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Assessment of Science and Technology Indicators in Sudan

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Assessment of Science and Technology Indicators in Sudan

Dr. Samia Satti Osman Mohamed Nour[1]

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Abstract

This paper employs both the descriptive and comparative approaches and uses the Organisation for Economic Cooperation and Development's definition of Science and Technology (S&T) indicators (OECD, 1997) to discuss S&T development in Sudan. We find that the low level and the insufficient financial and human resources devoted to S&T development together with inadequate economic structures mean that Sudan lags behind the leading developing countries in terms of S&T input-output indicators. We find that the insufficient financial and human resources hampered the potential role of R&D to contribute toward economic development, adaptation to imported technologies and development of local technologies in Sudan.

Keywords: S&T, R&D, Economic Development, Sudan, Developing countries.

JEL classification: O10, O11, O30

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1. INTRODUCTION

In recent years, a new economic system has evolved that is characterized by both globalization and the rise of information and communication technologies. This has driven the need for development in science and technology (S&T), which has become more than simply an element of economic growth and industrial competitiveness, but is now also essential for improving social development, the quality of life and the global environment. For instance, the high level of economic and social development in today's industrialized countries is largely the result of past intensive investment in S&T; similarly, newly industrialized countries are catching up because of their active development of S&T.

"*Access to scientific and technological knowledge and the ability to exploit it are becoming increasingly strategic and decisive for the economic performance of countries and regions in the competitive globalized economy. The 50 leading S&T countries have enjoyed long-term economic growth much higher than the other 130 countries of the rest of the world. Between 1986 and 1994 the average growth rate of this heterogeneous group of countries was around three times greater than that of the rest of the world. The average economic wealth per capita of these 50 countries has grown by 1.1% per year. On the other hand, the per capita income of the group of 130 countries – which perform less well in education, science and technology – has fallen over the same period by 1.5% per year. These trends prefigure a new division of the global economy, based on access to knowledge and the ability to exploit it*". (OECD 1997, ix)

Hence, within this context, the aim of this paper is to assess S&T development indicators within the poor countries, in particular, to assess S&T development indicators in Sudan and compare the status of Sudan with the rest of the world.[2] Given the recent progress of economic globalization coupled with the emergence of new nations active in S&T in different parts of the world, this paper extends the comparison to include these new countries as well as those in Europe, the United States and Japan, and then draws some policy implications and recommendations for ways to enhance S&T performance in the poor countries, like Sudan.

This study differs in several ways from the several studies in the literature, which provides an excellent and interesting analysis of S&T Indicators and

[2] The Mediterranean region includes eight Arab countries or territories: Algeria, Egypt, Lebanon, Libya, Morocco, Palestine, Syria and Tunisia, while the Gulf includes six Arab countries: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates (UAE).

performance in the Arab, developing countries and Sudan. First, different from the studies in the Sudanese and Arab literature (Nour, 2004; 2005) we provide a more in-depth, comprehensive and up to date assessment of S&T input and output indicator by focusing only on Sudan as a case of poor Arab countries. Secondly, we extend our analysis to compare the case of Sudan with other Arab and African countries. 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 establish the information base necessary to stimulate S&T development and support new policies that aim to enhance S&T performance in the poor countries. This kind of study highlights recent efforts to create an active Sudanese S&T base but also emphasizes 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 government to obtain the most positive impact possible from technological progress in terms of growth, employment and the well-being of all poor Sudanese citizens. Finally, different from the studies in the Sudanese literature, a novel element in our analysis is that we use a new survey data based on primary data and 25 face-to face interviews with the officials policy makers and experts in the government and the academics 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. 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 paper is organized in the following way: section 2 discusses the literature available, focusing on the definition and significance of S&T indicators. Section 3 shows the general socio-economic characteristics of the Sudan. Section 4 discusses S&T development indicators in the Sudan, including a comparison of the indicators for Sudan with the rest of the world. Finally section 5 draws conclusions and proposes policies to enhance S&T performance in the Sudan, based on the results of Sudan R&D survey and the experiences of other countries.

2. THE DEFINITION AND SIGNIFICANCE OF SCIENCE AND TECHNOLOGY INDICATORS

The S&T system is often defined as consisting of all the institutions and organizations essential to the education of scientific people, for example, research and development (R&D) institutions, professional societies and professional organizations linking individual scientists to each other and to their socio-economic environment. The theoretical and empirical literature identifies the important role that S&T plays in promoting economic growth and development in both developed and developing countries.[3]

More recent literature addresses the contribution to S&T performance of the 'national systems of innovation'; a widely used modern term that reflects the link between technical and institutional innovative development, including S&T (e.g. Lundvall 1992; Nelson 1993). Lundvall says this broad definition includes "all parts and aspects of the economic structure and the institutional set-up affecting learning as well as searching and exploring – the production system, the marketing system and the system of finance present themselves as subsystems in which learning takes place" (Lundvall 1992, 12–13). In addition, Freeman and Soete argue:

"The many national interactions (whether public or private) between various institutions dealing with science and technology as well as with higher education, innovation and technology diffusion in the much broader sense, have become known as 'national systems of innovation'. A clear understanding of such national systemic interactions provides an essential bridge when moving from the micro- to the macro-economics of innovation. It is also essential for comprehending fully the growth dynamics of science and technology and the particularly striking way in which such growth dynamics appear to differ across countries", (Freeman and Soete 1997, 291).

All the definitions of the systems of innovation share the view that S&T institutions play a vital role in determining or influencing innovation and development. The literature on S&T development often distinguishes between input (resources) and output (performance) indicators. For instance, the European Second Report on S&T Indicators (OECD 1997) discusses numerous traditional input and output indicators for S&T development. The input indicators are generally divided into financial and human resources. First financial resource or input indicator includes

[3] For detailed theoretical and empirical literature and assessment studies, see for instance, Freeman and Soete (1997), Dasgupta and David (1994), Foray (1999), Mytelka (2001), Cooper (1991, 1994) Velho (2004). For earlier analyses of S&T in Arab region, see also Qasem (1998a, b), Zahlan (1999a, b), Fergany (1999), ESCWA (1999a, b), ESCWA–UNESCO (1998a, b)

“R&D expenditure – the most widely accepted indicator for evaluating and comparing S&T efforts in different countries and regions. In the absence of an average measurement to determine R&D within the economic structure and the needs of each country, political decision-makers use indicators such as the intensity of R&D (measured as a percentage of GDP or per capita)… In addition to financial resources, human resources are central to research and technological innovation activities”. There are also general demographic and human capital indicators, “such as the number of science and technology graduates and the number of scientists and engineers employed in R&D… [There are] four major points relating to human capital: demographic trends, the development of public spending on education, the performance of education systems and researchers and engineers active in R&D”. Furthermore, “Human resources in science and technology (HRST) are one of the key resources for economic growth, competitiveness and more general social, economic and environmental improvement”, (OECD 1997, 5, 58, 59).

Output indicators, on the other hand, “can be classified according to three parameters: economic, technological and scientific. As to economic outputs, many economists view increases in productivity as a major result of technological investment… The percentage of high-tech exports in total export figures emerges as a potentially useful means of measurement… Clearly not all results are measurable in economic terms. Scientists and engineers often cite the ‘learning experience’ as one major benefit of engaging in R&D activities. To assess the accumulated knowledge of a given country, its stock of technical knowledge must be quantified. Without doubt, patents and patents applications are the most commonly applied indicator in this respect and, irrespective of the shortcomings implicit in this approach, they continue to represent a very useful tool”. Finally there are direct research outputs or publications, “focusing on the impact of the publication output of a given country or zone and comparing it to the number of publications produced over a certain period of time” (OECD 1997, 79).

We use these definitions and the summary in Box 1 to evaluate S&T performance in section 4.

Box 1. Definition of S&T input and output indicators	
Types	S&T Indicators/Variables
S&T Input: Financial and Human Resources	1. Financial resources: percentage of R&D expenditure to GDP or expenditure per capita, R&D area of performance, and origin of funding change in public spending on education in relation to GDP 2. Human resources: HRST – the human capital engaged in science and R&D including the number of scientists and engineers employed in R&D total population size and proportion of young people, which represent the human resources potential of each country educational attainment of the labour force and graduation rates, which show the rate at which newly educated graduates are available at the country level to enter the labour force, particularly the scientific and technological qualifications and doctorate levels, including R&D staff numbers, particularly in S&T fields
S&T Output: Economic, Technological and Scientific Performance	1. Economic indicators: growth in productivity/economic outputs as a major result of technological investment percentage of high-technology exports in total exports 2. Technological indicators number of patents and patent applications 3. Scientific performance direct research output number of publications produced over a certain period of time

3. GENERAL SOCIO-ECONOMIC CHARACTERISTICS OF SUDAN

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 the Sudan it is useful to explain the general socio-economic characteristics of the Sudan. Table 1 shows the demographic structure and the major socio-economic characteristics for Sudan.

Table 1 shows the considerable diversity between Sudan, African and Arab countries and the world regions in terms of population, standard of economic development as measured by GDP per capita and human development index. Sudan generally has higher population numbers coupled with lower standards of economic development. The World Bank classification of economies puts Sudan among the lower medium-income economies. Moreover, the UNDP HDI shows that the average GDP per capita for Sudan falls within the world medium-income bracket and is, on average, lower than for those of the world and Arab countries. This also holds for the other HDI components: average life expectancy, literacy rate and combined enrolment ratios. Moreover, according to the UNDP indicators and estimates from the International Monetary Fund's World Economic Outlook (IMF 2002), as in most other typically poor developing countries Sudan is still suffering from the widespread and high rates of both unemployment and poverty.

Table 1- General socio-economic characteristics of the Sudan[4]

Country	Population[b] (millions) (2007-2008)	GDP per capita (PPP[c] US$)	Human Development Index [b] (%)	Life Expectancy[b] (years)	Adult Literacy Rate [b] (% aged 15 and above)	Combined enrolment ratio [b] (%)
	2007	2007	2007	2007	1999-2007	2007
Sudan [a]	39.2	2086	0.531	57.9	60.9	39.9
Africa	638.6	2,729	0.547	53.9	63.3	55.9
Asia	3178.8	5,837	0.724	68.8	82.1	64.5
Europe	720.8	24,775	0.902	74.9	99.2	88.2
Latin America and the Caribbean	437.5	10,077	0.821	73.4	91.2	83.4
Northern America	282.7	..	0.952	79.2	96.5	..
Oceania	26.9	..	0.900	76.4	93.0	..
Arab States	229.3	8,202	0.719	68.5	71.2	66.2
GCC	23.1	30,415	0.868	74.0	86.8	77.0
Central and Eastern Europe and the CIS	468.1	12,185	0.821	69.7	97.6	79.5
CIS	280.9	10,487	0.802	67.0	99.4	81.1
East Asia and the Pacific	1658.5	5,733	0.770	72.2	92.7	69.3
Latin America and the Caribbean	437.5	10,077	0.821	73.4	91.2	83.4
South Asia	1200.0	2,905	0.612	64.1	64.2	58.0
Sub-Saharan Africa	483.1	2,031	0.514	51.5	62.9	53.5
OECD	1048.6	32,647	0.932	79.0	..	89.1
European Union (EU27)	471.6	29956	0.937	79	..	91
High human development	784.2	12,569	0.833	72.4	94.1	82.4
Medium human development	3388.5	3,963	0.686	66.9	80.0	63.3
Low human development	240.2	862	0.423	51.0	47.7	47.6
World	5290.5	9,972	0.753	67.5	83.9	67.5

Source: UNDP (2009). Notes: [a] 2008, [b] 2007, [c] PPP – purchasing power parity.

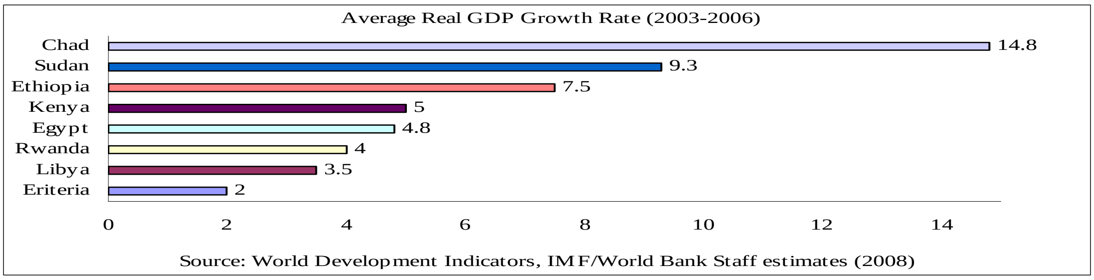
One stylised fact on the case of Sudan is that Sudan is large by regional standards, but its economy is small in global terms. According to World Bank and United Nations classification and definition, Sudan is classified among Sub-Saharan African countries and amongst the poor and low income and highly indebted countries. For instance, the UNDP and the World Bank shows the low GDP per capita income in Sudan which is in excess of only least developing countries, but less than all other World regions. Despite the high and increasing inflow of Foreign Direct Investment (FDI) to Sudan, but different from other World regions, Sudan suffered from the high increase in debt services both as percentage of GDP and as percentage of exports over the period (1990-2004). That was most probably because like most African countries, Sudan's economy has relied heavily on a large influx of foreign aid from different sources; Sudan is amongst the top ten recipients of gross Official Development Assistance

[4] The World Bank and United Nations Development Programme (UNDP) Human Development Report classify world countries differently according to income level. We use the World Bank classification of economies that puts Sudan in the lower middle-income category or group.

during (1990-2007). As for the structure of the economy, since long, the structure of Sudan economy is characterised by small share of industry, notably, manufacturing; high share of agriculture and services sectors in GDP and employment and dependence on primary exports, mainly, dependence on the exports of agricultural products. Agricultural sector remains Sudan's most important sector, employing 80% of the workforce and contributing 39% of GDP. Since gaining independence in 1956 and over the past decades, Sudan economy suffered from continuing economic instability and crisis, low GDP per capita income, presence of high rates of poverty, unemployment, inequalities, weak economic performance and an uneven growth until recent years. Therefore, according to World Bank classification, Sudan was classified amongst the least developed and highly indebted economy. Since the late 1990s, notably, 1997, due to implementation of macroeconomic reforms policies recommended by the IMF, Sudan then finally achieved great improvement in the performance of most macroeconomic indicators, impressive real economic growth and rapid increase in per capita incomes. Consequently, the Sudan turned from a low income economy into a lower medium income economy according to the World Bank classification.

In 1999, Sudan began exporting crude oil and in the last quarter of 1999, recorded its first trade surplus. Increased oil production expanded export and helped sustain GDP growth at 6.1% in 2003. In recent years after the exploitation of oil Sudan economy become increasingly dependent on oil exports, and the economy turned into an oil dependent economy. Currently oil is Sudan's main export, and the production is increasing dramatically. With rising oil revenues the Sudanese economy is booming, with a growth rate of about 9% in 2007. In recent years the increasing dependence on oil leads to sound but somewhat un sustained economic growth. Consequently, Sudan's real economic growth averaged about 9% during (2005-2006), putting Sudan among the fastest growing economies in Africa (WB, 2008)- see Figure 1 below. According to the World Bank (2008) Sudan is one of the newest significant oil producing countries in the World; Sudan is the third largest oil producers in Sub Saharan Africa (SSA) behind Nigeria and Angola. As a result, in recent years, the structure of the Sudanese economy has shifted over time, from predominantly reliant on agriculture for growth and exports, to its current reliance on the oil sector (WB, 2008)- See Figures 2-3 below. But the increasing dependence on oil leads to increasing debate for and against the incidence of the Dutch Disease in Sudan economy.

Figure 1 - Average Real GDP Growth Rate in Sudan compared to other African countries during the period (2003-2006)



Source: The World Development Indicators (WDI)/ IMF/World Bank Staff Estimate (2008)

Figure 2- Structural Change in Sudan Economy (1996-2007)

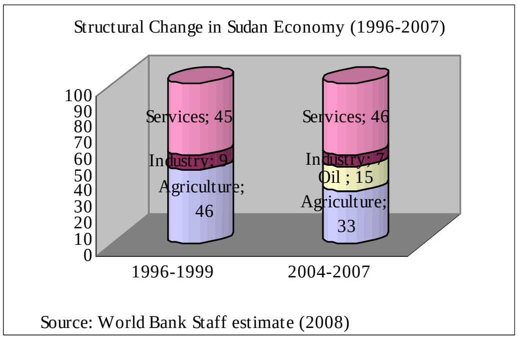
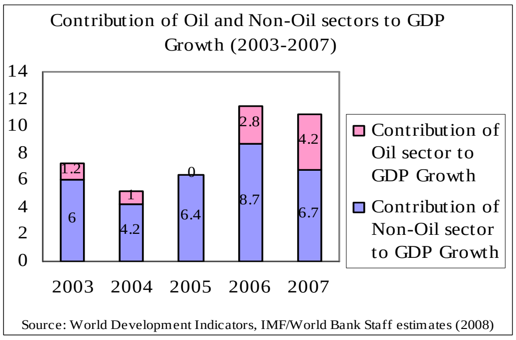


Figure 3- Contribution of Oil and Non-Oil Sectors to GDP Growth in Sudan (2003-2007)



Source: The World Development Indicators (WDI)/ IMF/World Bank Staff Estimate (2008)

Despite the recent fastest growth in the economy with new economic policies and infrastructure investments, Sudan still faces formidable economic problems, as yet it is one of the least developed countries in the world and it must rise from a very low level of per capita output. For instance, despite the recent impressive real growth and rapid increase in per capita incomes but emerging vulnerabilities and little progress in social indicators still exist. This is evidence from UNDP-Human Development Indicators (2007) and (2009) which indicate that Sudan has scored medium in human development in the last few years, it is classified amongst the bottom of developing countries in terms of HDI, as it ranked 147 and 150 out of 177 developing countries in 2007 and 2009 respectively.[5] Moreover, the global financial crisis and related shock in 2008 and 2009 resulted in low global oil prices, 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 Figure 4 below. We are aware of the fact that it may be useful to depart from the analysis of general standardize S&T indicators and to use in-depth economic, historical and social evidence to extend our analysis to focus more explicit on whether the production and export of oil (natural resource-

[5] See http://en.wikipedia.org/wiki/Sudan Accessed June 01st, 2010

based exports) affected the R&D infrastructure and the growth and development trajectory of Sudan economy. This may be particularly important in view of the fact that the production and export of oil has significant positive impacts on Sudan economy as it leads to impressive growth in GDP growth rate and structural change in the structure of Sudan economy, but unfortunately it is only un-sustained growth, mainly because of uncertainty and high fluctuation in oil price in the international market, for instance, the recent global financial and economic crisis lead to significant negative impact on Sudan economy due to high dependence on oil revenues and oil exports. But, since the comprehensive analysis of the positive-negative impacts of oil in Sudan economy needs detailed discussion and due to limitation on the size of this paper we leave that for a more in-depth analysis in our future research. Moreover, we are aware of the fact that it may be 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 paper. 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 before eleven years in 1999. Moreover, although oil leads to increase in public spending and increase in the share of development expenditure as a percentage of total public expenditure from 9% in 1999 to around 31% in 2004 but 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 mainly attributed to production and export of oil, but it is important to realize that at the macro level the share of spending on R&D as a percentage of GDP remained below 1% in the pre and post oil periods. In addition, also due to practical problems related to availability of adequate and reliable data unfortunately it will not be possible to give an in-depth 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 are available. Hence, apart from the limited impact of oil the next section of this paper examines whether this economic background affects S&T performance in the Sudan.[6]

[6] 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.

Figure 4 - GDP Growth Rate in Sudan (%) (1990-2009)

Sources: (1) Ministry of Finance and National Economy, (2) Central Bank of Sudan (3) Central Bureau of Statistics

4. SCIENCE AND TECHNOLOGY (S&T) INDICATORS IN THE SUDAN

Based on the definition of S&T indicators provided in section 2, this section explains the governance of S&T; input indicators (financial and human resources) and output indicators (scientific and technological performance) required to measure S&T performance in Sudan.

4.1 Governance of Science and Technology (S&T):

In the 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 made remarkable efforts, 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 engineering and technology. Sudan government have also realized 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, organize R&D and implement the country’s strategies in S&T and to ensure that S&T is utilized 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 the Ministry of Science and Technology (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 centralization 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 centers, governed by Ministry of Science and Technology, advised by a council and a number of committees; and (c) applied research conducted in some technical 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. The Ministry of science and technology includes some specialized research institutes and centers 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); 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, 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 multiplication of technology utilization in Sudan. In light of the 25 year long-term strategy a five-year strategy was identified and implementation work plan is developed. The 5 year work plan is targeting 8 key areas including information, communications and technology; 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 personale 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; utilizing 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.[7] 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.

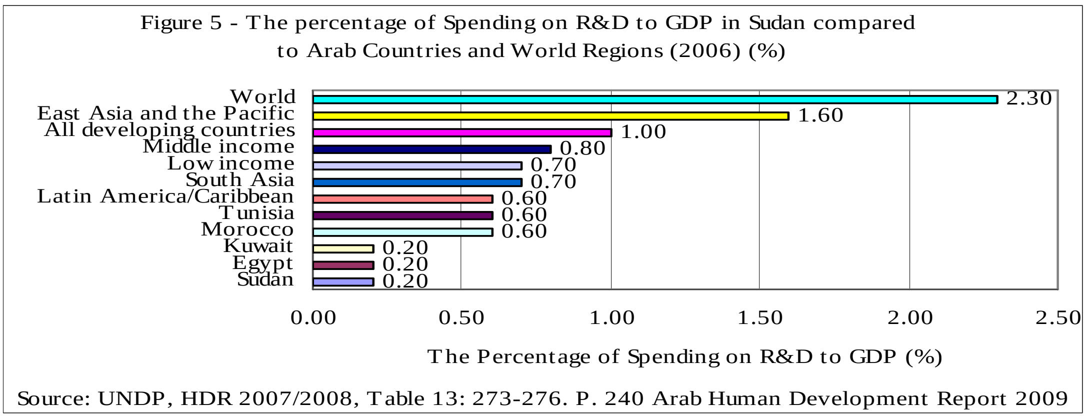
4.2. Human and Financial Input Indicators

In terms of both financial and human S&T input/resource indicators there are some differences between Sudan, the Arab, SSA countries as well as between them and other countries around the world. Table 2 shows that both financial and human S&T input indicators in Sudan lag behind the advanced and leading developing countries.

4.2.1. Financial Input Indicators

As for the financial resources in S&T, as in most other typically developing countries Sudan government seem to afford only little budget for S&T. For instance, in 2006, the rate of spending on R&D as a percentage of GDP in the in Sudan is only 0.2% falls behind the standard rate of the World, Arab countries, developing countries, East Asia and the Pacific, Latin America and the Caribbean, South Asia, Middle income and even Low income 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 Figure 5 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.

Figure 5 - 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

[7] See Sudan Ministry of Science and Technology (MOST) (2008), pp.3-6.

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 percent compared with the average for seven Arabic countries, which was 1.2 percent. In terms of expenditure on both education and R&D as percentage of GDP Sudan performs less than Arab countries. In particular, Table 2 shows that the financial resources devoted to S&T, as measured by the percentage share of GDP spent on R&D are poor in the Sudan, and Arab countries compared to both advanced and leading developing countries like Singapore and Korea. For instance, in the period 1996–2000, the 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 the Sudan was found to be less than Arab countries and the advanced countries.

Table 2- 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
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

Sources: [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..

Comparing S&T indicators between the Sudan and other Arab countries, data for 2006 shows that the rate of spending on R&D as a percentage of GDP in the 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 the in Sudan, Egypt and Kuwait - see Figure 5 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 the Sudan (near to only 5% of total financial support to S&T). There 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 GERD- see Table 3 below. Next to public sector, the private sector contributes 33.7% of GERD; the universities make only a minor contribution, 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 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 the Sudan and Mediterranean 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 industrialized countries, where more than half of R&D expenditure is financed by industry (OECD 1997).

Further problem concerning research funding is that not only comparatively, Sudan’s total Gross Domestic Expenditure on Research & Development (GERD) is rather fair at about 0.5% GDP, but also even though there has been a steady decline during the 1999 to 2005 period- see Table 3 below. This declining trend implies that the heavy reliance on the limited government and public funding is risky and resulted in poor S&T indicators and inadequate finance for R&D activities that appears form 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 the ministry of science and technology, although the rate of actual received budget relative to approved budget increased from near to 25.7% in 2003 to 74.7% in 2009 but the actual received budget relative to approved budget covers 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 4 below.

Table 3– 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%

Sources: UNESCO R&D Statistics (2006)

Table 4- 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											
	Actual Received Budget/ Approved Budget (%)						Approved Budget/ Proposed Budget (%)				
Institutions	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)

4.2.2. Human Resources Input Indicators

The human capital for S&T includes human resources in higher education; Masters and doctoral enrolments and the size of the university workforce and research and development personnel. Table 2 shows that there is a low number of scientists and engineers in R&D in Sudan, Arab countries compared to both advanced and leading developing countries.

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-folds, notably from 25 in 1993 to 85 in 2008, mainly, 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 liberalization and privatization policies and their related consequences in higher education leads 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, where as the share of the private universities and colleges increased from 44% in 1993 to 67% in 2008. The expansion in higher education in the period (1992-2007) leads to significant increase in both students enrolment and graduation rates in higher education and universities by 73.78% and 189.9% respectively. The number of students intake jumped from 6,080 in 1989 to 25018 in 1992/1993 and to 43477 in 2007. The number of female students rose to 40% of enrolment in 1995. However, the continued increase in the proportion of female students has not been accompanied by a comparable increase in their representation among faculty: merely 13% in 1995. The number of students enrolled in private higher education institutions increased nearly 9-fold within 4 years: from 2,686 in 1990-91 to 23,476 in 1994-1995- see Table 5 below. As for Masters and doctoral enrolments, generally, the number of people who participate in postgraduate studies in Sudan institutions is remarkable, see Table 5 below. Unfortunately the information on people who actually do Science research is not available from the various sources used in the writing of this paper. The distribution of postgraduate in

24 universities, indicate that for 18 universities located in Khartoum state the share of postgraduate students are higher than the other 14 universities located outside Khartoum state and in other Sudanese states, the share of Masters students are higher than doctoral and higher diploma.[8]

Table 5- Growth in higher education institutions and students enrolment in general and higher education in Sudan1992-2007

(a) High 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)			
	1992/1993	2000	Increase %
Pre-School Education	5813	8343	44%
Primary Education	8288	11923	54%
Higher Sec – Education	574	1457	154%

(d) Growth in Students Enrollment and Graduation in Higher Education and Universities (1992-2007)			
	1992/1993	2007	Increase %
Enrolled	25018	43477	73.78%
Graduated	13183	38217	189.9%

(e) % Students enrolled by field of study (1992-2000)				
	Number in 1992/1993	Number in 1999/2000	Change (1992-2000)	Growth Rate (1992-2000)
Education	4123	7269	3146	76%
Humanities & fine Art	4415	6412	1997	45%
Social sciences and Business Administration and law	2012	12591	10579	526%
Natural Sciences	1685	3894	2209	131%
Engineering sciences	2539	4545	2006	79%
Agriculture	2336	4553	2217	95%
Health and social services	1760	4036	2276	129%
Services	148	177	29	20%
Total	25018	43477	18459	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.	2885	2240	645	78%	22%	14%	19%	7%
M.Sc.	13340	7208	6032	54%	45%	63%	60%	67%
Higher Diploma	4878	2613	2265	54%	46%	23%	22%	25%
Total	21,103	12061	8942	57%	42%	100%	100%	100%

Source: (a) Ministry of High Education, (b) Ministry of General Education, (c) Elamin (2009).

[8] 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).

As for human resources for R&D in higher education and universities, many studies indicated a positive relation 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 insufficiency of human resources still remain as a serious problem hindered the promotion of S&T and R&D in the Sudan. In particular, as for universities, despite the presence of 28 public universities and 57 private universities having capacity of more than 500.000 students, but universities produce much more graduates in social sciences than in engineering and science- see Table 5 above. Furthermore, many graduates lack skills of effectively use modern tools and equipments, not to mention developing them, the number of PhD and Masters 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.[9] According to the international standard, the number of engineers and scientists per 10.000 is often used as an international standard indicator of achievement of acceptable level of research and development. For instance, the presence of less than ten engineers and scientists per10.000 people implies weak performance and presence of gaps in all research sector; the presence of fifteen engineers and scientists per10.000 people implies critical level of performance; the presence of thirty engineers and scientists per10.000 people implies the presence of acceptable performance in science and technology; and the presence of more than thirty engineers and scientists per10.000 people implies 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 science and technology system by applying the international indicator of 30 Scientists 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 further 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 the inadequate financial and human resources. Notably, the ratio of full-time researchers in Sudan was 0.2 per 10.000 persons in 1990 compared with the average for Arab countries, which was 1.7 per 10.000 persons. The ratio of engineers

[9] See Hassan (2009).

and technicians in 1990 was 1 per 3000- 5000 persons in Sudan compared with the Arab countries average of 1 per 1000 – 2000 persons. In 2008, the number of researchers per 10000 population in Sudan is only 0.7, which is very low compared to Arab countries (1.7) and developed countries (75).[10]

When comparing the Sudan with the Arab countries, we find that the Arab countries show better performance than Sudan in terms of the number of scientists and engineers in R&D. In terms of the human resources devoted to R&D, defined by the number of full-time equivalent (FTE)[11] researchers, and their distribution within R&D organizations, we find that the majority of FTE researchers are employed by higher education and the government public sectors. In Sudan the percentage share of FTE researchers 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 FTE researchers: at 13% and 20% in 2001 and 2002 respectively; while the private sector accounts for only 1% and 2% of total FTE researchers in 2001 and 2002 respectively in the Sudan. These findings for the case of Sudan seem consistent with the findings in Nour (2004; 2005) regarding the distribution of FTE researchers by employment institutions which implies the more dependence on the public sector in employment of FTE researchers and the small contribution of private sector in employment of 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 position in higher education institutions, but data from Ministry of Higher Education and Scientific Research indicates that there is a clear indication that at all the institutions, male still strongly dominate positions with virtually no female representation at some institutions in the Sudan. Furthermore, UNESCO information on the numbers of R&D workforce in Sudan from 1999 – 2005 indicate a very low number of female personnel even though there is an increase overall 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 researchers and technicians, but their respective shares in total R&D personnel over

[10] See Elamin (2009).
[11] The concept of full–time equivalent researcher is adopted by UNESCO statistics on R&D personnel.

the period (1999-2005) remained 49% and 20% respectively, see Table 6 below. Moreover, the distribution of staff and human resources in some institutions units in the Ministry of Science and Technology over the period (2003-2008) indicates that the share of researchers in workforce increased from 14% in 2003 to 20% in 2008, whereas, the share of technician 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 workforce is labour that constitutes about 60%, whereas, the share of both researchers and technicians together constitutes only 40% of the total workforce- see Table 7 below.

Table 6- Size of research and development Workforce – Sudan Total R&D personnel by sector of employment (FTE)

	1999	2000	2001	2002	2003	2004	2005
Total R&D Personnel							
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 (FTE 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 (FTE 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	15844	16017	16730	...	12982	13330	13958
Total Female	2,760	2,791	3,042	...	1,941	2,003	2,092
M/F	15844/2760	16017/2791	16730/3042	...	12982/1941	13330/2003	13958/2092
% 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	…	…	16102	…	…	…	…
Share in total							
Business enterprise			1%	9%			
Government			18%	91%			
Higher education			81%	…			
Researcher							
Total researcher	9,100	9,200	9,340	11,208	7,300	7,500	7,850
Total Male	6346	6416	6510	…	5746	5856	6186
Total Female	2,754	2,784	2,830	…	1,554	1,644	1,664
M/F	6346/2754	6416/2784	6510/2830	…	5746/1554	5856/1644	6186/1664
% 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)

Table 7- Institutions Units and staff distribution in the Ministry of Science and Technology (2003-2008)

(a) Human Resources (2008)										
Institution	No. of work force	Human Resources (2008)								
		Total number (2008)						% share in total (2008)		
		Researchers				Technician	labour	Researchers	Technician	labour
		PhD	MSc.	BSc.	Total					
NCR	746	65	131	57	253	162	331	34%	22%	44%
ARC	3369	136	241	115	492	251	2626	15%	20%	65%
ARRC	1373	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	7196	321	705	444	1470	1432	4294	20%	20%	60%

(b) Human Resources (2003)							
Institutions	Total number (2008)				% share in total (2008)		
	Researchers	Technician	labour	Total	Researchers	Technician	labour
NCR	318	373	238	929	34%	40%	26%
ARC	423	1434	3455	5312	8%	27%	65%
ARRC	282	548	608	1438	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	1182	2560	4440	8182	14%	31%	54%

Source: Ministry of science and technology Annual Reports (2003-2009)

Table 8 - 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 [6]	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 [6]	34%
Iran	14.30	37.58	30.03	10 [6]	36%

Sources: Sources: (a) Lall (2002) (b) UNDP (2002), Human Development Report (2002). (c) UNESCO (1996) and UNESCO: www.unesco.org Notes: (1) data refer to the year 1991 (2) 1993 (3) 1995 (4) 1996 (5) 1998 (6) 1999 (7) 2000 (**) data refer to 1996

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 8 above. Sudan and Arab countries score poorly compared to Korea and Singapore for the Harbison Myers Index[12], technical enrolment index, engineering enrolment index, gross enrolment ratio at tertiary education and the share of tertiary students in science, mathematics and engineering.[13] Hence, these findings imply the insufficiency of human resources necessary for the promotion of R&D and S&T in the Sudan.

4.3. Science and Technology Output Indicator and Impact

As we explained briefly in section 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 refereed 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 section 3, concerning the general economic characteristics of the Sudan economy; with those of section 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 2 shows that for both patent numbers and the percentage of high-technology exports Sudan and 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 the Sudan, 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 the Sudan shows low per capita income and also exhibits low S&T

[12] 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” (Lall, 1999: p.52).
[13] See also Muysken and Nour (2005) and UNDP–AHDR (2003).

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 Sudan' story is simpler: poor economic structure in combination with inadequate resources devoted to S&T development leads to poor S&T performance compared to advanced and developing world countries. Of course, the Sudan is now hugely dependent on oil, giving the impression that there are other ways to become rich than investing in S&T. The big question is whether the Sudan will stay rich once its oil reserves expire; despite its growing wealth from oil it still lack well-defined, targeted plans and policies and proper incentives to promote S&T performance. The Sudan need to benefit from the experience of other countries, for instance, in 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.

4.3.1. Scientific Publications[14]

As for research output and scientific publications, as output indicator the number of scientific publications depends on input financial and human resources devoted to S&T. 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.[15]

In terms of research outputs and publications, according to the Institute for Scientific Research, Sudan has relatively 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 agriculture research, and to some extent nuclear related research. Table 9 shows that the number of scientific publications for Sudan and Arab countries grew over the period 1970–1995; Egypt

[14] 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 Gulf and Mediterranean countries have only received one Nobel Prize between them: in 1999 an Egyptian scientist received the Nobel Prize for chemistry.

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

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 10 indicates that in terms of the average share of Sudan and African countries in world share of 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 no. 20 after Madagascar and Sudan is contributing only about 0.01% of world share of ISI-listed S&E papers over the period (2003-2007). This implies the problem of knowledge gaps even between Sudan and some African countries.

Table 9- Change in R&D spending and the Number of S&T publications (papers published in refereed international journals) in Sudan and the Arab countries (1970– 1997)

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
Bahrain	21	Na	453	3	-3.7	94.7	3.7	143
Kuwait	21	148	1936	5	32.3	42.2	67.1	1130
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	(3345)	3.375	192.6	165.7	87.2	1660
Oman	7	1	466	4.2	-9.6	83.1	10.8	382
Saudi Arabia	22	126	8306	9.5	-5.0	49.6	196.1	2421
Algeria	15	338	1431	5.3	-13.8	6.0	35.6	2588
Egypt	38	3261	12072	3.7	49.1	45.6	227.5	37073
Lebanon	45	743	500	2.9	319.7	27.6	7.5	444
Morocco	10	96	2418	5.1	12.3	5.9	74.9	7329
Syrian Arab Republic	6	38	471	4	25.5	64.6	24.2	2105
Tunisia	23	145	1832	6.8	37.2	75.2	28.9	1132
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	1936	4.6	27.8	36.4	20.6	1471
Iraq	14	380	931		4.7	-16.6	27.6	2840
Djibouti	1		Na	3.5	Na	Na	Na	Na
Average (total) medium income	23.155	5285	(30762)	4.75455	458.2	403.5	670.6	58688
Sudan	7	426	690	0.9	-60.3	13.6	10	2047
Yemen	11	4	155	10	-64.8	56.1	10.3	1041
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	3597
Average (total Gulf	17.333	276	(12117)	4.5333	178	298.4	294.1	4463
Average (total) Mediterranean	28.25	4621	(19123)	4.3571429	430	224.9	415.5	51574
Average (total) Arab region	15.885	5865	(35058)	4.23485	Na	Na	782.4	63945

Source: (a) UNESCO: www.unesco.com, and (b) Zahlan (1999b).

Table 10- 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: TWAS, May 2008[16]

4.3.2. Patent Applications

Table 2 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 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 patents applications as a measure for S&T output indicators, Nour (2004, 2005a; b; c) shows the low number of patents applications and hence S&T output indicators across the all Arab countries (*168)*, Arab Gulf countries (150), Arab Mediterranean countries (41 applications over the period 1990-1999) compared to Israel (*4659*) and advanced and leading developing countries like Singapore (27), Korea (*931*) and China (*793*).[17] Nour (2004, 2005a; b; c) find that the poor application to patent 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 patenting 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 11 below shows the

[16] See Hassan (2009).

[17] see for example, US Patent and Trademark office web site: www.uspto.gov

number of patent applications made between 1988 and 2005 in Sudan, 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 2002 the highest numbers of patent applications were filed by residents in Egypt followed by Saudi Arabia and Algeria. In 2002 the highest numbers of patent applications were filed by non residents in Sudan; followed by Morocco; United Arab Emirates; Algeria; Oman and Tunisia. The low number of patent application from residents than those of the non-residents of Sudan and all Arab countries is consistent with the findings in the literature, which indicate that in developing countries, however, patent applications made and patents held by residents of developing countries (domestic applications or patents) are few. Patents are overwhelmingly foreign residents owned. In most developing countries, domestic applications accounted only for 1% to 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 grounds, including non-use of the system by universities and local research institutions.[18] The low number of patents filed by residents of the Sudan and Arab countries can be related to low S&T activity in the country. 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 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 the Sudan implies that the Sudan lacks industries that are internationally competitive, which can also be interpreted in terms of there being a poor economic structure. Moreover, Table 11 shows that Sudan and African countries together have filed far fewer patents than South Africa, the highest numbers of patent applications were made by South Africa; it is followed by Zimbabwe; Mali; Tunisia; Tanzania; Sudan and Libya. According to 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 11 below.

[18] 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

Table 11- Patents for Sudan compared to Selected Arab Countries and Selected African countries (1988-2005)

(a) Patents for Selected Arab Countries (1988-2002)

	Patent applications, nonresidents					Patent applications, residents				
	1988-1998	1999	2000	2001	2002	1988-1998	1999	2000	2001	2002
Algeria	734	248	33,620	72,257	88839	152	34	30	52	42
Egypt	1845	1,146	1,081	923	798	998	536	534	464	627
Iraq	18	..	..	..	..	68	..	..	..	..
Lebanon		..	104	..	..		..	0	..	..
Libya	23	..	..	..	..	12	..	..	..	..
Mauritania		..	..	..	..		..	..	..	..
Morocco	237	3,649	51,907	74,468	89,300	90	0	104	0	0
Oman		..	..	2,174	75,825		..	..	0	0
Saudi Arabia	3097	1,144	..	683	552	129	72	..	46	61
Somalia		..	..	..	..		..	..	..	..
Sudan	156,694	80,424	115,855	150,388	177,336	6	2	5	5	2
Syrian Arab Republic		..	47	0	30		..	249	0	0
Tunisia	128	..	..	195	72,604	46	..	..	0	0
United Arab Emirates	8	24,218	56,158	75,414	89,666		0	0	0	0
Total Arab						1501				

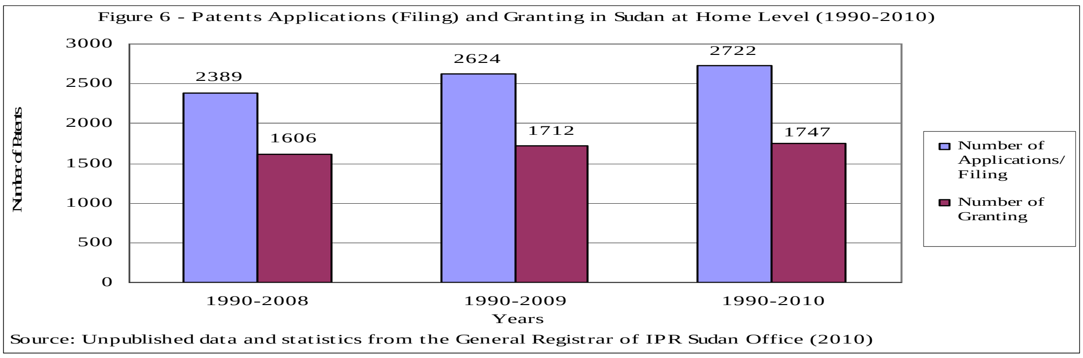
(b) Patents for Selected African Countries (pre 1995-2005)

	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	3694
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) World Development Indicators database (2005); (b) UNESCO (2006).

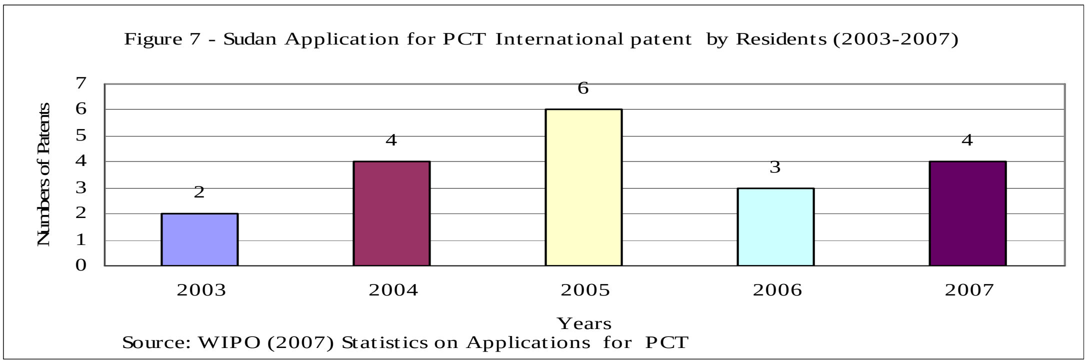
The low numbers of patents is probably because Sudan has insufficient science and technology infrastructure. For instance, Figure 6 indicates the growth in the number of both filling and granting of patents over the period (1990-2010) at the home level, but this should not hide the fact that the grant of international patents is very limited. For instance, Figure 7 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 (1 and 1) (54 and 88,960) in 2001 and 2002 respectively.

Figure 6 - 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)

Figure 7 - the application for Sudan's Application for PCT International patent by residence (2003-2007).



Source: WIPO (2007) Statistics on Applications for PCT

4.3.3. Share of High Technology Manufacturing Exports

When comparing the average share of exports of high-technology goods manufactured, our findings in Table 2 above indicate that in 2001 the highest share of high technology exports was made by Morocco, it is followed by Sudan and then other Arab countries. According to Table 2 above, Sudan is similar to the Arab countries have a low share of high-technology manufacturing exports compared to advanced and leading developing countries. In addition, the share of hi-tech 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.[19] This can be explained in relation to our earlier findings concerning the Sudan inadequate economic structure, poor spending on R&D, low number of scientists and engineers in R&D and low patent filings.

4.2.4. Productivity Growth

In terms of S&T impact as measured by economic growth, Table 12 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 Arab countries. However, during 1999–2001, the Sudan shows 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.

[19] See for instance, Haddad (2002); Lall (1999) and UN COMTRADE data 2000 and 1996.

Table 12- Real GDP growth and GDP per capita annual growth rates in the Sudan and Arab countries

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[1])						
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

Source: [a] UNDP (2003) and [b] IMF (2002). [1] GCC – Gulf Cooperation Council.

4.3.5. Demand for and Supply of Technologies, Technology Infrastructures, and Technology Achievement Index[20]

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 (2005). 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 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 % of value added in total manufactures using WDI (2010) data for 2000 and Sudan Ministry of Industry (2005) the Comprehensive Industrial Survey data for (2001), the result is value added in machinery and transport equipment/GDP, which we use as a measure of specialization in production related to technology.[21] When using this measure, our results show a low technological

[20] 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).

[21] Since the recent data from the WDI (2010) is available only for 2000, we therefore use an additional and alternative set of indicators from the Sudan Ministry of Industry (2005) the 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,

specialization in Sudan, which is most probably attributed to lack of both basic and high technology infrastructure (BTI and HTI) in Sudan- see Tables 13-14 below.[22] On average both the BTI and HTI for Sudan are poor. Overall, poor BTI is to blame for the low HTI (Rasiah 2001). Consequently, due to lack of both basic and high technology infrastructure and the low technological specialization Sudan shows poor performances in terms of technology achievement index. According to UNDP (2001) HDI classification of world countries according to technology achievement index, Sudan is classified as being marginalized adopter of new technologies; amongst marginalized adopter countries in terms of the technology achievement index; Sudan is ranked 71 and placed between Tanzania and Mozambique. Sudan poor performance lags far behind the world's advanced and leading developing countries which are either leader or potential leader in technology. In fact, Sudan also lags behind the countries classified as being dynamic adopters of new technologies in both Arab and Africa regions, notably, Tunisia (51); Syria (56); Egypt (57); Algeria (58); Zimbabwe (59), Senegal (66), Ghana (67), Kenya (68) and Tanzania (70) - see Table 14 below.

Table 13- 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

Note (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).

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the only available data from the Sudan Ministry of Industry (2005) the 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.

[22] 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, the lower the capacity and resources for high technology development.

Table 14- Basic and high technology infrastructure and technology achievement index in Sudan

	2004	2005	2006	2007	2008
(a) Basic Technology Infrastructure (BTI)[a]					
Basic education (enrolment in primary schools)[a]	3966944	4299737	4624302	4785952	5253117
Secondary education (enrolment in Secondary schools)[a]	546305	637812	639827	636156	680767
Health (Physicians Per thousand people) of Population[a]	20	22.6	28.6	29.9	22.1
Communications (main telephone lines per thousand people)[a]	29	18	20		
(b)High Technology Infrastructure (HTI)[b]					
R&D investment: R&D expenditure as % of GDP[b] (1996–2000)[b]	0.5				
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]	0.4				
Diffusion of old innovations[c]					
Telephones (mainline and cellular, per 1,000 people) 1999[c]	9				
Electricity consumption(kilowatt-hours per capita) 1998[c]	47				
Human skills[c]					
Mean years science of schooling(age 15 and above) 2000[c]	2.1				
Gross tertiary enrolment ratio (%) (1995-1997)[c]	0.7				

Sources: (a) Sudan Central Bureau of Statistics (2010) (b) UNDP (2003), (c) UNDP (2001)

4.4. S&T, R&D, Economic Development, Adaptation to Foreign Technologies and Development of Local Technologies

Based on the above findings, this section uses a new survey data based on primary data and 25 face-to face interviews with the officials policy makers and experts in the government and the academic staff in the public and private universities.[23] 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.[24] As for the contribution of R&D the majority of the respondents 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.[25] 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

[23] The interviews were conducted with the officials and experts (20%), academics in the public (60%) and private (20%) universities. The interviews were conducted with academics 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%).

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

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

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 15 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.[26] Moreover, the lack of human resources (researchers and qualified worker in R&D fields) is also mentioned but of somewhat less importance.[27] When comparing the points of views of the different respondents we find that the views of the private universities; public universities and 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 important as compared to the opinions of both the public universities and official and experts- see Table 16 below.

Table 15- The importance and contribution of R&D to satisfy the economic development in Sudan

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%
The contribution of R&D				
	officials and experts	Private universities	Public universities	All
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 16- The Main Problems hindering the role of R&D and contribution to satisfy the economic development in Sudan

	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"

[26] As indicated by 100%, 100% and 92% of the respondents respectively.
[27] As indicated by 88%, 84%, and 88% of the respondents respectively.

As for the main problem 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.[28] This is followed by the other problems such as the lack of finance from private sector; lack of management and organization ability and lack of coordination and the lack of R&D culture.[29] Finally the less important factors include the lack of favorable 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 worker in R&D fields).[30] When comparing the points of views of the different respondents we find that from the perspective of the public universities the lack of favorable conditions and the necessary facilities; the lack of awareness and appreciation of the economic values of R&D; lack of management and organization ability and the lack of coordination and the lack of R&D culture seems to be the less important problems, while from the perspective of the official and experts the less important problems are the lack of finance from private sector and the lack of human resources (researchers and qualified worker in R&D fields). Finally, from the perspective of the private universities the less important problems are the lack of favorable 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 worker in R&D fields) respectively- see Table 17 below.

Table 17- The Main Problems of R&D in Sudan

	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 worker 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%
Others				

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

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

[28] As indicated by 100 of the respondents.
[29] As indicated by 96% the respondents.
[30] As indicated by 92%, 92% and 88% of the respondents respectively.

motivation and making availability of sufficient human resources (researchers and qualified worker in R&D fields); improvement of management and organization ability and coordination; 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 and improvement of awareness and appreciation of the economic values of R&D.[31] This is followed by other solutions such as the creation of more favorable conditions and offering all the necessary facilities and improvement of R&D culture.[32] When comparing the points of views of the different respondents we find that the views of the private universities; public universities and official 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 universities and official and experts, from the perspective of the public universities, the suggestions with regards to the creation of more favorable 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 18 below.

Table 18- The Main solutions for the problems of R&D in Sudan

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 worker 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%
Others				

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

5. CONCLUSIONS

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

[31] As indicated by 100 of the respondents.
[32] As indicated by 96% the respondents.

When comparing S&T input and output indicators of the Sudan with those of the Arab, Africa 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 of share in international publication 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 of somewhat less importance. We find that the main problem hindering R&D includes the lack of finance from public sector; lack of management and organization ability; lack of coordination and 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, lack of R&D culture, lack of finance from private sector, lack of favorable conditions and the necessary facilities; lack of awareness and appreciation of the economic values of R&D, lack of human resources (researchers and qualified worker in R&D fields) respectively.

Our results show that the main suggestions to improve R&D includes 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 worker in R&D fields); improvement of management and organization ability and coordination; 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 and improvement of awareness and appreciation of the economic values of R&D. This is followed by the creation of more favorable conditions and offering all the necessary facilities and improvement of R&D culture.

Hence, our analysis indicates that in order to improve S&T performance, Sudan need 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 thus a need to adopt new policies for partnership with the private sector. Sudan needs to form a body to formulate a policy on man power resources for S&T, and suggest measures to minimize brain-drain impacts. Sudan, need to continue building relatively well-developed S&T infrastructure, mainly, 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. Restructuring the economic system, encouraging the private sector and implementing effective S&T cooperation and integration with other Arab and Africa countries will most likely enhance S&T development and hence long-term harmonious development in the Sudan.

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