGIAR Centers' is a *new legal entity* intended to unite the Centers.[108] The CGIAR Fund is a new

> multidonor, multiyear funding mechanism set up to provide strategic financing to support priority agricultural research areas...[It] will finance Mega Programs under the SRF [Strategy and Results Framework] for implementation by the Centers and their partner institutions implementing the Programs. It is intended to facilitate harmonization of donor support by providing a single entry point for financing through three designated funding "windows".[109]

Can the CGIAR model be applied in the area of climate change?

The focus of the Centres' research, the significant spillovers of their activities, their strong interaction with national agricultural research institutions, and their autonomy to

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[104] See http://www.cgiar.org/impact/challenge/index.html. The Programs approved so far are: Water and Food**,** HarvestPlus (interdisciplinary, research to breed nutrient dense staple foods)**,** Generation (use of molecular biology to create a new generation of plants)**,** the Sub-Saharan Africa Challenge Program (SSA CP)**,** Climate Change, Agriculture and Food Security" (CCAFS)**.**
[105] See Technical Advisory Committee (2001), *Regional Approach to Research for the CGIAR and its Partners*. TAC Secretariat, SDR/TAC:IAR/01/09, FAO, Rome.
[106] See http://www.cgiar.org/changemanagement/index.html.
[107] Idem.
[108] Idem.
[109] See http://www.cgiar.org/exco/exco17/exco17_cgiar_fund_development.pdf.

pursue their specific missions, have been crucial for the Centres' successful performance in the almost 40 years of the CGIAR's existence.

However, changing circumstances, including the broadening of the Centres' mandates, the reduction in unrestricted funding, and the growing role of the private sector in agricultural research, have required significant adjustments in the policies and organization of the CGIAR[110].

While the CGIAR´s experience may provide useful lessons, the possibility of establishing a similar network of institutions for the coordinated development and broad diffusion, as public goods, of climate change adaptation and mitigation technologies, poses a large number of political, strategic and managerial challenges.

Science is normally more amenable to cooperative work and dissemination as a public good than technology, which generally requires adaptation to particular needs and circumstances. In an international scenario dominated by the private development and appropriation of technologies, a set of public institutions of excellence in research would be a useful mechanism to undertake a common program of activities. Existing national institutions may welcome additional international funding, but governments may be reluctant to lose control over them.[111] Given the vast array of fields where research is needed to generate adaptation and mitigation technologies, defining a set of priorities would require scientific competence and political commitment. A mechanism of monitoring and evaluation should also be put in place. As the CGIAR experience shows, such a mechanism would be essential to define priorities, ensure an efficient utilization of resources and to achieve the concrete results that are urgently needed.

In designing a possible international network of research institutions to work on climate change technologies, the following issues should be considered:

- selection of participating institutions or establishment of new ones;
- funding mechanism and plans;
- governance of collaborating institutions and capacity to engage in joint research;
- mechanisms to determine research priorities, distribute tasks, monitor progress and evaluate the achievement of the defined objectives;
- conditions for cooperation with and use of technologies held by the private sector;
- establishment of common policies on diffusion of research outputs and use of the IPRs system;
- participation of developing countries´ institutions in research and means for facilitating access by developing countries to all relevant research results.

[110] In accordance with the CGIAR Change Steering Team, '[S]ince its inception in 1971, the CGIAR System has evolved into an increasingly complex entity, characterized by complicated governance structures. The result is a loss of efficiency due to overlaps in mandates, cumbersome monitoring and review procedures, an inability to harmonize funding and resource allocation and a lack of authority to enforce decisions. There is no mutually agreed "compact" outlining the obligations of donors and Centers (CGIAR Change Steering Team, op. cit., p.2).

[111] As noted above, the CGIAR Centres are *international* entities that are not subject, hence, to the jurisdiction of the national government of the country where each Centre was established.

V. CONCLUSION

Technology is crucial to face the effects of climate change. The diffusion of existing technologies and the development and transfer of new ones need to be undertaken on a large scale and in the short term. The unprecedented challenge posed by climate change finds the developing countries in a phase of expansion of their R&D capacity, but with growing differences among them. While national efforts may be feasible and show positive results in some cases, they are likely to be insufficient to provide the necessary tools that those countries need.

Since the adoption of the UNFCCC, technological cooperation has been on the agenda, but little action has been taken. There seems to be, however, an increasing recognition, at least by developing countries, that such cooperation must be effectively implemented. There are different models to do so and, understandably, delicate decisions to be made. But there are useful experiences and many options open for policy makers to put in practice what has so far remained a mere aspiration.

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