

Innovation, Sustainability, Development: A New

MANIFESTO



Trends in the Global Distribution of R&D since the 1970s: Data, their Interpretation and Limitations

Elisa Arond and Martin Bell

R&D Data



About this paper

The 1970 'Sussex Manifesto' was one of the earliest global policy reports to use statistical data about R&D that were starting to become available on an internationally comparable basis, though only in a very sketchy form for developing countries. It demonstrated the marginal position of that group of countries as contributors to the world's R&D, accounting for only about 2 per cent of the global total. It also couched some of its core recommendations about policy in terms of quantitative indicators of R&D, but highlighted several major limitations of such indicators as tools for policy. This Background Paper revisits the global data to review how the distribution of R&D between groups of countries has changed since the 1960s, in particular with respect to the marginal position of developing countries. It reveals mixed trends. The economies that were 'developing' in the 1960s now account for a much larger share of the global total, but this is concentrated in a small number of countries that are highly R&D-intensive and/or very large like India and China, leaving many others still playing only a marginal role. The paper also returns to some of the Manifesto's concerns about the limitations of R&D indicators as a basis for policy debate. It notes a surprising persistence of many of those earlier limitations.

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About the Manifesto project

In 1970 a radical document called The Sussex Manifesto helped shape modern thinking on science and technology for development. Forty years on, we live in a highly globalised, interconnected and yet privatised world. We have witnessed unprecedented advances in science and technology, the rise of Asia and ever-shifting patterns of inequality. What kind of science and technology for development Manifesto is needed for today's world? The STEPS Centre is creating a new manifesto with one of the authors of the original, Professor Geoff Oldham. Seeking to bring cutting-edge ideas and some Southern perspectives to current policy, the New Manifesto will recommend new ways of linking science and innovation to development for a more sustainable, equitable and resilient future.

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TRENDS IN THE GLOBAL DISTRIBUTION OF R&D SINCE THE 1970s: DATA, THEIR INTERPRETATION AND LIMITATIONS

Elisa Arond and Martin Bell

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1. INTRODUCTION

1.1 Background

This is one of a pair of closely linked Background Papers for the STEPS Manifesto project. Both papers focus on statistical data about research and experimental development (R&D) and on the role of such data as a tool for illuminating issues about scientific and technological (S&T) activities that may contribute to innovation (I). They see that as a dual role: one is concerned with providing descriptive background information about differences and trends in STI activities; the second is concerned with detailed information and analysis intended more directly to inform policy and management decisions about those activities. But both also give considerable attention to the limitations of R&D data in those roles - with particular emphasis on their limitations in the context of developing countries that are engaged in the process of creating, changing and building their STI 'systems'.

Both papers have also been stimulated by the opportunity that the STEPS Manifesto project provided to reflect on the forty year period of change since the appearance of the 1970 report commissioned by the United Nations Advisory Committee on the Application of Science and Technology to Development (ACAST) that came to be known as the 'Sussex Manifesto'.¹ That earlier report is a particularly interesting take-off point for such historical reflection, partly because of its timing. Its production in 1970 coincided with the period when the OECD and UNESCO were developing the first internationally standardised methods for collecting statistical data about science and technology, with a particular focus on R&D. But that starting point is also significant because the 1970 'Manifesto' used R&D data in three important ways.²

- First, in setting out its core challenge about transforming global efforts to strengthen scientific and technological capabilities in developing countries, it deployed one of the earliest compilations of descriptive data about the global distribution of R&D between different groups of countries, looking at Gross Domestic Expenditure on Experimental Research and Development, or 'GERD'. It estimated that developing countries accounted for only around 2 percent of total global expenditure on R&D at the time, so highlighting the marginal role of those countries in creating the world's new knowledge.
- Second, it couched some of its core recommendations about policy in terms of quantitative R&D indicators. In particular, it identified a key target of raising the developing countries' R&D intensity (ratio of GERD to GDP) from about 0.2 per cent to about 0.5 per cent during the 1970s (The Second Development Decade), so raising those countries' share of total global R&D expenditure to around 4-5 per cent.
- But third, the Manifesto also highlighted several important inadequacies in such R&D statistics, and hence it attached considerable qualifications to their use in these ways. The limitations included (i) large problems about the availability and quality of the underlying R&D data themselves, (ii) the fact that, in any case, the definitions of R&D used for statistical purposes captured only a very narrow segment of scientific and technological activities that might contribute to innovation, and (iii) that there was much more to achieving effective and 'appropriate' technical change (or innovation) than just the scale of scientific and technological inputs, even if these are seen as being much broader than just R&D.

¹ Singer et al (1970). The report was prepared by a group of scholars associated with the University of Sussex (from the Institute of Development Studies, located on the campus of the university, and from the Science Policy Research Unit, a research institute of the university). Having been described pejoratively in the UN General Assembly as 'a manifesto', it later became known as: *The Sussex Manifesto*.

² This was perhaps not surprising because one of the Manifesto's authors, Christopher Freeman, was also at the heart of the OECD and UNESCO efforts to develop standardised methods for collecting internationally comparable data about R&D.

1.2 The aims and structure of the Background Paper

This Background Paper has three main aims:

- To provide an overview of how the global distribution of R&D activity between groups of countries has changed since the time of the 1970 Manifesto.³
- To provide a detailed explanation about the sources and methods lying behind the overview data that has already been used in a summarised form in another Background Paper for the project.⁴
- To review in a contemporary light some of the original Manifesto's concerns about the limitations of R&D indicators as a basis for policy debate about science, technology and innovation.

Two aspects of the scope of these aims are important.

First, although the diversity of STI statistics and indicators has expanded considerably since the preoccupation with R&D in the 1970s⁵, the paper concentrates only on R&D – and within that, only on indicators of aggregate R&D expenditure.⁶ This is consistent with the scope of the original Manifesto and provides a manageable focus for the review of change over the subsequent forty years. But it also has an important contemporary relevance because current efforts to strengthen the basis of STI statistics and indicators in Africa are also heavily centred on R&D.⁷

Second, in commenting on the limitations of R&D-centred data and indicators, we address two kinds of issue. One is concerned with problems about the 'quality' and availability of the R&D statistics we use. The other is about limits to the policy-related usefulness of these and other R&D-centred indicators as a basis for informing policy debate and decision-making – both about R&D and more broadly about science, technology and innovation.

The remainder of this paper is organised in three sections. First, Section 2 provides an introduction to the sources we have used to compile data about the distribution of R&D between countries since the early 1970s. This section also introduces some of the difficulties that need to be borne in mind when reviewing and interpreting the data later. We then present the data in Section 3. Section 4 returns to elaborate a little further on questions about limitations and problems – not only those involved in interpreting this specific use of such data, but also those that arise more generally in using such statistics to inform policy, especially in developing countries.

2. DATA SOURCES AND LIMITATIONS

In this section, we briefly describe the types of R&D reported, explain the sources of data for this paper, minimally address their coverage and explain some of the key limitations and difficulties in using them.

³ As explained later, our data series start in 1973, rather than with the very rough estimates for the mid-1960s that were used in the original Manifesto.

⁴ Ely and Bell (2009)

⁵ In particular, in addition to the great diversity of measures now used in small-scale surveys and individual projects, standardised data about a wider range of 'inputs' to innovation are now collected on a national basis in many countries via Innovation Surveys within the framework of the OECD Oslo Manual. Also, a range of data about 'outputs' of innovative activity are also collected, ranging from the records of scientific publications and patented inventions to the incidence of different types of innovation enumerated in Innovation Surveys.

⁶ This is elaborated in Section 2 below.

⁷ See, for example, NEPAD (2005); Gault (2008); and Kahn (2008).

2.1 Types of R&D Data reported

This paper is concerned exclusively with statistics about R&D inputs (i.e. with resource inputs to R&D activities), not with measures of 'outputs' from them (e.g. data on scientific publications, patents, etc.). More specifically, it concentrates on R&D inputs as measured by expenditure on R&D, and not, for example, as measured by headcounts of personnel. Also, we focus on aggregate expenditure at the country level. Consequently, in our presentations of data in Section 3, we do not address any of the disaggregations that are commonly used in the major statistical sources in this area – for example, disaggregation between different sectors of R&D performance (or financing), or between the socio-economic objectives of R&D. Thus, we focus solely on what is usually described as Gross Domestic Expenditure on Experimental Research and Development (GERD).

R&D is defined by UNESCO and OECD as follows:

Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications.
(UNESCO 1978; OECD 1963)

GERD is supposed to 'cover all R&D carried out on national territory in the year concerned' (OECD 2008:3), and this is usually presented in terms of two kinds of indicator:

- (i) Total GERD – total absolute expenditure on research and development (expressed in local currency or in equivalent US or 'international' dollars⁸);
- (ii) R&D Intensity – the ratio of GERD to GDP (expressed as a per cent);

We discuss both of these here, though giving most attention to the first. We also use a third type of indicator that is typically used in reviews of the global distribution of R&D between countries and groups of countries.

- (iii) Global Share – the contribution of GERD by country or region to the estimated world total of GERD (expressed as a percentage share).

2.2 The data sources

Internationally comparable data about R&D can be described as being accumulated through a hierarchical structure with three main levels.

- Surveys and estimates within individual countries
- Syntheses and summaries across groups of countries covering particular regions (e.g. the European Economic Community or Latin America) or other sub-global groupings (e.g. the OECD)
- Globally integrated compilations that attempt to cover all countries across all regions.

In order to compile our review of trends over the 40-year period since the original Sussex Manifesto in 1970, we draw on these sources in different ways and some explanation is required.

We have drawn only indirectly on sources at the first (country) level and no further comment is needed here, though we note later that many of the problems about data comparability, reliability

⁸ There are some complications about the exchange rates for data used in this study. This will be discussed later in Section 2.3 and Section 3.

and availability at the two levels of more aggregated compilation originate at this initial level. We have also not drawn directly on sources at the second (regional) level, except for the OECD, and then only for the purposes of checking the data available in more aggregated sources, or to fill in data gaps for individual countries. Since sources at this level have often provided large parts of data used in global syntheses, we provide a little more background information about them below.

We have relied primarily on sources at the third level – those that have attempted to provide global syntheses. Two of these have been particularly important: the syntheses provided by Jan Annerstedt for earlier years (1973 and 1980) and the global compilations provided by UNESCO for the later years (UIS 2004; UIS 2009a). We provide background information separately below about each of these.

2.2.1 Syntheses and summaries across groups of countries at a regional level

R&D data was first surveyed at national and regional levels using varied methodologies and frameworks, only later compiled into international comparative surveys following extensive efforts toward harmonization. Both the institutions and their methods of surveying have changed over time.⁹ By the 1970s, 'industrialised' countries were following two standards: OECD - Organization of European Economic Co-operation (Western countries) and CMEA – Council for Mutual Economic Assistance (also known as Comecon, the economic organisation of communist countries, mostly Eastern European states), which was disbanded in 1991. Coverage for other regions has mostly been under efforts toward global integration by UNESCO, with the exception of Latin America, which followed a system developed under the Organization of American States (OAS – previously PAU, the Pan-American Union) with the support of OECD. UNESCO's global level efforts will be described in the following section.

The 1970 Sussex Manifesto cites three sources for its rough calculations of global R&D distribution – OECD data for the 'developed market economies', UNESCO and the Pan-American Union data for the 'developing economies'. It excluded the centrally-planned economies from its calculations for lack of data. (Singer et al 1970: 5)

Though we have not relied on OECD's database primarily, some additional comments on this statistical source are relevant, as its methodology has proven influential worldwide. OECD's early efforts began with the first international workshop on the methodology of R&D statistics in Frascati, Italy in 1963, resulting in the publication of the Frascati Manual¹⁰ (OECD 1963), today the most widely-accepted standard methodology for the collection of R&D statistics. Later statistical manuals include the Oslo Manual (OECD 1992) on technological innovation more broadly than just R&D, and the Canberra Manual (OECD 1995) on human resources devoted to S&T. OECD reports on a variety of STI indicators, not just the three detailed above. One hundred of the measures in their Main Science and Technology Indicators series concern resources devoted to R&D, and an additional 35 are measures of output and the impact of S&T activities.¹¹ However, its coverage includes only a select group of countries – the OECD member states and, since the 1990s, a few select non-member economies. (OECD 2008)

⁹ For a detailed history, see publications by Godin available at <http://www.csic.ca/>. For some examples of early efforts and calls for action on developing international standards, see Bernal (1939), Dedijer (1960), and Dedijer (1968). Bell (2009) also reviews this earlier history.

¹⁰ The sixth revision was published in 2002.

¹¹ More specifically, the detailed categories of indicators reported by OECD include: Total GERD, R&D Intensity; R&D Personnel (FTE); GERD by source of funds; GERD by performance sectors; Researchers (headcount); Business Enterprise Expenditure on R&D (BERD); Business Enterprise R&D Personnel (FTE); BERD by source of funds; BERD performed in selected industries; Higher Education Expenditure on R&D; Higher Education R&D Personnel (FTE); Government Expenditure on R&D; Government R&D Personnel (FTE); Government Budget Appropriations or Outlays for R&D by socio-economic objectives (GBAORD); R&D Expenditure of Foreign Affiliates; Patents; Technology Balance of Payments (TBP); International trade in highly R&D-intensive industries. (OECD 2008)

In addition to OECD, today's major regional statistical agencies are Eurostat, the statistical office of the European Union, and RICYT, the Network of Science and Technology Indicators – Iberoamerican and Interamerican (Red de Indicadores de Ciencia y Tecnología Iberoamericana), covering Latin America, Spain and Portugal, which was founded in 1995. RICYT has played a fundamental role in disseminating the Frascati Manual to Latin America, and has also led efforts toward the development of the Bogota Manual (RICYT 2001), an adaptation of the Oslo Manual to the Latin American context, and the 2006 'Lisbon Manual' for surveying and collecting statistical data on information and communications technology and related issues of access, etc. (RICYT 2006; 2009). As regional statistical sources, Eurostat and RICYT both inform UNESCO and OECD databases.

Thus though we do not rely primarily on any of these statistical resources for this paper, we do so indirectly because these regional or other sub-global sources feed into the global syntheses.

2.2.2 The global syntheses by Jan Annerstedt

Various references in the 1970s and 1980s review the global distribution of R&D resources and refer to data gathered by Jan Annerstedt at Roskilde University.¹² Unlike the 1970 Sussex Manifesto, Annerstedt made great efforts to incorporate all world regions, including the centrally-planned economies. For his 1973 data, Annerstedt drew from his own collection of national and regional R&D statistics, built up with help from the OECD Development Centre, as well as additional data from OECD's Science and Technology Indicators Unit and UNESCO's Statistical Office. He also adjusted this data according to further information and advice he received from OECD in order to better address problems of standardisation (different definitions and methods among regions). For his 1980s data, Annerstedt also indicates UNESCO's statistical yearbooks as a major source. (Annerstedt 1988: 140-141, footnote 15)

Annerstedt covered the basic R&D-centred statistics we have described above – total GERD, per cent global share of GERD (or GERD contribution as a percentage of world total), and R&D Intensity (GERD as a percentage of GDP). Annerstedt also compiled data on human resources in R&D.

2.2.3 The global syntheses by UNESCO

The United Nations Educational, Scientific and Cultural Organization (UNESCO) is the only institution that has attempted to collect and publish S&T statistics from a more or less world-wide spread of countries on a periodic basis. It started collecting S&T data from Member States in 1967, including data on R&D, and these were published in considerable detail in the *UNESCO Statistical Yearbook* for a number of years after 1968. However, following the withdrawal of the United States from UNESCO in 1984, its statistical activities were run down for a number of years and this had a particularly serious effect on the compilation and publication of R&D statistics. The organisation became more active again in this area in the 1990s, especially after the establishment of the UNESCO Institute of Statistics (UIS) in 1999. Since then it has published several bulletins and 'fact sheets' summarising global R&D and other indicators of science and technology efforts (e.g. UIS 2004; 2007; 2009c). However, these remain much more limited in scope and detail than the earlier publications.

As well as taking a global approach to its geographical coverage, UNESCO sought for many years to compile statistics for a much wider array of scientific and technological activities than just R&D. Initially, this interest centred on what were described as 'related scientific activities' – including things like scientific documentation services. Later the emphasis embraced the core idea of 'scientific and technological activities' (STA) that included, but was not limited to, R&D.¹³ This proved

¹² These include Agarwal (1979); Norman (1979); Bell et al (1981); and Annerstedt (1988).

¹³ Early on, UNESCO and OECD devised theoretical and statistical frameworks, defining a broad concept of "scientific and technical activities" (STA), which include R&D, "scientific and technical services" (STS) and "scientific and technical education and training" (STET). STS covers activities in museums, libraries, translation

to be too complex for countries to address at all effectively. With respect to the specific area of statistics on R&D, UNESCO initially followed its own methodology, relying on national reporting to UNESCO surveys, but since 1978 has moved towards the standardisation offered by the Frascati manual.¹⁴

Currently, the UIS database reports data on financial and human resources devoted to R&D, drawing from data provided by OECD, Eurostat and RICYT for the respective groups of countries covered, as well as relying on their own survey data provided by UNESCO Member States through their biennial S&T data collection efforts. (UIS 2009b).

2.2.4 Our selection and use of these sources

For our purposes, we have relied primarily on Annerstedt’s global syntheses of data for 1973 and 1980 (Annerstedt 1979; Annerstedt 1988), only minimally supplementing Annerstedt’s summaries with additional data for 1980 from the same UNESCO data sources he describes using. We have not used data on human resources in the tables presented in Section 3. We have drawn from several UNESCO sources to present data for 1990, 1999/2000 and 2007. These include aggregations presented in the UIS 2004 Bulletin (data for 1990 and 1999/2000 in our table), and the UIS 2009 data release (UIS 2009a) (data for 2007).

In summary, our use of sources can be summarized as follows:

Table 1 Summary of Data Sources Matched to Years in our Data Tables

Year	1973	1980	1990	1999/2000	2007
Source(s)	- Annerstedt (1979)	- Annerstedt (1988) - UNESCO report (1984) for limited R&D intensity data	- UIS Bulletin (2004) - OECD (2008) for the Republic of Korea only	- UIS Bulletin (2004) - UIS data release (2009a) for the Republic of Korea, Singapore and Brazil - OECD (2008) for Taiwan only	- UIS data release (2009a) - OECD (2008) for Taiwan only

2.3 The classification of country groups

We began this exercise with a retrospective purpose linked to the reference point of the original Sussex Manifesto (Singer et al 1970). This aim created considerable problems about how to classify individual countries into larger groups, in particular into ‘developed’ and ‘developing’ countries. These problems were immediately evident in the earliest data sources. The Manifesto made a broad comparison between these groups, but *excluded* the centrally-planned economies from their estimates. Annerstedt (1979; 1988) also compared ‘developed’ and ‘developing’ countries, but

and editing of S&T literature, surveying and prospecting, testing and quality control, etc. STET refers to S&T education and training, notably in tertiary education. The STA concept has evolved ever since to encompass, among other things, human resources devoted to S&T (HRST), innovation, science literacy, international trade in high-tech products, patents, scientific publications. [...Though the] OECD limited its data collection to R&D early on, UNESCO persevered for quite some time – with varying degrees of success – in attempting to measure both STET and some aspects of STS.’ (UIS 2001:2)

¹⁴ ‘UNESCO and OECD have been using the same basic definitions for the coverage of the financial and human resources devoted to R&D although, until quite recently, they had been using individual approaches to defining the “sectors” of the domestic economies where R&D efforts were performed (or financed).’ (UIS 2001:4) The definitions and classifications presented in the UIS 2008 manual are based on the *Recommendation concerning the International Standardization of Statistics on Science and Technology* (UNESCO 1978) and the *Frascati Manual* (OECD 2002).

included the centrally-planned economies to create a more complete picture. He also then separated out different sub-groupings for more detailed comparisons, partly as regional geographical groups and partly to reflect political and economic differences (e.g. 'market' and 'centrally-planned' economies). These complications were then compounded by the fact that UNESCO sources for the later years used yet another system of country groupings.

In order to arrive at consistently comparable groups of countries across the full time-series, we initially attempted to reconstruct the later national UNESCO data into groupings that corresponded exactly with those used by Annerstedt (in his data for 1973 and 1980). However, we soon realised this was not possible (or at least not easily achievable), partly because both the Annerstedt and UNESCO sources incorporated estimations for missing data in their aggregations, without providing explicit details needed to reconstruct the estimates. In other words, we could not accurately reconstruct the groupings just with the data available from these two sources. We therefore decided instead to use the broader aggregations of countries used by Annerstedt for 1973 and 1980 *and* those used by UNESCO for 1990, 1999/2000 and 2007.

- We attempted to make the country composition of these categories relatively consistent across the time-series by making a number of adjustments to the UNESCO categories where that was possible.
- We also attempted to make as transparent as possible some of the more important of the remaining inconsistencies – partly by providing an explanation here, and partly by identifying data for a few individual countries that seemed to raise issues warranting separate consideration from the categories into which they had been placed.

This exercise is, however, imprecise as we explain further. In particular, there are several complications about classifying countries into groupings such as 'developed' or 'developing', as done by the original Manifesto and Annerstedt. For our purposes many of these are technical points, and in the global picture of R&D perhaps not hugely significant. However, they at least have potential to undermine the comparison of data across countries or regions and over time. We address these under three headings: The Definition of 'Developing' and 'Developed', The Classification Assigned by Data Sources, and Classification as a Dynamic Process.

The Definition of 'Developing' and 'Developed'

The criteria used to define 'developing' and 'developed' are not universally agreed. Those used to ascribe countries to such categories have in some cases been (or are) economic while others involve combined indicators of social, economic, or political characteristics. Today there is no universally agreed grouping of 'developing' countries, even within the United Nations.¹⁵ Nonetheless, the category of 'developing' countries (and also a further category of 'less developed') is used by the UIS in its latest data release, alongside its disaggregation of data by geographic region. (UIS 2009a)

The Classification Assigned by Data Source

A second issue is that different data sources assign the same countries, or even groups of countries, to different 'developed' and 'developing' categories (Table 2), without necessarily clarifying the

¹⁵ Since the 1960s through today, various definitions have been used to refer to the broad disparities between groups of countries in the world. Other (sometimes synonymous) terms used include 'industrialised', 'advanced', Global 'North'/'South', 'underdeveloped', 'emerging', 'market/non-market', 'First/Second/Third World'. We also note that there is an entire literature and multiple sets of indicators devoted to deciphering the 'meaning of development' - from Dudley Seers to Amartya Sen, the World Bank Development Report to the Human Development Index of the UNDP, all of which we cannot evaluate or otherwise delve into here. Nonetheless we would like to acknowledge this term is fraught with diverse interpretations and connotations, including political and ethical.

criteria used. In particular, some countries that Annerstedt had grouped under 'developed' for early years were for later years placed under the 'developing' country group by UNESCO. The most extensive instance arises because of the dissolution of the Soviet Union and the transition of the other centrally planned socialist economies. These countries were identified as a single group by Annerstedt and included in the 'developed' category, but as indicated in Table 2 below, they were reallocated between the 'developed' and 'developing' categories by UNESCO. The other significant cases that we are aware of involve South Africa and South Korea. As indicated in Table 2, both were classified as 'developed' by Annerstedt and, somewhat perversely, as 'developing' by UNESCO.

Table 2 **Changing Classifications by Data Source**

Source, Year & Classification		
Region/Country	<i>Annerstedt data for 1973 & 1980</i>	<i>UNESCO data for 1990, 1999/2000 & 2007</i>
<i>CMEA/Centrally-planned</i>	All classified as Developed	Split into two groups. (i) CIS-Asia classified as Developing (ii) CIS-Europe and Central & Eastern Europe classified as Developed
<i>South Africa</i>	Classified as Developed	Classified as Developing
<i>South Korea</i>	Classified as Developed (included in the Japan total)	Classified as Developing

We have left these re-classifications between 'developed' and 'developing' country categories embedded in our own presentation of the data. But we also continue to identify the '(Ex) Centrally-Planned Economies' as a distinct group through the whole time series, while also identifying separately the data for the specific cases of South Africa and South Korea (The Republic of Korea).

Classification as dynamic process

This third type of problem arises because countries change their economic, social, and other characteristics over time. Consequently, depending on the criteria one uses to define 'developed' and 'developing' (see earlier comments), individual countries may in principle migrate from one category to the other, making regional comparisons across a forty-year time-span still more complicated.

Neither of our main data sources allowed for such inter-category migration, maintaining a fixed classification of countries through the periods they covered. But nor did they provide explicit information about the criteria behind the classifications they used. Again, therefore, we have not tried to invent our own method for the dynamic re-classification of countries, and have simply accepted the classification used in our sources. However, we do separately identify a few individual countries that might be considered by some as candidates for such re-classification.

In summary, we have broadly tried to use through the whole time series the same country categories and terminology that Annerstedt set up in 1973. The result is a set of slightly 'messy' compromises. However, we have tried to assist interpretation of the data by making these reasonably transparent and by separately identifying data for a few specific countries. Furthermore, it is worth noting that the consequence of shifting some countries' relatively small R&D contributions from one group to

another is often not likely to change the bigger picture of the global distribution in any major way, given the level of aggregation we are using.

2.4 Some of the limitations of R&D statistics

As noted earlier, the 1970 Sussex Manifesto not only made use of nascent global compilations of statistics about R&D; it also highlighted several of the limitations of such data. In this Background Paper for the New Manifesto, we also give considerable attention to the limitations of the R&D statistics we present in Section 3. We distinguish here in this section between two types of limitation:

- The first covers problems that are specifically about the particular R&D data we use in this paper. These are statistics about only one aspect of R&D: its *magnitude* at the level of countries, groups of countries and the global total, as reflected in: (i) data about Gross Expenditure on R&D (GERD) and (ii) this expenditure normalised by the scale of countries' economies – the GERD/GDP R&D-intensity indicator. The kinds of limitation we note in this first category are about the 'quality' or 'reliability' of those statistics, issues that have implications for assessing and interpreting the data compilations we present. We therefore refer to these kinds of problem as '*Internal*' limitations – they are concerned specifically with problems and qualifications that relate to the historically descriptive purposes of this paper and others with similar purposes.
- The second type of limitation is broader. It is about the usefulness of these and other R&D-centred statistics for policy-related purposes – even if they are available in a reasonably 'reliable' form. Our comments in this category are therefore about problems that limit the extent to which such statistics can act as useful inputs to policy debate and decision-making, especially in the context of developing countries at relatively early stages of strengthening and creating the main features of their science, technology and innovation systems. We describe these as '*Policy-Related*' limitations.

Problems and limitations in R&D statistics arise at all levels in the hierarchy within which they are collected and cumulatively integrated, from country level compilations to global syntheses. Given the aims of this paper, we focus on problems as they appear from the perspective of data users at the upper end of that hierarchy – i.e. problems about using internationally aggregated compilations of R&D statistics to map out relatively long term trends within (groups of) countries, as well as cross-sectional differences between them.

We provide a summary of some of the more important '*Internal*' limitations at this stage *before* readers encounter the data to which they refer. We discuss the second later in Section 4.

Although the perspective we take here is about using R&D statistics that are already compiled at a relatively high level of international aggregation, most of those problems arise initially as limitations at lower levels in the hierarchy of data acquisition and compilation. Nevertheless some of them result from approaches taken at the higher level of global syntheses. We do not attempt to provide an exhaustive review of all these difficulties, merely to note a few that seem particularly important. These are as follows.

2.4.1 Limited harmonisation of R&D survey and estimation methods

Three kinds of inconsistency between countries and over time seem to be important.

- Differences arise in the definitions underpinning surveys, and perhaps more importantly in the operational application of definitions in survey procedures and responses. This was particularly

the case in earlier years,¹⁶ and although considerable improvements have been made in many countries over the decades, significant difficulties remain, especially with regard to variation in defining some sectors and categories of data, as highlighted by UNESCO and others.¹⁷ (UIS 2003:20)

- The density and representativeness of survey samples varies widely. This is particularly important with respect to the common difference in developing countries between *relatively* complete government reporting and considerable under-reporting of business enterprises and other non-government organisations. The result is not just bias in the composition of the different types of R&D performer and funder, but also underestimation of country totals. Both of these problems usually arise to unknown extents in different countries and they change in unknown ways over time.¹⁸
- It is common to estimate R&D in the education sector, rather than survey it directly, but the methods for this also differ and change.

2.4.2 Limited standardisation in the use of complementary economic data

Expenditure data, collected in current local currencies, have to be (a) adjusted with respect to capital costs and depreciation, (b) converted to a common currency and, for some purposes, (c) deflated to constant prices. In none of these areas has there been consistency between countries or over time in how this is done. In particular, data from the Annerstedt sources were converted at official exchange rates, while data from the UNESCO sources for 1990 and after were converted with World

¹⁶ In 1979 Annerstedt pointed out, 'There is not one single, globally accepted standard as to how to define and delimit R&D activities for statistical purposes. No international agency has been able to advise authoritatively the many national statistical units as to the kind of activity that should be considered and in what statistical categories the data should be collected, processed and presented.' (Annerstedt 1979: 40) However, he also acknowledged a trend toward some international norm. In 1978, the general conference of UNESCO had adopted a *Recommendation concerning the international standardization of statistics on science and technology*, with the aim of achieving some agreement towards general recommendations on the statistical categories in which data should be collected, processed and presented. In 1988, Annerstedt reinforced the point, writing that 'anyone interested in comparisons ought to be concerned about the deplorable fact that "science and technology", "experimental development", "research work", and similar notions refer to slightly different activities in different countries and are performed by different organizations with different objectives.' (Annerstedt 1988:131)

¹⁷ Reppy (1998) provides some examples of this problem in her discussion of trends in international spending for military R&D. 'In theory, all governments follow the definitions of research and development set out in the Frascati manual; in practice, ambiguities abound. Definitional issues arise, for example, where research is both fundamental and directed towards specific ends; where engineering and testing for development shade over into early production; and where technological fixes to operating systems require further development work.' (p 42)

¹⁸ For example, in 2008 OECD reports that data for some countries including Brazil, India, and South Africa are underestimated. For South Africa this translates to a 10-15% underestimate of R&D expenditure and is explained by the absence of an available business register. Also, some countries have more extensive survey coverage than others, particularly in areas such as services and higher education. For example, 'for Korea, social sciences and the humanities are excluded from the R&D data and for the United States, capital expenditure is not covered'. (OECD 2008:24-6) UNESCO also reports that 'The data from the OECD countries are much more complete and reliable than those from some of the developing economies, for which the R&D statistics often refer only to the public sector and higher educational institutions and sometimes also include elements of non R&D (though still S&T) activities. The quality of our data therefore may vary from very satisfactory to very partial and should thus be interpreted with great care.' (UIS 2001: 46-7)

Bank PPP rates.¹⁹ 2007 data are based on the recent revision of PPP rates in 2008, while data for 1990 and 1999/2000 were published in 2004 based on prior PPP rates. This is an area of considerable difficulty and these revisions can have a significant impact on the data, as we note later, for example, with respect to the data for China and India for 1999/2000.²⁰

2.4.3 Missing country data and under-representation of country categories

The non-reporting of country data for inclusion in regional or global syntheses has been a major difficulty through the whole period from Annerstedt's early syntheses to those of the UNESCO UIS in recent years. Not surprisingly, such non-reporting has been greatest among the developing countries, and especially the Least Developed Countries.²¹ The UIS has made a number of estimates to thicken up the data for developing countries, but considerable questions must inevitably surround the data for those countries.²² However, for the purposes of this paper – the exploration of differences and trends for broad country groupings - this uncertainty is probably much less important than it might seem. A very large proportion of the infrequently responding countries were among the smallest and/or least R&D-intensive, so even quite large gaps and inaccuracies in the data for these countries probably make very little difference to the aggregate patterns.

In this study we have had to take these kinds of difficulty more or less as given, rather than attempting to adjust any of the details. This has been primarily because of the limited resources available. But another type of problem has precluded any such adjustment even if it had been feasible in terms of resources.

2.4.4 The limited access to disaggregated data

Most of the data for recent decades compiled by the UNESCO UIS has been published only in the form of regional aggregates, without the detailed country level data as had previously been available in UNESCO Statistical Handbooks. This has precluded adaptation of the data (or its presentation in different kinds of aggregate grouping) - although the UIS has been helpful in responding to some of our queries to enable us to make a few minor rearrangements in the tables that follow.

3. THE GLOBAL DISTRIBUTION OF R&D EXPENDITURE: 1973 TO 2007

As noted earlier, the original Manifesto was centrally concerned about the very high concentration of R&D among a small number of OECD countries. It argued for a major effort to change that pattern by

¹⁹ *Purchasing Power Parities* or PPP conversion factors are intended to enable a more accurate comparison of GNPs across different countries, by taking into account the difference in domestic prices for a comparable basket of goods. (World Bank 2010a)

²⁰ PPP estimates for over 100 developing countries are revised every few years through the International Comparison Program (ICP) coordinated by the World Bank and separately by the Eurostat-OECD PPP program for over 40 OECD member and some non-member economies. An ICP was started in 2005, with PPP estimates released in 2007, benchmarked to 2005. (World Bank 2010b) 'The new PPPs replace previous benchmark estimates, some dating back to the 1980s. The new estimates are in some cases significantly different from the previous estimates. As a result, the data converted into PPPs have changed significantly, more so than for the OECD countries, which were also recently benchmarked to the year 2005.' (OECD 2008: 8)

²¹ In 2003, the UIS reported on responses to UIS S&T questionnaires over the period between 1990 and 2001, noting that 56 countries reported on four or more occasions, 27 countries reported between one and three times, and 106 countries did not respond at all. Of the 106 non-responders, 37 were in Africa, 16 in Asia, 29 in Latin America and the Caribbean, 16 in Oceania and 8 in Europe. (UIS 2003: 25-26)

²² 'The world and regional situations presented in the present document may be biased owing to lack of data – particularly where many developing countries are concerned – and the serious partiality in many existing statistics. They should, therefore, be interpreted with care.' (UIS 2001: 1) Though UNESCO Member States are obliged to provide data to UNESCO, 'this requirement does not always translate to reality', and data density is rather low for non-OECD countries. (UIS 2003:23)

strengthening the R&D (and related) capabilities and activities of developing countries. In particular, in order to demonstrate the very unequal international division of labour in science and technology, it highlighted a pattern of global distribution of R&D that came to be frequently cited at that time: 70 – 28 – 2. In other words 70% of global R&D expenditure was accounted for by the USA; 28% by other market economies; and only 2% by ‘developing’ countries in Asia, Africa, and Latin America (Singer et al 1970:5).

Annerstedt (1988) reiterated this concern and its connection to global inequality more broadly. ‘The concentration of R&D resources in a small number of countries has been a major feature of global inequality.’ (p. 129) Referring specifically to his data for both 1973 and 1980, he argued that ‘the majority of the countries in the world are forming a research desert, and that the remaining countries can be looked upon as a small number of R&D oases.’ (p. 129)

Much more recently, a *Declaration on Science and the Use of Scientific Knowledge* in 1999²³ indicated similar concerns about issues of access and participation in the creation of scientific knowledge more broadly, stating:

Most of the benefits of science are unevenly distributed, as a result of structural asymmetries among countries, regions and social groups, and between the sexes. As scientific knowledge has become a crucial factor in the production of wealth, so its distribution has become more inequitable. What distinguishes the poor (be it people or countries) from the rich is not only that they have fewer assets, but also that they are largely excluded from the creation and the benefits of scientific knowledge.

(paragraph 5)

We explore here the extent to which, and the ways in which the inter-country and R&D-centred aspect of those ‘structural asymmetries’ has altered since the 1970s, while bearing in mind the significant limitations in such aggregate figures, as just outlined. The overall synthesis of the data is presented in Annex 1, but we provide less complex tables and figures as we address selected aspects of the picture.

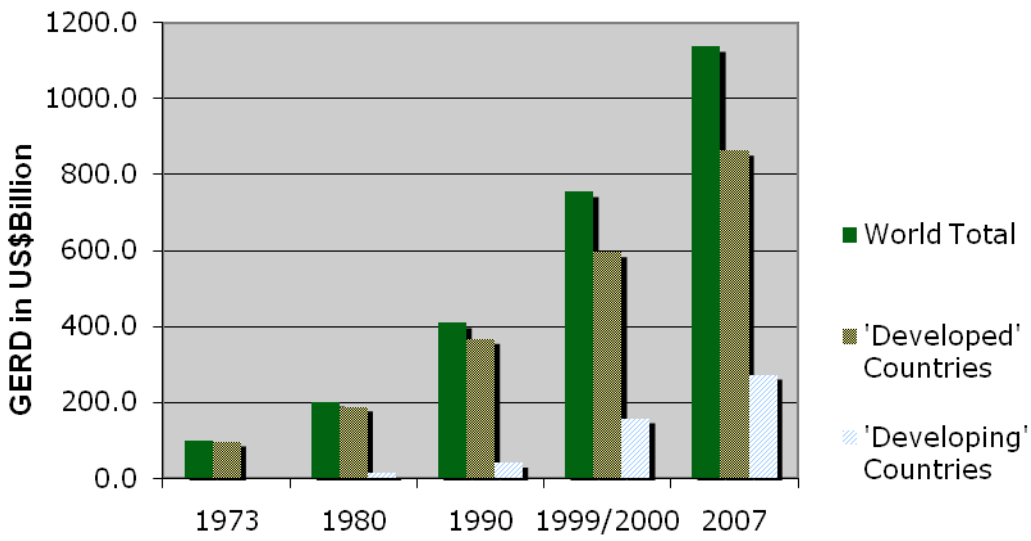
We begin with a world overview of R&D expenditure (GERD) from 1973-2007, looking at the changing distribution between ‘developed’ and ‘developing’ countries – defined as we explained earlier. We proceed to examine the global picture at a more disaggregated level, beginning briefly with changes among the developed countries. We then review in more detail the changes among developing countries, dealing separately with geographic regions of Latin America, Africa, and Asia – elaborating in slightly more detail on Asia, including data for particularly R&D intensive countries that account for a very large share of the total. Finally, we close this section with a brief discussion on trends in R&D Intensity.

3.1 World Overview: The ‘Developing’/‘Developed’ Country R&D Gap

Figures 1, 2 and 3 provide a highly condensed overview of trends in global GERD, R&D intensity and shares of the global total. The first of these indicates that there has been a continuing increase in global expenditure on research and development activities since the 1970s - more than a tenfold increase from about US \$100 billion in 1973 to nearly 1,138 billion in 2007 (Figure 1). But this has not quite kept up with the general growth of the world economy as measured in GDP. This is reflected in the estimates for global R&D intensity: falling from 2.1 per cent in 1973 to a more or less stable level of about 1.7 per cent between 1990 and 2007 (Figure 2).

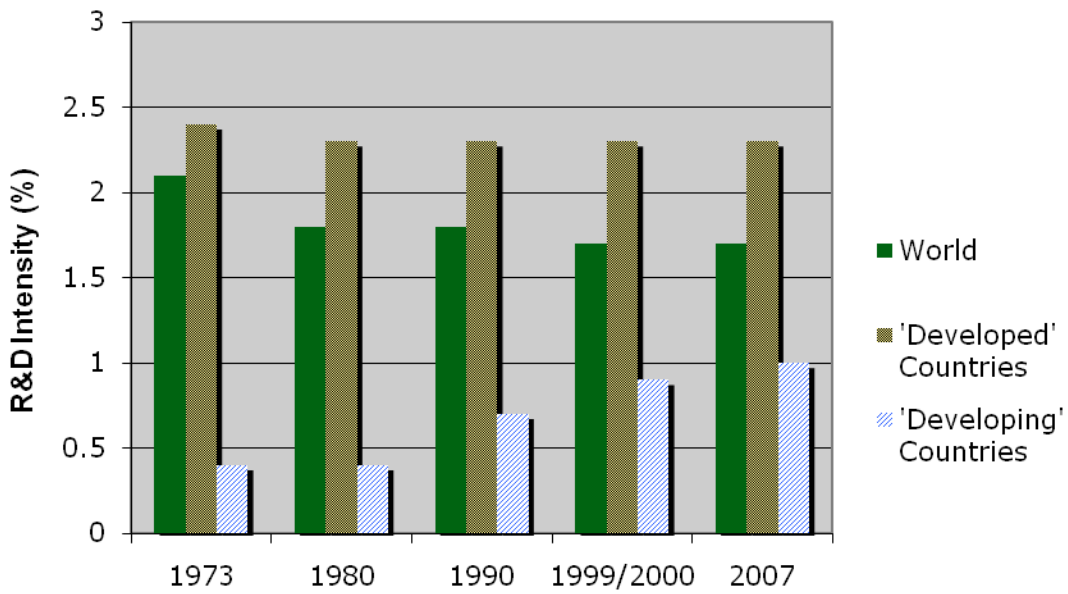
²³ This Declaration was produced at the World Conference on Science for the Twenty-first Century: A New Commitment, convened by UNESCO and the International Council for Science (ICSU) in Budapest.

Figure 1 Total R&D Expenditure (GERD in US\$Billion)



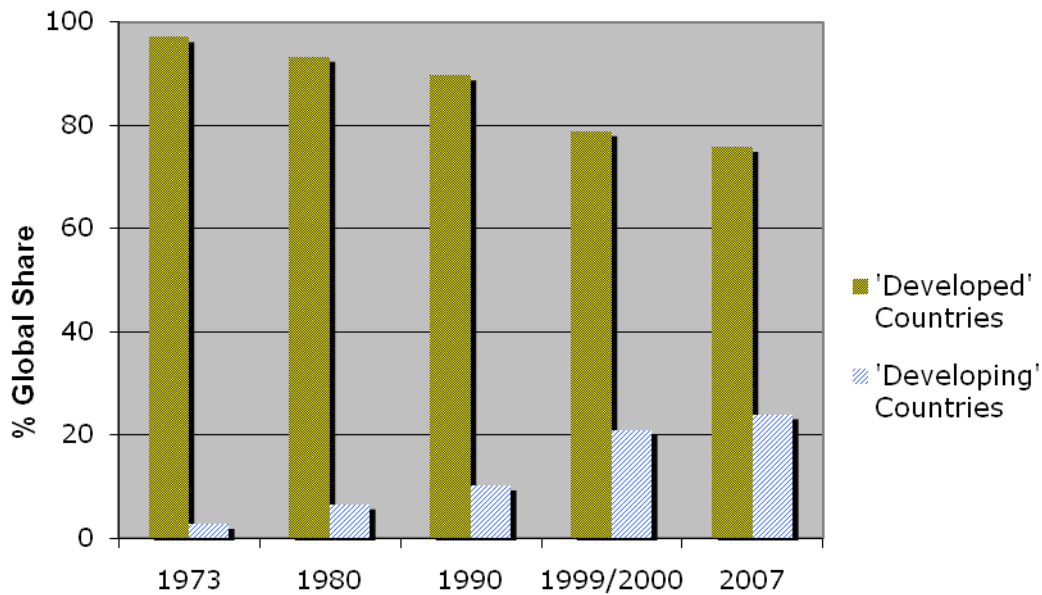
Source: various (Annerstedt, UIS)

Figure 2 R&D Intensity (GERD as Percentage of GDP)



Source: various (Annerstedt, UIS)

Figure 3 GERD as Percentage of Global Share



Source: various (Annerstedt, UIS)

However, these global aggregates hide a considerable difference between the trends for the developed and developing countries. While the R&D intensity of the former as an aggregate group remained more or less constant at about 2.3 – 2.4 per cent, it rose very considerably for the overall group of developing countries – more than doubling from about 0.4 per cent to 1.0 per cent. Consequently, the share of that group in the world’s total R&D activity increased substantially – rising eightfold from about 2.8 per cent to a little over 24 per cent (Figure 3). Along the way, by 1980 the share had reached 6.6 per cent – already exceeding the target of 4-5 per cent that had been called for in the 1970 Sussex Manifesto.

But this global overview hides considerable differences *within* the two groups of countries. In particular, the increase in the developing countries’ R&D has been highly concentrated in a limited number of countries, especially in Asia. We explore these issues below, with reference to Table 3.

Table 3 Global Distribution of R & D Expenditure: 1973 to 2007 in US\$ Billion and as Global Share (%)

		1973		1980		1990		1999/2000		2007	
		GERD		GERD		GERD		GERD		GERD	
		US \$	Share	US \$	Share	US \$	Share	US \$	Share	US \$	Share
		Billion ¹	%	Billion ¹	%	Billion ¹	%	Billion ¹	%	Billion ¹	%
A. 'Developed' Countries²		97.2	97.2	189.6	93.4	367.9	89.8	596.7	79.0	864.2	75.9
	North America	33.7	33.7	62.9	31.0	156.4	38.2	281.0	37.2	394.5	34.7
	Other Market Economies	30.7	30.7	71.7	35.3	186.9	45.6	293.8	38.9	444.9	39.1
	of which, Japan ³	7.9	7.9	20.7	10.2	67	16.3	98.2	13.0	147.6	13.0
	<i>Sum of above</i>	64.4	64.4	134.6	66.3	343.3	83.8	574.8	76.1	839.4	73.8
B. (Ex) Centrally Planned⁴		33.0	33.0	55.2	27.2	24.6	6.0	22.5	3.0	50.0	4.4
C. 'Developing' Countries (D+E+F)		2.8	2.8	13.4	6.6	42.0	10.2	158.4	21.0	273.7	24.1
D. Asia⁵		1.8	1.8	8.1	4.0	25.4	6.2	131.3	17.4	215.2	18.9
	China	-	-	-	-	12.4	3.0	50.3	6.7	104.9	9.2
	India	-	-	-	-	2.5	0.6	20.0	2.6	24.8	2.2
	Republic of Korea	-	-	-	-	7.3	1.8	17.1	2.3	41.7	3.7
	Taiwan	-	-	-	-	-	-	8.5	1.1	16.6	1.5
	Singapore	-	-	-	-	-	-	2.4	0.3	6.0	0.5
	Hong Kong	-	-	-	-	-	-	-	-	2.2	0.2
	<i>Sum of above</i>	-	-	-	-	-	-	115.4	15.3	196.19	17.2
E. Latin America		0.8	0.8	3.5	1.7	11.3	2.8	21.3	2.8	33.3	2.9
	Brazil	-	-	-	-	-	-	11.5	1.5	17.3	1.6
F. Africa⁶		-	-	-	-	5.2	1.3	5.8	0.8	10.4	0.9
	South Africa	-	-	-	-	2.9	0.7	3.6	0.5	4.1	0.4
	Other Sub-Saharan countries	0.1	0.1	0.6	0.3	1.9	0.5	1.1	0.1	2.8	0.2
G. Arab States in Africa and Asia		0.2	0.2	1.0	0.5	2.4	0.6	1.7	0.2	4.7	0.4
WORLD TOTAL*		100.2	100	203	100	409.8	100	755.1	100	1,137.9	100

*Rounding of values leads to some discrepancies between totals shown for groups of countries and sums of their component members in the table. For details of sources and notes, see Annex 1.

3.2 The 'Developed' Countries

As noted earlier, the first two components of the commonly cited 70 – 28 – 2 distribution of global R&D in the 1960s referred to the developed countries. Annerstedt noted that this 70-28 division between the US and all other market economies was more-or-less true in the first half of the 1960s, but he pointed out that the centrally planned economies were not included in these figures, and also emphasised that R&D statistics did not exist for many of the other market economies or were of poor quality.

In his own estimates for 1973, he included the centrally planned economies' 33 per cent share of the global total *within* the 'developed countries' share (97.2 per cent).²⁴ He also took account of improved data for both the other market economies and the developing countries. As shown in Table 3, one consequence was that, despite the increase in R&D in developing countries, the share of the 'developed countries' (i.e. North America, Europe *and* the centrally-planned economies) still accounted for some 97.2 per cent of the world's total R&D expenditure. In other words the highly marginal position of the developing countries had changed very little from the 1960s until 1973.

However, *within* the developed countries (excluding centrally-planned), the R&D activities of countries outside North America had increased sharply, partly in Europe, but strikingly in Japan. Consequently the 70-28 shares of North America and the other market economies had shifted to 51-46 by 1973. (Annerstedt 1988: 134)

Thereafter as the global share of the 'developed countries' (North America, other market economies *and* the former centrally planned economies)²⁵ fell from 97.2 per cent in 1973 to 75.9 per cent in 2007, significant changes occurred *within* the group following the dissolution of the Soviet Union.

- The share of the global total accounted for by the 'ex-centrally-planned economies' of the former Soviet Union fell from 33 per cent in 1973 to just 3.0 per cent in 1999/2000, rising only slightly to 4.4 per cent in 2007. (Row B in Table 3)
- Correspondingly, the share accounted for by North America and other market economies taken together moved from a total of 64.4 per cent of the global share in 1973 to 83.8 per cent in 1990 and remaining close to 75 per cent between 1999 and 2007.

Then *within* the North American and other market economies group, there were other substantial changes.

- North America actually lost share between 1973 and 1980, regaining some 7.2 per cent between 1980 and 1990, and then falling again to 34.7 per cent of global share in 2007.
- Consequently, the share of 'Other Market Economies' grew between 1973 and 1990, reaching 45.6%, then dropping down to about 39% in 1999/2000 where it has stayed through 2007.
- Following its rapid increase in global share by 1973, Japan's contribution to the global total continued to increase, reaching 16% in 1990 and remaining at an astounding 13% from 1999/2000 through 2007.

²⁴ In order to keep the history of this group of countries visible, it is also shown separately as Row B in Table 3.

²⁵ Actually (as explained earlier) from 1990 the ex-centrally-planned economies are split in the allocation between developing and developed countries. CIS Europe and the Central and Eastern European countries are included in the former, while CIS Asia countries are in the latter.

3.3 The 'Developing' Countries

There were also substantial differences between regions and countries within the group of developing countries. Annerstedt emphasized this point with respect to the growth of this group's R&D between the late 1960s and early 1970s, and again with respect to the striking growth in share by 1980 (6.6 per cent). Such differences continued through to 2007.

With respect to regions, the differences in the changing share of global R&D are clear in Table 3.

- The Asian share increased more than threefold over the seventeen years between 1973 and 1990 - from 1.8 per cent to 6.2 per cent; and it then more than tripled again over the next seventeen years to 18.9 per cent in 2007. (Row D)
- The Latin American share increased from 0.8 per cent in 1973, via 2.8 per cent in 1990 to only a slightly larger 2.9 per cent in 2007. (Row E)
- The African share (including Arab States in Africa) increased from about 0.3 per cent in 1973 to 1.3 per cent in 1990, and then fell to a lower level of 0.9 per cent in 2007. (Row F)

Thus, the Asian region accounted for almost 80 percent of the total increase in the developing countries' R&D between 1973 and 2007. Slightly less than 4 per cent was accounted for by Africa.

But these stark differences were not simply 'regional'. There were also sharp differences between countries *within* the regions. Annerstedt noted this already with respect to the changes by 1980 when he pointed out that trends toward increased R&D expenditure in 'developing countries' was greatly due to the growth in investments in certain countries with 'comparatively large R&D systems such as China, India and Brazil'. (1988:129) This has continued, though the key countries have not been entirely confined to China, India and Brazil. We explore this further for each of the regions.

3.3.1 Latin America

R&D expenditure in Latin America and the Caribbean (LAC) grew at roughly the same rate as in the developing countries as a whole between 1973 and 1980, and again through the next decade to 1990. Thereafter, especially in the 1990s, although total GERD continued to increase, the rate of increase lagged behind that of the total developing country group. As a result, over the whole period from 1980 to 2007 the rate of growth in the LAC region was around half that in the whole group, and its share of all developing country R&D halved from 25 per cent to 12 per cent.

The relatively slow growth for the LAC region was also highly concentrated among a few countries. Annerstedt pointed out that this was already evident in the 1973-1980 period when the relatively high rate of increase was largely accounted for by countries with the largest R&D systems, such as Brazil, Argentina and Mexico. In later years, Brazil has become particularly dominant, accounting for more than half of the region's R&D in 1999/2000 and 2007.

3.3.2 Africa

It is difficult to present a clear picture for Africa as a single entity partly because of the kinds of country classification problem noted earlier, and partly because of the very limited and unequal availability of data for countries in the region. Annerstedt defined Africa as Sub-Saharan Africa, excluding South Africa; and he described this region as 'part of the Third World R&D desert'. But he also noted 'signs of change' between 1973 and 1980 with a slight increase in the region's share of the global total from 0.1 per cent to 0.3 per cent. Over the subsequent periods, Table 3 indicates that for Africa as a whole (now defined to include South Africa, Row F), R&D expenditure first jumped to account for about 1.3 per cent of the global total in 1990 and then increased steadily in absolute

terms through to 2007. But a large part of the total and much of the absolute increase through that period was accounted for by South Africa (plus a small contribution from the Arab states in Africa). Moreover, the growth of R&D through the 1990s and up to 2007 was relatively slow, and the region's share of the global total fell to less than 1 per cent through that period. For Sub-Saharan Africa (excluding South Africa), the rate of growth of R&D through the period from 1990 was slower than for Africa as a whole, and its share of the global total fell from 0.5 per cent to 0.2 per cent – a figure that was smaller than it had been nearly thirty years earlier in 1980.

3.3.3 Asia

As noted above, R&D in Asia (excluding Japan) grew particularly rapidly through the whole period. Correspondingly the region's share of all R&D in developing countries increased from around 60 per cent before 1990 to around 80 per cent in the early 2000s. But this was also highly concentrated among a small number of countries *within* the region that had particularly high rates of growth of R&D. As Annerstedt had suggested would be the case, two of these were large countries with already large R&D systems in the 1970s: both China and India roughly trebled their shares of global R&D between 1990 and 2007.²⁶ But others like Korea, Taiwan, Singapore and Hong Kong were much smaller. Between them, these six countries accounted for 88 per cent of Developing Asia's R&D in 1999/2000, and they then continued to pull further ahead of the rest of the region – with their share rising to 91 per cent by 2007.

Behind these changes in levels of R&D in Asia, and in the associated shares of regional and global totals, there is a further distinctive feature of the Asian experience. This is about changes in R&D-intensity (the GERD/GDP ratio), which, as shown in Table 4, are strikingly different from those in the other regions. The increases in levels of R&D described earlier for those other regions have run more or less in proportion to changes in GDP, and R&D intensity has changed little: it has been more or less constant at 2.3 – 2.4 per cent in the developed countries over the whole period since the 1970s, at around 0.5 – 0.6 per cent for Latin America from 1990 to 2007; and at about 0.4-0.6 per cent for Africa between 1980 and 2007.

In contrast it has risen dramatically in Asia between 1973 and 2007 – increasing threefold from 0.4 per cent to 1.2 per cent. The increase in R&D intensity was particularly striking in some of the individual countries where it took place 'on top of' extremely fast overall GDP growth, and outpaced the rate of change for the region as a whole. It almost doubled in China and Korea between 1990 and 2007 - nearly twice the 50 per cent increase for the region as a whole; and it increased from about 2.0 per cent to 2.6 per cent in Taiwan and Singapore over the shorter period between 1999/2000 and 2007. Only in India did it remain more or less constant – running from 0.8 per cent in 1990, the same level as China, to the same figure in 2007, only slightly more than half the level in China.

²⁶ A qualification is needed here with respect to the data for 1999/2000 in the middle of this trend. These are presented in our table as reported by UNESCO in 2004 – i.e. before publication of the World Bank's revision of the PPP indices that were particularly significant for developing countries, and especially for China and India. We have not presented revised estimates for R&D expenditure for this year, but it is interesting to note their implications for these two countries that make such a large contribution to the total of Asian R&D. Their levels of R&D fall by about 50 per cent, so reducing both the Asian and Developing country shares of the global total by about four percentage points. However, since the data for all countries in 2007 *have* been estimated on the basis of the revised PPP indices, this adjustment would, in effect, have no significant effect on the overall trend between 1990 and 2007, merely lowering a previously over-estimated kink in the middle.

Table 4 R&D Intensity (GERD as a Percentage of GDP): 1973 To 2007

		1973	1980	1990	1999/2000	2007
A. 'Developed' Countries²		2.4	2.3	2.3	2.3	2.3
	North America	2.3	2.2	2.6	2.7	2.6
	Japan ³	-	-	3.1	2.9	3.4
B. (Ex) Centrally Planned⁴		4.3	4.6	-	-	-
C. 'Developing' Countries		0.4	0.4	0.7	0.9	1.0
D. Asia⁵		0.4	-	0.8	1.1	1.2
	China	-	-	0.8	1.0	1.5
	India	-	-	0.8	0.7	0.8
	Republic of Korea	-	-	1.8	2.3	3.5
	Taiwan	-	-	-	2.0	2.6
	Singapore	-	-	-	1.9	2.6
	Hong Kong	-	-	-	-	0.8
E. Latin America		0.3	0.5	0.5	0.6	0.6
	Brazil	-	-	-	0.9	1.0
F. Africa⁶		0.3	0.4	0.6	0.3	0.4
	South Africa	-	-	1.0	0.8	1.0
	Other Sub-Saharan countries	0.3	0.4	0.5	0.2	0.3
WORLD TOTAL		2.1	1.8	1.8	1.7	1.7

For details of sources and notes, see Annex 1.

Thus, it was largely this particular group of Asian countries that, as well as contributing a very large proportion of the rising level of R&D expenditure in the developing countries as a whole; was driving up the R&D intensity of Developing Asia overall, and hence, with a little input from Brazil, pushing up the research intensity of the developing countries as a whole.

3.3.4 R&D in the Developing countries: summary picture

Despite all the limitations in the data, there seems to be a reasonably clear overall pattern of change in R&D activity across the three developing country regions. This strongly suggests that although the share of global R&D accounted for by developing countries has increased spectacularly since the 1970s, this has not involved a significant reduction in the gross inequalities noted by the original Sussex Manifesto in 1970. Instead, within each region, the process of remarkable change over this period seems to have been highly concentrated among countries in ways that have not removed the old fault lines of inequality and structural asymmetry – just relocated them. Certainly, there is now a larger number of oases in what was Annerstedt's 'Third World R&D desert' of the 1970s, but there still remains a very large amount of desert. Moreover it is much larger than suggested by our analysis of data for societies defined by national boundaries because, like other deserts, the R&D desert is no respecter of such boundaries and spills over, for example, into large parts of society in China, India and Brazil. But that is not a lot different from the R&D deserts that cover, for instance, substantial parts of society in North America or Europe.

But one must bear in mind that data about R&D are data about only a fraction of the wider domain of scientific and technological activities. Even less do they provide an adequate basis for mapping the geographical or social location of innovation activities. R&D statistics of the type we have used here

have corresponding limitations as a basis for informing policy about strengthening and building science, technology and innovation systems in developing countries, an issue we discuss in the following section.

4. POLICY-RELATED LIMITATIONS OF R&D STATISTICS AND INDICATORS

It is commonly argued that the availability of reliable and internationally comparable statistics is an important basis for policy about science, technology and innovation in developing countries, and such arguments typically identify statistics and indicators about R&D as a cornerstone of that information base for policy-making. But also, over the last forty years or so a huge literature has been created to address the limited usefulness of R&D data in playing that policy-related role.

We do not attempt here to review that broad difference of opinion, or to reach any conclusion about it. Nor do we even intend to try and review at all systematically or comprehensively the full array of arguments about the policy-related usefulness of R&D statistics.²⁷ Instead we concentrate on a few issues that arise in connection with the kinds of R&D statistics we have reviewed in the previous section, focusing in particular on policy-making about science, technology and innovation in developing countries. These selected issues fall into two groups.

- Limits to the usefulness of R&D statistics in illuminating the component of STI-related policy that is concerned specifically with *policy about R&D*;
- Limits to the usefulness of R&D statistics in informing policy decisions concerned with the much wider overall field of *policy about science, technology and innovation*.

4.1 The usefulness of R&D statistics for policy about R&D

As emphasised earlier, we have concentrated in this report on only one type of R&D statistic: a measure of the overall scale of a country's R&D activities, usually normalised in the form of the GERD/GDP intensity indicator. This focus is not unusual. It has been common in many international and national reports about R&D in developing countries, especially in reports concerned with policy in countries at relatively early stages of changing and strengthening their STI systems for which a wider range of indicators may not yet have been developed.

It may therefore be pertinent to note the rather obvious point that the only kinds of policy decision that can be illuminated by indicators of the scale of a country's R&D are decisions about trying to change that scale. Such an indicator can illuminate little about other important issues – e.g. decisions about the balance between different kinds of R or D (e.g. basic or applied R); about the balance between different kinds of social, economic and other objective that should be pursued by R or D; about the kinds of organisation where R&D should be undertaken (e.g. in government institutes or production enterprises); or about how different elements of R&D should be funded. Even less can such indicators of the aggregate national scale of R&D illuminate the very large part of the 'nitty-gritty' of R&D policy that consists of decisions about the programmes and projects that should be undertaken.

Beyond that, indicators of the scale of R&D provide, on their own, a pretty limited basis even for decisions about its scale. Christopher Freeman highlighted this on several occasions at the early stages of his work on the development of such indicators – as in a discussion in the early 1960s with Stefan Dedijer, another pioneer in the development of R&D statistics. Recalling some years later this

²⁷ Recent broad reviews of these and other science and technology and innovation indicators are provided in Godin (2002), Smith (2005), Gault (2007), and Freeman and Soete (2009).

discussion about the policy role of cross-country comparisons of R&D/GDP ratios, Freeman (1988) noted that:

Somewhat naively, I tried to maintain that no one would base big policy decisions on such single comparisons and that it would be essential to take into account such factors as comparative industrial structures, levels of defence R&D, size of country, level of economic development, and absolute as well as relative comparisons. (p 116-117)

Dedijer had maintained the contrary view that simple league tables of R&D/GDP ratios were critically important in influencing policy decisions about the scale of resource allocation to R&D. Freeman reported that, despite his earlier misgivings: 'After 25 years of working with R&D statistics and making international comparisons, I would have to agree that he (Dedijer) was largely right'. (Freeman 1988: 117) He went on to cite the examples of Finland, France and Austria where such single comparative indicators, combined with simple arguments about catching up and falling behind, had provided a powerful basis for raising levels of government resource allocation to R&D. He might easily have added the earlier example of the US where, in the late 1950s as the Cold War intensified, the National Science Foundation had used indicators of comparative R&D levels in the US and USSR as a persuasive tool to lever the government into higher levels of expenditure. He could also have drawn on similar examples from many developing countries by the mid 1980s; and numerous others have subsequently used the same statistical tool for political leverage in the interests of securing higher expenditure on R&D. Such efforts to influence policy have often focused on a specific target set quite arbitrarily in terms of the convenient round number of 1 percent of GDP; and they have commonly focused heavily on raising government expenditure on R&D as the main mechanism for achieving the target.

Thus, if the policy priorities in particular countries are about securing substantial increases in the scale of R&D expenditure, especially expenditure by government, then internationally comparable measures of the scale of national R&D (relative to GDP) are a policy tool with a long history of proven usefulness. This experience therefore endorses, for instance, the direction currently being pursued in Africa, where plans to strengthen the base of statistical information for STI policy-making are being focused initially on basic R&D-centred statistics. One of the main purposes for this is about monitoring progress towards the agreed aim of the African Ministers of Science and Technology to raise R&D expenditure in the region to 1 per cent of GDP. However, the policy relevance of such R&D-intensity indicators may be much more limited if merely expanding the scale of national R&D is not the central policy priority. Indeed effort to develop such indicators, plus the subsequent focus on them in policy debate and analysis, is likely to distort attention away from other higher priorities.

This highlights questions about developing a more diverse array of R&D indicators, rather than just focusing on the GERD/GDP ratio. Such diversity has been a central feature of statistical surveys of R&D since the earliest days of international standardisation in this area. In particular both the OECD and UNESCO frameworks have involved disaggregated information about R&D activities to distinguish for instance:

- the different kinds of organisations that perform (and fund) R&D – (government, business enterprises and higher education institutions);
- the different kinds of R or D – (basic research, applied research and experimental development);
- the different socio-economic objectives being addressed by R&D – (defence, energy, space, economic development, health and environment, and so forth).

In principle such data, and the indicators that can be derived from them, provide a basis for informing a much wider range of policy issues about R&D than merely its scale. But in practice, especially for many developing countries, problems about the availability and 'quality' of data are usually much

greater in these areas than they are for measures of the scale of R&D – considerable as we have already suggested those often are. In particular:

- Inconsistencies in definition, interpretation and operational reporting often pre-empt meaningful analysis. (For example, data involving distinctions between such categories as 'basic research' and other types of R or D are widely distrusted and rarely used);
- Survey coverage is often sharply constrained. (For example, data about socio-economic objectives typically refer only to government R&D. Also, reporting of R&D at all may be absent for some organisational categories such as enterprises or universities). Thus country-level reporting with respect to most kinds of disaggregation is often even lower than it is for aggregate R&D expenditure.

Consequently, the practical reality is that, for many developing countries, the available statistical basis for comparative analysis does not extend far beyond data about aggregate levels of R&D, and hence it provides very limited illumination of policy issues beyond those about the scale of R&D. One might therefore argue that it is important in many developing countries to give much greater attention to building more comprehensive and reliable statistical systems that can illuminate a wider range of policy issues about R&D. But before going down that track, it is important to consider broader questions about the significance of policy for R&D within the much wider field of policy about science, technology and innovation. This then opens up questions about the wider policy usefulness of intensified efforts to develop more diversified types of R&D-centred data.

4.2 The usefulness of R&D statistics for policy about science, technology and innovation

One of the qualifications that the authors of the 1970 Manifesto attached to their focus on R&D was that this activity was only a small fraction of the much wider spectrum of scientific and technological activities that contributed to the implementation of technical change (or innovation). They identified the importance of various 'scientific and technological services' that, although not included in the definition of R&D, were closely related to it. But they also had a much wider view of the domain of science and technology policy that went far beyond policy for R&D, even if that included such closely related activities:

Policy for science and technology in this broader sense is concerned not merely with generation of new knowledge in the R&D system, but also with the dissemination and application of existing and new knowledge throughout the economy, and with the reciprocal interaction between science, technology and the economy. (Singer et al 1970: 3)

Their approach to quantifying the relative magnitudes of R&D and this wider spectrum of scientific and technological activities involved only a small and rather vague step:

... large resources amounting in many advanced countries to 2 and even 3 per cent of GNP are currently allocated for research and development. Many times this amount are additionally spent in applying the results of this R and D. (Singer et al 1970: 2)

But how many times larger than R&D are the non-R&D elements of overall scientific and technological activities? Perhaps not surprisingly, there have been few answers to that. However, one step towards thinking about an answer is to start by suggesting that scientific and technological activities consist of the things that scientists and engineers do by way of their employed occupation. Systematic data about those activities are rare, perhaps itself a reflection of the dominating preoccupation with R&D in the STI statistical community.²⁸ However, one compilation of such data

²⁸ In contrast to the scarcity of information about all the things that scientists and engineers do, there is a considerable amount of statistical information about the employment of scientists and engineers in R&D.

from the US at least sheds interesting light on the issue. These data refer to people who have degree qualifications in science and engineering disciplines and/or are employed in 'scientific and engineering' occupations. As summarised in Table 5 below they indicate the proportions whose 'main activity' falls into different categories. Bearing in mind that these data are about one of the most R&D-intensive economies in the world, the relative importance of some of the categories is quite striking.

- Only 10 per cent of all the scientists and engineers undertake R&D as their main activity. In other words the main activity of about 90 per cent consists of *non-R&D* activities;
- In contrast, a larger proportion (13 per cent) carries out various 'design' activities, including the design of computer applications, systems, etc.
- Even more of them (19 per cent) undertake various management-related activities, frequently concerned with managing projects, quality and productivity.
- The proportion undertaking various kinds of professional service (e.g. health, financial, or legal services) is the same as the proportion undertaking R&D *and* 'design' activities combined (23 per cent).

Arguably, the first three groups (Rows A, B and C) are involved in some way or other in innovation – the central focus of science and technology policy in many countries. But only about one-quarter of this group undertakes R&D as their main activity, and three-quarters do not. In addition, we are gradually learning that a large number of scientists and engineers engaged in activities like those in Rows D – G probably also contribute to innovation – for example scientists and engineers working in professional services such as finance and health care. But they normally fall outside the scope of what is typically covered by 'innovation policy' and even further outside the scope of R&D policy.

Table 5 The Main Activities of Scientists and Engineers in the US: 2003 ¹

Types of scientific and technological activity	Proportion of Totals	
	A-G	A-C
A Research (basic and applied) and technological development	10%	24%
B Design (of equipment, processes, structures, models, plus computer programming and systems development, etc.)	13%	31%
C Management/Supervision (of people, projects, quality, productivity, etc.)	19%	45%
Sub-Total (A – C)	42%	100%
D Business, administrative and production activities (in accounting, personnel, sales, maintenance, etc.)	21%	
E Professional services (financial, healthcare, legal, etc.)	23%	
F Teaching	11%	
G Other specified	3%	
All Above	100%	

Source: US NSF (2003) - aggregated from more detailed categories in the original. Note: 1. Scientists and engineers are personnel with degree qualifications in science and engineering disciplines and/or employed in scientific and engineering occupations.

On this basis, one might argue that statistics about R&D in the US cover only about 10 per cent of the country's 'scientific and engineering' activities, and hence that R&D policy has a similarly narrow scope relative to policy for science and technology more generally.

It is far from clear what the relevance of this is for developing countries. Clearly that depends in part on which countries one includes in that category. But at the very least it seems unlikely that many of them would be more R&D-intensive than the US (in terms of personnel), hence requiring *more* than 10 per cent of their scientists and engineers to be engaged in R&D. This implies that there may be much more important things to measure about science, technology and innovation in those countries than merely R&D – even if that enumeration was to extend beyond just the aggregate scale of R&D.

But that leads to a broader issue about the influence of statistical information on policy. It is widely agreed that statistical enumeration tends to focus policy attention on what has been measured. In the case of statistics about science and technology therefore, a preoccupation with statistics about R&D (accounting for, say, only 10 per cent of scientific and technological activities) might be thought likely to 'distort' the orientation of policy away from other kinds of S&T priority (accounting for, say, the other 90 per cent). This may be especially important at the relatively early stages in the process of changing and creating STI systems in developing countries. In such situations, efforts to create maps and models of the emerging systems are usually heavily shaped and influenced by the kinds of statistical information that are available – typically about R&D. Consequently, there is a considerable likelihood that the structure of the emerging system will be shaped to fit the R&D-dominated maps and models.²⁹

It might be more useful to reverse that relationship so that statistics, maps and models are constructed in order to try and reflect the reality of emerging and evolving science, technology and innovation systems in developing countries. One might then find that focusing the collection of statistical information about science, technology and innovation so heavily on R&D, even on several dimensions of R&D in addition to just its size, would be less useful than is widely advocated. Instead, it might be much more useful to develop simple statistical information about other larger and more important components of science, technology and innovation systems – perhaps in particular on design and engineering activities (especially outside manufacturing contexts), and about 'informal' types of innovation undertaken on the basis of 'traditional' or 'indigenous' knowledge resources.

²⁹ This issue about the policy-shaping role of statistical systems is addressed in much more detail in the companion Background Paper: Bell, M. (2009) *Innovation Statistics and Innovation System Models Policy Tools and Policy-making in Developing Countries*.

6. ANNEX 1

Table 6 Global Distribution of R&D Expenditure: 1973 to 2007

	1973			1980			1990			1999/2000			2007		
	GERD		GERD	GERD		GER	GERD		GERD	GERD		GERD		GER	
	US \$	Share	/GDP	US \$	Share	D/GD	US \$	Share	/GDP	US \$	Share	/GDP	US \$	Share	D/GD
	Billion ¹	%	%	Billion ¹	%	%	Billion ¹	%	%	Billion ¹	%	%	Billion ¹	%	%
A. 'Developed' Countries²	97.2	97.2	2.4	189.6	93.4	2.3	367.9	89.8	2.3	596.7	79.0	2.3	864.2	75.9	2.3
North America	33.7	33.7	2.3	62.9	31.0	2.2	156.4	38.2	2.6	281.0	37.2	2.7	394.5	34.7	2.6
Other Market Economies	30.7	30.7	1.6	71.7	35.3	-	186.9	45.6	-	293.8	38.9	-	435.1	39.1	-
of which, Japan ³	7.9	7.9	-	20.7	10.2	-	67	16.3	3.1	98.2	13.0	2.9	147.6	13.0	3.4
Sum of above	64.4	64.4	-	134.6	66.3	-	343.3	83.8	-	574.8	76.1	-	829.6	73.8	-
B. (Ex) Centrally Planned⁴	33.0	33.0	4.3	55.2	27.2	4.6	24.6	6.0	-	22.5	3.0	-	50.0	4.4	-
C. 'Developing' Countries (D+E+F)	2.8	2.8	0.4	13.4	6.6	0.4	42.0	10.2	0.7	158.4	21.0	0.9	273.7	24.1	1.0
D. Asia⁵	1.8	1.8	0.4	8.1	4.0	-	25.4	6.2	0.8	131.3	17.4	1.1	215.2	18.9	1.2
China	-	-	-	-	-	-	12.4	3.0	0.8	50.3	6.7	1.0	104.9	9.2	1.5
India	-	-	-	-	-	-	2.5	0.6	0.8	20.0	2.6	0.7	24.8	2.2	0.8
Republic of Korea	-	-	-	-	-	-	7.3	1.8	1.8	17.1	2.3	2.3	41.7	3.7	3.5
Taiwan	-	-	-	-	-	-	-	-	-	8.5	1.1	2.0	16.6	1.5	2.6
Singapore	-	-	-	-	-	-	-	-	-	2.4	0.3	1.9	6.0	0.5	2.6
Hong Kong	-	-	-	-	-	-	-	-	-	-	-	-	2.2	0.2	0.8
Sum of above	-	-	-	-	-	-	-	-	-	115.4	15.3	-	196.19	17.2	-
E. Latin America & Caribbean	0.8	0.8	0.3	3.5	1.7	0.5	11.3	2.8	0.5	21.3	2.8	0.6	33.3	2.9	0.6
Brazil	-	-	-	-	-	-	-	-	-	11.5	1.5	0.9	17.3	1.6	1.0
E. Africa⁶	-	-	-	-	-	-	5.2	1.3	0.6	5.8	0.8	0.3	10.4	0.9	0.4
South Africa	-	-	-	-	-	-	2.9	0.7	1.0	3.6	0.5	0.8	4.1	0.4	1.0
Other Sub-Saharan countries	0.1	0.1	0.3	0.6	0.3	0.4	1.9	0.5	0.5	1.1	0.1	0.2	2.8	0.2	0.3
G. Arab States in Africa and Asia	0.2	0.2	0.3	1.0	0.5	0.3	2.4	0.6	0.3	1.7	0.2	0.2	4.7	0.4	-
WORLD TOTAL*	100.2	100	2.1	203	100	1.8	409.8	100	1.8	755.1	100	1.7	1,137.9	100	1.7

* Rounding of values leads to some discrepancies between totals shown for groups of countries and sums of their component members in the table

Annex 1 continues with Notes and Sources associated with this table on the following two pages.

Annex 1 cont.

Notes for Tables

¹ To enable international comparisons, Annerstedt converted national data for 1973 and 1980 from national currencies to US dollars using official exchange rates with some modifications. For 1990, 1999/2000 and 2007 data, UNESCO relied on PPP rates provided by the World Bank to convert national data. Data for 2007 only were converted by UIS and OECD using the recently revised PPP rates (in 2008, PPP rates were released, revised to a 2005 benchmark). UIS and OECD point out that revisions have a significant impact on the data, and that to improve comparison, these revised PPP rates should be applied retrospectively to 1999/2000 and even possibly to some 1990 data. Such revision for this table was not possible as complete country-level data was not available. We have pointed out this important limitation in the text in Section 2.4, and we comment on the particular cases of India and China in Section 3.3.3.

² This includes North America and Other Market Economies, which in turn includes Europe (Western Europe in 1973 and 1980, and the European Union plus European Free Trade Association-EFTA in later years), Japan, Oceania, Israel, and Turkey. For 1973 and 1980 only, it also includes South Africa and South Korea (The Republic of Korea). The (ex)-centrally planned economies of Eastern Europe and the USSR are also included in this total for all years. CIS Asia countries are thus included only in 1973 and 1980, when they formed part of the USSR.

³ For 1973 and 1980, includes Japan and South Korea: thus South Korea not included in (D) 'Asia' for 1973 and 1980.

⁴ For 1973 and 1980 this is 'Eastern Europe', including the USSR, and contributes to the 'developed' country total. For later years this group is somewhat synonymous in composition (though not in name, due to the dissolution of the USSR) and includes countries in CIS-Europe, CIS-Asia and Central and Eastern Europe (UNESCO categories). This category is split, however, in its contribution to the totals of 'developed' and 'developing' countries for 1990, 1999/2000, and 2007, where countries in CIS-Europe and Central and Eastern Europe contribute to 'developed' totals and countries in CIS Asia contribute to 'developed' countries (as part of 'Asia'). This split is described in the text of Section 2.3.

⁵ Japan is not included in 'Asia', but under 'Other Market Economies' in (A). Arab States in Asia are not included for 1973 or 1980.

⁶ For 1973 and 1980, the 'Africa' total excludes South Africa and 'Arab states in Africa', following Annerstedt's categorisation. South Africa instead contributes to the 'developed' country total for these early years (as part of 'Other Market Economies'), while 'Arab States in Africa' are combined with 'Arab States in Asia' and contribute to the 'developing' country total. We have thus continued this row of 'Arab States in Africa and Asia' throughout the table for comparison (G). In 1990, 1999/2000 and 2007, 'Africa' includes South Africa, 'Other Sub-Saharan countries' and Arab States in Africa, which explains why the sum of South Africa and other Sub-Saharan countries does not match the total for 'Africa' in these later years.

Annex 1 cont.

Sources for Tables

- For 1973, data are from Annerstedt, J. (1979) *A Survey of World Research and Development Efforts. The Distribution of Human and Financial Resources to Research and Experimental Development in 1973*, Paris: OECD Development Centre & Roskilde: Roskilde University Center's Institute of Economics and Planning.
- For 1980, data are from Annerstedt, J. (1988) 'The Global R&D System: Where is the Third World?' Chapter 9 in *From Research Policy to Social Intelligence: Essays for Stevan Dedijer*, Basingstoke : Macmillan, pp. 129-141; and, R&D intensity data from UNESCO (1984) *Estimation of World Resources for Research and Experimental Development 1970-1980*, Division of Science and Technology Statistics, Office of Statistics, Paris: UNESCO.
- For 1990 and 1999/2000, regional totals are from the UIS (2004) *Bulletin on Science and Technology Statistics*, Issue No. 1, April 'A Decade of Investment in Research and Development (R&D): 1990-2000', which indicates source of data as 'Regional estimations based on UIS data and UNESCO (1993; 1996; 1998), *World Science Report*, Paris; UIS (2001) *The State of Science and Technology in the World, 1996-1997*, Paris: UNESCO Institute for Statistics. Exceptions for 1999/2000 include individual country data for: Republic of Korea, Taiwan, Singapore, Hong Kong and Brazil, which are drawn from OECD (2008) *Main Science and Technology Indicators* data and the UIS (2009a) Science and Technology Data Release.
- For 2007, data are from UIS (2009a) Science and Technology Data Release, available online at <http://stats.uis.unesco.org/unesco/> and OECD (2008) *Main Science and Technology Indicators*, Paris: OECD.

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