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Towards a Framework for Conceptualising International Cooperation in Science Technology and Innovation

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Abstract: This paper proposes a framework to identify the various dimensions inherent in the concept of international cooperation in science, technology, and innovation (STI). The study employed two methods to identify an integrative framework where the agency perspectives of international cooperation can be integrated and contrasted. First, surveys of four major international cooperation agencies with an explicit commitment to STI funding were conducted. The study looked at how individual agencies define and classify this type of investment as well as their approach to development and innovation. Second, we distil from the literature two innovative theoretical frameworks that inform international cooperation in STI initiatives. The first approach focuses on the inputs and outputs of innovation, and the second is the Systems of Innovation that emphasises the capabilities and development of actors, institutions, and organisations that participate in national innovation systems. Building upon these two methods, we posit a set of minimum attributes that any STI governance system should have. We also provide a tentative typology of such a system.

Keywords: Governance, Science, Technology and Innovation, International Cooperation, Systems of Innovation

JEL Classifications: F50, F55, O19, O33.

1. Introduction

There is a gap in the literature on the global governance of technology and development with respect to international cooperation in science, technology, and innovation (STI). The majority of studies on international STI projects are conducted by the cooperation agencies themselves using their own conceptual frameworks, methods, and practices. Thus, the studies are not aggregative, i.e. they cannot produce the bigger picture of STI cooperation and its relative

effectiveness. This problem is partly due to the absence of an analytical framework where the various perspectives of agencies can be integrated and contrasted. Without an integrative conceptual framework, the "accounting" of international cooperation in this area will remain non-aggregative and evaluation remains anecdotal.

Precise definitions as well as indicators used when discussing STI for development are important. This is because a lack of clear and coherent definition of STI funding makes objective assessments impossible with important implications both for the funding agency and the recipients. These implications were discussed in a paper (Arroio, 2012) that focused on dimensions of key governance related to international cooperation in STI including decision making processes via votes, project selection and evaluation, research themes, regional focus and investment types.

In this paper, two approaches were employed in identifying an integrative framework. First, we conducted a survey of four major international cooperation agencies with an explicit commitment to STI funding namely the World Bank, the Canadian International Development Research Centre (IDRC), the European Union's Framework Programme for Research and Technological Development (EU-FP7) and philanthropy, the Bill and Melinda Gates Foundation (BMGF). We looked at how individual funding agencies define and classify this type of investment as well as their approach to development and innovation. Second, we distilled from the literature two theoretical frameworks that inform international cooperation in STI initiatives. The first we call the "black box" approach because it focuses on inputs and outputs of innovation, and the second is the Systems of Innovation perspective that emphasises the capabilities and development of actors, institutions, and organisations that participate in national innovation systems. Building upon these two steps we posited a set of minimum criteria that any STI governance system should meet including: ample coverage, preservation of heterogeneity and conceptual parsimony. In Section 3, we display a tentative typology of such a system.

The key components of our approach and methodology include a literature review of major works on innovation, development and international cooperation in Science, Technology and Innovation. In addition, we carried out a desk-based analysis of the STI programmes of selected international institutions. The criteria for case selection included agencies that have consistently invested in STI and that are representative of the various levels of governance: global (the World Bank), regional (the EU – FP7), national (the IDRC) and private philanthropy (the Bill and Melinda Gates Foundation). In-depth and open-ended interviews were conducted with five senior and experienced professionals from three of the above institutions. The analysis is conceptual rather than empirical.

2. Theoretical Perspectives on STI and Development

The idea that innovation is the driver of long-term economic growth predates the birth of economics as a discipline and was called political economy (the "marginalist" revolution of the turn of the twentieth century). The Great Depression and the subsequent Keynesian response turned the attention to business cycles for a good half century, but the focus on growth and the role of innovation never completely disappeared. Rather, it has advanced, punctuated by seminal contributions such as that of Schumpeter (1911, 1934), Solow (1956), Freeman (1982), Freeman and Soete (1997), Lall (1992), Perez and Soete (1988), Nelson and Winter (1982), Lundvall (1992), Nelson (1993), and Romer (1990).

While these important perspectives vary greatly in their theoretical foundations and prescriptions, they share a few beliefs such as the central role of science and technology. Economists agree that these two types of knowledge comprise the knowledge base of innovation, which is productivity-enhancing. They also agree that innovation encompasses the ability of firms to transform knowledge into productive capacity and final products, and the entrepreneurial spirit that creates demand for these new products. Thus, innovation involves processes that are broader than R&D, although it is often associated with funding, promotion, and strengthening of the capabilities associated with scientific research and technological development. See for example, Dalpe and Anderson (1993), Poh *et al.* (2001), Fagerberg and Srholec (2008), Frenz and Ietto-Gillies (2009), and Hakyeon *et al.* (2011).

A review of the four agencies' documents and reports together with the interviews shows that two schools of thought in the economics of innovation have greatly influenced the design of policies to promote international cooperation in STI: the Linear Model, or theories of supply-push, and the National System of Innovation approach.

Neoclassical economic growth theory and, particularly the family of endogenous growth, drive the Linear Model. For the purpose of current discussion, the main contribution of this framework is to include human capital to the modelling of economic growth and non-competitive markets in the sector that produces innovation for firms. The methodological character of this school leads to the assumption that innovation is a "black box" in which mechanics are not of central interest; the process is assumed functional by effect of market forces. These explanations limit themselves to incorporating stylised measure of inputs (e.g. private research and development (R&D) investment, proportion of college graduates in the labour force, etc.) that are transformed in the black box into outputs (e.g. productivity).

The National Systems of Innovation framework is driven by an evolutionary economic theory and emphasises a systemic approach. The regular starting point for analysis in this school is to define the scope of the system, either by geography (local, regional, national, supranational), industrial sector or technological sector. Secondly, it characterises the ecology of the system, including the private and public institutions and organisations specialised in educating and training human resources (universities, research laboratories and other education institutions), the firms (producers of final goods and services, suppliers of inputs and equipment, service providers, etc) and their various forms of representation and association, and the public and private organisations that are relevant to the promotion and regulation of innovative activities (private and public banks and financing agencies, Intellectual Property Rights organisations, etc). Thirdly, this type of analysis identifies the main institutions of the system, not only those formal and codified (laws and regulations) but also those tacit practices and mores governing the relation of actors in the system. These elements are then brought together in what Freeman (1982) called "reasoned history" because this type of analysis seeks to be sensitive to the specific historical path that resulted in the particular system configuration that is observable at the time of study.

A full survey of each school of innovation is beyond the scope of this paper. Rather, we are interested in acknowledging the main conceptual and theoretical elements of each that have percolated into the management of international cooperation in STI. The nuance of the arguments relating to the different frameworks is often lost as the ideas filter into governance, but some traits are recognisable in the ma nagement of international cooperation for innovation and, as we posit in this paper, these traits shape the goals and practices of these agencies.

2.1 Perspectives on International Cooperation, STI and Development

This section presents the result of the survey of four major international cooperation agencies with an explicit commitment to STI funding. In Section 2.2 we summarise and analyse how the World Bank, the IDRC, the EU-FP7 and the BMGF define and classify investment in STI. Although the theoretical and practical boundaries between Science, Technology and Innovation are by no means clear, we attempt to go beyond these "fuzzy edges", drawing out the investment focus as outlined in funding agencies' policy mandates and other documents.

We highlight various elements in the STI concept employed by funding agencies, such as linkages between the development of technological and other capabilities, links between research and the industrial base, and we also consider the agencies' approach to the issue of risk and innovation. Section 2.2

takes a closer look at their conceptual framework for dealing with the linkages between development and innovation.

2.2 Science, Technology, and Innovation

This section is driven by a simple question: how do international cooperation agencies frame their expenditure in STI conceptually? What type of investment does the agency focus on? Does it seek to promote scientific development or is the aim to fund technology and innovation or even the development of broader systems of innovation? This section reviews reports and documents in addition to interviews to determine the investment perspective of the four agencies. The aim is not to highlight the stylised indicators traditionally used to measure and compare innovation efforts (R&D statistics, education indicators, number of patents granted and individual firm performances, etc) but rather, to more fully grasp the rationale behind STI disbursements.

The IDRC's main focus is to support the scientific base in developing countries. Its mandate is "to initiate, encourage, support and conduct research into the problems of the developing regions of the world and into the means for applying and adapting scientific, technical and other knowledge to the economic and social advancement of those regions" (IDRC Act, 1970 subsection 4.1). IDRC encourages and supports researchers from developing countries to conduct research in their own institutions and regions, "to build up the research capabilities, the innovative skills and the institutions required to solve their problems." The Centre funds researchers and technicians to improve scientific and technical capacities (IDRC, 2009).

The Centre adopts a "grants-plus" approach to supporting research for development. This means that the IDRC is also a research partner and adviser that engages with its recipients throughout the research process as a mentor and on a peer-to-peer basis. It engages with its grant recipients in framing research problems, improving research designs, and selecting and implementing research methods. According to the IDRC, "this can take the shape of formal training, less formal mentoring with IDRC staff and more established researchers or, increasingly, peer-to-peer *relations* between IDRC staff and IDRC supported researchers. Centre staff and grantees actively contribute new ideas and theories, influence relevant research and policy agendas, and strengthen new generations of researchers." In addition, IDRC acts as a research broker that furthers networking among its various grantees, helps strengthen research-to-policy linkages, and facilitates access to research materials and other services. The centre argues that this "grants-plus" approach helps to make the research more open, accountable, and effective.

Although much of the funding was channelled towards improving innovation theory, it is only recently that IDRC had begun to consider financing

to "close the innovation cycle." This support is limited to universities as these are considered "key actors within the national innovation system upon which to focus." Research priorities include examining ways to enhance the quality and relevance of university research; the internationalisation of universities, including teaching and research standards; and training a new generation of STI policy researchers. Notwithstanding its declared aim to provide "support to build stronger linkages between universities and other important actors in innovation systems to close the innovation cycle that is, to connect research to commercialisation and development", the role of firms, that is of the actors that effectively implement "new or significantly improved product (good or service), or processes" in marketplaces, is scarcely mentioned.

Interestingly, IDRC takes on board the concept of "risk", but it is mainly concerned with mitigating risks associated with the implementation of research projects. The Centre believes that "research is an inherently risky business, more so in the developing world. Supporting research and capacity building in the developing regions of the world sometimes means working in contexts where research infrastructure is weak, institutions are fragile, and political and economic conditions are unstable. Yet, the flipside of risk is the potential for reward. The Centre is not risk-averse; it takes risks knowingly." This perception falls short of the conception of risk involved in innovation, that is, of the opportunities and benefits associated with the commercialisation and development of a new product or process. Thus, although acknowledging the importance of "closing the innovation cycle", the IDRC does not take on board the relation between research, development and commercialisation of results and thus, investment does not fully address the "innovation" equation.

At the Bill and Melinda Gates Foundation there is an explicit commitment to applied Research and Development (R&D) resulting in innovation, and risk is taken on board as a critical variable inherent to the innovation process. Innovation is seen to be "unpredictable" and the role of governments, companies, and other institutions to accelerate it, is recognised. According to the "2010 Annual Letter from Bill Gates", the foundation's key role is investing in innovations that would not otherwise be funded, and whereby the project has a long-term goal and is willing to take large risks on new approaches. In his words: "Our framework involves funding a range of ideas with different levels of risk that they could (not?) fail. The ones with low risks are where the innovation has been proven at a small scale and the challenge is to scale up the delivery. High-risk innovations require the invention of new tools. It is critical that we understand in advance what might prevent an innovation from succeeding at scale." The foundation has the resources to support this commitment and expenditure is closely tied to the delivery of results or "innovation-based solutions."

The foundation's mandate is based on "the premise that innovation in product, process, and organisation is essential to realise the greatest gains possible for the world's poor. In the global health arena, we have placed particular attention on science and technological innovation, improving upon existing interventions and driving the development of new ones" (Gates, 2010). As shown in other studies (McCoy *et al.,* 2009; Arroio, 2012), the BMGF has promoted research capacity mainly in the leading universities in the developed world, although there are efforts to bridge the gap by funding projects run by scientists in the developing countries. Examples include the Grand Challenges in Global Health and the Think Tank Initiative, co-sponsored with the William and Flora Hewlett Foundation and the IDRC, that is dedicated to strengthening independent policy research institutions in developing countries. In 2012, the BMGF entered into agreements to work with scientists in Brazil and China (Gates, 2012). Notwithstanding some initiatives to promote collaboration, the Foundation has no policy mandate to support local R&D solutions in developing countries or to strengthen the research base in these countries. Likewise, the link to firms and other actors in local innovation systems are not explored.

The World Bank, on the other hand, up until the 1980s was significantly engaged in funding directed at building and strengthening Science and Technology infrastructure in a broad sense. This was particularly true in the 1970s and 1980s when the Bank provided financing for a full range of activities, including linking the supply and demand for STI services, fostering university and industry cooperation, restructuring public R&D institutes to make them more responsive to industry needs, projects to enhance technology development in industry, and projects focused on Metrology, Standards, Testing, and Quality (MSTQ) systems, among others. Crawford et al., 2006, in their "Review of World Bank Lending for Science and Technology, 1980-2004", developed a taxonomy for identifying projects that enabled differentiation between Agricultural and non-agricultural STI Projects and classification of non-agricultural projects along five categories: 1) comprehensive S&T Development Projects; 2) Human Resource Development Projects; 3) Technology Development Projects; 4) Health Projects and; 5) Environmental Projects.

In the 1990s, the Bank's overall approach became less focused on the capabilities to build systems of innovation, and programmes were redirected to private sector "competitiveness" and infrastructure development. This was accompanied by recommendations for improvements to the policy and institutional frameworks, including more openness to trade and foreign direct investment, strengthening of Intellectual Property Rights regimes to align with World Trade Organisation (WTO) and European Union standards, development of national competitiveness policy, including antimonopoly regulations and the setting up and strengthening of antimonopoly institutions and creating

appropriate legal framework and business environment for potential investors and particularly for venture capital (Goel *et al.*, 2004). The inappropriateness and destructive effects of such policies on various innovation systems has been broadly documented (Chang, 2002; Chesnais, 2004).

More recently, the Bank has endeavoured to focus on the early approach to STI, as discussed, for example, in the 2007 and 2009 STI Global Forums. The aim is to "understand the lessons of previous and on-going STI capacity building experiences and map out new and more effective ways for governments, industry, academia, foundations, and donors to work together to apply STI capacity building to development." It was argued that "STI capacity building must fit into broader efforts to build the productive capacities of countries" (World Bank, 2008).

Their framework also emphasises the role of developing local capabilities and the centrality of the local dimension to close the innovation cycle. According to the Bank, "the key to successful technology development and dissemination is to empower local innovation. If external change agents provide local people with the tools to solve their problems, they will use them. Technology development and dissemination has to be a process of *co-creation*." (Arnold *et al.,* 2000 in World Bank, 2008).

Although acknowledging the role of innovation and local capabilities, the importance of strengthening firms to improve innovative capacity and results is not explored. Indeed, while innovation policies are expected to support private sector development, innovation and private sector programmes are purposefully kept separate. The Bank argues "developing countries need to establish applied engineering research institutes that focus their R&D efforts on developing simple low-cost technologies. However, it is not enough simply to produce prototypes of better equipment. Designs and blueprints have to be developed and transferred to small and medium enterprises (SMEs) that could produce, market, and distribute them to customers in local and regional markets. In this way, STI capacity building projects will support and reinforce parallel programmes aimed at private sector development" (World Bank, 2008). It is only indirectly that international funding of STI is expected to benefit firms in developing countries.

The European Union Framework Programme (FP) funding is directed almost entirely to promoting scientific collaboration. Implemented since 1984, the FP is the EU's main instrument for funding research. The 7th Research Framework Programme (FP-7), starting in 2007, is "motivated by the aim to achieve research excellence, to attract scarce human resources for research and also to build STI capabilities through people and institutions (European Commission, 2006)." It allows researchers to work together on collaborative research projects to advance knowledge, and promotes cooperation among

universities, industry and research centres across the European Union, as well as with the rest of the world. Funding is directed towards major scientific challenges, including health; food, agriculture and biotechnology; information and communication technologies; nano-sciences, materials and production technologies; energy; environment; transport; social and economic sciences; space; and security. Science is the driving force rather than applied R&D, technology or innovation, although these may result from collaborations.

Although various FP7 sponsored research programmes include partnerships with firms, a 2009 study commissioned by the European Commission, confirms that "the 'narrow' R&D paradigm is still the core driver for STI cooperation." According to this document, in the narrow paradigm, international science and research collaboration is linked to drivers that are "intrinsic" to the science dynamics and the envisaged effects are:

- Contribution to the quality of science through cross-fertilisation, competition, access to world class researchers, facilities and groups;
- Solving scientific problems that need input from various international teams;
- Increasing the scope of research by combining complementary knowledge, pooling funding and human resources, sharing risks, increasing computational power;
- Better access to scarce human resources for research;
- Increasing (international) productivity and visibility of research;
- Contribution to building institutional capacity in research organisations.

2.3 Development and Innovation

In addition to looking at the Science, Technology and Innovation dimensions, we also consider the funding agencies' position regarding the concepts of "development" and "development and innovation." We examine documents that address questions such as: is fostering economic growth the foremost goal of the agency? Or is it poverty alleviation? Is the agency using indicators other than GDP per capita, for instance, the Millennium Development Goals (MDGs)? Does the agency consider and incorporate local perspectives on development? How does the agency consider innovation in relation to development goals? Does the adopted approach stem from a linear perspective, based on the idea that innovation will result from "natural" endogenous growth and market mechanisms or is the evolutionary, systemic approach preferred? Are initiatives implemented consistently with the first or latter perspective? Finally, we consider if there is room for a broader System of Innovation approach encompassing the heterogeneous agents (national and multinational

enterprises, R&D organisations, education, training, financial agents, etc.) and related activities in productive systems.

According to a World Bank interviewee, in the 1990s, STI capacity building at the Bank became closely tied to the poverty reduction agenda. The reason for this was that by explicitly considering STI as a development issue, in the same manner as agriculture and agricultural research are considered development issues, there would be no "distraction" from the Bank's poverty reduction agenda, thus, justifying a more significant volume of operations in this area. The message was that STI capacity building is not a diversion from poverty reduction and the Millennium Development Goals; it is an essential tool for achieving the MDGs and reducing poverty.

While this perspective has some value, particularly considering that the MDGs do not incorporate goals related to the development of indigenous technological capabilities and thus the World Bank's emphasis on linking STI to the MDGs filled an important gap, a more sophisticated perspective of the role of STI in development is taking shape and this has been discussed at the Global STI Forums. According to this view, STI capacity building must become an integral component of all investment activities, as it was twenty and thirty years ago, when World Bank infrastructure and industrial development projects had explicit STI capacity building objectives. This focus on capacity building disappeared in the 1990s with the shift to policy-based lending and, according to the Bank, it needs to be revived and incorporated into agriculture and rural development, environment, private sector development, infrastructure programmes, etc. Thus, "donors should not only finance the physical investments but capacity building programmes as well. For example, when building infrastructure projects, outside contractors could be required to accept student interns and industrial attachments during all phases of the work, from engineering, design, construction, operations and maintenance." (World Bank, 2008).

The Bank goes on to observe that the "development of production sectors is still weakly integrated in poverty reduction strategies. Moreover, economic development strategies place excessive emphasise on promoting exports and FDI, and pay too little attention to fostering domestic private investment, domestic markets, domestic linkages, and domestic resources and capabilities. In addition, special international support measures for LDCs are oriented towards providing market access than to developing productive capacities. The increased attention for MDG-based, poverty-focused aid also comes at the cost of support for developing productive capacities, as does aid focused on direct welfare improvement." (World Bank, 2008)

As regards the IDRC, historically, the Centre has supported research on STI policies that contribute to economic growth and poverty alleviation in developing countries. This includes mapping the players involved in science and

technology policy, their roles, and linkages; developing science and technology strategies; and identifying the impacts of new and emerging technologies, including helping marginalised groups participate in such debates. IDRC argues that both economic growth and poverty reduction are the overlapping goals of research supported on particular sectors or thematic areas. In their own words: "More broadly, it aims at ending exclusion, creating opportunities, and progressively removing inequities that can exist along various dimensions (gender, class, ethnicity, age, religion, geography, etc). Different forms of inequity often compound and reinforce one another. Poverty reduction strategies address economic and non-economic forms of poverty, including poverty's social, cultural, political, environmental and ethical roots. Reducing poverty implies enabling and assisting people to take control over their lives and to realise their full potential."

IDRC promotes initiatives that improve understanding of the links between national systems of innovation and development, strengthening STI policies in several countries, and building the capacity of science journalists (through support of the World Federation of Science Journalists, support to the SciDev platform, and other mechanisms). The focus is on issues of governance and institutions as key drivers of development.

Given the strategic importance accorded by the Bill and Melinda Gates Foundation to the role of innovation in development, it is important to understand how innovation is expected to boost a country's social and economic development. The Foundation adopts the perspective that the "scientific process drives innovation – trial and error, taking calculated risks" (Gates, 2010a) and, as discussed previously, strives to engage in R&D that delivers "innovation-based solutions." The focus is on three programmes: Global Health, Global Development, and US Programmes that provide a significant supply side innovation push. The Global Health programme, as the largest grant making area, has received over US$13 billion since the foundation's establishment in 1994, for research priorities in two categories: infectious diseases and Family Health. The Global Development Programme offers grants in areas such as agricultural development; financial services for the poor; water, sanitation, and hygiene; and global libraries.

Bill Gates' "2010 Testimony to Congress" makes it clear that the Foundation believes that initiatives to foster social and economic development (aid) should be kept conceptually and de facto apart from R&D funding. Support for development is considered particularly important through foreign aid from the richest countries to poorer countries; aid is effective, as shown by "improvements in agriculture and health that have relied heavily on the generosity of rich countries" and "the generosity of these governments is key to long-term success." The BMGF documents that were examined do not consider

the role of industrial or technological policies for development or dimensions related to local institutional, technological or other capabilities.

Instead, we learn that "if we continue to innovate and to dedicate resources, huge gains in global health and development are ahead of us. If we keep pushing, we will be able to reduce poverty and prevent disease, which will help countries ultimately end their dependence on foreign assistance and allow more people to live healthy and productive lives without support from the U.S. or other donor governments. Already, South Korea, China, Mexico, and Brazil have graduated from heavy reliance on aid, and other nations want to follow in their footsteps." The conclusion is that countries will "catch-up", that is that they will follow a progression from any given development stage to another supposedly superior, as long as they adopt and diffuse innovations and follow scientifically-recommended best practices.

The European approach to research is designed specifically to "strengthen the scientific and technological bases of European industry and ensure competitiveness at an international level." At the national level, the report "Drivers of International Collaboration in Research" (European Commission, 2009), for example, found that improving domestic competitiveness is also becoming a major driver for many countries to engage in collaborative efforts and that an important trigger, alongside the opportunity aspect, is the fear that nationally-based R&D industries will relocate part of their research activities to more attractive (high quality, lower cost) regions in the world. In other words, "excellent science is increasingly seen as a magnet for international business investment." This review found that improved access to the best science and technology; building strong business relationships with interesting companies in similar clusters/domains abroad; improved market access for national businesses and enhancement of R&D related foreign direct investment were important assumptions of the benefits from STI collaboration. The EU observes, however, that most of the envisaged impact is indirect: few programmes and measures are directly related to building STI collaborations for the purpose of innovation or direct commercial gain.

How does this approach impact the European perspective on international collaboration, development and STI? The European Commission Report (2009) found that in most countries STI collaboration strategies with developing countries are mostly defined separately from mainstream STI policy making. Considering the broader EU context, it is argued that international cooperation forms an integral part of the EU scientific policy and although FP7 represents only a small proportion of research carried out in Europe, international scientific cooperation seeks to "address the challenges and opportunities of an interconnected world, and to contribute to peace and prosperity for European citizens. Europe wants to play a leading role in the world's research arena and help build a safe future."

The increased focus on competitiveness has led to a reorientation in the approach regarding international cooperation under the FP7 that is significantly different from the approach under previous Framework Programmes. This new approach aims to "integrate international S&T collaboration throughout the Framework Programme and to enable both geographical and thematic targeting" and this means "that no 'ring-fencing' is provided for international cooperation elsewhere in the FP." There are no funds that are to be used exclusively for projects under the heading "STI and development cooperation" and developing countries do not have to apply through the "International Cooperation" category, but rather can be candidates for funding in any research topic heading. In one sense, this may allow broader participation, but it is likely that resources will go to countries that are more capable of competing for these resources, including larger industrialised countries and emerging economies (Arroio, 2012). In any case, disbursement is strictly tied to cooperation in basic and applied science development Programmes. FP7 does not provide funding for local technological development (pilot projects, scale-up, engineering, commercialisation, marketing, etc.) nor support to firms and the final stages of the innovation process.

Despite the decoupling of development cooperation from STI and the relative scarcity of resources, the FP7 remains important for the developing world mainly because of the rich learning opportunities that are available via dense collaborative networks. In addition, the EU carries out significant research to understand and improve the framework conditions for international cooperation, and in developing approaches for proactive and better coordinated international STI governance. The regional union has produced documents discussing the policy framework for international cooperation since 1972 in addition to numerous studies and reports that are relevant for the discussion on development and STI cooperation.

3. A Tentative Typology for Analysing International Cooperation in STI

From the discussion above we discover that funding agencies emphasise slightly different facets of Science, Technology and Innovation and that they have varying perspectives and expectations regarding the role of STI and development. These has implications for project accountability and governance mainly because independent project evaluations based on conceptual coherence, common standards and empirically measurable indicators could improve coordination of international cooperation in this area and pave the way for more development oriented exploitation of potential synergies from "global partnerships" to fund STI projects. As stated by an interviewee: "We would like to have a bullet point list of some key M&E metrics that we can use to

know if we are meeting our implementation targets and also if the programme is meeting its development objectives." We argue that the conceptual framework used to analyse and develop quantifiable indicators is key to establishing and meeting development objectives.

Our purpose is not to promote the homogenisation of agency goals, projects, or mechanisms of cooperation. Instead, we want to propose a typology as a tool for the design of an accounting system of STI that is broad enough to comprise the heterogeneity of agencies and projects while facilitating the empirical study of international cooperation in STI at various levels of aggregation.

The minimum attributes necessary in a comprehensive STI typology include:

- *Ample coverage*: All or at least the majority of existing projects identified by the agencies as STI cooperation should be accounted for in this system.
- *Preservation of heterogeneity*: The system should not force a given project to fit a given category; rather, the system should have enough substantive categories to preserve and render the differences of distinct projects discernible.
- *Conceptual parsimony:* All accounting entries should correspond to a typology that map directly to the conceptual framework. Moreover, a typology should have no more themes than those necessary to characterise the underlying concept.

Using concepts from evolutionary economics, we develop a simple, yet, comprehensive typology of international cooperation in STI. As illustrated in Table 1, critical dimensions identified in this typology are type of expenditure and expected result of investment.

Expenditure type refers to the science, technology or innovation dimension of the agencies' disbursement considering if it targets: 1) funding for basic science and research; 2) funding for R&D or other innovation within firms, including production and technological skills, changes in organisation and management routines, marketing and modifications to production processes and; 3) support to advance Systems of Innovation, that is, in addition to support for investment types 1 and 2, additional funding for the development of technological, institutional, legal, regulatory and other dimensions to strengthen the broader system of innovation. Investments in this category would be closely tied to the policy subsystems examined in Cassiolato and Lastres (2003), and Cassiolato *et al.* (2008) system of innovation conceptual framework.

The second dimension, "expected result", focuses on the intended outcomes of STI investment. They are differentiated according to whether they represent funding that is expected to lead to solutions that can be assessed and quantified as innovation "output", mainly new products and processes, or, if they represent investment "inputs" that are expected to further social and economic development though the broad promotion of STI.

Table 1: International Cooperation in STI by Type of Expenditure and Expected Result

		Expenditure Type		
Expected Result		***Science & basic research***	***Innovation (R&D and other innovation)***	***Systems of Innovation***
	Output	EU/FP7	BMGF	-
	Input	IDRC	-	WB (1980s)

Source: Compiled by the author.

The typology highlights that both the FP7 and the BMGF adopt a strategy that prioritises research and innovation, leading to applied "solutions" (products and processes) to face development challenges, while according to this scheme, the IDRC and the World Bank favour the "input" aspects of STI and development. In this study, we have not been able to trace funding linked to system of innovation outputs, that is, financing for the various agents (science, firms and institutions) within systems of innovation that may lead to new product or process development that is, to quantifiable *outputs.* Similarly, the case studies selected for this typology do not illustrate disbursement strategies associated exclusively with R&D or other innovation inputs. This is because this expenditure type is more closely related with inter-firm technology acquisitions, that is, commercial property rights and other technological transactions.

From this schematic perspective, different types of international cooperation are associated with the approaches on STI and development held by the various funding agencies that were discussed in Sections 2.1 and 2.2. The typology obeys the minimum attributes posited initially, that is, it provides ample coverage in that a majority of STI cooperation projects can be accounted

for in this system; it preserves heterogeneity because it allows the differences between projects to be discernible and does not attempt to force a "one-size fits all" scheme; and finally, we have held to conceptual parsimony in that all dimensions within the typology can be traced to the conceptual frameworks on STI and development established in Section 1.

Three qualifying remarks are in order. Firstly, STI boundaries are not always clearly demarcated; an international collaboration project may include components of all three expenditures types: the advancement of basic science, innovation funding and development of local capabilities, in addition to expected results associated with both innovation output and the strengthening of local systems and capabilities. It is however, useful to keep the differences in mind when designing policies and strategies for STI funding.

In addition, STI cooperation agencies should be aware of so-called "linearity traps." Two of these traps have been identified in the literature. Firstly, the belief that initial (public) funding in (basic) science would automatically lead to (private or public) research and development and from there to applied (private) product development and the placement of new products on the market. A second trap, and that is complementary to the previous sequence, is the belief that investment in the science base, in R&D and in innovation by itself will lead sequentially and necessarily to social and economic development. Various authors have shown that in addition to System of Innovation financing, a series of macro-economic, cultural and institutional conditions must be in place. These conditions are context specific and not easily replicable (Freeman and Soete, 1997; Cassiolato and Vitorino, 2011).

Finally, in addition to the relevance of both the "output and outcome" approaches mentioned previously, all expected results of investment, whether in basic science or technological solutions, are "important for the common good", as convincingly argued by Stokes (1997). All three dimensions - science, technology and innovation - are central mainly because technological change and development represent the manifest outcomes of an active shaping and integrating of tacit experience or knowing (Polanyi, 1966). Separating these dimensions is purely on conceptual basis.

4. A Summary With A Governance Perspective

A key contribution of the paper is both conceptual and methodological with the specific aim to develop an original typology of international cooperation in STI by tracing the various approaches to the role of STI in development across funding agencies. Although we looked at only four agencies, it is hoped that this typology can be expanded and applied so that other research programmes, development and philanthropy initiatives, banks and STI funding organisms, amongst others, to develop policies and programmes based on Science,

Technology and Innovation. Although the complex nature of most scientific and technological undertakings does not permit easy categorisation, the political and evolutionary process of forging a consensus on a shared terminology may have important implications for an improved understanding between potential partners that could lead to increased effectiveness of international cooperation in STI.

In addition, the absence of a common strategy for international STI cooperation may lead to duplication in this field, with a resulting waste of resources and a reduced impact. A more coordinated approach with a view to identifying common priorities could lead to coordinated or joint initiatives within the international fora. The current piecemeal approach to STI and social and economic development has not significantly benefitted developing countries in their STI efforts, considering the increasingly dangerous global knowledge and technology divides (Sachs, 2009). It is hoped that this study provides a starting-point for discussions in relevant fora.

The field of international cooperation in STI is still in its early days, despite significant advances since the launch of the Sussex Manifesto (United Nations, 1968). There are fertile future areas of research in international cooperation in STI and development. Firstly, we need to better understand the links between international cooperation and local institutional aspects such as how do funding agencies accommodate the specific research and institutional structure of each country and what is the role assigned to the state? The role of partnerships among funding agencies, that is, the formal and informal relations established to discuss, coordinate and implement STI initiatives must be explored and debated. Various coordinating initiatives have sprung up in recent years, such as the International Forum for Research Donors, and regional efforts such as the *Programa Ibero-Americano de Ciencia e Tecnologia para o Desenvolvimento* (CYTED) or the European Strategic Forum for International S&T Cooperation (SFIC), but these are not as well known or as cohesive as the OECD based Development Assistance Committee (DAC). In this vein, the relations between the international AID or donor communities and those involved in international cooperation in ST&I have yet to be explored in greater detail.

An examination of the key ingredients necessary for policy design that promotes collaborative effort among public and private partners, including scientists, research laboratories and firms in the developing and developed world, and the implications of innovation networks for scientific advance and sustainable local growth is vital. In this context, public – private innovation and development partnerships looking at global environmental (and other challenges) are pivotal. These lead to dense networks of thematic issues and interconnections that are well beyond the scope of this paper but given their relevance to STI and development, deserve further study.

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