

- DRAFT -

## BACKGROUND DISCUSSION PAPER FOR THE L20 WORKSHOP

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### The Context

This meeting at UNU-Maastricht is one of several in a project that is exploring the possible creation of the "L20" - a regular forum at which the leaders of approximately 20 industrialized and developing countries would convene on a regular basis. The founding logic of the L20, advanced especially by Canadian Prime Minister Paul Martin, is to provide a means for managing global challenges that have proved difficult or impossible to settle efficiently through other mechanisms such as the G8.

Through a series of workshops and background papers the L20 team has refined the central concepts that could guide an L20. Notably, issues are ripe for L20 if they truly require attention of heads of government - for example, issues that require the brokering of complex package deals that cut across line ministries, and issues that require sustained high level attention because that is the one way to ensure proper follow-through. Moreover, the L20 offers the prospect of success in managing issues that require cooperation between industrialized and developing countries. Indeed, the closest analogy - the G20 group of finance ministers - was created in the wake of the Asian financial crisis and played an important role in easing adjustment to that crisis.

Our task is to see whether the L20, if it were convened, should focus on matters concerned with science and technology for development. Thus we must be severely practical. We must explore the issues to see where, if at all, leaders must be engaged and there are possibilities for meaningful agreement. Should "science and technology for development" be on the L20's agenda? If so, our meeting should conclude with some concrete ideas for possible elements of an L20 meeting on the topic and thus possible elements of a communiqué on science and technology for development. In effect, our goal is to anticipate how leaders from approximately 20 of the most important industrialized and developing countries could approach the issues in a collective fashion.

This background paper for the meeting is intended primarily to help frame the overall discussion of science and technology 'for development' and to set out a broad overview of major issues. It also attempts to distinguish, at least in principle, between a subset of those issues that might be relevant to an L20 agenda and those which, although perhaps equally important, might not be appropriate for attention at an L20 level. The paper goes a little beyond 'background' treatment of issues in a few areas. Although other papers for the meeting will provide the main detailed treatment of 'candidate' issues for an L20 communiqué, this paper also develops more detailed treatment of a small number of issues that are potentially relevant for an L20 agenda but not currently scheduled for coverage in the other papers.

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## Contents

### **1. SCIENCE AND TECHNOLOGY FOR DEVELOPMENT: RIPE FOR L20 INITIATIVES?**

- 1.1 Ripe and Relevant or not?*
- 1.2 What Kinds of L20 Initiative?*

### **2. FRAMING THE DISCUSSION**

- 2.1 Shifting Common Perspectives*
- 2.2 S&T Systems: The main components*
  - 2.2.1 Technology in the Production of Goods and Services*
  - 2.2.2 Capabilities for Design, Engineering , Entrepreneurship and Innovation Management*
  - 2.2.3 Capabilities for Knowledge Creation and Technology development*
  - 2.2.4 Capabilities for Scientific research*
- 2.3 Capability Components: Overlaps and Relative Magnitudes*
  - 2.3.1 Overlapping Capability Components*
  - 2.3.2 Some Relative Magnitudes*
- 2.4 Type (A) Knowledge Systems: Rich countries*
  - 2.4.1 Domestic Articulation*
  - 2.4.2 International Articulation*
- 2.5 Type (B) Knowledge Systems: Poor countries*
  - 2.5.1 Traditional Knowledge Systems: Scale, Erosion and Multiple Disarticulation*
  - 2.5.2 'Modern' Knowledge Systems: Scale, Imbalance and Multiple Disarticulation*
- 2.5 Some Major Issues*
  - 2.5.1 A Broad Overview*
  - 2.5.2 Which Issues for the L20?*
  - 2.5.3 A word of Caution: the Institutional Context for S&T Activities*

### **3. SOME SELECTED ISSUES FOR THE L20**

- 3.1 Generic Issues: the international migration of S&T human capital*
- 3.2 Sector-Specific Issues*
  - 3.3.1 Industry and Infrastructure: Technological Capability Development*
  - 3.3.2 S&T for Agricultural Development*

**ANNEX 1. Tables**

**ANNEX 2. References**

# 1. SCIENCE AND TECHNOLOGY FOR DEVELOPMENT: 'RIPE' FOR L20 INITIATIVES?

## 1.2 Ripe and Relevant or not?

In principle the broad topic of 'S&T for development' seems both ripe and relevant for attention via an L20 mechanism. This is partly a matter of timing. Over the last five years or so there has been a resurgence of interest at national and international levels in the challenges for science and technology in an increasingly interconnected but divided world. An L20 mechanism could be most timely in catching this surge of interest and helping to move it forward to more concerted action.

But more than just timeliness is involved. Several other considerations suggest that issues about 'S&T for development' meet other criteria indicating 'ripeness' and relevance for L20 engagement.

- (a) ***Cross-cutting problems.*** S&T policy issues raise *par excellence* problems that cut across the traditional 'vertical' structures of government. The difficulties arising from this have been increasingly recognised by national governments over recent years, generating numerous efforts to invent new organisational structures to address S&T-intensive issues that do not fit neatly into mono-ministerial silos. The same difficulties are also evident at the international level where a growing array of specialised agencies have been created to address different issues with intensive 'S&T' dimensions. A high-level governance structure like an L20 mechanism might be valuable in overriding and unblocking bureaucratic obstacles to effective links across these divisions at both national and international levels.
- (b) ***The S&T dimensions of 'non-S&T' international negotiations.*** Important S&T-related issues are often embedded in high level international negotiations that are seen primarily in non-S&T terms. For example, concerns about national and global security or about global climate change run into questions about poor countries' access to dual-use or clean technologies owned by rich countries. Also, negotiations about trade in agricultural and food products run into poor countries' perceptions of their vulnerability to trade barriers arising from stringent technological standards imposed by rich countries. An L20 engagement with 'S&T for development' could serve to move forward action in these areas.
- (c) ***Sustained follow-through.*** The recent resurgence of interest in issues about 'S&T for development' has generated an array of plans and proposals for action. As one example, the final report of the Millenium Project proposed that public financing of research should be raised by 2015 to at least \$7 billion per year to meet pressing challenges.<sup>2</sup> Given the common shortfall between such aspirations (even commitments) and delivery, there may be a strong case for an L20 mechanism that would put high-level 'weight' behind efforts to achieve concrete action on these plans and proposals about S&T for development.

However more sceptical views about the role of an L20 mechanism in this area may also be important.

- (a) It has already been common to try and address the problems facing cross-cutting S&T policy by lifting responsibility for the governance of S&T to a level of power that rises above and rides across the specialised silos of ministries and specialised international agencies. But at both national and international levels these efforts have a pretty poor record of success or even survival.

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<sup>2</sup> \$4 billion for public health, \$1 billion for agriculture and natural resource management, \$1 billion for improved energy technologies and \$1 billion for greater understanding of climate change.

- (b) Moreover, the barriers may have been raised recently. Although the resurgence of interest in issues about S&T for development has generated numerous proposals almost certainly calling for high level follow up, it has also created a wider array of organisations and actors with vested interests in (perhaps retarding) the various plans, programmes and hopes for action. So, while creating opportunities for L20 action, this situation may also have increased obstacles to the effectiveness of such action.
- (c) At the same time it is not entirely obvious that L20 members would see the L20 as the forum within which to pursue most effectively their interests in S&T issues. With much greater pluralism emerging in the power bases of global governance arrangements, different coalitions and interest groups may well form around particular S&T-related issues in ways that do not map neatly on to a group of 'The Big 20'. A recent example is the creation of the Asia Pacific Partnership for Clean Development and Climate involving collaboration between Australia, India, Japan, China, South Korea and the US in developing, deploying and transferring clean technologies.
- (d) There seems no inherent reason why an L20 mechanism would be more likely than existing mechanisms to bring S&T issues that are embedded in areas of international 'non-S&T' negotiations, higher up the action agenda or to move them any further in a 'for development' direction.

It is not clear how these considerations would balance out across the various 'S&T for development' issues.

## 1.2 What Kinds of L20 Initiative?

Only selected parts of the 'S&T for development' agenda could be usefully addressed by an L20 mechanism. The vast majority of required action can only be undertaken in developing countries themselves, and an L20-type body could do little more than offer exhortations and generalisations (probably misleading) about these areas for local action. Another large raft of issues do call for action at an international level, but in many cases such action is already undertaken by existing organisations and programmes (both multilateral and bilateral), and there may be little scope among those for effective value-added by an L20-type initiative.

But this does not mean that the main challenge for the Maastricht meeting is simply to sort out the array of 'S&T for development' issues into two categories: 'Yes' (relevant for L20) and 'No' (L20 value-added not apparent). Even among possible initiatives where an L20 mechanism could add value, it will be important to distinguish between initiatives that can be quite readily defined and brought towards action on the basis of existing information and understanding, and those where further clarification is needed before particular lines of action can be put forward with confidence. In other words, the task for the meeting may be not only to identify potentially relevant issues. Among those it will also be important to distinguish between issues that call for different kinds of L20 initiative – e.g. categories C, D and E in the table below.

**Issues about ‘S&T for development’ where the priority need is for:**

Greater or improved action at country level	Improved action through existing multi-lateral or bi-lateral bodies	New multi-national initiatives that have already been identified proposed or initiated	New International initiatives that can be defined fairly readily	New International initiatives that require further clarification	
<b><u>A</u></b>	<b><u>B</u></b>	<b><u>C</u></b>	<b><u>D</u></b>	<b><u>E</u></b>	
<b>Possible role for an L20 group</b>	<b>Little</b>	<b>Limited</b>	<b>Monitor and push forward progress</b>	<b>Move towards Action</b>	<b>Urge and support preparatory analysis</b>

## 2. FRAMING THE DISCUSSION

### 2.1 Shifting Common Perspectives

Over recent years much of the interest in aspects of ‘S&T for development’ has been set within quite short time horizons. One of several examples was the funding emphasis stemming from many donors’ perspectives on the role of the CGIAR in agricultural development during the 1990s. This emphasis pulled CGIAR activities ‘downstream’ towards applied work and relatively immediate application – an obviously important set of emphases, but ones that came to operate *de facto* as substitutes for, not as complements to, longer term S&T activities. Similarly, the emphasis on ‘Quick Wins’ in the conclusions of the Millenium project is again obviously important in connection with rapid achievement of the Goals, and it may even be the case that “... the specific technologies for achieving the Goals are known. What is needed is to apply them at scale”.<sup>3</sup> But there is some risk that such short term perspectives could come to dominate the discussion of ‘S&T for development’. This seems inappropriate. Apart from anything else, the core Millenium Goals are ‘only’ about halving the numbers in extreme poverty, and even if that is achieved by 2015 there will remain the other half of those numbers. It is pretty certain that the technologies and scientific understanding that will be needed in ten years time to address that remaining challenge are not all sitting on a shelf ready to be applied. It therefore seems important to consider how an L20 mechanism could add value to current debates by raising visions for action beyond the politically attractive short term.

Other shifts in perspective will also be important for the Maastricht meeting. For many years policy debates about science, technology and innovation in the world’s poorer societies are commonly framed in ways that involve one or more of the following three perspectives.

<sup>3</sup> *Investing in Development*, p.2.

- (1) Discussion about science and technology (S&T) frequently jumps directly to a discussion of Research and Development (R&D). S&T capabilities become identified as R&D capabilities and conclusions about S&T capability-building focus narrowly on strengthening R&D capabilities – though perhaps accompanied by caution about the need to strengthen the ‘demand’ for R&D.

**But:** ‘R&D’ leaves out many other S&T activities and capabilities that play centrally important roles in creatively exploiting knowledge for economic, social and political aims (e.g. a wide variety of design and engineering activities). At the same time, the ‘demand side’ is not something that exists outside S&T capabilities; it consists very largely of particular kinds of (non-R&D) S&T capability.

*In the US, one of the most R&D-intensive economies in the world, about 90 per cent of scientists and engineers do not undertake R&D as their main activity.*

US NSF statistics – see below

- (2) Cutting across such R&D-centred discussions, particular emphasis is frequently placed on the importance of a small set of high-profile technologies in which current advances are particularly rapid and which are identified as especially ‘dynamic’, ‘pervasive’ or ‘generic’.<sup>4</sup>

**But:** however pervasive they may be, any selection of high-profile technologies will inevitably divert discussion away from other kinds of technology that may be centrally important for, and perhaps far more pervasive in, large parts of society in poorer countries.

- (3) Questions about strengthening scientific and technological human resources commonly centre, sometimes exclusively, on formally organised education and training. As a result, proposals for action typically focus narrowly on the needs to expand, strengthen, reform and re-design universities and other tertiary-level education and training organisations.

**But:** although these organisations are centrally important in creating human capital with generic S&T skills and knowledge, this perspective seriously underplays the complementary role of business firms in adding detail, specificity and depth. Instead, firms are too often seen only as employers of scientists and engineers, and at best as vehicles for adding to their human capital only via various kinds of investment-free ‘learning’ (e.g. by ‘doing’). The critical importance of firms’ deliberate investment in training and in accumulating experience tends to fall out of the picture.

The Maastricht workshop should try and abandon these long-standing habits. They too easily lead to the exclusion of critically important issues. The framework outlined below is intended, among other things, to help avoid this.

## 2.2 S&T Systems: The main components

A comment about terminology is important here. It has become common in recent years to add ‘innovation’ to any policy discussion of ‘science and technology’, especially in the context of developing countries. Hence the proper title for this section should include the acronym ‘S, T & I’. However, I have never understood why anyone would enter a policy discussion about technology without presuming that the issue was essentially about innovation and, since it is

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<sup>4</sup> As a recent example, these were described in report of the Millenium Project Task Force on Science, Technology and Innovation (2005) as ‘platform’ technologies, identified as information and communication technologies, biotechnology, nanotechnology and new materials.

obvious in what follows that the focus of the framework outlined here is about ‘innovation’, I will stick with the ‘S&T’ formulation. In doing so I draw heavily on a framework that has already been outlined by Sagasti (2004) – as summarised below in Figure 1.<sup>5</sup> Its core consists of four sets of scientific or technological activities and the associated capabilities for undertaking them (running across the middle of the figure).

### ***2.2.1 Technology in the Production of Goods and Services (PGS in Figure 1)***

On the right of the figure are the activities and capabilities concerned with using existing technology in the production of goods and services. Technology here takes several forms: part is embodied in operational plant, machinery and other fixed capital like infrastructure facilities; part is embodied in the designs and specifications of products; part is embodied in procedures and protocols for production activities and for the maintenance of production facilities; and part consists of technology in the form of organisational aspects of production operations. Finally a large part is embodied in people in the form of the knowledge and skills they use to undertake production in combination with all the other forms of technology.

The characteristics of this bundle of different forms of technology are constantly being altered as a result of technical change and innovation.<sup>6</sup> This leads us leftwards in Figure 1 to the activities and capabilities used to generate and implement such change. In contrast to common perspectives, however, this does not lead us directly to R&D. Instead, the focus is first on a set of activities and capabilities that play a more direct and immediate role in generating and implementing technical change.

### ***2.2.2 Design, Engineering, Entrepreneurship and Innovation Management (DEE&IM in Figure 1)***

The core technology-related activity at the heart of almost all innovation is the creation of a set of specifications (or ‘designs’) of the change that is to be brought into use. These specifications may take a wide range of forms. They may consist of complex designs for physical structures, chemical molecules or semiconductor layouts that are created and held in the files of computer aided design facilities. Alternatively, they may be drawn in the dust on a workshop floor. Given the bundle of different kinds of technology used in production, they may consist of different kinds of design – specifications not only for hardware in products and processes and their input materials, but also for production procedures and protocols as well as for organisational arrangements for production and distribution.

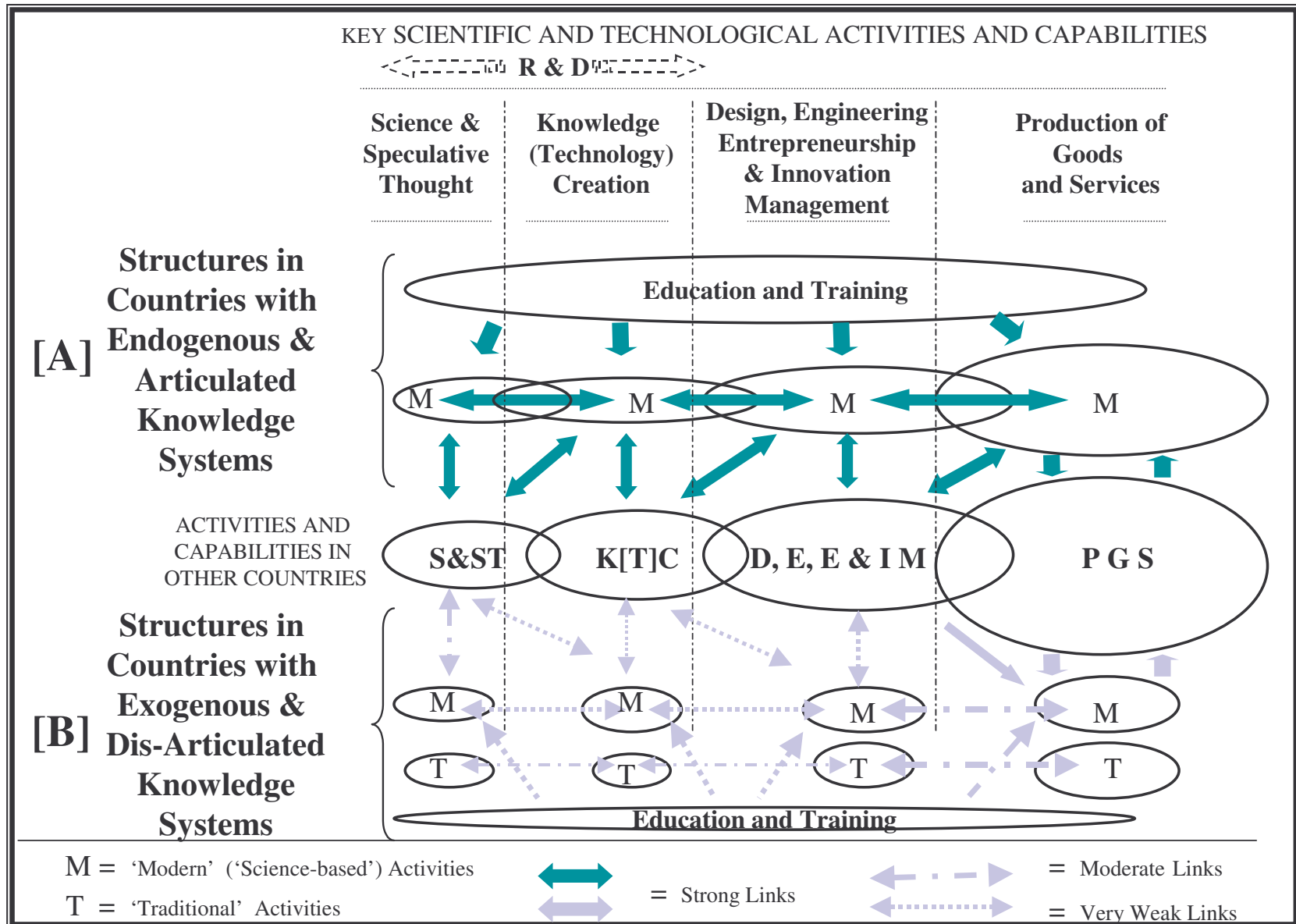
For modern types of technology, the creators of these designs and specifications typically consist of various kinds of engineer, but we must hold an open view of what an ‘engineer’ may consist of in this context – not only a university educated graduate working in an IT system design office in Bangalore, but also a West African small-holder planning the specifications for a new configuration of the annual planting of multiple rice varieties across the heterogeneity of agro-ecological conditions on a farm.

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<sup>5</sup> Though with modifications and developments for which he bears no responsibility.

<sup>6</sup> Terminology here is a minefield. Economists sometimes reserve the term ‘technical change’ for a specific set of phenomena that is much narrower than common usage; and ‘innovation’ is used in the literature with several different meanings. Here I will use both terms interchangeably to refer to any kind of change in the bundle of different forms of technology that is in operational use in a society, business enterprise or other organisation.

**Figure 1 S and T in Development: Contrasting Knowledge Systems**



But these technology-intensive capabilities are only part of the story. Other actors may identify in outline the need or opportunity for innovation for which the ‘engineers’ provide detailed specifications. ‘Entrepreneurs’ play that important role, but again we need a broad view. Either of the two forms of Schumpeterian entrepreneur may be involved, bringing together novel technology, market opportunity and financial resources. Alternatively, the entrepreneur may be an executive in a manufacturing company who identifies an opportunity to exploit in a local market an established technology that is well into the mature phase of its product life cycle. S/he may also be a rural district official who identifies and exploits an opportunity in the bureaucracy to bring simple technology and financial resources together to create a new health clinic in a small district centre.

In addition, more than ‘engineers’ and ‘entrepreneurs’ may be involved. Even for only moderately complicated innovations, various actors may have to be co-ordinated and scheduled in order to integrate the various inputs needed to achieve innovation. Hence ‘managers’ will also be often involved, and again these can span a wide spectrum. They may be computer-supported project managers responsible for integrating the different specifications and other inputs required to create and bring on stream a new petrochemical plant or a new port facility. Or they may be managers pulling together the specifications and hardware for equipment, power supplies and operating procedures to establish new rural vaccination programmes.

It is important to bear in mind that, across these different kinds of situation, designers, engineers entrepreneurs and managers (the human resource core of DEE &IM capabilities) may contribute to different scales of innovation. Technical changes/innovations may be *partial* in the sense that they involve quite small modifications to existing production facilities or systems - for instance:

- the introduction of a modified procedure for planting a crop,
- the modification of dockside machinery in a port,
- the installation of modified turbine blades during maintenance in an electrical power plant.

Alternatively, technical changes may be more *comprehensive* in the sense that they involve the creation of a new facility or system with a comprehensive bundle of characteristics - for example:

- the closely linked introduction of a package of new seed variety, new irrigation facilities and organisational arrangements, altered agronomic procedures and the use of new machinery;
- the construction of a complete new dock facility in a port, with advanced materials handling and IT systems, plus new customs clearance procedures;
- the construction of a complete new power plant incorporating new organisational arrangements, operating protocols and maintenance procedures alongside new equipment.

This distinction is important. Although it is frequently possible to ‘buy in’ from specialised supplier capabilities in other towns, regions or countries the forms of technology needed for ‘comprehensive’ types of technical change, it is usually much less possible to do so in the case of ‘partial’ innovations, which depend more heavily on the existence of change-generating capabilities located much more closely to the operational use of the technologies involved. At the same time, evidence from the chemical industry indicates that future operating efficiency is higher when engineering and project management capabilities of the prospective owner-operator of new plants interacts with those of specialised technology suppliers during the implementation of new projects. The same seems likely to be true for designing and implementing rural health centres or agricultural innovations.

A final feature of these DEE&IM capabilities is about the knowledge-base they draw on in playing their creative innovation role. Overwhelmingly they draw on existing stocks of knowledge that they already have available. For example, engineers designing road bridges for infrastructure projects draw almost entirely on existing design principles, methods, tools and data, and apply these to the varying requirements of different bridging situations. However, a key component of their existing knowledge stock consists of ‘experience’ – the knowledge about how particular design approaches and configurations contributed to problems and successes in previous bridge-designing projects. Similarly, engineers designing paper mills or petrochemical plants usually draw primarily on the same combination of existing principles, tools, methods and data, strongly fortified by experience derived from previous design projects and their outcomes. The balance between a formally structured elements of knowledge (principles, tools, data, etc.) and less formally organised experience may vary widely. The designers of semi-conductor layouts will draw especially heavily on the former, but West African rice farmers will draw particularly heavily on the latter in designing the annual configurations of plant varieties for their planting programmes.

Two qualifications to this picture are important.

*(a) The importance of explicit investment in accumulating experience*

It is misleading to think of experience as a kind of manna from heaven that falls without cost or effort on those who participate in these DEE&IM activities. Sure, some can be acquired and accumulated in this way. However, that is likely to be a slow and partial process. Not surprisingly, therefore, engineering companies allocate considerable effort and cost to capturing, storing, disseminating and reflecting upon key aspects of their experience – all as an important input to improving their capability for innovative activity in future. Similarly, West African rice farmers make considerable efforts to accumulate systematically their experience of yields and other outcomes from past designs of variety planting.

Moreover, these kinds of purposefully accumulated experience are not just concerned with design and engineering technicalities. In large organisations like major engineering consultancy companies, considerable effort and cost is also allocated to capturing and accumulating experience about the managerial and organisational aspects of the technical change projects for which their engineering inputs have been used. In principle also, such systematic learning about organisational and managerial aspects of innovation can be acquired and accumulated by smaller organisations and even one-household farming businesses, but that is a bit more difficult, typically requiring supplementary collaborative forms of organisation and management devoted specifically to capturing the experience of innovating in different ways.

*(b) New knowledge in innovation*

As a supplement to their existing stocks of knowledge and experience, designers/engineers may obviously draw periodically on recently created knowledge made available from external sources – for example, information from an agricultural experiment station about attainable yields with a new rice variety. In most circumstances such new knowledge is not radically different from what was previously available and enables relatively modest incremental improvements in performance to be achieved by technical change – both in partial modifications to existing production systems/facilities and in the comprehensive creation of new ones. In other circumstances, new knowledge may be more radically different from the existing stock used by designers/engineers – perhaps, but not always permitting more substantial improvements in performance or the introduction of totally new kinds of production activity.

Typically, however, designers/engineers play only quite modest roles in creating such new knowledge. They draw most of it from other more specialised actors undertaking various forms of technological development. When they do contribute directly themselves, as a result of their own experimentation and experience accumulation, the additions they make to the knowledge base are usually not dramatically novel. However, this does not mean that these DEE&IM activities are just a one-way conduit with respect to incorporating new knowledge into designs and specifications for innovation – a kind of mediating link running from R&D to innovation in production. On the contrary they play an equally important role running in the other direction – **from** the production of goods and services **to** the execution of R&D. They do this in two ways.

- First, they actively ‘pull’ on R&D when their existing knowledge-base is inadequate to meet effectively the challenges and opportunities they confront. Entrepreneurs/managers may pose demands for specifications of products or production systems for which engineers cannot provide effective designs on the basis of their existing knowledge stocks. Engineers/designers themselves may identify from their accumulated learning about past experience particular focal points where the search for new knowledge might be especially productive.
- Second, this ‘pull’ on technological development activities is not simply a very generalised ‘demand’ for innovation. When mediated through the design/engineering/management interface (recall, broadly defined), such generalised demand becomes concretised in the form of specific technical configurations or performance requirements that shape the search process undertaken by those who undertake technological development.

This important **two-way** role performed by DEE&IM capabilities in the innovation process takes us further left in Figure 1 towards knowledge creation and technology development.

### ***2.2.3 Capabilities for Knowledge Creation and Technology development (K[T]C in Figure 1)***

For the most part this component of overall S&T capabilities consists of capabilities for applied research and experimental development within R&D as a whole. The roles and characteristics of these capabilities need little elaboration here. However, given the ‘for development’ context of this overview, one point might be noted. Formally organised and ‘modern’, science-based knowledge-creation (as reflected in R&D definitions and statistics) is not the only mode of knowledge creation and technology development. Those activities can also be undertaken outside formally organised ‘D’ (as in much of the knowledge-creation that goes on in industrial firms), and they may also be undertaken in ways that rely heavily on ‘non-scientific’ trial and error or systematic, but not theoretically informed, experimentation.<sup>7</sup>

### ***2.2.4 Capabilities for Scientific research (S&ST in Figure 1)***

In large part this component of overall S&T capabilities consists of the capabilities required for ‘basic’, ‘strategic’ or ‘scientific’ research within overall R&D. Again, little elaboration is needed here, apart from a brief comment on the broad title of ‘speculative thought’ in Figure 1. This is included as a reminder that more than modern ‘scientific’ modes of knowledge creation may be involved here. ‘Traditional’ modes may also be important, relying more on ‘non-scientific’ accounts of natural and social phenomena than on the rigorous contrast between theoretical constructions and systematic experimentation.

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<sup>7</sup> The point here is not that these modes of knowledge creation are an exclusive peculiarity of developing countries. They also characterise a great deal of knowledge-creation in advanced economy contexts. However, given the much greater significance of traditional knowledge systems in developing countries (see later), their relative importance is very much greater in those contexts.

## 2.3 Capability Components: Overlaps and Relative Magnitudes

### 2.3.1 *Overlapping Capability Components*

One point about the four-part framework outlined above is quite obvious. The boundaries between those four capability components are far from clear and distinct. More important perhaps is a somewhat different issue. The differences between those four categories, albeit blurred, are only differences in kinds of capability and carry no associated organisational distinctions with them. On the contrary, across a huge array of circumstances there are innumerable ways in which these capabilities overlap with different organisational arrangements. Very roughly, this diversity can be encompassed by four patterns.

- The same kinds of capability may be undertaken in totally different kinds of organisation. For example, both business enterprises and universities undertake scientific research that is published in the academic literature. Similarly, design and engineering may be undertaken in organisations that specialise in those activities, selling their services to clients; or they may be undertaken in-house by business enterprises that use their own designs and specification as inputs to their production of goods and services.
- Correspondingly, different kinds of S&T capability may be located in the same kind of organisation – e.g. universities undertaking both technological development and scientific research.
- The same resources in particular organisations may undertake different kinds of S&T activity at different times. For example, engineers normally engaged in production activities may be mobilised into temporary teams to undertake design activities or technological development.
- Organisations may pool their different capabilities in temporary collaborative organisations to undertake linked S&T activities. For example, in the 1980s paper-making companies and specialised paper process engineering organisations in Sweden linked their engineering and R&D capabilities in a collaborative project organisation to develop the technology for a radically novel paper-making process.

The point here is, then, one about definitions. Capability categories do not map on to organisational categories. A different issue is about how effectively different capability types interact with each other. As illustrated at the top and bottom of Figure 1, such interactions may differ sharply in different societies, being well articulated in some societies and highly dis-articulated in others. This critically important issue is addressed in later Sections 2.4 and 2.5. First, it may be useful to note an aspect of the magnitudes of the capability categories in Figure 1.

### 2.3.2 *Some Relative Magnitudes*

Only one point is developed here: the relative size of R&D and DEE&IM capabilities. This is important because the latter are regularly forgotten - as illustrated in the recent resurgence of interest in issues about S&T in developing countries. Numerous reports have rightly highlighted the importance of strengthening 'S&T capabilities' in those countries. But in most of these studies the suggestions about action have drifted toward issues about only R&D capabilities. A welcome exception was in part of the study by Task Force 10 on Science, Technology and Innovation that gave considerable prominence to the role of 'engineers' within S&T capabilities. However, little of that emphasis carried through to the overall summary report (*Investing in Development*), where the only concrete actions about strengthening S&T capabilities were about increasing expenditure on R&D.

With policy-related data about S&T so dominated by data about R&D, such drifting from one to the other is perhaps understandable. However, data sources do exist to provide glimpses of the importance of non-R&D capabilities within overall S&T activities. The S&T personnel surveys by the US National Science Foundation are one example and they provides a useful perspective – as summarised in the Box below.

<b>‘S&amp;T Capabilities’: What do they do? A glimpse at the case of the US</b>		
<b><u>The Activities of Scientists and Engineers in the US: 2003</u></b>		
Research (basic and applied) and technological development	1,843,397	<b>10%</b>
Design (equipment, processes, structures, models) and computer programming, systems development, etc.	2,379,235	<b>13%</b>
Management/Supervision (people, projects, quality, productivity, etc.)	3,340,646	<b>19%</b>
Business, administrative and production activities (accounting, personnel, sales, maintenance, etc.)	3,719,954	<b>21%</b>
Professional services (financial services, healthcare, legal, etc.)	4,181,148	<b>23%</b>
Teaching	1,935,885	<b>11%</b>
Other specified	626,790	<b>3%</b>
<b>All Above</b>	<b>18,027,055</b>	<b>100%</b>

Source: Annex Tables 1, derived from the US NSF.

Leaving aside the large proportion of scientists and engineers providing professional services of various kinds (about one-quarter, rising to about one-third if teaching is included), several other features of the US stock of S&T personnel bear further emphasis:

- It is striking that, in this highly R&D-intensive economy, only 10 per cent of the responding scientists and engineers undertake R&D as their main activity. In other words about 90 per cent do something other than R&D;
- Compared with those undertaking R&D, a larger proportion (13%) carries out various kinds of ‘engineering design’, including the design of computer applications, systems, etc.
- Even more of them (19%) undertake various management-related activities, frequently concerned with managing projects, quality and productivity.

In other words, as a very rough approximation, the proportion of scientists and engineers who undertake something like DEE&IM activities in one of the most R&D-intensive economies in the world is three times larger than the proportion undertaking R&D.

Further light has been thrown on this issue by the implementation of national Innovation Surveys over the last decade or so. These have sought to provide more comprehensive understanding about innovation than is offered by R&D data. Such surveys have been undertaken in several

developing countries, and the resulting information about the range of human resources drawn on in innovation is illuminating. For instance, as illustrated by the survey for manufacturing industry in Argentina (see the box below), the scale of the human resources involved in formally organised R&D is about one-twentieth of those engaged in various kinds of ‘informal’ R&D, engineering, design and related management activities – a very rough approximation to the bundle of DEE&IM capabilities in Figure 1.

**S&T Capabilities and Innovation:  
Manufacturing Industry in Argentina, 2001**

*The Argentine Innovation Survey (1998-2001) indicates that only about 17 per cent of professional employees with qualifications in the natural sciences and engineering undertake R&D on a full-time basis. Another 10 per cent do so on a part-time basis. In other words, the overwhelming majority (nearly three-quarters of these scientists and engineers) apply their S&T capabilities in activities other than R&D, even on a part-time basis.*

*More broadly, related data indicate that only 0.9 per cent of all employees undertake R&D in a formally organised R&D department. However, another 17 per cent of employees undertake innovative activities consisting of ‘informal’ R&D (not organised in a specific R&D department) and also various industrial engineering, design and related management activities contributing to innovation.*

*In other words, while less than one percent of total employees are engaged in ‘formal’ R&D, nearly twenty times that number contribute to innovation via their activities in ‘informal’ R&D, industrial engineering, design and related management activities.*

Source: Annex Tables 2

These rough indications of the relative magnitudes of R&D and DEE&IM capabilities illustrate the narrowness of R&D-dominated perspectives on policy about ‘S&T for development’ at national and international levels.

This matters for policy not just because of the scale of the commonly neglected DEE&IM capabilities. It also matters because as noted above, these capabilities play three key roles in the innovation process:

- They design and implement innovation and change in the production of goods and services on the basis of existing stocks of knowledge, without drawing anything directly from R&D,
- They constitute the necessary capabilities for translating knowledge outputs from R&D into implemented innovation in producing goods and services,
- They crystallise in concrete form the ‘demand’ for innovation in production and channel it towards R&D.

The narrowness of R&D-myopia in policy also matters for policy because of an issue that has often been thought relevant primarily, or even exclusively, to R&D: the role of externalities in contributing to underinvestment in capabilities. But this is just as relevant with respect to investment in building DEE&IM capabilities, perhaps especially so because of the importance of

business enterprises in making that investment. Because of the emphasis on these capabilities later in this paper, this point may merit a little elaboration.

The area of design, engineering, entrepreneurship and innovation management is one where individuals have very limited control over investment decisions about strengthening their own human capital. They can of course choose to invest in their own education and training at universities and similar organisations. However, the kinds of human capital that can be created in these ways constitute only the rudiments of basic and generally applicable knowledge and skill for these areas. Beyond that, the necessary kinds of ‘deeper’ and detailed knowledge and skill are held by enterprises and rarely by education and training organisations. Investment in the acquisition of such knowledge by young engineers and related potential contributors to innovation is therefore made largely at the discretion of enterprises, not by individuals in the light of their personal career interests and earnings expectations. This is especially important because of the significance of ‘experience’ in the knowledge-base of these kinds of capability. Access to such experience is entirely dependent on the hiring decisions of enterprises in the first place, and then it depends very heavily on decisions made by enterprises to incur explicit further costs in enabling individuals to acquire and accumulate experience actively rather than just passively (like manna) as a by-product from their employment. But with personnel mobility very high in these areas, along with high spillover potential through other channels, one can only expect very significant underinvestment in building these kinds of capability. Not surprisingly, a growing body of studies suggest that in practice also there are important shortages of such capabilities in developing countries. This is an important contributor to key differences between Type (A) and (B) knowledge systems in Figure 1.

## **2.4 Type (A) Knowledge Systems: Rich countries**<sup>8</sup>

An important feature of the knowledge systems of rich countries is obviously their large scale, totally dwarfing those of poor countries. But the point stressed here is about the strong articulation of their systems, as illustrated at the top of Figure 1. This is evident in two ways.

### ***2.4.1 Domestic Articulation***

Despite considerable differences between them, the S&T systems of rich countries have developed over time strong linkages between the component types of capability. Typically the production of goods and services draws heavily on the designs and specifications for change from ‘local’ design and engineering capabilities; and a very large part of all innovation is driven and managed by local entrepreneurial and managerial capabilities. In turn, these DEE&IM capabilities link strongly linked ‘backwards’ to technology development capabilities - **from** which they draw new knowledge inputs for innovation, and **to** which they channel concrete and focused expressions of the demand for particular areas and forms of new knowledge. Beyond that, there usually exist strong interactions between scientific research and at least some areas of technological development in high-tech sectors and science-intensive technologies. These strong interconnections between different components of the ‘typical’ rich country innovation system have led to these being characterised as ‘endogenous’ systems. But this is only partly the case and only part of the overall picture.

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<sup>8</sup> The identification of Type [A] and [B] systems with advanced and developing countries is a gross simplification. The implied presumption that the difference is unchanging is just as bad, since a number of developing countries have moved partially or comprehensively quite long ways across the spectrum from [B] towards [A] in the last two or three decades. Nevertheless, the number doing so has been quite small and, for the purpose of framing the discussion here, these simplifications provide a useful starting point.

## 2.4.2 *International Articulation*

Perhaps just as important, and growing increasingly important, is the strong international articulation of the rich country innovation systems. These interconnections are partly reflected in trade in technology that is already embodied in goods and services – both final goods such as pharmaceutical products, and intermediate goods like machinery or advanced materials. They are also embodied in links running from design and engineering in other countries and the local production of goods and services – for instance the licensing of product designs or the import of engineering services.

But international articulation is also strong in connection with other capability components. Flows of knowledge run between design or technology development capabilities in different countries, and collaborative international arrangements are put in place for the joint execution of technology development and design. Similarly, there are strong knowledge flows between scientific capabilities in different countries, as well as increasingly frequent forms of collaboration in various areas of scientific research, while the scientific outputs from research are very frequently drawn into technological development in countries that did not create them.

## 2.5 **Type B Knowledge Systems: Poor countries**

As illustrated in the lower part of Figure 1, these dual patterns of strong articulation are much less evident in other societies - almost all the developing countries. This is partly because these societies incorporate two largely disconnected kinds of knowledge system. One, as in the advanced countries involves a set of activities and capabilities based on ‘Modern’ (i.e. western and science-based) forms of science, technology development, design and production (‘M’ in Figure 1). In the other, these activities are based on ‘traditional’ (or indigenous) forms of knowledge (‘T’ in Figure 1).

### 2.5.1 *Traditional knowledge systems*

Over the last decade or so the significance of traditional knowledge systems has come to be more widely recognised as the basis of the current and future livelihoods of enormous numbers of people. Production of goods and services by and for very large parts of the world’s population depends on such traditional or indigenous forms of knowledge.

However, although traditional (T) knowledge systems are deeply endogenous to the societies that use them, they are commonly dis-articulated in several senses.

- First, the component activities of the ‘T’ stream are at best very weakly linked among themselves.
- Second, although commonly juxtaposed, the components of the ‘T’ and ‘M’ streams are very poorly linked.
- Finally, the ‘T’ stream activities are also largely disconnected from the formal organisation of education and training, and they rely on informal and frequently weakening methods of inter-generational transmission.

*“... more than three-quarters of the world’s population relies on indigenous knowledge to meet their medical needs, and at least half relies on traditional knowledge and techniques for crops and food supplies. As about one-third ... does not have access to electricity, all modern technologies and production activities that depend on this source of energy are out of their reach.”*

Francisco Sagasti (2004: 54)

These multiple forms of dis-articulation severely constrain their ability to generate technical change and respond quickly to new opportunities and threats.

### 2.5.2 'Modern' knowledge systems

The characteristics of the 'Modern' parts of Type (B) systems can be characterised first by their small scale. This is illustrated first with respect to the per-head availability of capital-embodied technology. In part this is an unsurprising reflection of their relative economic poverty. But as shown in Table 1 below, the disparity between High-Income and Low-Income countries in the availability of capital embodied technology per head is much greater than the disparity in income level, and the disparity widens with respect to more 'technology-intensive' forms of capital good like PCs and mobile phones. Even in Upper Middle-Income countries such as Argentina, Malaysia or Poland the per capita availability of these forms of technology is only around one-third to one-quarter of the level in High Income countries – though the disparity more closely matches the difference in income levels.

**Table 1 Science and Technology in a Divided World: Capital Embodied Technology**  
Indexes across country groups at different income levels: 2000 \*

Country Groups	<u>Population</u> (Totals)			<u>Level of Income</u>	<u>Capital Embodied Technology Per Head</u>			
	<u>Million</u>	<u>(%)</u>	<u>Index</u>		<u>General/infrastructure Capital</u>		<u>'Technology-intensive' Capital</u>	
	<u>Million</u>	<u>(%)</u>	<u>Index</u>	<u>GDP per head</u> <sup>1</sup>	<u>Electric power consumption</u>	<u>Telephone main lines</u>	<u>Personal computers</u>	<u>Mobile phones</u>
<i>A Low Income – Excl. India</i>	<b>1,135</b>	19	A/B	<b>0.7</b>	<b>0.8</b>	<b>0.6</b>	<b>1.0</b>	<b>0.6</b>
<i>B All Low Income</i>	<b>2,175</b>	36	B/B	<b>1.0</b>	<b>1.0</b>	<b>1.0</b>	<b>1.0</b>	<b>.01</b>
<i>C Low-Middle Income</i>	2343	39	C/B	2.3	3.2	5.0	4.5	15.6
<i>D Upper Middle Income</i>	599	9	D/B	4.7	9.5	9.6	14.4	38.7
<i>E High-Income</i>	<b>975</b>	16	E/B	<b>14.7</b>	<b>29.1</b>	<b>26.8</b>	<b>84.8</b>	<b>135.5</b>
			E/A	<b>20.5</b>	<b>36.2</b>	<b>46.7</b>	<b>85.1</b>	<b>126.7</b>

\* See Annex 1 Table 3 for absolute values and further explanatory notes.

1. Current US\$, PPP

**Table 2 S&T in a Divided World: Human Capital and Knowledge Acquisition/Creation**  
Indexes across country groups at different income levels: 2000 \*

Country Groups	Index	Level of Income GDP per head <sup>1</sup>	Human Capital (Numbers of people)		New Knowledge Acquisition & Creation per head			S&T papers
			Tertiary Enrolment: S&T subjects	All Research Personnel	License payments (Imports)	R&D		
						All (GERD)	By Business (BERD)	
<i>A. Low Income – Excl. India</i>	A/B	<b>0.7</b>	<b>0.5</b>	<b>0.9</b>	<b>0.6</b>	[0.2] <sup>2</sup>	[0.1] <sup>2</sup>	<b>0.4</b>
<i>B. All Low Income</i>	B/B	<b>1.0</b>	<b>1.0</b>	<b>1.0</b>	<b>1.0</b>	[1.0] <sup>3</sup>	[1.0] <sup>3</sup>	<b>1.0</b>
<i>C. Low-Middle Income</i>	C/B	2.3	1.9	3.6	11.0	1 (C/C)	1 (C/C)	2.7
<i>D. Upper Middle Income</i>	D/B	4.7	6.8	10.8	33.0	1.5 (D/C)	0.9 (D/C)	14.2
<i>E. High-Income</i>	E/B	<b>14.7</b>	<b>8.3</b>	<b>19.7</b>	<b>373.7</b>	<b>[36.6]</b>	<b>[97.6]</b>	<b>98.0</b>
	E/A	<b>20.5</b>				<b>[181.0]</b>	<b>[1,650.7]</b>	
	E/C	<b>6.3</b>				<b>17.0</b>	<b>20.7</b>	

\* See Annex Table4 for absolute values and further explanatory notes.

1. Current US\$, PPP

2. Data are available for very few countries for 2000.

3. Reflects primarily India

Disparities in the scale of other aspects of S&T capability are also wide, as illustrated in Table 2. It is striking, however, that the differences between High-Income and Low-Income countries with respect to scientific and technological human capital are not substantially greater than the difference in income levels, and with respect to tertiary enrolment in scientific and technological subjects the difference is narrower than the income gap. On the other hand, with respect to several indicators of knowledge acquisition and creation, the disparities widen dramatically.

- Reflecting the much stronger international articulation of S&T systems in High-Income countries, their per-capita acquisition of technology imports via licensing is nearly 400 times greater than in Low-Income countries, and still about 10 times greater than in Upper Middle-Income countries.<sup>9</sup>
- Differences in total R&D expenditure (GERD) per head are also very much wider than differences in income levels - though the data available for the comparison with Low-

<sup>9</sup> A little caution is needed here because of the changing composition of licensing payments across the country groups, with licensed media-related payments probably rising as income level rise.

Income countries is very limited for 2000, and the relatively high level of R&D expenditure in Low-Income India make an enormous difference. Nevertheless, even if the Low-income countries are excluded, the gap remains very wide. Per capita expenditure on R&D in High-Income countries is about seventeen times greater than in Lower-Middle-Income countries – a disparity that is about three times greater than the difference in income levels.

- Differences are much wider with respect to per capita R&D expenditure by business enterprises (BERD, usually more directly involved in contributing to technical change than R&D in universities and government organisations. Again, the limitations of the data for the Low-Income countries make meaningful comparison difficult, especially with India excluded. But the disparity between High-Income and Lower-Middle Income countries remains very wide, with per-capita expenditure about twenty times greater in the former – and that gap is about three times wider than the difference in income levels.
- Finally, the per capita publication of scientific and technological papers in international journals provides an indication (albeit very rough and imperfect)<sup>10</sup> of wide disparities in the scale of scientific research – nearly one-hundred times greater in High Income countries than in Low Income ones, with that gap being more than six times greater than the difference in income levels.

These very large differences in the scale of S&T activities in the two kinds of system are clearly important. Despite the limitations of the indicators, it is evident that the scientific and technological poverty of poor countries is very much greater than their general economic poverty. But these differences in scale reflect only one feature of Type (B) knowledge systems. Just as important are various forms of dis-articulation and fragmentation. Two of these relate to the links within countries between the main S&T activities.

First, compared to the pattern in A-type knowledge systems, there is much less organisational overlap between them – in particular:

- Design, engineering and other innovation-managing capabilities (DEE&IM) are undertaken much less intensively (if at all) within organisations that undertake the production of goods and services. This has been commonly observed at the level of individual business enterprises, but also in recent studies at the level of spatially clustered groups of firms.
- Similarly, such formally organised R&D activities as are undertaken overlap organisationally to only a very limited extent with the activities of production enterprises. Instead, separate organisations like universities and public research institutes often undertake around 60 - 90 per cent of total national R&D – as reflected in the low BERD/GERD ratios shown in Table 2 above.

Second, the links and interactions running horizontally between the different types of S&T capability are typically very weak. This is not just a matter of weakness in links running from left to right in Figure 1 – **from** technology creation **to** the production of goods and services. Numerous studies in both industrial and agricultural contexts have indicated that effective links running the other way are also weak, perhaps weaker. In other words, the demand for knowledge-inputs to innovation running from the production of goods and services, via their identification,

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<sup>10</sup> A large proportion of the output from science in poor countries is published locally rather than in international journals. While a large part of the scientific output in rich countries is also published journal not covered in the statistical source, it is arguable that the relative importance of the unrecorded proportion of poor countries' scientific output is much more significant.

articulation and specification by DEE&IM capabilities, to technology development activities is typically very weak.

The consequences of these kinds of dis-articulation are important. They limit the extent to which the S&T capabilities that do exist in poor countries, albeit at very small scales, contribute to innovation. It is argued, therefore, that these capabilities typically do not constitute an endogenous system that contributes significantly to change in the technological basis for producing goods and services.<sup>11</sup> This has major implications: considerable caution is needed in interpreting the frequent call for major international efforts to strengthen the ‘S&T capabilities’ of developing countries. If this leads to increases in the scale of human and physical assets of individual organisations (especially in areas towards the left of Figure 1), the consequences in terms of change in the production of goods and services may be quite slight. ‘Connectedness’ or ‘articulation’ is an important component of capability.

But also, alongside the domestic forms of dis-articulation, many of the links with S&T activities in other countries are similarly weak.

- Poor countries’ collaboration with other countries in scientific research (as partly reflected in joint publications) accounts for a very small fraction of the global total of such collaboration, though interaction in this mode may actually be more significant than collaboration in technology development or design/engineering.
- In particular, it is striking that only a tiny fraction of total international collaboration in technological development is accounted for by links between organisations in rich and poor countries, either through R&D collaboration agreements or other types of arrangement involving more one-way knowledge flows such as technology licensing agreements (as suggested by the data for licensing payments in Table 2 above).

However, rather than being weak, one other aspect of the international articulation of the S&T systems in developing countries is usually very strong, often destructively so. This link is concerned with the international migration of highly qualified scientific and technological human resources. Large parts of this migration run between the rich countries, but very substantial parts run from poor to rich. As in other respects, there is a major difference between rich and poor countries in these migration patterns. Among the former, they are broadly symmetrical – flows out are offset by flows in (and the durations of absence are typically fairly short). Among the latter they are grossly asymmetric – flows out are very much greater than flows in (and the durations of absence are typically quite long). Recent debate has suggested that there are significant reverse flows to developing countries that offset the initial emigration outflows, and it has therefore become common to describe this phenomenon as one involving ‘Brain Circulation’, not ‘Brain Drain’. But, as suggested later, this seems a misleadingly benign perspective on the issue.

## **2.5. SOME MAJOR ISSUES**

### **2.5.1 A Broad Overview**

The framework outlined above suggests that the key problematic issues about ‘S&T for development’ can be grouped under five headings.

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<sup>11</sup> This has also led some to argue that the “system” element included in terms like “innovation system” or “knowledge system” is totally inappropriate when such concepts are transferred from the context of rich countries as a basis for discussing issues about S&T activities in poor countries.

*(a) The scale of S&T capabilities*

The **scale** of S&T capabilities in developing countries is not just disproportionately small relative to levels of economic activity. It is widely agreed that it is also substantially smaller than would be efficient since in most areas there are significant externalities that inhibit investment in creating those capabilities. It is not surprising therefore that almost all the major reports addressing issues about ‘S&T for development’ over recent years have called for these capabilities to be enhanced.

*(b) The structure of S&T capabilities*

At the same time, though, there are less well-recognised problems about **structure** as well as scale. Perhaps the most important of these is about the relative scale of R&D and other S&T capabilities. In particular, there are strong grounds for arguing that underinvestment in DEE&IM capabilities has been at least as significant as underinvestment in R&D, but has not been the focus of significant policy attention.

*(c) The domestic disarticulation of S&T capabilities and activities*

The problem of domestic disarticulation in the S&T systems of developing countries has also been widely recognised. Not surprisingly, therefore, contributions to policy debate have given considerable attention to aspects of organisational restructuring and re-design intended to increase the articulation of S&T activities. Behind such views has been the common hope that these measures will help to **deliver** innovation more effectively to the various sectors of the economy. Some voices have added the important qualification that effective articulation depends also on the nature and intensity of **demand** for knowledge that (in terms of Figure 1) runs ‘back’ from the production of goods and services. Much of the discussion of that demand factor has rightly focused on the broad policy context and wider institutional environment for innovative activity (e.g. the stability of the macro-economic environment or the characteristics of trade policy). However, much less attention has been given to the important role of DEE&IM capabilities as the focal point in the system where the poorly specified demand for knowledge and other inputs to innovation in the production of goods and services is identified and crystallised into concrete and specific forms.

*(d) International articulation - access to ‘technology’*

Numerous dimensions of globalisation have massively enhanced the accessibility of technology through international channels, but this has been particularly concentrated on forms of technology that are closest to technological ‘final products’ – e.g. embodied in imported goods and services. There remain considerable questions about developing countries’ access to ‘intermediate’ forms of technology that are drawn into the innovative activities of developing countries themselves. Such questions arise most significantly in two broad areas.

- The first is about recent developments of the intellectual property regimes in advanced countries and their international ‘harmonisation’ via TRIPS and related arrangements. Quite apart from their effect on the prices paid for technology in its more ‘final product’ forms (e.g. the specifications of pharmaceutical products or the products themselves), these developments are seen as seriously hindering, or even precluding, developing countries’ access to technology in its more ‘intermediate’ forms for use in their own innovative activities.
- The second, which may overlap with the first in some circumstances, arises in the context of international political relationships and negotiations that are primarily about ‘non-S&T’ issues – what I have earlier called ‘negotiation-embedded’ S&T issues. For developing country parties to such negotiations, a commonly important issue is about access to technology that may be blocked by advanced country governments on (ostensible) grounds

of security, or more generally by the commercial interests of technology creating corporations in advanced countries – as in the case of ‘clean technologies’ in the context of climate change negotiations.

(e) *International articulation – collaboration in S&T activities*

International collaboration in scientific research and technological development is frequently seen as an important mechanism for enhancing capabilities in developing countries, for increasing their access to ‘sticky’ knowledge located in the advanced countries, and for contributing more directly to innovation. However, as noted above, the incidence of such collaboration is commonly considered inadequate - at least with respect to collaboration in technological development.

(f) *International articulation – the migration of scientific and technological human capital*

The international migration of highly qualified scientific and technological human resources between rich and poor countries is highly asymmetric. While elements of ‘brain circulation’ are present, considerable questions arise about the extent to which these go anywhere near to offsetting the negative consequences of initial outward migration in many developing countries.

### 2.5.2 *Which Issues for the L20?*

Many of the issues outlined above must be addressed exclusively at the level of individual countries and, with respect to large elements of these, it is doubtful if an L20 mechanism could make much difference to the scale or effectiveness of local action. There are, however, a number of areas where action at an L20 level might help to achieve significant positive outcomes. Such action might amount to the clarification and endorsement of new directions to be taken, plus encouragement to the local actors who must pursue them. It might take the more concrete form of reinforcing implementation of the Paris Declaration on Aid Effectiveness – in particular, insisting on the harmonisation of donor approaches to supporting key areas of S&T-related action at the country level. There are also other aspects of the issues outlined above where significant international or cross-cutting elements are involved, and in these an L20 mechanism might be especially important.

It may be useful to organise such areas of possible action in three categories which combine aspects of the issues outlined above in ways that might better fit an L20 agenda. However, I will leave to others the task of identifying which of these fall into each of the three categories indicated in the table at the start of the paper:

- Areas where other initiatives are already under way or planned, and where an L20 might focus on monitoring progress and helping to drive it forward when it seems to be blocked.
- Areas where the basis of existing understanding and potential consensus seem adequate to permit an L20 to move forward with new initiatives in the reasonably near future.
- Areas where that basis does not yet exist, but where the importance of the issue is clearly recognised, indicating that L20 action should be to encourage and support intensive enquiry, analysis and consensus development.

The three categories are as follows.

1. ***Generic issues*** that cut across sectors and technologies. Three seem important candidates for action by an L20 group.
  - ***Issues about intellectual property regimes*** and their influence on the access to technology by developing countries and on the terms of such access.

- ***Issues about international scientific and technological collaboration*** where new approaches might yield high returns.
- ***Issues about the international migration of scientific and technological human resources*** where international actions now seems important.

Other papers on the first two of these issues are being prepared for the Maastricht meeting, so no further comment will be added here. Only the third will be taken forward for elaboration in Section 3 below.

2. ***Negotiation-embedded issues*** where significant current or prospective tension is attached to scientific or technological aspects of problems that are defined primarily in non-S&T terms. Such issues seem important in three areas.
  - ***Issues about developing country access to dual-use technologies*** - involving applications for both developmental as well as military/security purposes.
  - ***Issues about access to ‘clean’ technology arising in the context of climate change negotiations*** – where key questions are about access to technology in ‘intermediate’ forms and not just in the ‘final’ forms of equipment and engineering services sold by suppliers from the advanced economies.
  - ***Issues about scientific and technological capability building in connection with WTO and other negotiations over the liberalisation of trade in agricultural and related products*** – focusing on building capabilities needed not just to comply with technical standards and regulations but also to engage effectively in their definition and negotiation.

Although these appear to be extremely important issues, they will not be taken further here. Hopefully participants in the Maastricht meeting will throw further light on their relevance for L20 action.

3. ***Sector-specific issues about the scale, structure and articulation of S&T capabilities.*** These need to be taken together, and they need to be addressed at the level of specific sectors of the economy because the nature of the challenges differs widely between them. It is suggested that an L20 should focus on three such sectoral areas.
  - ***The agriculture sector***, where poverty-centred concerns, plus interests that range widely across bilateral and international bodies, call for concerted action at an L20 level.
  - ***The industry and infrastructure sectors*** where the needs for capability building in areas of design, engineering and management seem particularly strong and where the changing structure of international investment and trade in services provides new constraints on capability development, but also new opportunities if bold international action could be taken.
  - ***The medical and health care sector*** where there are wide-ranging challenges for international action.

The first two of these areas will be taken forward for further comment in Section 3. The third is left here simply as a heading. This is not because the issues in this area are unimportant. Clearly they are. Two other points are involved. First, this area lies far outside the expertise of this paper’s author. Second, there have already been a number of substantial international initiatives in this area over recent years, and many appear to be moving forward with considerable resources and

unusual speed. Whether an L20 mechanism could add further value to these steps seems debatable – perhaps not least by the participants in the Maastricht meeting.

### ***2.5.3 A word of Caution: the Institutional Context for S&T Activities***

One immensely important issue has been ignored so far, having been completely omitted from the framework summarised in Figure 1. That figure, already complicated, focused exclusively on scientific and technological activities and capabilities and on the interactions between them. It omitted entirely the wider context within which these activities are undertaken. But long ago, in what was probably the first S&T ‘system’ study, the Science and Technology Policy Instruments (STPI) project, funded by the IDRC of Canada, highlighted a simple important issue that cut across the experience of ten developing countries: policies about science and technology have remarkably little effect on development if they focus exclusively on scientific and technological activities that are undertaken in wider economic and policy contexts that are incompatible with the S&T aims being sought. Over the last decade or so, numerous ‘innovation systems’ studies have re-told that story in varied contexts across advanced, emerging and developing economies. The message is clear: the ‘institutional context’ for innovative activity has a major influence on how that activity takes place, on the nature of innovation capabilities that are accumulated (or not), and on the extent of articulation between them.

The specifics about which aspects of the institutional environment are important vary widely between and within developing countries, as do details about the ways in which they are likely to influence ‘S&T’ activities. This diversity cannot be pursued here, but any L20 initiatives about ‘S&T for development’ must take note of the wider policy and institutional contexts of any of the problems they address.

## **3. SOME SELECTED ISSUES FOR THE L20**

### **3.1 Generic Issues: The International Migration of Scientific and Technological Human Capital**

As noted earlier, most developing countries are tightly linked into the international migration of highly qualified scientific and technological human resources. Large parts of this migration run between the rich countries, but very substantial parts run from poor to rich. During the 1960s and 1970s these flows were seen in source countries as having almost entirely negative consequences – hence the common term: “Brain Drain”. But increasing emphasis has been given over the last decade to the fact that there may be compensating reverse flows. Some of these are financial – e.g. emigrants’ remittances to home countries. But some involve reverse flows of knowledge, skill and experience in two broad forms: ‘diaspora’ effects and return migration.

Consequently, what was once discussed as brain “drain” is now seen as brain “circulation”. However this corrective to the earlier one-sided perspective seems to have blurred important issues affecting most of the developing world. It is important to try and cut beneath the complications and note some simple basics.

First, before one takes account of any reverse flows, two points seem clear.

- Rich countries in aggregate benefit substantially from the immigration of highly qualified scientists and engineers from poor countries. In particular, employers gain access to highly skilled human capital that would otherwise be much scarcer, and probably more expensive.
- Conversely, poor countries incur losses from the initial emigration of their highly qualified human capital. Leaving aside the question of return, the extent of this loss depends on the number of emigrants and their opportunity cost – the foregone returns to their employment at home. The number is frequently very high, the foregone returns are very rarely zero (despite anecdotes about the large populations of doctoral taxi drivers in developing countries), and the durations of absence over which these returns are foregone are typically relatively long and frequently indefinite.

*“The United States is a nation of immigrants, and nowhere is this more evident than in the country’s research labs. Strip away the legions of foreign PhD students, postdocs and tenure track researchers, and the behemoth that is the US scientific enterprise would look much less impressive.”*

Nature, 427, 190-195 (15 Jan. 2004)

Then second, what can be set against this initial loss?

One recently influential view is that there is no such loss in the first place (Stark). It is argued that incentives for individuals in developing countries to invest in their own human capital are increased by the possibility of emigration and the associated expectations about opportunities for higher incomes in other (mainly advanced) countries. So, provided there are constraints on migration to ensure that at least some of those who make additional human capital investments do not migrate, the overall level of human capital in developing countries is raised, not reduced – i.e. there is a ‘brain gain’. However this argument has been convincingly challenged on both empirical and theoretical grounds (Faini, Schiff), and a summary of the latter merits repetition here: “...in a dynamic framework ... the brain drain is unambiguously larger than the brain gain ... the steady state is characterized by a net brain loss” (Schiff).

To offset that loss, there are the suggested reverse flows contributing to brain ‘circulation’. However, the evidence about these is far from convincing.

- While remittances from emigrants are very large in aggregate for many developing countries, there are good grounds for believing that they are relatively modest from highly skilled migrants (e.g. Faini).
- ‘Diaspora’ effects generated in their home countries by scientists, engineers and others who remain in rich countries can be important. But a large part of the evidence about this arises from the very specific circumstances of the growth of the Indian IT services industry, where substantial contributions were made by expatriate Indian scientists, engineers and entrepreneurs in Silicon Valley. Other experiences seem to have been much less valuable.
- Reverse migration effects, generated by emigrants returning with accumulated skills and experience, can also be important. But a large part of the evidence about this is derived from experience in Korea and Taiwan where returning scientists, engineers and managers played important roles. However, this occurred in the highly specific circumstances of

those countries that had already created very advanced RDD&E environments that both attracted back the emigrants and provided a context in which they could function effectively. In other words, the pre-existence of considerable ‘absorptive capacity’ appears to be a necessary condition for significant reverse migration effects.

There is no systematic balance sheet of outward and inward S&T capability flows associated with international migration. However, the situation is that, except in very favourable circumstances, any brain ‘circulation’ appears to be highly asymmetric. Reverse flows seem to be far smaller than initial outward flows, and the latter can sometimes be massively destructive, as in the case of the Ghanaian health care sector.

In considering a ‘for development’ response to this situation, there are strong grounds for not entertaining ideas about regulatory restrictions on migration.

- Views about human rights and individual freedoms are incompatible with measures that significantly restrict the international mobility of highly skilled (or other) people.
- Individual migrants from poor to rich countries typically add to the human capital they take with them – either by further education or, often much more important, by employment plus associated training and experience-acquisition that is unavailable except through such employment. This adds to their personal returns and to the returns to their employers in rich countries.
- From the perspective of the global allocation of resources, overall efficiency and welfare are increased when human capital is able to move from places where it yields low returns to places where returns are greater, especially if those also permit the deepening of human capital in ways that would not be possible without migration.

However the development process is about changing, not simply about accommodating resource allocation to, the prevailing global distribution of conditions that determine returns to human capital in different places. Although greater availability of highly skilled human capital is not the only input needed to achieve such changes, it seems to be an extremely important necessary input, especially in situations where critical mass effects are significant.

Moreover, it is the taxpayers of poor countries (and individuals), who make the investments in human capital that give rise to the migration-derived benefits in rich countries. From a returns-to-investment perspective, the assessment sketched above suggests two striking points

- Substantial proportions of the returns to very many poor countries’ investments in highly qualified scientific and technological (and other) human capital accrue to rich countries – spillovers from the poor to the rich;
- The off-setting share of the total lifetime returns to the investment in human capital that may eventually accrue to poor countries from ‘brain circulation’ appear not to be substantial except in very special circumstances. They will be even less significant when discounted to present values over the long time lags between the initial investments and the time when returns actually materialise.

Much of the policy discussion in this area in recent years appears to have nibbled at the wedge of the basic issues here: for example, (a) voluntary codes and agreements by individual advanced countries (e.g. the United Kingdom) that they will limit the intensity of recruiting in developing countries facing particular difficulties in skill retention, or (b) measures to try and reinforce diaspora effects and return migration.

However, almost entirely absent from recent policy discussions about this issue has been an approach that was elaborated by Jagdish Bhagwati in the 1970s. This rested on the clear idea that the losses incurred by developing countries (the foregone returns to their investments in highly skilled human capital) should be offset in some degree by a transfer of resources from the beneficiaries of spillovers from poor to rich countries. The mechanism was simple: the beneficiaries should be taxed in rich countries, with the tax proceeds used to create a ‘development fund’ for use in developing countries.

**It is suggested here that a modified form of this proposal should be the cornerstone of an L20 initiative in this area.** The main features the proposal would be:

- The tax - most simply identified as a proportion of salary costs - would be levied on employers of highly skilled immigrants in the rich countries.
- The tax rate would be relatively low (say, 5%) so that any influence on moderating emigration from poor countries or hiring in rich ones would be modest.<sup>12</sup>
- The tax proceeds would be vested in a specialised global fund (or ‘Facility’) and then used for highly skilled human capital development in poor countries.

**Very rough** calculations (Annex Table 5) suggest that a tax of this type (set at 5% of salary costs) **might** yield about US\$2,500 million if levied only in the US on employers of ‘Foreign Citizen’ scientific and engineering college graduates from ‘developing countries’. This figure would rise considerably in the US alone with wider definitions of the tax base, and it would increase further when the tax proceeds in other OECD countries are added.

In focusing on human capital development, the ‘facility’ might use some of these funds to address issues fairly directly linked to the international mobility of skills - such as mechanisms to enhance ‘diaspora’ contributions to development (if experience suggests that these are indeed valuable), or measures to accelerate return migration (in circumstances where these are shown to be effective). Attention could also be centred on capability building or ‘temporary’ capability replacement in areas where surges in the emigration of key human resources give rise to crises in human resource availability.

However, it seems highly desirable that the ‘facility’ should focus primarily on the aim of strengthening capabilities in developing countries. Together with developmental advances in other areas, this is the commonly highlighted as the longer term response to offsetting the losses that accrue from asymmetric ‘brain circulation’. With respect to ‘S&T’ capabilities in particular, this focus should take account of key issues about priorities outlined earlier, particularly with respect to ‘downstream’ innovation capabilities involving design, engineering, entrepreneurship and innovation management. The activities of the ‘facility’ would focus on these priorities in two sectoral areas.<sup>13</sup>

- Innovative schemes to strengthen capabilities in the areas of engineering and related management skills and experience for major infrastructure development, and manufacturing, mining and other industry development via FDI and local investment – as outlined below in Section 3.2.1.

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<sup>12</sup> Although the actual impact of such a tax will depend on the value of the supply and demand elasticities, it seems unlikely that a 5% tax would induce substantial changes in migration or hiring decisions.

<sup>13</sup> This report has not considered the healthcare sector. But if the S&T-related considerations stressed in this report also apply in that area, the ‘facility’ could well address that sector, especially as brain drain losses are often particularly pronounced there.

- Similarly innovative mechanisms to strengthen ‘downstream’ innovation capabilities associated with agriculture – as outlined below under 3.2.2.

### 3.2 Sector-Specific S&T Issues

The two problem areas elaborated in this section (‘S&T for development’ in the industry/infrastructure and agriculture sectors) involve the same three broad issues: serious limitations in the scale, structure and articulation of S&T capabilities. However, the problems and possible solutions take very different forms, calling for very different kinds of L20 initiative.

#### 3.3.1 Industry and Infrastructure: Technological capability development

#### 3.3.2 S&T for Agricultural Development

##### *Different modes of agriculture*

It is unhelpful to address issues about ‘S&T for agricultural development’ in a single framework. The issues are far too heterogeneous for that. But nor is it entirely useful to break that heterogeneity up into regions like Asia or Africa. Critically important differences cut across such boundaries. However, as a first step, quite a lot of traction on this heterogeneity can be gained with a simple distinction between two kinds of agriculture. As shorthand for these I will use ‘commercial’ and ‘smallholder’ as rough labels – but with reference immediately below to some of the wider features of the two categories.

##### ‘Commercial’ agriculture

is not necessarily ‘large-scale’ or entirely commercial, and may involve substantial subsistence elements. Important features typically include

- **capital-supported** farming – reasonable access to irrigation, roads, machinery, etc.
- **considerable agro-ecological homogeneity**, with correspondingly ‘simple’ farming systems
- **substantial control over many forms of stress**, with correspondingly low risks of wide yield variation,
- **relatively strong integration with supporting institutions** – e.g. markets for inputs and outputs and credit.

##### ‘Smallholder’ agriculture

is usually small-scale’, but not necessarily all subsistence and may involve substantial commercial components. Important features typically include:

- **capital poor farming** –limited or no access to irrigation, roads, agricultural machinery, etc.
- **very high agro-ecological heterogeneity**, with correspondingly complex farming systems
- **very high vulnerability to multiple forms of stress**, with correspondingly high risks of wide yield variation
- **relatively weak integration with supporting institutions** such as input/output markets or credit systems.

‘Commercial’ agriculture corresponds roughly to the form of agriculture where the combination of new high-yielding plant varieties and other ‘technology-intensive’ inputs contributed to the ‘Green Revolution’ in Asia and Latin America and much later in small parts of Africa. As that form of innovation spread and matured in the areas of ‘commercial’ agriculture, it contributed substantially to reducing poverty and food insecurity. But it also often contributed to considerable depletion or degradation of natural resources (especially with respect to water tables and soil salination), while also setting in motion the treadmill of increased pest vulnerability and declining resistance – leading to the escalating costs of maintenance research in national and international agricultural research systems. More recently, it is in this ‘commercial’ form of developing country

agriculture that the initial applications of GM and related biotechnological advances have made some impact – for example in the large-scale and highly homogeneous production of soya in Argentina and Brazil.

On the other hand, ‘smallholder’ agriculture corresponds roughly to the resource-poor form of agriculture where the ‘Green Revolution’ has had very limited, if any, impact; where agricultural yields and incomes have risen little over many years; and where poverty and food insecurity are especially heavily concentrated. At the same time, this form of agriculture is also intimately linked with natural resource and environmental depletion (especially with respect to soils and woodland). This form of agriculture exists in most Asian and Latin American countries where, although usually accounting for relatively modest and falling proportions of total agriculture production, it is still the major or sole foundation for the livelihoods of very large numbers of people. In African countries, however, it accounts for a very large and barely changing proportions of total agricultural activity, acting as the livelihoods basis for high proportions of the populations of most countries, and consequently for very large numbers of people. Even within rural areas, food insecurity, poverty and malnutrition do not map one-to-one to the geographical incidence of ‘smallholder’ agriculture, but the association is close.

The distinction between ‘smallholder’ and ‘commercial’ agriculture is significant not only with respect to past technological history and the current incidence of poverty, food insecurity and malnutrition. It is also very important with respect to questions about S&T for future agricultural development. The knowledge bases and associated organisational arrangements for creating, transforming and diffusing knowledge to support the two forms of agriculture have been, and largely remain, vastly different.

Consequently, there are also in principle, different kinds of implication for any potential L20 engagement with ‘S&T for agriculture. However, one thrust of the comments that follow is to suggest that in practice any L20 initiative might best be focused on only one of those sets of implications – those relating to ‘smallholder’ agriculture.

#### *Different knowledge systems*

The Green Revolution in ‘commercial’ agriculture was led by science-based plant breeding, initially carried out by international research institutes that later became part of the Consultative Group on International Agricultural Research (CGIAR). These institutes also contributed quite heavily to downstream activities in national research systems, running through trials and testing towards application. A growing group of such CGIAR institutes extended these kinds of knowledge input for innovation across a wider range of crops. Subsequently, national agricultural research and extension systems in the larger and/or more technologically advanced developing countries were considerably strengthened and took over an increasingly important role in contributing large parts of the knowledge base needed to sustain these kinds of innovation. At the same time, private sector businesses came to play a growing role.

It is hard to make a case that an L20 mechanism should address issues about S&T ‘for development’ in this form of agriculture in developing countries. Obviously this is not a problem-free zone, but: (i) NARS are typically quite strong and reasonably well developed; (ii) funding for research, development and innovation is typically in reasonable order, often drawing substantially on crop-centred levy schemes; (iii) various forms of linkage and interaction do frequently exist between knowledge creation and technology development on the one hand and farming on the other; (iv) the CGIAR system can and does make useful knowledge contributions; (v) the private sector is often substantially involved in some ‘downstream’ parts of this innovative activity, and also increasingly in research and technology development, even in some aspects of biotechnology;

and (vi) access by NARS to germplasm and related technical knowledge can typically be arranged internationally with public and private organisations, albeit at a price in the case of the latter.<sup>14</sup> While all of these system features could certainly be improved (e.g. linkages between research and the practice of farming, or access to privately appropriated technology), there is not a major system crisis. Nor is this form of agriculture centrally associated with the extremes of poverty and food insecurity. So why should an L20 mechanism address this area?

In contrast, ‘smallholder’ agriculture has relied much more intensively on ‘traditional’ and highly localised knowledge to sustain production and, in some circumstances, to improve it. This knowledge base has been largely owned and used by farmers themselves and has enabled them not only to manage complex crop patterns in the changing heterogeneity of agricultural conditions. It has also enabled them to undertake similarly detailed management of multiple genetic variants of particular crop plants across that agro-ecological heterogeneity, as well as to develop agricultural improvement (or at least to reduce retrogression) by micro-innovation via varietal selection, the modification of agro-ecological practice, and so forth. Until quite recently, such localised knowledge systems hardly interacted at all with the science-based systems of international and national agricultural research, development and extension. This was especially the case in most of Africa where the pipeline of agricultural technology that had been developed by the international

**“I can drive from Jakarta to Krawang.... and it’s rice all the way out ... and it’s rice all the way back. ... But the one time I was in Kenya, I remember driving up one hill and down the next and seeing twelve different agroclimatic zones and twelve different cropping patterns, and fifty different crops. I couldn’t believe the complexity of the farming systems...”**

C.P.Timmer (1991)

Institutes for ‘commercial’ agriculture in other regions was found largely inapplicable in the 1980s, and where international and domestic funding for national agricultural research and extension systems collapsed dramatically during the 1990s. At the same time, very few attempts have yet been made to apply GM and associated biotechnology methods to the development of technologies for ‘smallholder’ agriculture, and private sector business has little or no involvement, or even interest, in contributing to knowledge and innovation for such low-income and heterogeneous conditions that inevitably give rise to very small markets for new technologies.

It is extremely difficult not to make a case that an L20 mechanism should try to address issues about ‘S&T for development’ with respect to this form of agriculture. Across almost all the issues noted above in connection with ‘commercial’ agriculture, the S&T system characteristics are reversed: (i) NARS and associated training systems in agricultural science and technology are typically weak in the countries where ‘smallholder’ agriculture is most pervasive; (ii) funding for research, development and innovation is typically low and heavily dependent on short term donor support that is frequently tied to specific donor interests and often quite volatile; (iii) although the CGIAR system has increasingly made some effective knowledge contributions, they are still limited; (iv) but in any case the systemic interactions and organisational methods for effectively linking knowledge creation in national and international institutes to innovation in the practice of farming are usually not well developed; (v) the private sector is usually only involved in the

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<sup>14</sup> Though in several instances technology has been licensed at no charge for innovation directed to developing country agriculture. A type of concession that seems likely to remain open only while potential returns to such innovation remain low.

fringes of downstream innovation activities and has had very little interest in engaging in 'upstream' research or technology development; and (vi) although new germplasm and related technical knowledge is available in principle from international public and private organisations, the amount that is relevant (especially from the latter) is very limited, while often being poorly characterised and accessible from the former. In other words, there is for all practical purposes no effective modern 'S&T system' to support and complement traditional and localised knowledge systems in generating implemented innovation. Yet this form of agriculture is centrally associated with the extremes of poverty and food insecurity across Asia, Latin America and especially Africa.

A further difference between the two systems should be noted. Because of a set of deeply embedded and widely diverging views, together with a diversity of influential interest groups, it is far from clear that any L20 engagement with issues about S&T for the development of 'commercial' agriculture could mobilise an adequate consensus to take effective action. It is innovation in this form of agriculture that has generated particularly high levels of social concern and political action on the part of civil society groups, as well as scepticism among many government donor agencies. It is in association with this form of agriculture, for example, that what are seen as global public goods in the form of genetic knowledge, gene sequences and plant germplasm are being most intensively appropriated for private commercial interests ("Patenting Life"). It is also here that private corporate control over technology is being particularly heavily concentrated in the hands of a small number of corporations. It is with respect to this form of agriculture - both during the Green Revolution in the past, and in the current and prospective 'Gene Revolution', that the environmental costs of technological innovation are perceived to have been excessive and often irreversible (whether those perceptions are right or wrong is largely irrelevant for the purposes of this discussion). Moreover, this bundle of concerns about innovation in what I have summarised as 'commercial' agriculture has been important in contributing to the difficulties experienced by the CGIAR over the last decade or so - for instance, the sequestration of donor funding for the Group into "restricted" categories of activity, the problems in reaching consensus decisions about reform within the Group, and the difficulties experienced in building new relationships with the private sector and NGO/Civil Society communities. In short, this does not seem an area where an L20 initiative could easily attract political support.

At the same time, though, there are emerging positive threads of consensus in the arena of 'smallholder' agriculture. Leaving aside widespread recognition of the close linkage between this form of agriculture and the incidence of poverty, these include:

- a growing understanding of the importance of 'traditional' knowledge and farmers' own contributions to innovation,
- a growing understanding of the importance of systemic interactions between a complex set of actors and factors in 'downstream' areas of innovation in this form of agriculture.
- growing recognition of the emerging existence and importance of private sector actors as part of that complex,
- increasing recognition that, with due precaution about risks, advanced biotechnology methods can in principle and in practice make contributions to useful innovation in this form of agriculture, and not only in larger scale commercial agriculture.

It seems likely, therefore, that an L20 initiative in this area could attract considerable support and enthusiasm. However, perhaps to a greater extent here than in any other area, it would be too easy and totally misleading to narrow the task down to an issue about increased funding for agricultural R&D - an approach that was followed, for example, in the final report of the Millennium

Project.<sup>15</sup> There are strong grounds for believing that very large increases in agricultural R&D could be highly productive, especially if focused heavily on ‘smallholder’ agriculture. But there is an equally strong body of opinion suggesting that such a narrow focus would be immensely unproductive unless intimately linked to organisational and institutional change at numerous levels.<sup>16</sup>

### *Organisational and Institutional Change*

Organisational and institutional problems need to be addressed at three closely interconnected levels:

- (a) at the level of national agricultural research and innovation systems (and perhaps also at a sub-regional level in Africa),
- (b) at the level of bi-lateral donors and other funding organisations,
- (c) at the level of a spectrum of international organisations, within which the CGIAR is probably the core focus for change.

#### **(a) National agricultural research and innovation systems**

Although it is critically important, especially in most African countries, the key difficulty here is not simply the low level of funding for research and innovation activities (including for education and training in the necessary skills for those activities). It is also about two other things: (i) the low level of funding that is available to undertake those activities specifically in relation to ‘smallholder’ agriculture, and the (ii) the pervading weakness of the downstream areas of those activities, particularly with respect to the systemic interactions among them. The first of those problems is quite widely recognised and only the second needs elaboration here.

The issue about interaction among these agricultural DEE&IM capabilities has been increasingly well highlighted in recent years in the literature on ‘innovation systems’ in agriculture. However, the emphasis that has been given in much of this literature centres heavily on only part of the overall innovation system – the downstream activities that are most closely linked with farmers innovative activities and the interaction between these and the local agricultural experiment and research organisations engaged in the design and adaptation of specific technologies for local application. This emphasis is important and needed to offset common over-emphasis on the more upstream activities that has dominated policy for decades. However, the opposite imbalance in emphasis in the overall system should be avoided. This is especially important as the growth of opportunities for more fundamental advances in technology and underlying science seems likely to accelerate.

That highlights a key issue that has become clear in this area over recent years. There is no small set of ‘standard’ ways of organising and managing the interactive processes contributing to innovation in smallholder agriculture. This is partly because practice has been weak for decades,

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<sup>15</sup> Without reference any to other issues about agricultural science, technology and innovation, the report suggested that, from the additional \$7 billion to be allocated for research by 2015, “..\$1 billion would go towards agriculture and improved natural resource management by nearly tripling the current budget of the Consultative group on International Agricultural Research (CGIAR)”. (*Investing in Development*, p.49)

<sup>16</sup> A related issue is about the limitations of action about science, technology and innovation in this area even if these wider organisational and institutional issues are addressed. Recent studies have highlighted that, although agriculture is at the core of complex interconnected livelihoods in low-income smallholder communities, improved agricultural productivity may not be the driver that is primarily responsible for raising income. It may be that income from other livelihoods is the necessary basis for improvements in agriculture. Nevertheless, while agricultural innovation may not be the initiating driver in alleviating poverty, it is pervasively a necessary condition for doing so.

and it is partly because of the inherent diversity of agricultural settings across the whole spectrum of smallholder agriculture. But it is also because of the current phase of change that is creating quite new agricultural conditions. These include new market conditions as trade is liberalised and as new high quality product niches open up in advanced country markets. They include the emergence of new private sector actors becoming increasingly engaged in agricultural processing, marketing and the supply of seeds and other input goods and services. They also include the emergence of new technological conditions being created in upstream areas of the innovation process . This last is especially important because it will place a premium on effective articulation back **from** downstream developers, designers, entrepreneurs and managers of innovation (including farmers who may play all those roles) **to** the upstream contributors to innovation. The value of those upstream contributions will depend very heavily on the concrete specification of demand for new knowledge by these downstream actors, together with the strength of the ‘backward’ articulation from them to upstream technology development.

All this creates conditions calling for enormously inventive pluralism in the development of new ways to organise the key downstream elements of national innovation systems that aim to address smallholder agriculture. But it will also call for an intensive phase of deliberate efforts to capture, assess and learn from the experience of this inventive pluralism – in much the same way that large engineering companies and integrators of complex infrastructure products allocate considerable resources to accumulating, evaluating and learning from their project experience. That will not be cheap or easy, and it will require new attitudes and practices among innovation managers and their funding organisations – both nationally and internationally.

#### **(b) The CGIAR and other international organisations**

A considerable number of international organisations play important roles in relation to science, technology and innovation in agriculture in developing countries. Perhaps the most centrally placed of these is the Consultative Group on International Agricultural Research (CGIAR). Because of this central position it is probably the key piece in an international organisational jigsaw puzzle that is considered by many to be in need of fundamental re-configuration.

The CGIAR was an immensely important organisational invention designed in a set of very specific circumstances in the late 1960s and early 1970s. Since then five major developments have impinged on the structure and effectiveness of the organisation.

- The CGIAR evolved in several different directions. It was pulled into an increasing array of downstream activities – partly to fill gaps in areas that were not being addressed effectively (or at all) by national-level systems, and partly in response to donors who grew increasingly uneasy about what were seen as excessively long-term or inappropriate directions of upstream research. It also spread its activities across an increasingly wide array of problem areas, crop types, farming conditions and so forth – acquiring in the process a loosely knit family of 16 largely independent institutes.
- Since the mid-1980s donor funding has become increasingly tied to “restricted” activities of interest to the donor, and “unrestricted funding” for use under strategies decided by the Group itself has fallen dramatically.
- Having mostly been weak and ‘infant’ entities in the 1960s, the National Agricultural Research Systems in many developing countries, especially in some of the larger countries, have become large, increasingly effective and increasingly engaged in the upstream components of innovative activity – especially in connection with more ‘commercial’ forms of agriculture.

- The private sector has come to play a very much larger role in agricultural innovation globally and the agricultural innovation business has become very highly concentrated in a small number of firms. At the same time, this highly concentrated industry has come to appropriate a large part of the knowledge base and plant genetic resource underlying a considerable proportion of agricultural innovation in large-scale commercial agriculture in the advanced economies, and it has come to play an increasing role in some parts of the ‘commercial’ form of agriculture in developing countries.
- It has become increasingly evident that the structure of linked international-national innovation systems that achieved ‘Green Revolution’ success in the ‘commercial’ form of agriculture in developing countries is seldom effective in the conditions of ‘smallholder’ agriculture.

Not surprisingly a series of major studies and reviews of the Group since the late 1990s have stressed that the CGIAR is at a crossroads and requires fundamental reform. However, it has also become clear that the problem is deeper. Because of its unusual structure, dispersed decision-making processes, and the diversity of strong interest groups accumulated inside and around the Group, it is judged by many to have become incapable of generating and implementing its own reform in an adequately radical fashion.

Although, there is a diversity of views about the directions of required change, there is some consensus around the ideas that the CGIAR should (i) pull back from the extensive diversification of the 1970s and 1980s and concentrate in upstream areas of knowledge creation and basic technology development, (ii) build new forms of partnership arrangement with the mature NARS in many countries, (iii) play a major role on behalf of developing country agriculture in dealing with core issues in advanced biotechnology and the management of agricultural intellectual property. But little of that can be achieved without complementary arrangements for dealing with the component activities and institutes that will not fall within the selected strategic focus and core competence of a new CGIAR. Also little is likely to be achieved without a ‘new deal’ with funding donors.

However, it is at this point that another issue seems critical. It appears unlikely that a new constellation of the organisational jig-saw pieces can be configured around a restructured CGIAR that continues to play a major role in innovation for the ‘commercial’ form of agriculture in developing countries. As noted earlier, the political basis for consensus around such a configuration may not exist. On the other hand, a strategy that added a fourth element to the three noted above - a focus on innovation for ‘smallholder’ agriculture - might unlock an opportunity to re-invent the CGIAR some forty years after its initial invention.

### **(c) Bi-lateral donors and other funding organisations**

These actors are critical to un-ravelling and re-constituting in more workable forms the components of innovation systems – especially with respect to what I have summarised as ‘smallholder’ agriculture.

- They are centrally important for any new deal over funding for a re-invented CGIAR, and for associated new arrangements among the network of linked international organisations.
- They would be central in developing and supporting new organisational and funding structures around parts of current CGIAR activities that do not fit the new configuration.
- They will be central in expanding support for considerably larger, smallholder-centred downstream activities in national systems.

- But they will also have to recognise the importance of plurality and experiment in the ways of organising and managing such activities, and along with that they need to commit to systematic efforts to build learning about that experience centrally into programmes – as well as developing the patience to consider much longer time periods for experimentation and learning than has been common in the past.<sup>17</sup>

Addressing this bundle of inter-locked and cross-cutting issues that call for concerted action at levels that run from international organisations, through bilateral and related donors in advanced countries to national organisations in developing countries seems precisely what an L20 group might address.

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<sup>17</sup> In these respects the example of the Andhra Pradesh Netherlands Biotechnology programme seems illuminating. This long term project funded by the Netherlands, focused on rain fed smallholder agriculture. It explicitly recognised that the project was as much about developing new cultures, new ways of organising downstream activities in innovation and new and of managing the interfaces with upstream activities.

## **ANNEX 1 - TABLES**

**ANNEX TABLES 1: NSF DATA ABOUT THE ACTIVITIES OF US SCIENTISTS AND ENGINEERS**

**ANNEX TABLE S 2: DATA FROM THE ARGENTINE INNOVATION SURVEY**

**ANNEX TABLES 3: GLOBAL S&T INEQUALITIES – CAPITAL EMBODIED TECHNOLOGY**

**ANNEX TABLES 4 GLOBAL S&T INEQUALITIES - ACQUISITION AND CREATION OF KNOWLEDGE**

**With apologies to the participants at the Maastricht meeting, these tables are not yet available. They will follow later. Annex tables 5 about the brain drain are on the next page.**

**ANNEX TABLE 5: SELECTED STATISTICS ON THE ‘BRAIN DRAIN’**

**Table A Numbers and earnings of ‘Foreign Citizen’ Scientists and Engineers: US 2003 <sup>1</sup>**

<b>Country of Foreign Citizenship</b> (World Bank Country Categories)	<b>Number of Employees</b> (000s)	<b>Average Salary <sup>2</sup></b> (US\$ 000s)	<b>Total Earnings</b> (US\$ Millions)
Low Income Countries	347.7		
Lower Middle Income Countries	338.2		
Upper Middle Income Countries	135.8		
<b>Total ‘Developing’ Countries</b>	<b>821.7</b>	<b>59.9</b>	<b>49,262.7</b>
High Income Countries	398.3		

Notes

1. Source: National Science Foundation, Division of Science Resources Studies, Scientists and Engineers Statistical Data System (SESTAT)
2. Estimated from NSF Table from the National Survey of College Graduates (NSCG 2003), which collects data for **All** college graduates. The average salary was weighted for each country by the number of people in each main activity for which data on annual salaries was available.

**Table B Numbers and Earnings of ‘Foreign Citizen’ College Graduates: US 2003 <sup>1</sup>**

<b>Country of Foreign Citizenship</b> (World Bank Country Categories)	<b>Number of Employees</b> (000s)	<b>Average Salary <sup>2</sup></b> (US\$ 000s)	<b>Total Earnings</b> (US\$ Millions)
Low Income Countries	406.3		
Lower Middle Income Countries	452.5		
Upper Middle Income Countries	217.2		
<b>Total ‘Developing’ Countries</b>	<b>1,075.9</b>	<b>59.6</b>	<b>64,105.5</b>
High Income Countries	614.8		

Notes

1. Source: US National Science Foundation, National Survey of College Graduates (NSCG 2003)
2. Estimated from NSF data for **All** college graduates, weighted as in note (2) for table A

**Table C ‘Guesstimated’ Levy from Tax on Employers of ‘Developing Country’ Personnel**

<b>Category of Employees</b>	<b>Employing Countries</b>	<b>No. of Employees</b> (000s)	<b>Average Salary</b> (US\$ 000s)	<b>Total Earnings</b> (US\$ Millions)	<b>5% Levy</b> (US\$ Millions)
‘Foreign Citizen’ Scientists and Engineers <sup>1</sup>	US	821.7	59.9	49,262.7	2,463.1
‘Foreign Citizen’ All College Graduates <sup>2</sup>	US	1,075.9	59.6	64,105.5	3,205.3
‘Foreign Born’ in ‘Professional and Related’ Occupations <sup>2</sup>	US	2,718	? [60]	163,080.0	8,154.0
All ‘Immigrant’ with Tertiary Education	All OECD	?	?	?	?

#### Notes

1. Source: NSF National Survey of College Graduates, 2003 [SESTAT - as for Table (A) above].
2. Source: NSF National Survey of College Graduates, 2003 [As for Table (B) above].
3. US Census Bureau, Current Population Survey, 2004 ('Developing Country' = Region of origin: Asia, Latin America, Asia and other Areas – not corrected for OECD Asia etc.

### **ANNEX 2 – REFERENCES**

As is evident in the text, I have drawn extensively on the work of very many other people, with few and only partial referencing of those debts in this version of the paper. That omission will be rectified in a later version. In the meantime, I apologise to everyone whose contributions to the paper remain unacknowledged.