# Chapter 6
# Assessment of Science and Technology Indicators and the Need for Science and Technological Development in Sudan

**Abstract** This chapter investigates the status of S&T indicators in Sudan. We explain that the combination of poor S&T inputs/resources (both financial and human resources) together with an inadequate economic system as a whole, results in Sudan producing poor S&T outputs/performances. Moreover, we find that most R&D and S&T activities and (FTER) employment in Sudan occurs within the public and university sectors, while the private sector and industry make only a minor contribution. We find that the main problems hindering R&D include: the lack of finance from public sector; lack of management and organisational ability; lack of coordination and weak relationships, network and consistency and cooperation between universities and higher education institutions on the one side and the productive sector on the other side; lack of R&D culture; lack of finance from private sector; lack of favourable conditions and the necessary facilities; lack of awareness and appreciation of the economic values of R&D; and lack of human resources (researchers and qualified workers in R&D fields) respectively. Hence, our analysis indicates that in order to improve S&T performance, Sudan needs to invest heavily in both financial and human resources as well as to learn from the lessons of the advanced and developing S&T nations.

## 6.1 Introduction

Chapter 5 uses the data and results of the firm and macro surveys set out in Chap. 4 to assess skill and technology indicators and to examine the serious implications of the interaction between the deficient educational system and the high incidence of unskilled workers and skill mismatch. To complete our earlier analysis in Chap. 5

Nour, Samia (2012a), "Assessment of science and technology indicators in Sudan," the Journal of Science, Technology and Society, Vol. 17; No. 2; July 2012, pp. 321–352, SAGE Publications, Los Angeles/London/New Delhi/Singapore/Washington DC. DOI: 10.1177/097172181101700206.

S. Mohamed Nour, *Technological Change and Skill Development in Sudan*,
DOI 10.1007/978-3-642-32811-4_6, © Springer-Verlag Berlin Heidelberg 2013

above, in this chapter we use the most recent secondary data to discuss science and technology development indicators at the macro level in Sudan, compare the status of Sudan with the rest of the world and highlight the need for technological development and policies to enhance science and technology performance in Sudan. Our analysis in this chapter differs in several ways from the several studies in the literature, which provides an interesting analysis of S&T indicators and performance in the Arab, developing countries and Sudan. First, different from the studies in the Arab literature (Nour 2004, 2005a, b) we provide a more indepth, comprehensive and up to date assessment of S&T input and output indicator by focusing only on Sudan as a new case of the Arab countries. Secondly, we extend our analysis to compare the case of Sudan with other Arab, African and world countries. Given the recent progress of economic globalisation coupled with the emergence of new nations active in S&T in different parts of the world, our analysis in this chapter extends the comparison to include these new countries as well as those in Europe, the United States and Japan, and then draws some policies and recommendations for ways to enhance S&T performance in Sudan. Thirdly, different from the studies in the Sudanese literature we provide a more comprehensive analysis by including both S&T input and output indicators using more up to date data wherever possible. This is so we can help to improve understanding about the urgent need and necessity to stimulate S&T development and support new policies that aim to enhance S&T performance in Sudan and poor countries. Our study highlights recent efforts to create an active Sudanese S&T base but also emphasises the need to improve the quality of resources devoted to S&T development, which will ultimately contribute to and accelerate development in the country. Furthermore, it also helps to encourage the government to provide more incentives for the promotion of S&T indicators in Sudan to obtain the most positive impact possible from technological progress in terms of growth, employment and the wellbeing of all poor Sudanese citizens. Finally, different from the studies in the Sudanese literature, a novel element in our analysis is that we use new survey data based on primary data and 25 face-to-face interviews with the official policy makers and experts in the government and the academics and university staff in the public and private universities to examine the main factors hindering and those contributing towards the promotion of R&D and hence S&T development in Sudan. As mentioned in Chap. 4 above, the main purpose of this survey is to collect primary data to examine the causes of poor R&D activities and then to provide some recommendations to improve R&D and hence S&T indicators in Sudan.

The rest of this chapter is organised as follows: Sect. 6.2 shows the interaction between general socio-economic characteristics of Sudan and S&T. Section 6.3 discusses S&T development indicators in Sudan, including a comparison of the indicators for Sudan with the rest of the world. Finally, Sect. 6.4 draws conclusions and proposes policies to enhance S&T performance in Sudan, based on the results of the Sudan R&D survey and the experiences of other countries.

## 6.2 General Socio-Economic Characteristics of Sudan and S&T Indicators

S&T performance is often closely related not only to the resources directly devoted to its development but also to the whole economic structure that supports it. Therefore, before assessing S&T performance in Sudan it is useful to explain the interaction between the general socio-economic characteristics of Sudan and S&T indicators. In Chap. 2 above we show the general socio-economic characteristics and lower standards of economic development as measured by GDP per capita and human development index of Sudan as compared to African and Arab countries and the world regions. We explained that after the exploitation of oil in 1999 Sudan economy become increasingly dependent on oil exports, and the economy turned into an oil dependent economy. In recent years the increasing dependence on oil has led to sound economic growth, measured by GDP growth at 6.1 % in 2003 and averaged about 9 % during (2005–2007). However, unfortunately it is only unsustained growth, mainly because of uncertainty and high fluctuation in oil price in the international market, for instance, the recent global financial and economic crisis and related shock in 2008 and 2009 resulted in low global oil prices, lead to significant negative impact on Sudan economy, stagnating domestic oil production and caused reduction in GDP growth rate that dropped from 10.5 % in 2007 to 7.8 % and 5 % in 2008 and 2009 respectively (see Table 2.2 and Fig. 2.2 above).

We are aware of the fact that it may be useful to depart from the analysis of general standardise S&T indicators and to use indepth economic, historical and social evidence to extend our analysis to focus more explicitly on whether the production and export of oil (natural resource-based exports) affected the R&D infrastructure and the growth and development trajectory of Sudan economy. We are aware of the fact that it may be particularly important and interesting to explain the impact of oil in R&D and S&T, but due to practical problems related to availability of adequate and reliable data, unfortunately it will not be possible to discuss this issue in this chapter, so we leave that for a more indepth analysis in our future research. Furthermore, we believe that most probably the impacts of oil in R&D and S&T might be still very limited in view of the very recent start of production and exports of oil just 11 years previous in 1999. Moreover, although oil led to increases in public spending and increases in the share of development expenditure as a percentage of total public expenditure from 9 % in 1999 to around 31 % in 2004, its share declined and sustained at 24 % from the total public spending over the period 2006–2009. Furthermore, the development expenditures include all public spending in development issues including public spending on education, health, etc. Therefore, this implies that it is not at all clear and it is somewhat problematic to distinguish the share and growth of spending on R&D that is mainly attributed to production and export of oil, but it is important to realise that at the macro level the share of spending on R&D as a percentage of GDP most probably remained below the United Nations (UN) (1970) standardised level of spending 1 % of GDP on R&D in the pre- and post-oil periods (see Fig. 6.1 below). In addition, also due to practical problems related to availability of adequate and

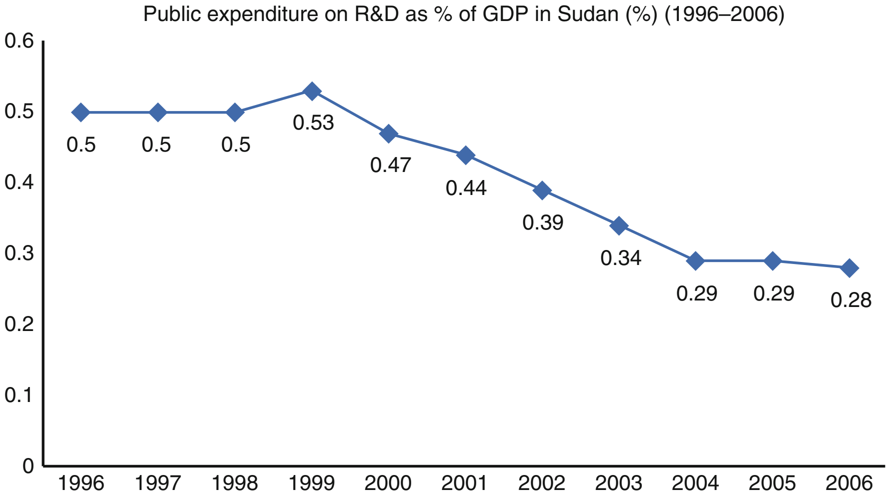


**Fig. 6.1** The rate of public expenditure on R&D as a percentage of GDP in Sudan (%) (1996–2006) (Source: UNESCO R&D Statistics (2006))

reliable data unfortunately it will not be possible to give an indepth analysis of the private spending on R&D or the impact of oil companies on R&D at the micro level. So, we hope to cover these issues in our future studies when adequate and reliable data is available. Hence, apart from the limited impact of oil, the next section of this chapter examines whether this economic background affects S&T performance in Sudan.[1]

## 6.3 S&T Indicators in Sudan

Based on the definition of S&T indicators provided in Chap. 3 above and the explanation of the interaction between the general socio-economic characteristics of Sudan and S&T indicators provided in Sect. 6.2 above, this section extends our assessment of technological indicators at the micro level presented in Chap. 5 above by explaining the technological indicators at the macro level. It is useful to start by explaining the governance of S&T; next we examine input indicators (financial and human resources) and output indicators (scientific and technological performance) required to measure S&T performance at the macro level in Sudan.

[1] One limitation of the comparison in our analysis is that we use data and information from two different local and international sources; the scarcity of data and information covering all indicators limited our attempt to use a unified source.

### 6.3.1 Governance of S&T

In Sudan the history of S&T governance dates back to the 1970s, when the National Council for Research (NCR) was established in 1970 as a governmental body responsible for formulating policies and plans and coordinating national efforts in this respect. The mandate of NCR was transferred to the Council of Higher Education and Scientific Research in 1991–1992. In S&T education, the government has expanded higher education institutions, there are 85 universities and colleges (private and public), 40 universities and colleges are in the field of applied sciences and about 25 colleges in the fields of engineering and technology. The Sudanese government has also realised the importance of creating high level national science bodies by establishing two important institutions: the National Council for Science and Technology (NCST) and the Ministry of Science and Technology (MOST). The role of the NCST is to formulate the policies of S&T, organise R&D and implement the country's strategies in S&T and to ensure that S&T is utilised in the plans, projects and institutions of the government. A significant development in terms of institutional framework for S&T development in Sudan was the establishment of MOST in 2001. The formation of MOST signified the high priority and importance attached to the promotion of science and technology and to coordinate efforts of national and international links and formulate national strategy for S&T. It led to the centralisation of the public research institutes under the supervision of MOST whereby the public research institutes in the various fields were previously under the jurisdiction of their respective ministries. Scientific research is conducted and governed in three levels: (a) basic research conducted by universities and governed by the Council of Ministry of Higher Education and Scientific Research; (b) R&D research conducted by corporations and centres, governed by MOST, advised by a council and a number of committees; and (c) applied research conducted in some technical department of ministries, administered by the executive authority of each ministry. Given the division among the three sectors, under the new institutional framework, MOST faced the challenges to work as government high coordinating body to coordinating the various diverse fields of research and meeting the needs of the various ministries and industries. MOST includes some specialised research institutes and centres including: Agricultural Research Corporation (ARC); Animal Resources Research Corporation (ARRC); National Centre for Research (NCR); Industrial Research and Consultancy Centre (IRCC); Sudan Atomic Energy Corporation (SAEC); Sudanese Metrology Authority (SMA); Central Laboratories (CL); Sudan Academy of Sciences (SAS); and Social and Economic Research Bureau (SERB).

In terms of S&T planning and in view of the increasingly competitive global environment and rapid advance in technology and increasing importance of S&T in accelerating economic growth and development, the previous comprehensive National Strategy (1992–2002) and current National Quarter Century Strategy (2007–2031) give long-term perspective of S&T development in Sudan. The previous comprehensive National Strategy (1992–2002) provided comprehensive strategies for Science and technology (S&T) development through the preparation of a national plan for scientific research, development of information centres and scientific research as well as the establishment of a national information network, adoption and modification of the important technology system to suit national environment, development of capabilities to invent technology and the maximum utilisation of technology in Sudan. In light of the 25 year long-term strategy, a 5 year strategy was identified and implementation work plan is developed. The 5-year work plan is targeting eight key areas including information, communications and technology and development of scientific research. The plan aims to promote S&T by: promulgating the legislations, laws and regulations conductive to the enhancement of scientific research; recruiting personnel with high abilities and competencies in the fields of scientific research; adopt innovative means to encourage the private sector to participate in scientific research, funding it and benefiting from it; utilising the results of scientific research and modern technology in decision–making and sustainable development planning; developing and disseminating science and knowledge among the people; benefiting from the experience of others in scientific research and also contributing to the advancement of basic sciences.[2] Unfortunately, the implementation of these comprehensive strategies, however, was not fully carried out mainly due to the inadequate financial and human resources needed for S&T development as we explain below.

## *6.3.2 Human and Financial Input Indicators*

In terms of both financial and human S&T input/resource indicators there are some differences between Sudan, and the Arab and Sub-Saharan African countries as well as between them and other countries around the world. Table 6.1 shows that both financial and human S&T input indicators in Sudan lag behind the advanced and leading developing countries.

### 6.3.2.1 Financial Input Indicators

As for the financial resources in S&T, as in most other typically developing countries the Sudanese government seem to afford only a limited budget for S&T. For instance, in 2006, the rate of spending on R&D as a percentage of GDP in Sudan was only 0.2 %, falling behind the standard rate of the world, Arab countries, developing countries, East Asia, Pacific, Latin America and the Caribbean, South Asia, middle income and even low income countries, which spend on R&D as a percentage of GDP about 2.3 %, 0.6 %, 1.0 %, 1.6 %, 0.6 %, 0.7 %, 0.8 %, 0.7 % respectively (see Fig. 6.2 below). The rate of spending on R&D as a percentage of GDP in the developing countries is five times the rate of spending in Sudan. This reflected negatively on the number of researchers and publications, as we will explain below.

---

[2] See Sudan Ministry of Science and Technology (2008), pp. 3–6.

**Table 6.1** S&T resource indicators of the Sudan, Arab and world countries

| Country | Public expenditure on education as % of GDP[a] | | Public expenditure on education as % of government expenditure [a] | | R&D expenditure as % of GDP[a] | Number of scientists and engineers in R&D (per million population) [a] | Number of patents[a, b] | High-technology exports as % of manufactured exports[a] | |
|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1998–2000 | 1990 | 1998–2000 | 1996–2000 | 1996–2000 | 1990–1999 | 1990 | 2001 |
| Sudan | 0.9 | Na | 2.8 | Na | 0.5 | 225 | 0 | .. | 7 |
| *Gulf countries* | | | | | | | | | |
| Bahrain | 4.2 | 3.0 | 14.6 | 11.4 | Na | Na | 2 | 0 | 0 |
| Kuwait | 4.8 | Na | 3.4 | Na | 0.2 | 212 | 27 | 4 | 1 |
| Oman | 3.1 | 3.9 | 11.1 | Na | Na | 8 | 3 | 11 | 3 |
| Qatar | 3.5 | 3.6 | Na | Na | Na | 591 | 0 | 0 | 0 |
| Saudi Arabia | 6.5 | 9.5 | 17.8 | Na | Na | Na | 103 | 0 | Na |
| UAE | 1.9 | 1.9 | 14.6 | Na | Na | Na | 15 | 0 | Na |
| Average Gulf | 4.0 | 4.4 | 12.3 | 11.4 | 0.2 | 270 | 25 | 2.5 | 1 |
| *Mediterranean countries* | | | | | | | | | |
| Algeria | 5.3 | Na | 21.1 | Na | Na | Na | Na | 0 | 4 |
| Egypt | 3.7 | Na | Na | Na | 0.2 | 493 | 38 | 0 | 1 |
| Lebanon | Na | 3.1 | Na | 11.1 | Na | Na | Na | Na | 3 |
| Morocco | 5.3 | 5.5 | 26.1 | 26.1 | Na | Na | Na | 0 | 11 |
| Syria | 4.1 | 4.1 | 17.3 | 11.1 | 0.2 | 29 | 3 | 0 | 1 |
| Tunisia | 6.0 | 6.8 | 13.5 | 17.4 | 0.5 | 336 | Na | 2 | 3 |
| Average Mediterranean | 4.9 | 4.9 | 19.5 | 16.4 | 0.3 | 286 | 20.5 | 0.4 | 3.8 |
| Norway | 7.1 | 6.8 | 14.6 | 16.2 | 1.7 | 4,112 | 97 | 8 | 12 |
| Sweden | 7.4 | 7.8 | 13.8 | 13.4 | 3.8 | 4,511 | 285 | 13 | 18 |
| UK | 4.9 | 4.5 | Na | 11.4 | 1.8 | 2,666 | 76 | 23 | 31 |
| Korea, Rep. of | 3.5 | 3.8 | 22.4 | 17.4 | 2.7 | 2,319 | 931 | 18 | 29 |

(continued)

**Table 6.1** (continued)

| Country | Public expenditure on education as % of GDP[a] | | Public expenditure on education as % of government expenditure [a] | | R&D expenditure as % of GDP[a] | Number of scientists and engineers in R&D (per million population) [a] | Number of patents[a, b] | High-technology exports as % of manufactured exports[a] | |
|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1998–2000 | 1990 | 1998–2000 | 1996–2000 | 1996–2000 | 1990–1999 | 1990 | 2001 |
| Singapore | Na | 3.7 | Na | 23.6 | 1.1 | 4,140 | 12 | 39 | 60 |
| China | 2.3 | 2.1 | 12.8 | Na | 0.1 | 545 | 793 | 0 | 20 |

[a]UNDP (2003).

[b]United States Patent and Trademark Office (USPTO) website: http://www.uspto.gov. Patent data for Korea, Norway, Singapore, Sweden and the UK obtained from UNDP (2003) and refers to patents granted in 1999 to residents per million people. For China and all Arab countries, patent data was obtained from USPTO during 1991–1999 and refers to the number of registered US patents where the inventor of the patent is resident in the selected countries.

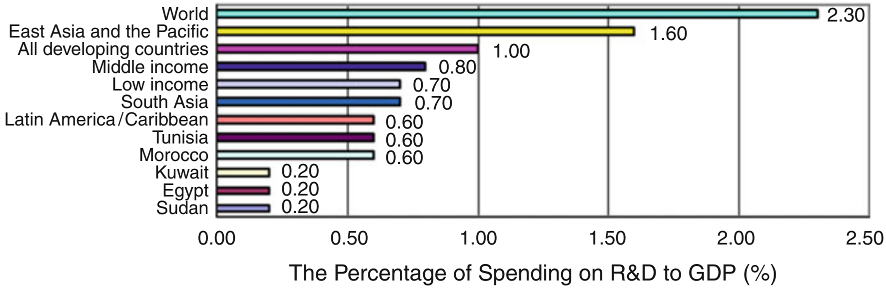


**Fig. 6.2** The rate of spending on R&D as a percentage of GDP in Sudan compared to other Arab and world regions (2006) (Source: UNDP, HDR 2007/2008, Table 13: 273–276. P. 240 Arab Human Development Report 2009)

In Sudan the implementation of the comprehensive strategies in the field of S&T, was not fully carried out mainly due to the inadequate financial and human resources. The S&T indicators showed that S&T development was relatively low compared with the average for Arab countries. This was evident as the percentage expenditure in research to total government expenditure in 1998 for Sudan was only 0.04 % compared with the average for seven Arab countries, which was 1.2 %. In terms of expenditure on both education and R&D as percentage of GDP, Sudan performs less than Arab countries. In particular, Table 6.1 shows that the financial resources devoted to S&T, as measured by the percentage share of GDP spent on R&D are poor in Sudan and Arab countries, compared to both advanced and leading developing countries like Singapore and Korea. For instance, in the period 1996–2000, Sudan devoted only 0.1 % compared to Arab countries that devoted an average of only 0.3 % of their GDP to R&D whereas Sweden, one of the leading advanced industrial countries, spent 3.8 % of GDP on R&D. Similarly, spending on education, as measured by percentage of both GDP and total government expenditure, for Sudan was found to be less than Arab countries and the advanced countries.

Comparing S&T indicators between Sudan and other Arab countries, data for 2006 shows that the rate of spending on R&D as a percentage of GDP in Sudan is comparable to the rate of spending in Egypt and Kuwait, but falls behind the rates of both Morocco and Tunisia, notably, the rate of spending on R&D as percentage of GDP in Morocco and Tunisia is three times the rate of spending on R&D in Sudan, Egypt and Kuwait (see Fig. 6.2 above). Moreover, statistics indicate a very high dependence on the public sector on the financial support to S&T (near to 95 % of total financial support to S&T) compared to a very low contribution of the private sector in Sudan (near to only 5 % of total financial support to S&T). There is thus a need to adopt new policies for partnership with the private sector. Investigation of the sectoral distribution of R&D spending by sources of funding in Sudan in 2005 indicates that the public sector is responsible for the majority of R&D activities, accounting for 39.2 % of all Gross Domestic Expenditure on Research & Development (GERD) (see Table 6.2 below). Next to public sector, private sector contributes 33.7 % of GERD; the universities make only a minor contribution,

**Table 6.2** Gross domestic expenditure on R&D (GERD) by sector of performance (%) in Sudan (1999–2005)

| | Total gross domestic expenditure on R&D (GERD) | | | | GERD by sector of performance (%) | | |
|---|---|---|---|---|---|---|---|
| | Local currency (Sudanese dinar) (000) | PPP$ (000) | As percentage (%) of GDP | Per capita (PPP$) | Business enterprise (%) | Government (%) | Higher education (%) |
| 1999 | 14,300,000 | 195,816 | 0.53 | 6.0 | 31.5 | 38.5 | 30.1 |
| 2000 | 14,900,000 | 191,746 | 0.47 | 5.7 | 31.5 | 38.9 | 29.5 |
| 2001 | 15,240,000 | 196,190 | 0.44 | 5.8 | 31.5 | 39.3 | 29.2 |
| 2002 | 15,400,000 | 186,387 | 0.39 | 5.4 | 31.8 | 39.0 | 29.2 |
| 2003 | 15,650,000 | 176,066 | 0.34 | 5.0 | 31.9 | 39.0 | 29.1 |
| 2004 | 16,373,000 | 165,184 | 0.29 | 4.6 | 33.6 | 38.3 | 28.1 |
| 2005 | 19,284,000 | 179,085 | 0.28 | 4.9 | 33.7 | 39.2 | 27.1 |

Source: UNESCO R&D Statistics (2006)

accounting for 27.1 % of GERD. These findings for the case of Sudan seem consistent with the results in Nour (2004, 2005), which implies that in Sudan as in the Gulf and Mediterranean Arab countries the public sector is responsible for the majority of R&D activities and government seems to play a major role in R&D compared to higher education. Moreover, despite the fact that the contribution of the private sector (business enterprises) is near to one third and exceeds the contribution of higher education institutions in Sudan however, this should not hide the fact that business does not seem to play a major role in R&D compared to government. Our findings imply that Sudan is similar to Arab Mediterranean countries, which appear to be more dependent on the public sector than the Arab Gulf countries, reflecting a lack of incentives for private sector institutions to invest in R&D in Sudan and Mediterranean countries compared to the Gulf. The minor contribution of the private sector to R&D activities and spending in Sudan and Arab countries compares poorly to most of the industrialised countries, where more than half of R&D expenditure is financed by industry (OECD1997).

A further problem concerning research funding in Sudan is that not only is Sudan's total GERD is rather fair at about 0.5 % GDP, but also there has been a steady decline in Sudan's total GERD during the 1999–2005 period (see Table 6.2 below). This declining trend implies that the heavy reliance on the limited government and public funding was risky and resulted in poor S&T indicators and inadequate finance for R&D activities that is apparent from the low rates of both the actual received budget relative to approved budget and the approved budget to the proposed budget. For instance, for all institutions of MOST, although the rate of actual received budget relative to approved budget increased from near to 25.7 % in 2003 to 74.7 % in 2009, the actual received budget relative to approved budget covered only 74.7 % of the approved budget in 2009. Implementation of projects is most probably constrained by inadequate finance, for instance, over the period 2003–2009 the average rate of implementation for national ministries and northern states is 60 % (see Table 6.3 below).

#### 6.3.2.2 Human Resources Input Indicators

The human capital for S&T includes human resources in higher education, Master's and doctoral enrolments and the size of the university workforce and research and development personnel. Table 6.1 shows that there are a low number of scientists and engineers in R&D in Sudan and the Arab countries compared to both advanced and leading developing countries. We explain below about human resources in S&T, higher education and research institutions in Sudan.

Beginning with human resources in higher education institutions in Sudan, in the early 1990s, enrolment in both general education and higher education rapidly increased. For instance, during the period 1992–2000 the enrolment rates in both primary (basic) education and in higher secondary education rapidly increased by 54 % and 154 % respectively. As for higher education, following the higher education revolution in the early 1990s, notably 1992/1993, the total number of universities and colleges increased by more than three fold, notably, from 25 in 1993 to 85 in 2008; the number of public government universities increased from 6 universities in 1990 to 14 in 1993 and to 28 in 2008; the private universities and colleges increased from 11 in 1993 to 57 in 2008. The higher education revolution together with the implementation of economic liberalisation and privatisation policies and their related consequences in higher education, led to significant structural change in the share of public and private sectors in higher education institutions in Sudan. For instance, the share of the public government universities declined from 56 % in 1993 to 33 % in 2008, whereas the share of private universities and colleges increased from 44 % in 1993 to 67 % in 2008. The expansion in higher education in the period 1992–2007 led to significant increases in both student enrolment and graduation rates in higher education and universities by 73.78 % and 189.9 % respectively. Student intake jumped from 6,080 in 1989 to 25,018 in 1992/93 and to 43,477 in 2007. The number of female students rose to 40 % of total enrolment in 1995. However, the continued increase in the proportion of female students has not been accompanied by a comparable increase in their representation amongst the faculties: merely 13 % in 1995. The number of students enrolled in private higher education institutions increased nearly nine fold within 4 years: from 2,686 in 1990–1991 to 23,476 in 1994–1995 (see Table 6.4 below). As for Master's and doctoral enrolments, generally, there is remarkable increase in the number of people who participate in postgraduate studies in Sudanese institutions (see Table 6.4 below). The distribution of students enrolled in postgraduate programmes in 24 universities in Sudan indicates that the share of postgraduate students enrolled in 18 universities located in Khartoum state is higher than the share of postgraduate students enrolled in 14 universities located in other Sudanese states. Furthermore, the intensity of students enrolled in the Master's programmes is

**Table 6.3** Performance of R&D funding in public research institutions, national ministries and Northern states (2003–2009)

(a) Performance of funding in major public research institutes/ centers

| Institutions | Actual received budget/ Approved budget (%) | | | | | | Approved budget/ Proposed budget (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2007 | 2008 | 2009 | 2003 | 2004 | 2005 | 2007 | 2008 |
| Head of Ministry | … | … | … | … | 53.3 | 70.5 | 28.4 | … | … | … | … |
| Agricultural Research Corporation (ARC) | 21.5 | 29 | 44 | 45.8 | 74.8 | 73.7 | 24.2 | 17 | 53 | 19 | 40 |
| Animal Resources Research Corporation (ARRC) | 22.4 | 36 | 42 | 53.6 | 77.3 | 72 | 34.4 | 20 | 32 | 12 | 22 |
| National Centre for Research (NCR) | 36.9 | 37 | 14 | 46.8 | 76.6 | 82 | 25.4 | 55 | 1.23 | 21 | 16 |
| Industrial Research and Consultancy Centre (IRCC) | 37 | … | … | 55.5 | 72.2 | 83.2 | 31.7 | … | … | … | … |
| Sudan Atomic Energy Corporation (SAEC) | 35.7 | … | … | 61.2 | 66.7 | 73.7 | 53.8 | … | … | … | … |
| Sudan academy for science | … | … | … | 50.6 | 83.3 | 86.3 | … | … | … | … | … |
| Social and Economic Research Bureau (SERB) | … | … | … | … | 83.3 | 87.5 | … | … | … | … | … |
| Central Laboratories (CL) | … | … | … | 46.9 | 83.3 | 83.3 | … | … | … | … | … |
| Sudanese Metrology Authority (SMA) | … | … | … | 88.5 | … | … | … | … | … | … | … |
| Total | 25.7 | … | … | 49.1 | 73.7 | 74.7 | 28.2 | … | … | … | … |

(b) Performance of the national ministries and Northern states

| indicators | Year | No of projects | Implemented 100 % | Implementation ongoing | Not implemented | Average performance of area (%) |
|---|---|---|---|---|---|---|
| National ministries | 2007 | 234 | 42 | 165 | 36 | 63 |
| | 2008 | 165 | 28 | 127 | 10 | 63 |
| | 2009 | 212 | 57 | 149 | 6 | 62 |
| Total ministries | 2007–2009 | 620 | 127 | 441 | 52 | 62 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Northern states | 2007 | 19 | 2 | 11 | 6 | 70 |
| | 2008 | 53 | 10 | 27 | 16 | 55 |
| | 2009 | 41 | 13 | 18 | 10 | 54 |
| Total states | 2007–2009 | 113 | 25 | 56 | 32 | 59 |
| Grand total | 2007–2009 | 733 | 152 | 497 | 84 | 60 |
| National ministries and states | 2007 | 262 | 44 | 176 | 42 | 50 |
| | 2008 | 218 | 38 | 154 | 26 | 52 |
| | 2009 | 253 | 70 | 167 | 16 | 61 |
| Grand total National ministries and states | 2007–2009 | 733 | 152 | 497 | 84 | 54 |

Source: Ministry of science and technology annual reports (2003–2009)

**Table 6.4** Growth in higher education institutions and students enrolment in general and higher education in Sudan1992–2008

(a) Higher education institutions 1993–2008

| | 1993 | 1994 | 1996 | 1998 | 2000 | 2002 | 2003 | 2004 | 2005 | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|
| Total number | | | | | | | | | | |
| Government Universities | 14 | 23 | 26 | 26 | 26 | 26 | 27 | 27 | 27 | 28 |
| Private universities and colleges | 11 | 12 | 16 | 18 | 23 | 36 | 37 | 46 | 46 | 57 |
| Other high education institutions | … | … | … | … | … | 3 | 2 | 2 | 3 | … |
| Total | 25 | 35 | 42 | 44 | 49 | 65 | 66 | 75 | 76 | 85 |
| Share in total (%) | | | | | | | | | | |
| Government universities | 56 | 66 | 62 | 59 | 53 | 40 | 41 | 36 | 36 | 33 |
| Private universities and colleges | 44 | 34 | 38 | 41 | 47 | 55 | 56 | 61 | 61 | 67 |
| Other high education institutions | … | … | … | … | … | 5 | 3 | 3 | 4 | … |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

(b) Enrollment in higher education: % Student enrollment ratio in higher education by field of study (%)

| | |
|---|---|
| Students enrolled in education | 10.9 |
| In arts and humanities and social science | 14.7 |
| Enrolled in medical science, (Health and environment) | 10.9 |
| In agricultural sciences | 6.3 |
| In engineering science | 10.7 |
| In basic science | 7.1 |
| Share of education, arts and humanities and social science in total enrolment | 25.60 |
| Share of agricultural, basic science, engineering science medical science, (Health and environment) in total enrolment | 35.00 |
| Share of others in total enrolment | 39.40 |

(c) Enrolment in primary (basic) education: Percentage increase in general education schools (1992–2000)

(continued)

**Table 6.4** (continued)

| | 1992/1993 | 2000 | Increase % |
|---|---|---|---|
| Pre-school education | 5,813 | 8,343 | 44 |
| Primary education | 8,288 | 11,923 | 54 |
| Higher secondary education | 574 | 1,457 | 154 |

(d) Growth in students enrollment and graduation in higher education and universities (1992–2007)

| | 1992/1993 | 2007 | Increase % |
|---|---|---|---|
| Enrolled | 25,018 | 43,477 | 73.78 |
| Graduated | 13,183 | 38,217 | 189.9 |

(e) Growth in students enrollment by field of study (%) (1992–2000)

| | Number in 1992/1993 | Number in 1999/2000 | Change (1992–2000) | Growth rate (1992–2000) (%) |
|---|---|---|---|---|
| Education | 4,123 | 7,269 | 3,146 | 76 |
| Humanities and art | 4,415 | 6,412 | 1,997 | 45 |
| Social sciences and business administration and law | 2,012 | 12,591 | 10,579 | 526 |
| Natural sciences | 1,685 | 3,894 | 2,209 | 131 |
| Engineering sciences | 2,539 | 4,545 | 2,006 | 79 |
| Agriculture | 2,336 | 4,553 | 2,217 | 95 |
| Health and social services | 1,760 | 4,036 | 2,276 | 129 |
| Services | 148 | 177 | 29 | 20 |
| Total | 25,018 | 43,477 | 18,459 | 74 |

(h) Distribution of postgraduate students in Khartoum state (in 14 universities) and other states (in 18 universities) in Sudan (2006)

| Degree | Total number | | | Share in total (%) | | | | |
|---|---|---|---|---|---|---|---|---|
| | Total | Khartoum state (14 universities) | Other states (18 universities) | Khartoum state (14 universities) | Other states (18 universities) | Total | Khartoum state (14 universities) | Other states (18 universities) |
| Ph.D. | 2,885 | 2,240 | 645 | 78 | 22 | 14 | 19 | 7 |
| M.Sc. | 13,340 | 7,208 | 6,032 | 54 | 45 | 63 | 60 | 67 |
| Higher diploma | 4,878 | 2,613 | 2,265 | 54 | 46 | 23 | 22 | 25 |
| Total | 21,103 | 12,061 | 8,942 | 57 | 42 | 100 | 100 | 100 |

Source: (a) Sudan Ministry of Higher Education and Scientific Research, the annual higher educational statistics report: Various issues (1993/1994–2009/2010), (b) Sudan Ministry of General r Education, the annual general educational statistics report: Various issues (1993/1994–2009/2010), (c) Elamin (2009) higher than the intensity of students enrolled in the doctoral and higher diploma programmes in other Sudanese states.[3]

As for human resources for R&D in higher education and universities, many studies indicated a positive relationship between science and technology achievements and the number of engineers and scientists. Despite the significant expansion of higher education and graduate training in the last two decades, the lack of human resources still remains a serious problem that has hindered the promotion of S&T and R&D in Sudan. In particular, despite the presence of 28 public universities and 57 private universities with a capacity of more than 500,000 students, universities produce many more graduates in social sciences than in engineering and science (see Table 6.5 below). Furthermore, many graduates lack the skills to effectively use modern tools and equipment, not to mention develop them. The number of postgraduate and Master's degree graduates in engineering per year is very low, the overall ranking is low, and is continually slipping and consequently, the universities have weak research culture and capabilities.[4] According to the international standard, the number of engineers and scientists per 10,000 people is often used as an international standard indicator of achievement of an acceptable level of research and development. For instance, the presence of less than 10 engineers and scientists per 10,000 people implies weak performance and the presence of gaps in all research sectors; the presence of 15 engineers and scientists per 10,000 people implies a critical level of performance; the presence of 30 engineers and scientists per 10,000 people implies an acceptable performance in science and technology; and the presence of more than 30 engineers and scientists per 10,000 people implies an advanced level in research and development. In Sudan, according to the comprehensive strategy (1992–2002) the standard was 0.02 per 10,000 people. This implies that in Sudan, in order to have satisfactory performance in the science and technology system by applying the international indicator of 30 scientists and engineers per 10,000 people, and based on the last population census (2008), Sudan should have 120,000 scientists and engineers. But the actual number is less than 20,000. This implies that more efforts, resources and time are needed to be equal or near to the international standard. In Sudan the implementation of comprehensive strategies in the field of S&T was not fully carried out mainly due to inadequate financial and human resources. Notably, the ratio of full time researchers in Sudan was 0.2 per 10,000 people in 1990 compared with the average for Arab countries, which was 1.7 per 10,000 people. The ratio of engineers and technicians in 1990 was 1 per 3,000–5,000 people in Sudan, compared with the Arab countries average of 1 per 1,000–2,000 people. In 2008,

[3] See Nkwelo (2008). Naturally, the University of Khartoum – the biggest in Sudan – has the most postgraduate students and one would expect that its science faculties (Engineering and Architecture, Mathematical Sciences, Sciences, Dentistry, Medicine, Medical Laboratory Sciences, Pharmacy, Agriculture, Animal Production, Forestry and Veterinary Science) contribute significantly to the high numbers of postgraduate students (Nkwelo 2008).

[4] See Hassan, A. O. (2009a).

**Table 6.5** Size of research and development workforce and total R&D personnel by sector of employment (FTER) in Sudan (1999–2005)

| Total R&D Personnel | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|
| Total R&D Personnel | 18,604 | 18,808 | 19,772 | 23,726 | 14,923 | 15,333 | 16,050 |
| Total researcher | 9,100 | 9,200 | 9,340 | 11,208 | 7,300 | 7,500 | 7,850 |
| Total Researchers (HC) per million inhabitants | 262 | 260 | 258 | 304 | 224 | 225 | 230 |
| Total Technicians and equivalent staff | 3,674 | 3,714 | 4,641 | 5,569 | 2,947 | 3,028 | 3,170 |
| Total Technicians (HC) per million inhabitants | 106 | 105 | 128 | 151 | 90 | 91 | 93 |
| Other supporting staff (FTER and HC) | 5,830 | 5,894 | 5,791 | 6,949 | 4,676 | 4,805 | 5,030 |
| % Distribution total R&D personnel | | | | | | | |
| Total researcher | 49% | 49% | 47% | 47% | 49% | 49% | 49% |
| Total researchers (HC) per million inhabitants | 1% | 1% | 1% | 1% | 2% | 1% | 1% |
| Total technicians and equivalent staff | 20% | 20% | 23% | 23% | 20% | 20% | 20% |
| Total technicians (HC) per million inhabitants | 1% | 1% | 1% | 1% | 1% | 1% | 1% |
| Other supporting staff (FTER and HC) | 31% | 31% | 29% | 29% | 31% | 31% | 31% |
| R&D personnel | | | | | | | |
| Total R&D personnel | 18,604 | 18,808 | 19,772 | 23,726 | 14,923 | 15,333 | 16,050 |
| Total male | 15,844 | 16,017 | 16,730 | … | 12,982 | 13,330 | 13,958 |
| Total female | 2,760 | 2,791 | 3,042 | … | 1,941 | 2,003 | 2,092 |
| M/F | 15,844/2,760 | 16,017/2,791 | 16,730/3,042 | … | 12,982/1,941 | 13,330/2,003 | 13,958/2,092 |
| % of female in total | 14.8 % | 14.8 % | 15.4 % | … | 13.0 % | 13.1 % | 13.0 % |
| Total | | | | | | | |
| Business enterprise | … | … | 180 | 475 | … | … | … |
| Government | … | … | 3,490 | 4,745 | … | … | … |
| Higher education | … | … | 16,102 | … | … | … | … |
| Share in total | | | | | | | |
| Business enterprise | | | 1 % | 9 % | | | |
| Government | | | 18 % | 91 % | | | |
| Higher education | | | 81 % | … | | | |
| Researcher | | | | | | | |

(continued)

**Table 6.5** (continued)

| Total R&D Personnel | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|
| Total researcher | 9,100 | 9,200 | 9,340 | 11,208 | 7,300 | 7,500 | 7,850 |
| Total Male | 6,346 | 6,416 | 6,510 | ... | 5,746 | 5,856 | 6,186 |
| Total Female | 2,754 | 2,784 | 2,830 | ... | 1,554 | 1,644 | 1,664 |
| M/F | 6,346/2,754 | 6,416/2,784 | 6,510/2,830 | ... | 5,746/1,554 | 5,856/1,644 | 6,186/1,664 |
| % of female (%) in total | 30.3 % | 30.3 % | 30.3 % | ... | 21.3 % | 21.9 % | 21.2 % |
| Total | | | | | | | |
| Business enterprise | ... | ... | 50 | 224 | ... | ... | ... |
| Government | ... | ... | 1,168 | 2,242 | ... | ... | ... |
| Higher education | ... | ... | 8,122 | 8,742 | ... | ... | ... |
| Share in total | | | | | | | |
| Business enterprise | | | 1 % | 2 % | | | |
| Government | | | 13 % | 20 % | | | |
| Higher education | | | 87 % | 78 % | | | |

Sources: UNESCO R&D statistics (2006)

the number of researchers per 10,000 people in Sudan was only 0.7, which is very low compared to Arab countries (1.7) and developed countries (75).[5]

When comparing Sudan with the Arab countries, we find that the latter show better performance than Sudan in terms of the total number of scientists and engineers in R&D. In terms of the human resources devoted to R&D (defined by the total number of full time equivalent researchers (FTER)[6] and their distribution within R&D organisations), we find that the majority of researchers (FTER) are employed by the higher education and government public sectors. In Sudan the percentage share of researchers (FTER) in the higher education is estimated to be 87 % and 78 % in 2001 and 2002 respectively. Next to the university sector, it is the public or government sector that has the second largest percentage share of researchers (FTER): at 13 % and 20 % in 2001 and 2002 respectively, while the private sector accounts for only 1 % and 2 % of total researchers (FTER) in 2001 and 2002 respectively in Sudan. These results for the case of Sudan seem consistent with the results in Nour (2004, 2005) regarding distribution of researchers (FTER) by employment institutions, which implies greater dependence in the public sector on the employment of researchers (FTER) and small contribution of the private sector in the employment of researchers (FTER). Again, it is the lack of incentives for private sector institutions to hire that leads to this disparity.

Moreover, despite the growth in the size of the university workforce and research and development personnel and the number of academic staff according to academic professional positions in higher education institutions, data from the Ministry of Higher Education and Scientific Research indicates clearly that at all the institutions, males still strongly dominate positions, with virtually no female representation at some institutions in Sudan. Furthermore, UNESCO information on the numbers of R&D workforce in Sudan from 1999–2005 indicates a very low number of female personnel even though there has been an increase over the years. Moreover, the share of females is not only low but also declined from 14.8 % in 1999 to 13 % in 2005 in total R&D personnel, and from 30.3 % in 1999 to 20.2 % in 2005 in total researchers. Despite the increase in the number of researchers and technicians, their respective shares in total R&D personnel over the period 1999–2005 remained at 49 % and 20 % respectively (see Table 6.5 below). Moreover, the distribution of staff and human resources in some institutions' units in the MOST over the period 2003–2008 indicates that the share of researchers in the workforce increased from 14 % in 2003 to 20 % in 2008, whereas, the share of technicians declined from 31 % in 2003 to 20 % in 2008 and the share of labour increased from 54 % in 2003 to 60 % in 2008. This implies that the majority of the workforce is labour that constitutes about 60 %, whereas the share of both researchers and technicians together constitutes only 40 % of the total workforce employed in MOST over the period 2003–2008 (see Table 6.6 below).

---

[5] See Elamin (2009).

[6] The concept of full time equivalent researchers (FTER) is adopted by UNESCO statistics on R&D personnel.

**Table 6.6** Institutions units and staff distribution in the Sudan Ministry of Science and Technology (2003–2008)

(a) Human resources (2008)

| | | Human resources (2008) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Total number (2008) | | | | | | % share in total (2008) | | |
| | | Researchers | | | | | | | | |
| Institution | No. of work force | PhD | MSc. | BSc. | Total | Technician | labour | Researchers | Technician | labour |
| NCR | 746 | 65 | 131 | 57 | 253 | 162 | 331 | 34 % | 22 % | 44 % |
| ARC | 3,369 | 136 | 241 | 115 | 492 | 251 | 2,626 | 15 % | 20 % | 65 % |
| ARRC | 1,373 | 78 | 99 | 174 | 351 | 369 | 653 | 28 % | 20 % | 52 % |
| IRCC | 286 | 14 | 65 | 19 | 98 | 36 | 152 | 34 % | 13 % | 53 % |
| NAEC | 311 | 9 | 97 | – | 106 | 114 | 91 | 34 % | 37 % | 29 % |
| SAS | 112 | 5 | 11 | – | 16 | 75 | 21 | 14 % | 67 % | 19 % |
| CL | 116 | 3 | 9 | 34 | 46 | 26 | 44 | 40 % | 22 % | 38 % |
| SMA | 603 | 1 | 7 | 43 | 51 | 370 | 182 | 8 % | 61 % | 30 % |
| ESRD | 94 | 6 | 23 | 2 | 31 | 19 | 44 | 33 % | 20 % | 47 % |
| MOST(HQ) | 186 | 4 | 22 | – | 26 | 10 | 150 | 14 % | 5 % | 81 % |
| Total | 7,196 | 321 | 705 | 444 | 1,470 | 1,432 | 4,294 | 20 % | 20 % | 60 % |

(b) Human Resources (2003)

| | Total number (2008) | | | | % share in total (2008) | | |
|---|---|---|---|---|---|---|---|
| Institutions | Researchers | Technician | labour | Total | Researchers (%) | Technician (%) | Labour (%) |
| NCR | 318 | 373 | 238 | 929 | 34 | 40 | 26 |
| ARC | 423 | 1,434 | 3,455 | 5,312 | 8 | 27 | 65 |
| ARRC | 282 | 548 | 608 | 1,438 | 20 | 38 | 42 |
| IRCC | 82 | 94 | 70 | 246 | 33 | 38 | 28 |
| NAEC | 27 | 48 | 24 | 99 | 27 | 48 | 24 |
| ESRC | 15 | 7 | 18 | 40 | 38 | 18 | 45 |
| ERC | 35 | 56 | 27 | 118 | 30 | 47 | 23 |
| Total | 1,182 | 2,560 | 4,440 | 8,182 | 14 | 31 | 54 |

Source: Ministry of science and technology annual reports: Various issues (2003–2009)

In addition, there are fewer human resources in S&T in Sudan, and both the Gulf and Mediterranean Arab countries compared to more developed countries, shown in Table 6.7 above. Sudan and the Arab countries score poorly compared to Korea and Singapore for the Harbison Myers Index,[7] technical enrolment index, engineering enrolment index, gross enrolment ratio at tertiary education and the share of tertiary students in science, mathematics and engineering.[8] Hence, these findings imply the insufficiency of human resources necessary for the promotion of R&D and S&T in Sudan.

### *6.3.3 Science and Technology Output Indicator and Impact*

As we explained briefly in Sect. 6.2, the literature distinguishes between S&T outputs, which can be measured in terms of publications and patents, and S&T impact, which can be measured in terms of economic growth. This section discusses S&T output as measured by the number of patent filings and scientific publications (in the international literature) but discusses S&T impact as measured only by the share of high-technology manufacturing exports. Owing to limitations concerning data availability it is not possible to address the impact of technological development on economic/productivity growth in much detail.

We integrate the findings in Sect. 6.3, concerning the general economic characteristics of the Sudanese economy, with those of Sect. 4.2 regarding S&T input indicators. Using a systematic approach we assess S&T performance in terms of inputs and the economic system as a whole. Our analysis aims to explain the connection between the S&T system, S&T profile and the economic or productive structure of Sudan. For example, Table 6.1 shows that for both patent numbers and the percentage of high-technology exports, Sudan and the Arab Gulf and Mediterranean countries are substantially lagging behind the advanced and leading developing countries.

In our view, which is backed up by general S&T literature, the weakness of the S&T base in Sudan and the Arab regions should be interpreted not only in terms of a lack of appropriate inputs but also in relation to a poor economic system as a whole. Measuring the strength of the economic and welfare systems using income per capita implies that Sudan shows low per capita income and also exhibits low S&T activity; this seems consistent with the idea that strong S&T is necessary for economic growth and development. Prior to the heavy dependence on oil, the poor economic structure in combination with inadequate resources devoted to

[7] According to Lall (1999): “Harbison Myers Index is the sum of secondary enrolment and tertiary enrolment times five, both as a percentage of age group. Technical enrolment index is tertiary total enrolment (times 1000) plus tertiary enrolment in technical subjects (times 5000), both as a percentage of population. Engineering skills index is the same as the previous index, with tertiary enrolments in engineering instead of enrolment in technical subjects”. See Lall (1999), p.52.

[8] See also Muysken and Nour (2006) and UNDP-AHDR (2003).

**Table 6.7** Skills indicators in the Sudan Arab and World countries (1992–2000)

| Country | Skill indices (1995) | | | Gross enrolment ratio (%) at tertiary education | Share tertiary students in science, math and engineering |
|---|---|---|---|---|---|
| | Harbison Myers Index[a] | Technical enrolment index[a] | Engineering enrolment index[a] | 1998[b] | 1994–1997[b] |
| Arab Gulf (GCC) | | | | | |
| Bahrain | Na | Na | Na | 25.2 | NA. |
| Kuwait | 19.10 | 36.49 | 30.57 | 21.08 | 23 |
| Oman | 8.95 | 5.35 | 4.44 | NA | 30 |
| Qatar | Na | Na | Na | 27.66 | NA. |
| Saudi Arabia | 13.45 | 18.96 | 14.42 | 20.71 | 18 |
| UAE | 12.20 | 7.51 | 5.70 | 12.10 | 27 |
| Average Gulf countries | 13.425 | 17.0775 | 13.7825 | 21.35 | 24.5 |
| Arab Mediterranean | | | | | |
| Algeria | 11.65 | 31.14 | 21.55 | 15 | 50 % |
| Egypt | 16.45 | 16.10 | 13.87 | 39 | 15 % |
| Lebanon | 21.60 | 46.89 | 34.60 | 36 | 17 % |
| Morocco | 9.55 | 23.73 | 11.46 | 9 | 29 % |
| Syria | 13.35 | 23.47 | 17.67 | 6 | 31 % |
| Tunisia | 12.55 | 24.49 | 16.15 | 17 | 27 % |
| Average Mediterranean | 14.19 | 27.64 | 19.22 | 20.33 | 28.17 % |
| Other Arab countries | | | | | |
| Libyan Arab Jamahiriya | Na | Na | Na | 56 | Na. |
| Jordan | 18.55 | 39.27 | 27.64 | 29[1] | 27 |
| Iraq | Na | Na | Na | 13 | Na |
| Sudan | 2.80 | 3.50 | 2.92 | 7 | Na |
| Yemen | 4.45 | 4.60 | 4.17 | 11 | 6 |
| Mauritania | 3.55 | 5.28 | 3.74 | 6 | Na |
| Average all Arab countries | 12.01 | 20.48 | 14.92 | 19.636 | 12.091 |
| Other advanced countries | | | | | |
| Norway | 38.85 | 73.52 | 60.25 | 64.83 | 18 % |
| Sweden | 34.45 | 64.50 | 49.94 | 62.3 | 31 % |
| Canada | 62.05 | 103.02 | 86.01 | 58.93 | Na. |
| USA | 50.25 | 88.10 | 68.98 | 75.66 | Na. |
| UK | 37.55 | 68.69 | 49.83 | 58.39 | 29 % |
| Australia | 50.55 | 112.70 | 84.29 | 63[6] | 32 % |
| Japan | 30.05 | 63.54 | 63.54 | 44 | 23 % |
| Korea, Republic of | 36.10 | 132.06 | 113.83 | 71.69[1] | 34 % |
| Iran | 14.30 | 37.58 | 30.03 | 10[1] | 36 % |

Sources: [a]Lall (1999), [b]UNDP (2002), Human Development Report (2002)
(1) Data refer to the year 1999

S&T development leads to poor S&T performance in Sudan compared to advanced and developing world countries. After the heavy dependence on oil, and despite the growing wealth from oil Sudan still lacks well-defined, targeted plans, policies and proper incentives to promote S&T performance. Sudan needs to benefit from the experience of other countries, for instance, other Arab countries, for while the Gulf countries perform better than the Mediterranean countries in economic terms they lag behind in measurements of S&T performance. Therefore, the big wealth from oil, far from contributing to the improvement of S&T performance in the Gulf may actually hinder it as it masks the need to develop incentives and effective policies to enhance S&T development.

#### 6.3.3.1 Scientific Publications

As for research output and scientific publications, as an output indicator the number of scientific publications depends on input financial and human resources devoted to S&T[9]. The international standard rate is 70–80 researchers for every 10,000 people; currently in Sudan the rate is 0.2. This reflected negatively on the number of publications per researcher per year, which is 0.03 in average compared to the international rate of 2 papers for each researcher.[10]

In terms of research outputs and publications, according to the Institute for Scientific Research, Sudan has produced quite a number of publications between the years 1994–2004, even though the numbers are very low for a country with so many tertiary and research institutions. The publications of selected research institutes involved in R&D as cited by ISI gives the impression that Sudan has a strong inclination towards health related research, followed by agricultural research, and to some extent nuclear related research. Table 6.8 shows that the number of scientific publications for Sudan and the Arab countries grew over the period 1970–1995; Egypt and Saudi Arabia show the largest overall number. Sudan performed better than some Arab countries, but meanwhile, perform less than Egypt, Saudi Arabia, Kuwait, Algeria, Morocco, Tunisia, Jordan and Iraq in terms of the number of scientific publications, which could be a consequence of the superiority of these countries compared to Sudan in terms of most of the S&T indicators: total expenditure on both education and R&D; number of R&D employees; and number of R&D scientists and engineers. Moreover, Table 6.9 indicates that in terms of the average share of Sudan and African countries in world share of Institute for Scientific Information- science and engineering papers

[9] The OECD (1997) report indicates that prizes awarded to individual scientists is an extreme indicator of S&T performance and is one way of measuring R&D output. Of all scientific prizes, the Nobel Prizes for science, which have been awarded to scientists in the fields of chemistry, physics and medicine/physiology since 1901, are probably the most prestigious. The Arab countries have only received one Nobel Prize between them: in 1999 an Egyptian scientist received the Nobel Prize for chemistry.

[10] See Sudan Ministry of Science and Technology (2008), p.65

**Table 6.8** Change in R&D spending and the Number of S&T publications (papers published in referred international journals) in Sudan and the Arab countries (1970–1997)

| | Enrolment in tertiary[b] | Publications [c] | | Share of public spending on education % GDP | Percentage change in GDP Per capita | Percentage change in R&D Spending | Total R&D Spending (US$ Million)[I] | Researchers (FTER)[i] |
|---|---|---|---|---|---|---|---|---|
| Country | 1998 | (1970–1975)[b] | (1990–1995)[c] | (1995–1997)[a] | (1992–1996)[a] | (1992–1996)[a] | 1996 | 1996 |
| Bahrain | 21 | Na | 453 | 3 | −3.7 | 94.7 | 3.7 | 143 |
| Kuwait | 21 | 148 | 1936 | 5 | 32.3 | 42.2 | 67.1 | 1,130 |
| United Arab Emirates (UAE) | 10 | 1 | 579 | 1.9 | 196.4 | 0.9 | 10.9 | 313 |
| Qatar | 23 | Na | 377 | 3.6 | −32.4 | 27.9 | 5.5 | 74 |
| Average (total) high income | 18.75 | 149 | (3,345) | 3.375 | 192.6 | 165.7 | 87.2 | 1,660 |
| Oman | 7 | 1 | 466 | 4.2 | −9.6 | 83.1 | 10.8 | 382 |
| Saudi Arabia | 22 | 126 | 8,306 | 9.5 | −5.0 | 49.6 | 196.1 | 2,421 |
| Algeria | 15 | 338 | 1,431 | 5.3 | −13.8 | 6.0 | 35.6 | 2,588 |
| Egypt | 38 | 3,261 | 12,072 | 3.7 | 49.1 | 45.6 | 227.5 | 37,073 |
| Lebanon | 45 | 743 | 500 | 2.9 | 319.7 | 27.6 | 7.5 | 444 |
| Morocco | 10 | 96 | 2,418 | 5.1 | 12.3 | 5.9 | 74.9 | 7,329 |
| Syrian Arab Republic | 6 | 38 | 471 | 4 | 25.5 | 64.6 | 24.2 | 2,105 |
| Tunisia | 23 | 145 | 1,832 | 6.8 | 37.2 | 75.2 | 28.9 | 1,132 |
| Palestine | 31 | Na | 51 | Na | Na | Na | Na | Na |
| Libyan Arab Jamahiriya | 58 | 96 | 348 | 2.7 | 10.3 | 26.1 | 16.9 | 903 |
| Jordan | 31 | 61 | 1,936 | 4.6 | 27.8 | 36.4 | 20.6 | 1,471 |
| Iraq | 14 | 380 | 931 | | 4.7 | −16.6 | 27.6 | 2,840 |
| Djibouti | 1 | | Na | 3.5 | Na | Na | Na | Na |
| Average (total) medium income | 23.155 | 5,285 | (30,762) | 4.75455 | 458.2 | 403.5 | 670.6 | 58,688 |
| Sudan | 7 | 426 | 690 | 0.9 | −60.3 | 13.6 | 10 | 2,047 |
| Yemen | 11 | 4 | 155 | 10 | −64.8 | 56.1 | 10.3 | 1,041 |

(continued)

**Table 6.8** (continued)

| Country | Enrolment in tertiary[b] | Publications [c] | | Share of public spending on education % GDP | Percentage change in GDP Per capita | Percentage change in R&D Spending | Total R&D Spending (US$ Million)[I] | Researchers (FTER)[i] |
|---|---|---|---|---|---|---|---|---|
| | 1998 | (1970–1975)[b] | (1990–1995)[c] | (1995–1997)[a] | (1992–1996)[a] | (1992–1996)[a] | 1996 | 1996 |
| Mauritania | 4 | Na | 27 | 3.6 | Na | Na | 4.3 | 509 |
| Somalia | Na | 1 | 79 | Na | Na | Na | Na | Na |
| Comoros | 1 | | Na | 3.8 | Na | Na | Na | Na |
| Average (total) low income | 5.75 | 431 | 951 | 4.575 | −125.1 | 69.7 | 24.6 | 3,597 |
| Average (total Gulf) | 17.333 | 276 | (12,117) | 4.5333 | 178 | 298.4 | 294.1 | 4,463 |
| Average (total) Mediterranean | 28.25 | 4,621 | (19,123) | 4.3571429 | 430 | 224.9 | 415.5 | 51,574 |
| Average (total) Arab region | 15.885 | 5,865 | (35,058) | 4.23485 | Na | Na | 782.4 | 63,945 |

[a]ESCWA –UNESCO (1998)
[b]Qasem (1998)
[c]Zahlan (1999a, b).

**Table 6.9** The average share of Sudan and African countries in world share of ISI-listed S&E papers (2003–2007)

| | Africa | World share (%) |
|---|---|---|
| 1. | South Africa | 0.372 |
| 2. | Egypt | 0.272 |
| 3. | Tunisia | 0.111 |
| 4. | Morocco | 0.089 |
| 5. | Nigeria | 0.088 |
| 6. | Algeria | 0.074 |
| 7. | Kenya | 0.054 |
| 8. | Cameroon | 0.029 |
| 9. | Tanzania | 0.029 |
| 10. | Ethiopia | 0.026 |
| 11. | Uganda | 0.024 |
| 12. | Ghana | 0.019 |
| 13. | Senegal | 0.018 |
| 14. | Zimbabwe | 0.016 |
| 15. | Burkina Faso | 0.012 |
| 16. | Cote d'Ivoire | 0.012 |
| 17. | Botswana | 0.011 |
| 18. | Malawi | 0.011 |
| 19. | Madagascar | 0.011 |
| 20. | Sudan | 0.010 |
| | Rest of Africa (33 countries) | 0.096 |
| | Total Africa | 1.383 |

Source: Third World Academy of Sciences (TWAS) (May 2008) (See M.H.A. Hassan (2009b)

(ISI-listed S&E papers) over the period 2003–2007, of the African countries, South Africa has the best percentage share of total world scientific publications; it is followed by Egypt, Tunisia and Morocco respectively. However, the average share of Sudan is very low, for instance, Sudan is ranked 20 after Madagascar, and contributed only about 0.01 % of world share of ISI-listed S&E papers over the period 2003–2007.[11] This implies the problem of knowledge gaps even between Sudan and some African countries.

#### 6.3.3.2 Patent Applications

Table 6.1 above shows the low number of patent applications made by Sudan and the Arab countries compared to advanced and leading developing countries like Singapore, Korea and China. In light of our earlier findings, this can be attributed to

[11] The Institute for Scientific Information (ISI) offered bibliographic database services, it maintains citation databases covering thousands of academic journals, indexing service the Science Citation Index (SCI), as well as the Social Sciences Citation Index (SSCI), and the Arts and Humanities Citation Index (AHCI), ISI-listed S&E papers offers citation of science and engineering papers.

Sudan and the Arab countries' low percentage share of GDP spent on R&D and the small number of scientists and engineers in R&D. The low number of patent applications implies a low level of innovative activities in Sudan and the other Arab countries compared to both advanced and developing countries.

Regarding the use of the number of patent applications as a measure for S&T output indicators, Nour (2004, 2005a, b) shows the low number of patent applications over the period 1990–1999 and hence S&T output indicators, across all the Arab countries (168), Arab Gulf countries (150), Arab Mediterranean countries (41) compared to advanced and leading developing countries like Singapore (27), Korea (931) and China (793).[12] Nour (2004, 2005a, b) finds that the poor application to patent rate can be attributed to the low percentage share of spending on R&D to GDP and the number of scientists and engineers in R&D in the Arab countries compared to advanced and developing countries like Singapore, Korea and China. The low patent applications imply the low innovative activities across the Arab countries compared to both advanced and leading developing countries like Singapore, Korea and China. In addition, Table 6.10 below shows the number of patent applications made between 2007–2010 in Sudan and the Arab countries, by residents and non-residents of Sudan and the Arab countries. During that period residents made fewer patent applications than non-residents in all Arab countries. Among the Arab countries in 2007–2010, the highest number of patent applications was filed by residents in Egypt followed by either Saudi Arabia or Morocco, followed by Algeria and Jordan; the highest number of patent applications was filed by non-residents in Egypt followed by Morocco, Algeria, Saudi Arabia and Jordan. In 2007 the lowest numbers of patent applications were filed by residents and non-residents in Yemen and Sudan. The low number of patent applications from residents than those of non-residents of Sudan and all the Arab countries is consistent with the findings in the literature, which indicate that in developing countries patent applications made and patents held by residents of developing countries (domestic applications or patents) are few. Patents are overwhelmingly foreign resident-owned. In most developing countries, domestic applications accounted only for 1–8 % of total applications. Thus, the role of the patent system is less visible to domestic users of the patent system in developing countries. The reason for the low level of patenting in developing countries by their nationals and residents can be explained by a number of reasons, including non-use of the system by universities and local research institutions.[13] The low number of

[12] See for example, US Patent and Trademark office website: www.uspto.gov, Accessed 9 September 2005.

[13] See for instance, 'WIPO Patent Agenda Study' by Getachew Mengistie, the Ethiopian Intellectual Property Office, A/39/13 Add.1 available at: http://www.wipo.int/documents/en/document/govbody/wo_gb_ab/doc/a_39_13add1.doc, Accessed 02 February 2008.

**Table 6.10** Patents for Sudan compared to selected Arab Countries and selected African countries (1995–2010)

(a) Patents for selected Arab countries (2007–2010)

| | (a) Patent applications, nonresidents | | | | (b) Patent applications, residents | | | |
|---|---|---|---|---|---|---|---|---|
| | 2007 | 2008 | 2009 | 2010 | 2007 | 2008 | 2009 | 2010 |
| Algeria | 765 | | | 730 | 84 | | | 76 |
| Egypt | 1,589 | 1,649 | 1,452 | 1,625 | 516 | 481 | 490 | 605 |
| Jordan | 507 | 535 | 446 | 429 | 59 | 50 | 60 | 45 |
| Morocco | 782 | 834 | 856 | 882 | 150 | 177 | 135 | 152 |
| Saudi Arabia | 642 | | | 643 | 128 | | | 288 |
| Sudan | 13 | | | | 3 | | | |
| Yemen | 24 | | | 55 | 11 | | | 20 |
| Total Arab | 4,322 | 3,018 | 2,754 | 4,364 | 951 | 708 | 685 | 1,186 |

(c) Patents for selected African countries (pre 1995–2005)

| | Pre 1995 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | All years |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| South Africa | 2200 | 123 | 111 | 101 | 115 | 110 | 111 | 120 | 113 | 112 | 100 | 87 | 3,694 |
| Zimbabwe | 42 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 53 |
| Mali | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 25 |
| Tunisia | 14 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 19 |
| Tanzania | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 12 |
| Sudan | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 |
| Libya | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |

Sources: (a) The World Bank- World Development Indicators Database (2012). (b) The World Bank- World Development Indicators Database (2012). (c) UNESCO (2006)

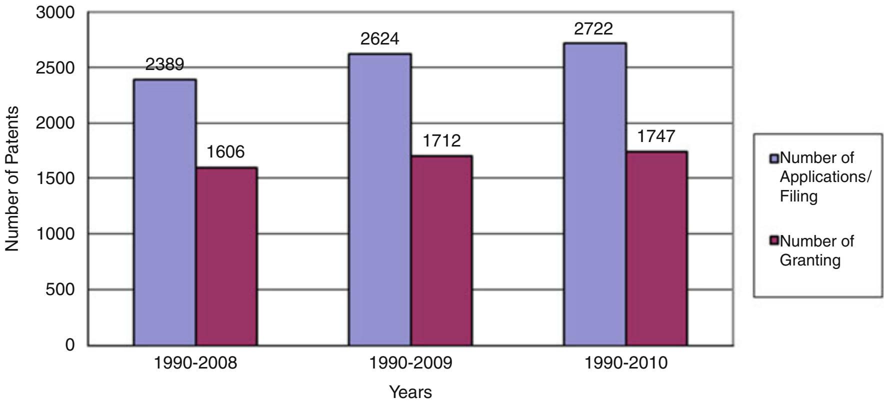


**Fig. 6.3** Patents applications (Filing) and granting in Sudan at home level (1990–2010) (Source: Unpublished data and statistics from the General Registrar of IPR Sudan Office (2010))

patents filed by residents of Sudan and the Arab countries can be related to low S&T activity in the countries. The low number of patents recorded by non-residents, however, needs a different interpretation. It is partially because there is a lack of adequate patent legislation, but more importantly it is also due to the lack of an economic structure within which to take advantage of patents. Foreign companies will only register a patent in a country if they fear that a local competitor might exploit their technology without paying for it. Therefore the low number of patents filed by non-residents in Sudan implies that Sudan lacks industries that are internationally competitive, which can also be interpreted in terms of there being a poor economic structure. Moreover, Table 6.10 shows that Sudan and the African countries together have filed far fewer patents than South Africa; the highest numbers of patent applications were made by South Africa, followed by Zimbabwe, Mali, Tunisia, Tanzania, Sudan and Libya. According to the United States Patent and Trademark Office (USPTO) report, Sudan produced only seven patents in about 40 years, with no patents at all in the period 1992–1995 and this puts it much lower than most African countries in terms of patents (see Table 6.10 below).

The low number of patents is probably due to Sudan's insufficient science and technology infrastructure. For instance, Fig. 6.3 indicates the growth in both the filling and granting of patents over the period 1990–2010 at the home level, but this should not hide the fact that the granting of international patents is very limited. For instance, Fig. 6.4 below shows the limited international application for Sudan's application for PCT International patent by residents during the period 2003–2007. In addition, according to IPR-Sudan Profile (2003) patents applications filed and/or registered by ARIPO imply that applications by residents are less than by non-residents in 2001 and 2002 respectively.

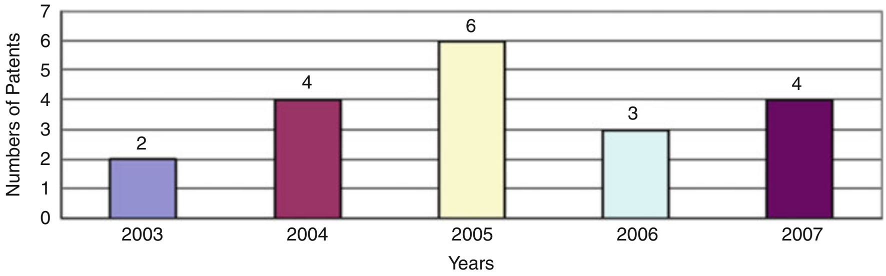


**Fig. 6.4** The application for Sudan's application for PCT international patent by residence (2003–2007) (Source: WIPO (2007) Statistics on Applications for PCT)

#### 6.3.3.3 Share of High-Technology Manufacturing Exports

When comparing the average share of exports of high-technology goods manufactured, our findings in Table 6.1 above indicate that in 2001 the highest share of high-technology exports was made by Morocco, followed by Sudan and then other Arab countries. According to Table 6.1 above, Sudan is similar to the Arab countries in having a low share of high-technology manufacturing exports compared to advanced and leading developing countries. In addition, the share of high-technology manufactured goods in Sudan and all the Arab countries in 1995–1997 is well below that of the world average or the corresponding figures for Brazil, Korea, Latin America and the Caribbean, Mexico and Singapore.[14] This can be explained in relation to our earlier findings concerning Sudan's inadequate economic structure, poor spending on R&D, low number of scientists and engineers in R&D and low patent filings.

#### 6.3.3.4 Productivity Growth

In terms of S&T impact as measured by economic growth, Table 6.11 shows significant increase in annual growth rate for average GDP per capita in Sudan during the periods 1975–2001 and 1990–2001 and the average real GDP growth rate during the period 1995–2000 in Sudan is higher than the average for the Arab countries. However, during 1999–2001, Sudan shows a slight drop in the trend of real annual GDP growth rate, whereas the rate of Sudan is higher than the average for developing countries. Sudan is experienced rapid economic growth followed by slight slow down, that most probably due to its heavy dependence on oil (see Fig. 6.1 above).

[14] See for instance, Haddad (2001), Lall (1999).

**Table 6.11** Real GDP growth and GDP per capita annual growth rates in the Sudan and Arab countries (1975–2001)

| Country | GDP per capita annual growth rate (%)[a] | | Real annual GDP growth (%)[b] | | | |
|---|---|---|---|---|---|---|
| | 1975–2001 | 1990–2001 | 1995–2000 Average | 1999 | 2000 | 2001 |
| Sudan | 0.8 | 3.2 | 6.3 | 6.9 | 6.9 | 5.3 |
| *Arab Gulf (GCC[c])* | | | | | | |
| Bahrain | 1.1 | 1.9 | 4.3 | 4.3 | 5.3 | 4.8 |
| Kuwait | −0.7 | −1.0 | 3.8 | −2.9 | 2.9 | −0.6 |
| Oman | 2.3 | 0.6 | 3.6 | −0.2 | 5.1 | 7.3 |
| Qatar | NA | NA | 9.4 | 5.3 | 11.6 | 7.2 |
| Saudi Arabia | −2.1 | −1.1 | 1.9 | −0.8 | 4.9 | 1.2 |
| UAE | −3.7 | −1.6 | 5.7 | 3.9 | 5.0 | 5.1 |
| Total GCC | −0.6 | −0.2 | 4.8 | 1.6 | 5.8 | 4.2 |
| *Arab Mediterranean* | | | | | | |
| Algeria | −0.2 | 0.1 | 2.9 | 2.3 | 2.8 | 3.4 |
| Egypt | 2.8 | 2.5 | 5.3 | 6.0 | 5.1 | 3.3 |
| Lebanon | 4.0 | 3.6 | 2.3 | 1.0 | −0.5 | 2.0 |
| Morocco | 1.3 | 0.7 | 1.9 | −0.1 | 1.0 | 6.5 |
| Syria | 0.9 | 1.9 | 3.0 | −2.0 | 0.6 | 2.7 |
| Tunisia | 2.0 | 3.1 | 5.1 | 6.1 | 4.7 | 5.0 |
| Total Mediterranean | 1.8 | 2.0 | 3.4 | 2.2 | 2.3 | 3.8 |
| Arab State | 0.3 | 0.7 | 3.9 | 2.4 | 4.1 | 3.8 |
| Developing countries | 2.3 | 2.9 | 5.3 | 3.9 | 5.7 | 4.0 |

[a]UNDP (2003).
[b]IMF (2002).
[c]GCC Gulf Cooperation Council.

#### 6.3.3.5 Demand for and Supply of Technologies, Technology Infrastructures, and Technology Achievement Index

We measure the demand for and supply of technologies in Sudan using the measurement of demand for and supply of technologies in the Gulf countries discussed in Muysken and Nour (2006).[15] Our results show that on the demand side when using the share of chemicals, manufactured goods, machinery and equipment, transport equipment, petroleum products in total imports as a measure of the demand for imported technology or dependence on foreign technologies, we

[15] According to the UNDP (2001), the technology achievement index (TAI) focuses on four dimensions of technological capacity that are important for reaping the benefits of the network age. TAI includes: (1) Creation of technology as measured by the number of patents granted per capita and receipt of royalty and licenses fees from abroad; (2) Diffusion of recent innovations as measured by diffusion of Internet and export of high and medium technology products as a share of all exports; (3) Diffusion of old innovations as measured by diffusion of telephone and electricity; and (4) Human skills as measured by mean years of schooling and gross enrolment ratio of tertiary students enrolled in science, mathematics and engineering (UNDP 2001).

find heavy dependence on imported technology or dependence on foreign technologies in Sudan. It may be interesting to complement our analysis by also examining the supply side. We measure the supply side by multiplying the manufactures/GDP ratio taken from the Central Bank of Sudan Annual Reports Issues (2000–2002), by value added in machinery and transport equipment as a percentage of value added in total manufactures using World Development Indicators (WDI) (2010) data for 2000 and Sudan Ministry of Industry (2005) Comprehensive Industrial Survey data for (2001); the result is value added in machinery and transport equipment/GDP, which we use as a measure of specialisation in production related to technology.[16] When using this measure, our results show a low technological specialisation in Sudan, which is most probably attributed to lack of both basic and high-technology infrastructure (BTI and HTI) (see Tables 6.12 and 6.13 below).[17] On average both the BTI and HTI for Sudan are poor. Overall, poor BTI is to blame for the low HTI (Rasiah 2002). Consequently, due to lack of both basic and high-technology infrastructure and the low technological specialisation, Sudan shows poor performances in terms of technology achievement index. According to the UNDP (2001) HDI classification of world countries according to technology achievement index, Sudan is classified as being a marginalised adopter of new technologies; amongst marginalised adopter countries in terms of the technology achievement index, Sudan is ranked 71 and placed between Tanzania and Mozambique. Sudan's poor performance lags far behind the world's advanced and leading developing countries which are either leaders or potential leaders in technology. In fact, Sudan also lags behind the countries classified as being dynamic adopters of new technologies in both Arab and African regions, notably: Tunisia (51); Syria (56); Egypt (57); Algeria (58); Zimbabwe (59); Senegal (66); Ghana (67); Kenya (68); and Tanzania (70) (see Table 6.13 below).

[16] Since the recent data from the WDI (2010) is available only for 2000, we therefore use an additional and alternative set of indicators from Sudan Ministry of Industry (2005) 'Comprehensive Industrial Survey Data for 2001'. The observed differences in both measures are most probably because of the differences in the definitions used by both sources. For instance, the only available data from the Sudan Ministry of Industry (2005) 'Comprehensive Industrial Survey Data for 2001' is based on the International Standard Industrial Classification of all economic activities according to ISIC 1968 rather than ISIC Rev 3.

[17] Rasiah (2002) defines basic technology infrastructure (BTI) as weighted proxies representing basic education (enrolment in primary schools), health (physicians per thousand people) and communications (main telephone lines per thousand people), and defines high-technology infrastructure (HTI) as weighted proxies representing R&D investment and R&D scientists and engineers per million people. Rasiah also argues that BTI is an essential but not sufficient condition for economies to achieve advanced technological capacity; the incidence of economies generating innovation is higher when they also have the high-technology support institutions. The lower the BTI implies the lower the capacity and resources for high-technology development.

**Table 6.12** Demand for and supply of technologies in the Sudan (1992–2010) (%)

| | Demand for technologies | | | Supply of technologies |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| 1992 | 39 | 56 | 84 | |
| 1993 | 47 | 62 | 84 | |
| 1994 | 49 | 56 | 76 | |
| 1995 | 52 | 62 | 78 | |
| 1996 | 51 | 60 | 80 | |
| 1997 | 48 | 59 | 77 | |
| 1998 | 57 | 67 | 80 | |
| 1999 | 50 | 60 | 73 | |
| 2000 | 54 | 64 | 71 | 30 |
| 2001 | 54 | 67 | 73 | 8 |
| 2002 | 57 | 67 | 72 | |
| 2003 | 58 | 72 | 78 | |
| 2004 | 59 | 77 | 80 | |
| 2005 | 61 | 78 | 83 | |
| 2006 | 61 | 80 | 85 | |
| 2007 | 65 | 82 | 85 | |
| 2008 | 61 | 73 | 80 | |
| 2009 | 62 | 74 | 77 | |
| 2010 | 56 | 67 | 71 | |
| 1992–2010 | 55 | 68 | 78 | 19 |

(1) The share of chemicals, manufactured goods, machinery and equipment in total imports (2) The share of chemicals, manufactured goods, machinery and equipment, transport equipment in total imports (3) The share of chemicals, manufactured goods, machinery and equipment, transport equipment, petroleum products in total imports (4) The supply side refers to technological specialization and is measured by the share of value added in machinery and transport equipment/GDP

Source: (a) The demand for technology is calculated from the Sudan Ministry of Foreign Trade and Central Bank of Sudan Annual Foreign Trade Statistical Digest various issues (1992–2010) (b) the supply of technology is calculated from the Central Bank of Sudan Annual Reports Issues (2000–2002), the World Bank-WDI-World Global Development Finance (2010) data for (2000) and the Sudan Ministry of Industry (2005) the Comprehensive Industrial Survey data for (2001)

### 6.3.3.6 S&T, R&D, Economic Development, Adaptation to Foreign Technologies and Development of Local Technologies

Based on the above findings, this section uses new survey data based on primary data and 25 face-to-face interviews with the official policy makers and experts in the government and academic staff in the public and private universities.[18]

[18] The interviews were conducted with officials and experts (20 %), and academics in the public (60 %) and private (20 %) universities. The interviews were conducted with academic staff in the fields of science (36 %), engineering (36 %) and social sciences (8 %) including both males (80 %) and females (20 %). The distribution of the interviewed institutions includes public universities represented by Khartoum University (60 %), private universities represented by University of Medical Sciences and Technology (20 %), Ministry of Science and Technology (12 %) and Ministry of Higher Education and Scientific Research (8 %).

**Table 6.13** Basic and high technology infrastructure and technology achievement index in Sudan (2004–2010)

| | 2004 | 2005 | 2007 | 2009 | 2010 |
|---|---|---|---|---|---|
| (a) Basic Technology Infrastructure (BTI)[a] | | | | | |
| Basic education (enrolment in primary schools)[a] | 3,966,944 | 4,299,737 | 4,785,952 | 5,800,000 | |
| Secondary education (enrolment in Secondary schools)[a] | 546,305 | 637,812 | 636,156 | 753,000 | |
| Health (Physicians Per thousand people) of Population[a, d] | 20 | 22.6 | 29.9 | 30 | |
| Communications (main telephone lines per thousand people)[a, d] | 29 | 18 | | 30 | |
| (b)High Technology Infrastructure (HTI)[b] | | | | | |
| R&D investment: R&D expenditure as % of GDP (2004–2005)[e] | 0.29 | 0.28 | | | |
| R&D scientists and engineers per million people[b] (1996–2000)[b] | 225 | | | | |
| (c)Technology Achievement Index [c] | | | | | |
| (TAI) TAI rank value[c] | 0.071 | | | | |
| Diffusion of recent: innovations[c] | | | | | |
| High- and medium technology exports (as % of total goods exports) 1999[c, f] | 0.4 | | 0.6 | 29 | |
| Diffusion of old innovations[c] | | | | | |
| Telephones (mainline and cellular, per 1,000 people)[c, f] | 1,029 | 570 | 345 | 370 | 375 |
| Electricity consumption(kilowatt-hours per capita)[c] | 67 | 79 | 96 | 114 | |
| Human skills[c] | | | | | |
| Mean years science of schooling(age 15 and above) 2000[c]–2011 [d] | 2.1 | | | | 3.1 |
| Gross tertiary enrolment ratio (%) (1995–1997)[c] | 0.7 | | | | 5.9 |

[a]Sudan Central Bureau of Statistics (2010).
[b]UNDP (2003).
[c]UNDP (2001).
[d]UNDP (2011).
[e]UNESCO (2006).
[f]WB-WDI (2012).

The main purpose of this survey is to collect primary data to examine the causes and consequences of poor R&D activities, to examine the main factors hindering and those contributing towards the promotion of R&D and then to provide some recommendations to improve R&D and hence S&T development in Sudan.

As for the importance of R&D the majority of the respondents indicate the importance of R&D in satisfying the needs for economic development, followed by development of local technologies and finally adaptation to imported foreign technologies.[19] As for the contribution of R&D, the majority of the respondents

[19] As indicated by 96 %, 84 % and 76 % of the respondents respectively.

indicate the contribution of R&D in satisfying the needs for economic development, followed by adaptation to imported foreign technologies and finally development of local technologies.[20] When comparing the points of views of the different respondents we find that from the perspective of the private universities, the importance of R&D is viewed with high importance compared to both public universities and officials and experts. However, from the perspective of the private universities, the contribution of R&D is still susceptible, especially with regards to the role of R&D in the development of local technologies; by contrast the views of the public universities, official and experts seem to be somewhat optimistic regarding the role of R&D (see Table 6.14 below).

Regarding the main problems hampering the important contribution of R&D in satisfying the needs for economic development, development of local technologies and adaptation to imported foreign technologies, the majority of the respondents indicate the lack of finance to cover the high costs of R&D as the main problem.[21] Moreover, the lack of human resources (researchers and qualified worker in R&D fields) is also mentioned but of somewhat less importance.[22] When comparing the points of views of the different respondents we find that the views of the private universities, public universities, official and experts seem to be consistent and in agreement with regards to the serious problem of the lack of finance in hampering R&D; from the perspective of both private universities and officials and experts, the importance of the lack of finance in hampering R&D for adaptation to imported foreign technologies is viewed with high importance compared to public universities. However, from the perspective of the private universities, the importance of the lack of human resources seems to be somewhat less compared to the opinions of both the public universities and official and experts (see Table 6.15 below).

As for the main problems hindering R&D, the majority of the respondents indicate the lack of finance from public sector and the weak relationship, network and consistency and cooperation between universities and higher education institutions on the one side and the productive sector (agriculture, industry, services) on the other side.[23] This is followed by the other problems such as the lack of finance from the private sector; the lack of management and organisational ability; and the lack of coordination and R&D culture.[24] Finally the less important factors include the lack of favourable conditions and the necessary facilities; the lack of awareness and appreciation of the economic values of R&D; and the lack of human resources (researchers and qualified workers in R&D fields).[25] When comparing the points of views of the different respondents we find that from the perspective of the public universities, the lack of favourable conditions and the

[20] As indicated by 72 %, 56 % and 48 % of the respondents respectively.

[21] As indicated by 100 %, 100 % and 92 % of the respondents respectively.

[22] As indicated by 88 %, 84 % and 88 % of the respondents respectively.

[23] As indicated by 100 % of the respondents.

[24] As indicated by 96 % of the respondents.

[25] As indicated by 92 %, 92 % and 88 % of the respondents respectively.

**Table 6.14** The importance and contribution of R&D to satisfy the economic development in Sudan (2010)

| Important | Officials and experts (%) | Private universities (%) | Public universities (%) | All (%) |
|---|---|---|---|---|
| (a) The importance of R&D | | | | |
| Satisfying the needs for economic development | 100 | 100 | 93 | 96 |
| Development of local technologies | 80 | 100 | 80 | 84 |
| Adaptation to imported foreign technologies | 80 | 100 | 67 | 76 |
| (b) The contribution of R&D | | | | |
| Satisfying the needs for economic development | 80 | 40 | 80 | 72 |
| Development of local technologies | 60 | 20 | 53 | 48 |
| Adaptation to imported foreign technologies | 20 | 40 | 73 | 56 |

Source: Own calculation based on Nour (2010), Sudan R&D Survey 2010

**Table 6.15** The main problems hindering the role of R&D and contribution to satisfy the economic development in Sudan (2010)

| | Officials and experts (%) | Private universities (%) | Public universities (%) | All (%) |
|---|---|---|---|---|
| Satisfying the requirements of economic development | | | | |
| Lack of human resources (researchers and qualified worker in R&D fields) | 100 | 80 | 87 | 88 |
| Lack of finance to cover the high costs of R&D | 100 | 100 | 100 | 100 |
| Development of local technologies | | | | |
| Lack of human resources (researchers and qualified worker in R&D fields) | 100 | 60 | 87 | 84 |
| Lack of finance to cover the high costs of R&D | 100 | 100 | 100 | 100 |
| Adaptation to imported foreign technologies | | | | |
| Lack of human resources (researchers and qualified worker in R&D fields) | 100 | 60 | 93 | 88 |
| Lack of finance to cover the high costs of R&D | 100 | 100 | 87 | 92 |

Source: Own calculation based on Nour (2010) "Sudan R&D Survey 2010"

necessary facilities; the lack of awareness and appreciation of the economic values of R&D; lack of management and organisational ability and the lack of coordination and the lack of R&D culture seems to be the less important problems, whilst from the perspective of the officials and experts the less important problems are the

**Table 6.16** The main problems of R&D in Sudan (2010)

| | Officials and experts (%) | Private universities (%) | Public universities (%) | All (%) |
|---|---|---|---|---|
| Lack of finance from public sector | 100 | 100 | 100 | 100 |
| Lack of finance from private sector | 80 | 100 | 100 | 96 |
| Lack of human resources (researchers and qualified workers in R&D fields) | 80 | 60 | 100 | 88 |
| Lack of management and organization ability and lack of coordination | 100 | 100 | 93 | 96 |
| Weak relationship, network and consistency and cooperation between universities and higher education institutions on the one side and the productive sector (agriculture, industry, services) on the other side | 100 | 100 | 100 | 100 |
| Lack of favorable conditions and the necessary facilities | 100 | 80 | 93 | 92 |
| Lack of R&D culture | 100 | 100 | 93 | 96 |
| Lack of awareness and appreciation of the economic values of R&D | 100 | 80 | 93 | 92 |

Source: Own calculation based on Nour (2010) "Sudan R&D Survey 2010"

lack of finance from the private sector and the lack of human resources (researchers and qualified workers in R&D fields). Finally, from the perspective of the private universities the less important problems are the lack of favourable conditions and the necessary facilities; the lack of awareness and appreciation of the economic values of R&D; and the lack of human resources (researchers and qualified workers in R&D fields) respectively (see Table 6.16 below).

As for the main suggestions and solutions to improve R&D, the majority of the respondents indicate the availability of sufficient finance from public sector; availability of sufficient finance from private sector; offering incentives and motivation and making availability of sufficient human resources (researchers and qualified workers in R&D fields); improvement of management and organisational ability and coordination; improvement and strengthening the relationship, network and consistency and cooperation between universities and higher education institutions on the one side and the productive sector (agriculture, industry, services) on the other side; and improvement of awareness and appreciation of the economic values of R&D.[26] This is followed by other solutions such as the creation of more favourable conditions and offering all the necessary facilities and improvement of R&D culture.[27] When comparing the points of view of the different respondents we find that the views of the private universities, public universities, officials and experts seem to be consistent and in agreement with regards to the suggestions and solutions for improvement of R&D. However, different from the opinions of both the private

[26] As indicated by 100 % of the respondents.

[27] As indicated by 96 % of the respondents.

**Table 6.17** The main suggestions for enhancing the development of R&D in Sudan (2010)

| Extremely important moderately important | Officials and experts (%) | Private universities (%) | Public universities (%) | All (%) |
|---|---|---|---|---|
| Availability of sufficient finance from public sector | 100 | 100 | 100 | 100 |
| Availability of sufficient of finance from private sector | 100 | 100 | 100 | 100 |
| Offering incentives and motivation and making availability of sufficient human resources (researchers and qualified workers in R&D fields) | 100 | 100 | 100 | 100 |
| Improvement of management and organization ability and coordination | 100 | 100 | 100 | 100 |
| Improvement and strengthen the relationship, network and consistency and cooperation between universities and higher education institutions on the one side and the productive sector (agriculture, industry, services) on the other side | 100 | 100 | 100 | 100 |
| Creation of more favorable conditions and offering all the necessary facilities | 100 | 100 | 93 | 96 |
| Improvement of R&D culture | 100 | 100 | 93 | 96 |
| Improvement of awareness and appreciation of the economic values of R&D | 100 | 100 | 100 | 100 |

Source: Own calculation based on Nour (2010) "Sudan R&D Survey 2010"

universities and official and experts, and from the perspective of the public universities, the suggestions with regards the creation of more favourable conditions and offering all the necessary facilities and the improvement of R&D culture seems to be less important compared to other suggestions (see Table 6.17 below).

## 6.4 Conclusions

This chapter shows the status of S&T indicators in Sudan. From our analysis it is clear that Sudan lags behind the world's developed and leading developing countries in terms of the same S&T input and output indicators. We explain that the combination of poor S&T inputs/resources together with an inadequate economic system as a whole, results in Sudan producing poor S&T outputs/performances. Moreover, we find that most R&D and S&T activities and (FTER) employment in Sudan occurs within the public and university sectors, while the private sector and industry make only a minor contribution.

When comparing the same S&T input and output indicators of Sudan with those of the Arab countries and world's other developed and developing countries, our findings indicate that Sudan lags behind in terms of most S&T input indicators (both financial and human resources). That also holds for the average share of high-technology exports, GDP per capita growth, number of scientific publications, level and share in international publications and number of patent filings.

Our findings indicate that despite the important role of R&D in satisfying the needs for economic development, development of local technologies and adaptation to imported foreign technologies. However, the contribution of R&D seems to be constrained mainly by the lack of finance to cover the high costs of R&D as the main problem, moreover, the lack of human resources (researchers and qualified worker in R&D fields) is also mentioned but is of somewhat less importance. We find that the main problems hindering R&D include: the lack of finance from public sector; lack of management and organisational ability; lack of coordination and weak relationships, network and consistency and cooperation between universities and higher education institutions on the one side and the productive sector (agriculture, industry, services) on the other side; lack of R&D culture; lack of finance from private sector; lack of favourable conditions and the necessary facilities; lack of awareness and appreciation of the economic values of R&D; and lack of human resources (researchers and qualified workers in R&D fields) respectively.

Our results show that the main suggestions to improve R&D include: availability of sufficient finance from public and private sectors; offering incentives and motivation and making availability of sufficient human resources (researchers and qualified workers in R&D fields); improvement of management and organisational ability and coordination; improvement and strengthening of the relationships, network and consistency and cooperation between universities and higher education institutions on the one side and the productive sector (agriculture, industry, services) on the other side and improvement of awareness and appreciation of the economic values of R&D. This is followed by the creation of more favourable conditions and offering all necessary facilities and improvement of R&D culture.

Hence, our analysis indicates that in order to improve S&T performance, Sudan needs to invest heavily in both financial and human resources as well as to learn from the lessons of the advanced and developing S&T nations. Such investment can be more effective if they are made according to targeted, well-defined plans that connect with policies covering industry, science and technology and accompanied by an improvement in the economic system, there is thus a need to adopt new policies for partnership with the private sector. Sudan needs to form a body to formulate a policy on manpower resources for S&T, and suggest measures to minimise brain-drain impacts. Sudan needs to continue building relatively well-developed S&T infrastructure, and a sufficient number of highly qualified university and R&D personnel to put the country in a good position in terms of globally competing in S&T.

So far Sudan does not possess all the human and financial resources necessary to promote S&T. However, Sudan could have a wider range of capabilities to promote S&T if it pooled and integrated its resources. Reforming the economic system, encouraging the private sector, implementing effective S&T cooperation and integration with other Arab and African countries will most likely enhance S&T development and hence long-term harmonious development in Sudan.

Our results in this Chapter at the macro level is consistent with the findings at the micro level presented in Chap. 5 above and support our third and second hypotheses in Chap. 1 above concerning the low skill and technology levels at the macro and micro levels and that in the short- and medium-term, Sudan is unable to rely on local technologies and will remain heavily dependent on foreign technologies respectively. Our findings in this Chapter is consistent with the findings concerning the low skill level and need for skill upgrading presented in Chap. 5 above and also support our first hypothesis in Chap. 1 above that Sudan needs to promote local skills and local technologies in order to implement the five strategies of: reducing poverty; achieving economic diversification; reducing unemployment and restructuring the labour market; building local technological capacity; and achieving long-term stabilised, sustainable and balanced economic growth and development.

## References

Elamin, H. B. (2009). *Science, technology and innovation indicators*. UNESCO sub-regional training workshop, Cairo: Sudan Ministry of Science and Technology, September 28–30, 2009.

ESCWA-UNESCO (Economic and Social Commission for Western Asia-United Nations Educational, Scientific and Cultural Organization). (1998). *Research and development system in the Arab states*: *Development of science and technology indicators* (E/ESCWA/TECH/1998/3). Cairo.

Haddad, M. (2001). *Export competitiveness: Where does the Middle East and North Africa region stand? Background paper to economic trends in the MENA region*. Cairo: Economic Research Forum (ERF). In ERF. (2002). *ERF economic trends in MENA region 2002: Chap. 2*: *Financial and capital markets, privatization and FDI*. Cairo: AUC.

Hassan, A. O. (2009a). *Sudan National Innovation System*. Paper presented at the Presidential Initiative on the Reform of Science and Technology System in the Sudan, Friendship Hall, January 5–6, 2009.

Hassan, M. H. A. (2009). *Promoting excellence in STI for sustainable development in Africa*. Paper presented at the International Workshop on Science and Technology Systems in Sudan, Khartoum, January 5–6, 2009.

IMF. (2002). *World economic outlook: The Middle East and North Africa regional outlook*. Washington, DC: International Monetary Fund.

Lall, S. (1999). *Competing with labour: Skills and competitiveness in developing countries* (Issues in Development Discussion Paper No. 31, p. 17). Geneva: Development Policies Department, ILO.

Muysken, J., & Nour, S. (2006). Deficiencies in education and poor prospects for economic growth in the Gulf Countries: The case of the UAE. *Journal of Development Studies, 42*(6), 957–980. Taylor and Francis Ltd.: UK.

Nkwelo, M. (2008). *The science and technology system of the republic of Sudan*. UNESCO, 2008.

Nour, S. (2004, March 24–28). *Science and Technology (S&T) development indicators within the Arab Mediterranean countries*. Paper prepared for the Fifth Mediterranean Social and Political Research Meeting, organised by the Mediterranean Programme of the Robert Schuman Centre for Advanced Studies at the European University Institute, Florence, Italy.

Nour, S. (2005a, September). Science and Technology (S&T) development indicators in the Arab region: A comparative study of Arab Gulf and Mediterranean countries. *The Journal of Science, Technology and Society* (SAGE Publications), *10*(2), 249–274 (Published in *UNU-*

*INTECH Discussion Paper Series* UNU-INTECHDPS2005-3, Maastricht, the Netherlands, August 2005).

Nour, S. (2005b, November). *Technological change and skill development in the Arab Gulf Countries*. Doctoral dissertation, Maastricht University Press, Maastricht, The Netherlands.

Nour, S. (2010, January–June). Firm Survey (2010).*Technological change and skill development: A comparative study of chemical, food, metal and textile small, medium and large scale enterprises in the Sudan*. Khartoum, Sudan.

OECD (Organisation for Economic Co-operation and Development). (1997). *The second european report on science and technology indicators (1997)* (pp.37, 90, 91). Paris: OECD.

Qasem, S. (1998b). Research and development systems in the Arab states: Development of science and technology indicators, Chapter 4. In *Economic Trends in MENA Region 2002*. Cairo: Economic Research Forum and the American University in Cairo.

R&D Survey. (2010, June). *Sudan R&D Survey*: *Efforts for enhancing R&D in the Sudan: Interview with policy makers in the government and academic staff in public and private universities in Sudan*. Khartoum.

Rasiah, R. (2002, March). *TRIPs and capability building in developing economies*. (UNU/INTECH Discussion Paper Series No. 2002–1).

Sudan Central Bureau of Statistics Population Census Data. (2010c). *5th Sudan population and housing census (2008)*. Khartoum: Sudan Central Bureau of Statistics.

Sudan Ministry of General Education, the annual general educational statistics report: Various issues (1993/1994–2009/2010). Unpublished reports, Sudan Ministry of General Education, Khartoum.

Sudan Ministry of Higher Education and Scientific Research, the annual higher educational statistics report: Various issues (1993/1994–2009/2010). Unpublished reports, Sudan Ministry of Higher Education and Scientific Research, Khartoum.

Sudan Ministry of Industry. (2005, July). *The comprehensive industrial survey*. Khartoum, Sudan, Vol. 4:www.industry.gov.sd

Sudan Ministry of Science and Technology (MOST). (2008). *Status of science and technology in Sudan*. Paper presented in the Commission on Science and Technology for Development, Eleventh session, pp.3–6, 65, 26–30 May 2008.

Sudan Ministry of Science and Technology (MOST), the annual science and technology reports: Various Issues (2003–2009), unpublished reports, Sudan Ministry of science and technology, Khartoum.

The General Registrar of IPR Sudan Office. (2010). *Unpublished data and statistics from the General Registrar of IPR Sudan Office*. (*2010*). Khartoum: The General Registrar of IPR Sudan Office. Accessed 10 July 2010.

The International Monetary Fund. (2002). *World Economic Outlook: the Middle East and North Africa Regional Outlook*, Washington, DC: The International Monetary Fund.

The United Nations Development Programme (UNDP)-Arab Human Development Report (AHDR). (2004). *Towards Freedom in the Arab world the UNDP*. New York/Amman: Regional Bureau for Arab States (RBAS)/National Press.

The World Bank- World Development Indicators Database. (2012, April). http://data.worldbank.org/indicator/IP.PAT.NRE. Accessed 5 June 2012.

The World Bank- World Development Indicators Database. (2012, April). http://data.worldbank.org/indicator/IP.PAT.RESD/countries. Accessed 5June 2012.

The World Bank, World Development Indicators database. (2011). Accessed 25 June 2011.

The World Bank, World Development Indicators database (WDI). (2012). Accessed 15 April 2012.

Third World Academy of Sciences (TWAS) (May 2008), cited in Hassan, M. H. A. (2009). *Promoting excellence in STI for sustainable development in Africa*. Paper presented at the International Workshop on Science and Technology Systems in Sudan, Khartoum, 5–6 Jan, 2009.

U.S. Patent and Trade mark office web site: www.uspto.gov

UNDP. (2001). *Summary human development report (2001): Making new technologies work for human development*. New York/Oxford: UNDP/Oxford University Press.
UNDP. (2002). *Human development report (2002): Deepening democracy in a fragmental World*. New York/Oxford: UNDP/Oxford University Press.
UNDP. (2003). *Human development report (2003): Millennium development goals: A compact among nations to end human poverty*. New York/Oxford: Oxford University Press.
UNDP (United Nations Development Programme). (2011). *Human development report 2011: Sustainability and equity: A better future for all*. New York: UNDP, Palgrave Macmillan.
UNDP (United Nations Development Programme). Human development report. (2009). *Human development report 2009: Overcoming barriers: human mobility and development*. New York: Palgrave Macmillan.
UNDP (United Nations Development Programme). (2007/2008). *Human Development report 2007/2008: Fighting climate change: Human solidarity in a divided world*, (pp. 231–232, 292–293). New York: Palgrave Macmillan.
UNDP (United Nations Development Programme). (2010). *Human Development Report 2010: The Real Wealth of Nations: Pathways to Human Development*. Human development report 2010 —20th Anniversary Edition New York, NY: UNDP/Palgrave Macmillan, Statistical Tables, Statistical Annex, Table 12: Decent Work, p.191.
UNESCO (2006): UNESCO R&D Statistics (2006): www.unesco.org
UNESCO Institute of Statistics Data and Statistics. (1996). *UNESCO statistical yearbook: The World Education Indicators on school life expectancy 1992*: www.unesco.org
United Nations. (UN) (1970). *United Nations science and technology for development, proposals for the Second United Nations development decade*. United Nations, New York.
United Nations Development Programme UNDP- The Arab Human Development Report AHDR. (2003). *Arab Human Development Report (2003): Building a Knowledge Society*. UNDP. New York, Regional Bureau for Arab States (RBAS), Amman, Jordan: National Press, July. p. 56; Table 5.1 p.102.
WIPO. (2007). Statistics on Applications for PCT.
WIPO Patent Agenda Getachew Mengistie Study of Ethiopian Intellectual Property Office, A/39/13 Add.1 available at: http://www.wipo.int/documents/en/document/govbody/wo_gb_ab/doc/a_39_13add1.doc
Zahlan, A. B. (1999a). *The Arabs and the challenges of science and technology: Progress without change*. Beirut: The Centre for the Study of Arab Unity.
Zahlan, A. B. (1999b). *Science Policy for the Twenty-First Century: Mobilization and Development*. In *ESCWA Proceedings of the Expert Group Meeting on Science and Technology Policies and Strategies for the Twenty- First Century,* ESCWA, Beirut, 10–12 March 1999, pp. 14–16.