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Assessment of skill and technology indicators at the macro-micro levels in Sudan

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Abstract

In this paper we examine skill and technology indicators at the macro and micro levels in Sudan. Different from the Sudanese literature, a novel element in our analysis is that we use new primary data from the macro and firm surveys and we provide a new contribution and fill the gap in the Sudanese literature by examining five hypotheses on the causes and consequences of low skill and technology indicators at the macro and micro levels in Sudan. We verify our first hypothesis that the interaction between the deficient educational system - caused by low quality of education- and the high share of unskilled workers leads to poor provision of training; low skill levels; skills mismatch; low transfer of knowledge/external schooling effect; weak technology indicators and dependence on foreign technologies at the micro level. We confirm our second hypothesis that the poor local technology indicators/indigenous capability to build the local technology and heavy dependence on foreign technology can be attributed to lack of R&D activities/efforts, due to a lack of funding, low skill levels, weak linkages, lack of networks systems and collaboration between universities and industry/firms, low transfer of knowledge and a lack of entrepreneur perspective. We support our third hypothesis that the transfer of knowledge/external schooling effects is successful at the micro level but unsuccessful at the macro level due to low educational qualifications and deficient educational and training systems. We confirm our fourth hypothesis that skill and technology indicators are significantly determined by firm size and industry. We support our fifth hypothesis concerning the consistency of upskilling plans at the macro-micro levels. Finally, one advantage and interesting element in our analysis is that we provide a new contribution to the Sudanese literature, since we explain the causes, consequences and interaction between the low skill and technology indicators and the transfer of knowledge. We recommend further efforts to be made to improve skill and technology indicators and transfer of knowledge at the macro and micro levels which are all essential for economic growth and development in Sudan.

Keywords: Skill, technology, firm size, industry, Sudan

JEL classification: J24, L25, O12, O15, O30,

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1. Introduction

Economists have long recognized the essential role of technical progress in the creation, acceleration and sustainability of economic growth and improvement of the quality of life in any society. Both the endogenous growth theories and empirical literature acknowledge the importance of human capital accumulation for economic growth. Endogenous growth literature also elaborates on the interaction and complementary relationship between technological progress and human capital to create, reinforce, accelerate and sustain economic growth (cf. Lucas, 1988; Romer, 1990; Freeman and Soete, 1997). Moreover, economists also highlight the role of high levels and quality of skills as critical factors for competitiveness associated with the rapid progress of globalization and fast technological progress in the developed and developing countries. Considerable debate in the literature is on the effects of human capital and the diffusion and transfer of technology to the developing countries to accelerate the catching-up process. For instance, the Nelson and Phelps (1966) model allows human capital levels to affect the speed of technological catch-up and diffusion. Romer (1990) has also argued that the level of human capital may have an influence on growth of technological innovation both directly and through its effect on the speed of the "catch-up" process. Benhabiab and Speigel (1994) adapted the Nelson and Phelps (1966) framework to allow for the catching-up of technology with those of the leading countries. In their view, the level of education not only enhances the ability of a country to develop its own technological innovations, but also its ability to adapt and implement technologies developed elsewhere. Endogenous growth theory predicts that in the long run economic growth at the aggregate level is determined by endogenous sources of technological change: human capital, learning by doing, spillovers of knowledge and external effect of human capital. Endogenous growth literature revealed several robust facts and interesting implications that paved the way for growth and it also provided some insights for a possible role for government policy.

In this paper we use the framework of the new growth literature presented above to examine and assess skill and technology indicators at the micro-macro level in Sudan. First, our analysis aims to provide empirical investigation of the causes and consequences of low skill and technology indicators, notably, the causes and consequences of the deficient educational system and the implications of the high share

of unskilled workers and serious skills mismatch at the macro-micro levels. Second, we examine the factors hindering the transfer of knowledge/external schooling effects at the macro-micro levels. To examine our hypotheses about the serious implications of the interaction between the deficient educational system and the high share of unskilled workers, we focus on the Sudan as a case study of the Arab countries and we use a combination of secondary and a new primary data covering the macro and micro levels based on the macro and firm surveys (2010).[2] Mainly, we use the results of the macro survey to show the causes of the deficient educational system and consequences on low skill levels, poor provision of training, skills mismatch and low transfer of knowledge at the macro level. Moreover, we use the results of the firm survey to show that the high incidence of unskilled workers leads to low skill level, poor provision of training, skills mismatch, poor technology indicators and a heavy dependence on foreign technologies at the micro level. Based on these objectives, in this paper we test five hypotheses: first, the interaction between the deficient educational system-caused by low quality of education- and the high share of unskilled workers leads to serious implications: poor provision of training; low skill levels, skills mismatch; low transfer of knowledge/external schooling effect; weak technology indicators and dependence on foreign technologies at the macro-micro levels. The second hypothesis is that the low level of local technology indicators/poor indigenous capability to build the local technology and heavy dependence on foreign technology can be attributed to lack of R&D activities/efforts, due to a lack of funding, low skill levels, low transfer of knowledge, lack of entrepreneur perspective, weak linkages, lack of networks systems and collaboration between universities and industry/firms. The third hypothesis is that the transfer of knowledge/external schooling effects is successful at the micro level and unsuccessful at the macro level due to low educational qualifications and deficient educational and training systems. The major consequences are the lack of networks and collaboration between universities and firms, low R&D efforts and low technology indicators. The fourth hypothesis is that skill and technology indicators are

[2] The firm survey (2010) on "Technological Change and Skill Development: A Comparative Study of Chemical, Food, Metal and Textile Small, Medium and Large Scale Enterprises in the Sudan" covered 100 medium and large size firms active in the chemical, food metal and textile industries in Sudan (2010). It held in Sudan in 2010 and aims to assess skill and technology indicators and effect of unskilled workers across chemical, food, metal and textile small, medium and large size establishments in Sudan. The macro survey on "Reform of Education, Human Resources Development and Policy Intervention" has been circulated amongst 40 of policy makers and experts in 8 public, university, educational, training and research institutions in Sudan (2010). It held sin Sudan in 2010 and aims to examine the causes and consequences of low skills and the deficient educational system in the Sudan. The response rates of the firms and macro surveys are 87% and 90% respectively. In addition, the survey's data was supported by ten face-to-face interviews with firm managers and five interviews with the officials.

significantly determined by firm size and industry. The fifth hypothesis is that the implemented upskilling plans are consistent at the macro and micro levels.

Compared to the Sudanese literature, we provide new evidence and add to the few recent studies in the Sudan to improve understanding and highlight the need for upskilling, the low skill level, low technological level and dependency on foreign technologies. Compared to Sudanese and Arab literature, our research is important for elaborating and providing a more in-depth analysis, not only for assessing the Sudan skill-technology indicators using a more comprehensive set of indicators based on the new growth literature, but also for analysing the causes and consequences of low skills and technology, the relation between them at both the macro and micro levels, and for addressing policy aspects aiming to enhance them. Basically, we identify upskilling as an essential element for building adequate human resources needed for the fulfilment of long run economic growth and sustainable development strategies in Sudan: achieving economic stabilization, balanced development, economic diversification, reducing poverty, reducing unemployment, restructuring and reducing mismatch in the labour market, creation of adequate and appropriate employment opportunities, enhancing self-reliance on domestic capital and workers, building institutional reform and technological development. We show that the low skill level is basically attributed to the deficient educational system –due to low quality of education– and high incidence of unskilled workers at the macro and micro levels respectively. The importance of our analysis is the identification of the numerous implications of the interaction between a poor educational system and an excessive share of low educated workers that leads to low skill levels, poor provision of training, skills mismatch, low transfer of knowledge, poor technology indicators and high dependence on foreign technologies. We add to the results in the Sudanese literature (Hassan, 2009; Elamin, 2009) regarding the lack of technology policy, technical skills, R&D, technology culture in the Sudanese society and the mismatch in the labour market due to deficient educational system and cultural reasons (Jalal al-Din, 2002). Using new primary data based on the firm survey (2010) we provide a new contribution and fill the gap in the Sudanese literature by examining the major factors hindering R&D at the micro level and by explaining that the lack of local efforts for technology development at the micro level is mainly related to low R&D efforts that are attributed to low skill level, lack of entrepreneur perspective, lack of networks systems, fruitful cooperation between universities and firms, lack of resources, and lack of social awareness and concern in

Sudan. Our new findings concerning the low levels and problems hindering R&D at the micro level are consistent with the results in the Sudanese literature at the macro level (Nour, 2010) which imply that the low level of R&D and the main problems hindering R&D at the macro level include lack of finance from public sector; lack of management and organization ability; lack of coordination and weak relationship, network, consistency and cooperation between universities and higher education institutions and productive sector (agriculture, industry, services), lack of R&D culture, lack of finance from private sector, lack of favorable conditions and necessary facilities; lack of awareness and appreciation of the economic values of R&D, lack of human resources (researchers and qualified workers in R&D fields) respectively. Moreover, we provide new contribution and fill the gap in the Sudanese literature by investigating the significance of the incidence and transfer of knowledge/external schooling effects, the factors hindering them at the macro and micro levels in the Sudan. Our results concerning the surprising contradicting views relating to the transfer of knowledge seems to be consistent with the results in the Arab literature (e.g. Muysken and Nour, 2006; Nour, 2005). Unlike the few recent studies of skill and technology in the Arab countries, one advantage of our analysis is that we provide a more specific analysis that focuses only on the Sudan as a new case of Arab countries. Moreover, our findings concerning the channels of technology transfer, the positive impacts the technology transfer brings to output/production and the wide variation between the level of technology transfer in the different industrial scales and activities/sectors are consistent with some very few findings in the Arab literature (e.g. Nour, 2005; Elsabaa, 1997). In addition, our results are consistent with the Arab Gulf literature (Nour, 2005) and the general literature, which illustrates that across firms skill and technology indicators (the use of ICT, R&D, patent, product and process innovations), level of technology use and channels of transfer are significantly determined by firm's characteristics defined by firm size and industry.

Based on the above, the rest of this paper is organized as follows: Section 2 shows the causes and consequences of the deficient educational system and the high incidence of unskilled workers and their implications on low skill levels, poor provision of training, skills mismatch, lack of knowledge transfer, low level of local technology and heavy dependence on foreign technology. Section 3 presents the micro-macro views about the upgrading of skill and technology and their potential implications. Section 4 provides the conclusions.

2. Causes and consequences of low skill and technology indicators

Based on the above, in this section we show the causes and consequences of low skill and technology indicators, it is useful to begin with the causes and consequences of deficient educational system and high incidence of unskilled workers at the micro-macro levels in Sudan.

2. 1 Causes and consequences of deficient educational system

The results of the macro survey indicate that, at the aggregate level, the official efforts to promote and upgrade the levels of local skill have been relatively successful only in some sectors.[3] In general, there has been a serious failure and shortcoming of the upskilling process, which is mainly attributed to: (1) inadequate availability and misallocation of resources; (2) the deficient educational system; (3) failure of educated and trained workers to transfer knowledge; and (4) inadequate training provision.[4]

We begin our discussion by the second reason i.e. the deficient educational system, because we want to argue that both inadequate training provision and the failure of educated and trained workers to transfer knowledge are direct implications of deficient education, while the misallocation of resources is indicated as one cause of both deficient education and the poor provision of training.

A. Causes of deficiency in the educational system

With respect to the second cause, Table 1 shows that the deficiencies of the educational system appear in all the basic, technical, secondary and tertiary educational systems. Major causes are the low quality and internal efficiency of the educational system, the lack of infrastructure (due to inadequate investment/public spending on education) and the lack of teachers and mentors.[5] Other important factors are the inadequate assessment and monitoring of educational needs, the lack of modernization and dynamism and inadequate planning for educational needs.[6] Finally, the lack of flexibility of educational institutions and the weak linkages/networks between universities, colleges, technical and training institutes are also mentioned, but are of somewhat less importance.[7] That also holds good for the low involvement and spending by the private sector.[8] Moreover, the major serious problem for the technical

[3] As reported by 56% of the respondent policy makers and experts to the macro survey.
[4] As indicated by 100%, 97%, 94% and 92% of the respondent policy makers and experts respectively.
[5] As reported by 92%, 92% and 91% of the respondent policy makers and experts to the macro survey respectively.
[6] As indicated by 87%, 86% and 84% of the respondent policy makers and experts to the macro survey respectively.
[7] As reported by 83% and 83% of the respondent policy makers and experts to the macro survey respectively.
[8] As indicated by 79% of the respondent policy makers and experts to the macro survey.

education is the weak incentives for spending and enrolment in technical education.[9] For instance, the share of public spending on education in GDP in the Sudan (0.9%) is low compared to Arab Gulf countries like Saudi Arabia (9.5%) and other advanced Asian countries such as Korea (3.6%) and Malaysia (7.9%) (The UNDP, 2004) – see our discussion of the supply side of educational policies in Nour (2011).

We observe that, according to 92% of the respondents to the macro survey, the low quality and efficiency of the educational system appears from the low quality at technical, tertiary, higher secondary and basic education relative to international standards respectively.[10] Important causes are the low rates of accomplishments and motivation at technical, higher secondary and basic education levels relative to international standards, but the problem is somewhat less at the tertiary education level.[11] Other serious problems are the low quality of teachers and mentors, the low public current expenditure per pupil, the low survival rates and high drop-out and the high pupil/teacher ratios,[12] while less important causes include the high repetition rates.[13]

Table 1 - The Causes of deficient educational system in the Sudan, 2010

Causes of Deficiency	**General educational system (basic+ technical+ secondary + tertiary) (%)**	**Basic education (%)**	**Technical education (%)**	**Secondary education (%)**	**Tertiary education (%)**
Inadequate assessments and monitoring of educational needs.	87%	86%	94%	86%	83%
Low quality / efficiency of educational system.	92%	86%	92%	94%	94%
Inadequate planning for educational needs	84%	81%	94%	78%	81%
Lack of flexibility of educational institutions.	83%	81%	78%	81%	92%
Low spending and weak incentives for enrolment in technical education.	94%	-	94%	-	-
Lack of modernization and dynamism.	86%	78%	94%	83%	89%
Low involvement and spending by private sector	79%	78%	89%	72%	78%
Weak linkages [networks] between universities, colleges, technical and the training institutes.	83%	-	-	-	83%
Lack of infrastructures due to Inadequate investment (public spending on education).	92%	97%	97%	92%	81%
Lack of teachers and mentors.	91%	94%	97%	86%	86%

Source: Own calculation based on the macro survey (2010).

[9] As reported by 94% of the respondent policy makers and experts to the macro survey.
[10] As reported by 92%, 89%, 89% and 86% of the respondent policy makers and experts to the macro survey respectively.
[11] As indicated by 97%, 89%, 89% and 86% of the respondent policy makers and experts to the macro survey respectively.
[12] As reported by 100%, 94%, 89% and 89% of the respondent policy makers and experts to the macro survey respectively.
[13] As indicated by about 81%, of the respondent policy makers and experts to the macro survey.

B. Consequences of the deficient educational system

a. mismatch between the output of education and the market needs

We find that both the deficient basic (primary and secondary) and tertiary educational systems together lead to serious mismatch between the output of education and the market needs. In particular, about 92% and 72% of the respondents to the macro survey reported that the mismatch is mainly attributed to deficiency of both tertiary and basic education respectively. Moreover, the follow-up interviews with policy makers and experts show that the mismatch is attributed to the deficient educational system[14], the lack of coordination and planning to meet the critical skill needs and the cultural/social reasons: preference for white-collar jobs and biased against technical education and technical jobs. For instance, the deficiency of tertiary educational system is caused by the inconsistent structure: the share of students enrolled in the Sudan in 2000 in all social sciences, humanities and art faculties (65%) was much higher than those of sciences, math and engineering (35%). The share of students enrolled in sciences, math and engineering in the Sudan is also low compared to both Algeria (50%) and China (53%) (The UNDP, 2002; 2003; UNDP-AHDR, 2003) – cf. our discussion on the demand for education in Nour (2011).[15]

b. lowering skill levels

From the Sudan population census data (2008) and the educational matrix for the period 1960-2008 set out in Table 2, we observe the low skill levels – defined by educational level of total population. The share of low educated (99%-95%) is much higher than that of high educated (1% - 5%) in total population over the period (2000-2008). That also indicates a minimal skill upgrading, defined by the relative rise in the share of high educated population and the relative decline of the share of low educated population during the period (1960-2008).[16] In addition, the Sudan central bureau of statistics Statistical data (2004-2008) on the distribution of economically active population by occupational classification (2004-2008) shows the low skill level defined by occupational levels, for instance, the share of unskilled population (86% - 83%) is much higher than that of high skilled population (14% - 12%)- see Table 3

[14] As in most other developing countries, the mismatch is attributed to deficiency in the educational system.
[15] These results are also consistent with the findings of both El Sabaa (1997) and Haan (1999) and Nour (2005) in the UAE, see for instance, (El Sabaa, 1997: 20-21) and (Haan, 1999: 37).
[16] At the aggregate level, the educational matrix implies the distribution of population according to educational level: low level of education refers to illiterate, literate, primary and preparatory school; medium level of education includes secondary, post-secondary and below university; and high level of education includes university and postgraduate levels.

below. That also implies that rather than improvement there was even a slight deterioration in skill upgrading defined by the decreasing share of high skilled despite a falling share of unskilled during the period (2004-2008)- see Figures 1-2 below. Furthermore, as we explain below, the low skill levels at the macro level is consistent with that at the micro level.

Table 2 - The Sudan educational matrix: The distribution of Population by educational level (1960-2008)

Total population [a, b]		**Low**	**Medium**	**High**	**Not stated**	**Total**
1960 [a]	Total	0.996000	0.004000	0.000000	0.000000	1
1965 [a]	Total	0.994000	0.006000	0.000000	0.000000	1
1970 [a]	Total	0.992000	0.007000	0.001000	0.000000	1
1975 [a]	Total	0.988000	0.010000	0.002000	0.000000	1
1980 [a]	Total	0.981000	0.018000	0.003000	0.000000	1
1985 [a]	Total	0.971000	0.027000	0.002000	0.000000	1
1990 [a]	Total	0.972000	0.023000	0.004000	0.000000	1
1995 [a]	Total	0.966000	0.029000	0.005000	0.000000	1
2000 [a]	Total	0.959000	0.034000	0.007000	0.000000	1
2008 [b]	Total	0.768000	0.139300	0.053200	0.039700	1
2008 [b]		**Low**	**Medium**	**High**	**Not stated**	**Total**
Total Sudan (Gender) [b]	Male	0.432900	0.078000	0.029100	0.021500	0.561500
	Female	0.335000	0.061300	0.023900	0.018200	0.438400
	Total	0.768000	0.139300	0.053200	0.039700	1
Total Sudan (mode of living) [b]	Rural	0.295600	0.085200	0.039800	0.018300	0.438900
	Urban	0.454200	0.053200	0.013000	0.020200	0.540600
	Nomad	0.018100	0.001000	0.000200	0.001200	0.020500
	Total	0.768000	0.139300	0.053200	0.039700	1
Total population [b]		0.768000	0.139300	0.053200	0.039700	1
2008 [b]		**Low**	**Medium**	**High**	**Not stated**	**Total**
North (Gender) [b]	Male	0.375400	0.068200	0.027800	0.021500	0.492900
	Female	0.295300	0.056900	0.023600	0.018200	0.394000
	Total	0.670600	0.125100	0.051300	0.039700	0.886700
South (Gender) [b]	Male	0.057700	0.009800	0.001500	0.000000	0.069000
	Female	0.039800	0.004300	0.000500	0.000000	0.044600
	Total	0.097200	0.014100	0.001800	0.000000	0.113100
Total population [b]		0.768000	0.139300	0.053200	0.039700	1
2008 [b]		**Low**	**Medium**	**High**	**Not stated**	**Total**
North (mode of living) [b]	Rural	0.268000	0.079300	0.038800	0.018300	0.404400
	Urban	0.384600	0.044900	0.012400	0.020200	0.462100
	Nomad	0.018100	0.001000	0.000200	0.001200	0.020500
	Total	0.670600	0.125100	0.051300	0.039700	0.886700
South (mode of living) [b]	Rural	0.027700	0.005900	0.001100	0.000000	0.034700
	Urban	0.069600	0.008200	0.000700	0.000000	0.078500
	Nomad	0.000000	0.000000	0.000000	0.000000	0.000000
	Total	0.097200	0.014100	0.001800	0.000000	0.113100
Total population [b]		0.768000	0.139300	0.053200	0.039700	1

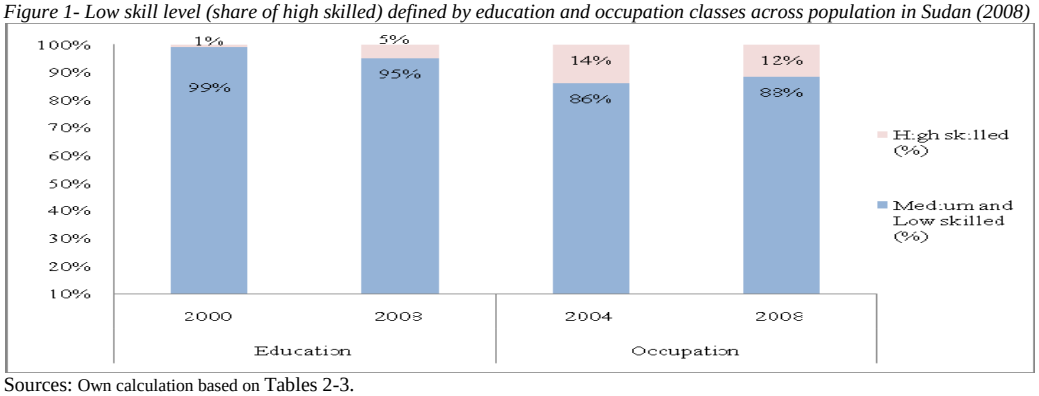
Source: Own calculation from (a) Barro and Lee (2000), cited in Ali Abdel Gadir Ali (2006) "On Human Capital in Post-conflict Sudan: Some Exploratory Results", API/WPS 0602, p. 14, (b) Adapted from Sudan Central Bureau of Statistics Population Census Data (2010): The Fifth Sudan Population and Housing Census (2008).
Note: figures for 2008 refers to total population with six (6) years old and over

Table 3- Economically active population defined according to major occupational groups classification, defined by gender and main geographic area in Sudan (2004-2008) (%)

Major Occupational Groups[17]	2004			2008		2008			2008	
	M	W	MW	M	W	MW	M	W	North	South
Professional, scientists, technical, associate professionals and related workers	8.80	14.72	10.46	3.58	2.39	9.78	10.92	7.41	4.76	1.23
Administrative and managerial workers	5.25	0.10	3.81	5.03	0.55	5.57	7.43	1.69	5.35	0.23
White Collar high skilled (WCHS)	14.05	14.82	14.27	8.61	2.94	11.55	12.73	9.08	10.10	1.45
Clerks and related workers	4.00	5.90	4.53	1.43	0.72	2.15	2.12	2.22	1.94	0.21
Sales workers and shop and market service workers	15.00	3.15	11.67	5.68	5.05	10.73	8.40	15.61	4.15	6.58
White Collar low skilled (WCLS)	19	9.05	16.2	7.11	5.76	12.88	10.51	17.83	6.09	6.78
Agriculture animal husbandry and forestry workers	46.90	69.59	53.26	21.66	14.52	36.18	32.01	44.90	17.07	19.11
Blue Collar high skilled (BCHS)	46.90	69.59	53.26	28.58	15.28	43.86	42.24	47.25	24.13	19.73
Production and related workers, transport equipment operators and laborers	20.04	6.53	16.25	na	na	na	na	na	na	na
Blue Collar low skilled (BCLS)	20.04	6.53	16.25	21.10	4.46	25.56	31.18	13.78	22.03	3.52
Services workers, workers not classifiable by occupation and unemployed workers	na	na	na	na	na	na	na	na	na	na
Craft and related trades workers	na	na	na	6.92	0.76	7.68	10.22	2.36	7.06	0.62
Plant and machine operators, and assemblers	na	na	na	3.03	0.14	3.17	4.48	0.42	3.01	0.16
Elementary occupations	na	na	na	18.07	4.32	22.39	26.70	13.36	19.03	3.36
Not Stated	na	na	na	2.26	3.90	6.16	3.35	12.06	6.16	0.00
Total	100	100	100.							
White Collar (WC= WCHS + WCLS)	33.05	23.87	30.47	15.72	8.70	24.42	23.24	26.90	16.19	8.23
Blue Collar (BC=BCHS +BCLS)	66.94	76	70	49.68	19.73	69.41	73.42	61.03	46.16	23.25
High skilled (HS= WCHS)	14	15	14	8.61	2.94	11.55	12.73	9.08	10.10	1.45
Medium and Low skilled (MLS=WCLS + BCHS+BCLS)	86	85	86	56.79	25.50	82.30	78.86	83.93	52.25	30.03

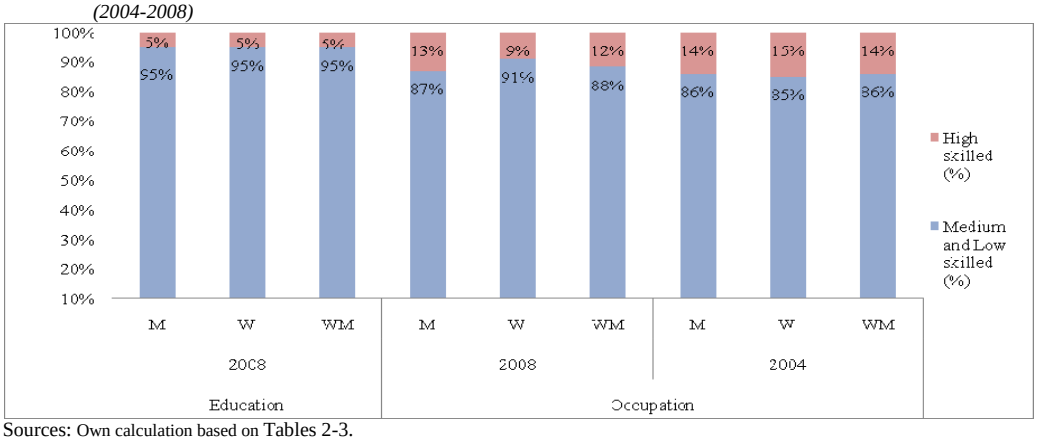
Sources: Adapted from the Arab Labor Organization (2007), (2) Central Bureau of Statistics– Department of Internal Commerce and Pricing. (3) Own calculation based on Sudan central bureau of statistics population census data (2010).

Figure 1- Low skill level (share of high skilled) defined by education and occupation classes across population in Sudan (2008)



Sources: Own calculation based on Tables 2-3.

Figure 2- Low skill level (share of high skilled) defined by gender, education and occupation classes across population in Sudan (2004-2008)



Sources: Own calculation based on Tables 2-3.

[17] The ILO International Standards Classification of Occupations (ISCO) are aggregated in the following way (high skilled includes only the category of WCHS, while medium and low skilled include all other categories: WCLS, BCHS and BCLS):
White-Collar high-skilled (WCHS) includes legislators, senior officials, managers, professionals, technicians and associate professionals.
White-Collar low-skilled (WCLS) includes clerks, services workers, shop and market sales workers.
Blue-Collar high-skilled (BCHS) includes skilled agricultural and fishery workers, craft and related trade workers.
Blue-Collar low-skilled (BCLS) includes plant and machine operators and assemblers and elementary occupations.

c. hampering transfer of knowledge

Our results in Table 4 show that the low quality of education hindered the easy transfer of knowledge and external schooling effects. According to the macro survey, only 36% of the respondent policy makers and experts reported that the incidence of knowledge transfer/external schooling effect is successful, while around 61% reported that the transfer of knowledge/ the external schooling effects are constrained by several factors. The major important factors include: the low quality of training, the lack of awareness about the importance of the external effect of schooling, the low quality of education, the prevailing conditions in the firms do not encourage external effects, failure of skilled workers to deliver knowledge to unskilled workers and failure of unskilled workers to acquire knowledge from skilled workers.[18]

In strong contrast to this view, the results of the firm survey show that, at the micro/firm level, the incidence of knowledge transfer/external schooling effect is successful among about 77% of the respondents firms. It is only unsuccessful within about 23% of the respondent firms because of the following: the low quality of training, failure of skilled workers to deliver knowledge to unskilled workers and failure of unskilled workers to acquire knowledge from skilled workers, the low quality of education and the prevailing conditions in the firm do not encourage the external effects within firms.[19] These results support our third hypothesis that the transfer of knowledge/external schooling effects is successful at the micro level but unsuccessful at the macro level due to low educational qualifications and deficient educational and training systems.

Table 4 - The factors constrained the transfer of knowledge/ external schooling effect in the Sudan, 2010

Factors constrained the transfer of knowledge / External Effect of Schooling	Officials
Low quality / return from education	89%
Low return form / quality of training compared to international standard	92%
Prevailing conditions in the Firm conditions do not encourage the external effect	89%
Failure of skilled workers to deliver their knowledge and experiences to benefit unskilled workers.	78%
Failure of unskilled workers to acquire the knowledge and experience from skilled workers	75%
Lack of awareness on the importance of the external effect	92%

Source: Own calculation based on the macro survey (2010)

This contradicting optimistic-pessimistic views at the micro and macro levels regarding the incidence and success of knowledge transfer/external schooling effect

[18] The transfer of knowledge and external schooling effects refers to knowledge transferred from knowledge holders (high skilled workers/people) to knowledge recipients (low skilled workers/people) - cf. Cowan, Soete and Tchervonnaya (2001: 9). Knowledge in this sense refers to know how or tacit knowledge embodied in people, and is different from the broad definition of technology, which refers to both embodied and disembodied knowledge.

implies that the transfer of knowledge/ the external schooling effects is probably successful within firms but unsuccessful between firms and within society at large. This is consistent with our observations from the follow-up interviews that the transfer of knowledge is hindered by both the low quality of education and the lack of cooperation with university sector due to inadequate awareness and lack of social partnership between public sector, private sector, university sector and society. The weak linkages and lack of networks between universities, colleges, technical and training institutes and the productive sectors is mentioned by 83% of the respondents to the macro survey as factor that constrains the efficiency of educational system – it probably also constrains the transfer of knowledge. An additional factor is that the transfer of knowledge within society at large is probably hindered by the incidence of high illiteracy rate and incidence of high mismatch between educational output of population and labour market. Mainly due to the excessive share of unskilled workers that probably hindered their sufficient benefit from high skilled workers and population.[20] This is probably also due to a lack of incentives at the aggregate level.[21]

Finally, the macro survey indicates that the contribution of both educated and trained population to promote the local skills is constrained by several causes. Major causes are the inadequate incentives for trainers, the lack of interaction to market needs (mismatch), the lack of information on educational and training needs in the productive sectors and their demand for graduate students and the uncertainties about the future value of investment in education and training.[22] Other important causes are: the uncertainties about future skill needs and the high costs to finance education and training.[23] Relatively less important causes include the lack of a system of certification of skilled acquired and risk aversion, i.e. the preference of more certain short term

[19] Another possible explanation for the low transfer of knowledge can be interpreted in relation to the prevailing conditions within private firms. Since within private firms there may be fewer incentives for the incidence of transfer of knowledge from high to low skilled workers.

[20] This result is consistent with the finding of the UAE as reported by El Sabaa (1997), who notes: "It is widely observed that industrial entrepreneurs in the technically advanced projects are strictly against leakage of their technologies outside their factories. Thus, they minimally contribute to developing the technology environment in the country. This adverse impact has been amplified by the unwillingness of foreign as well as local entrepreneurs to employ local manpower, to train them in their factories, either because they doubt their capabilities, or for fear to leaking their technology secret to other competitors. The limited supply of local industrial manpower, coincided with the unwillingness to employ them in both foreign and local industries applying advanced technologies, resulted in constricting the role supposed to be played by expatriate manpower in transferring technology to the industrial sector in the Gulf region. Moreover, the large scale industries despite using more sophisticated advanced technologies, however, they minimally contribute to elevate the technology transfer to the local industrial sector, as they strictly keep their operational and managerial techniques as top confidential secrete and prevent their leaking outside their units. To some extent, the chance of their flow to the rest of the operating factories seems better in the medium size factories" (El Sabaa, 1997: 22, 24-25).

[21] The lack of transfer of knowledge can be interpreted as a lack of absorptive capacity, mainly related to deficiencies of education and continued dependence on imported technologies.

[22] As indicated by 97%, 92%, 92% and 92% of the respondent policy makers and experts respectively.

[23] As reported by 86% and 86% of the respondent policy makers and experts.

returns to available jobs than long term skill investments.[24] These factors probably also contribute to hinder the transfer of knowledge within society at large.

d. poor provision of training

Both the deficient educational system and the excess supply of low skilled workers lead to a low skill level and hinder the provision of training. Table 5 shows that both the policy makers and experts (officials) and firm managers mentioned the low educational qualifications of workers among the important factors constraining the provision of training. Other important factors are the lack of appreciation/ information about training, the lack of finance to cover the high cost of training, the lack of trainers and mentors, inadequate assessment and planning for training programmes and the mismatch problem. Moreover, the results of the firm survey illustrate that the low provision of training appears from the following: (1) The lack of an in house training unit –only 27% of the respondent firms have an in house training unit; (2) The complete absence of public financial support: for instance, none of the respondent firms received any government subsidies to support training provision; (3) The selective training provision: in the year 2008, the priority for training among the respondent firms was mostly given to production workers, production engineering staff, management staff and services workers;[25] (4) The limited type of training: most of training provision is focused on the job training, and on the job and off the job combined, which are preferred by 72% and 56% of the respondent firms respectively. The other types of training such as: off the job within the firm (training centre), off the job outside the firm (specialist training centre inside the country) and (outside the country) are very limited.[26] (5) The limited sources of information about training opportunities, as most of the information about training opportunities is provided by private trainers (local and foreign companies) and the chambers of commerce. Few firms find information from government and semi government units, other firms working in the same sector and public educational institutions/ universities.[27, 28]

[24] As indicated by 83%, and 78% of the respondent policy makers and experts respectively.
[25] As reported by 51%, 48%, 36% and 21% of the respondent firms respectively.
[26] As indicated by 42%, 48% and 38% of the respondent firms respectively.
[27] As reported by 46%, 32%, 27%, 26% and 21% of the respondent firms respectively.
[28] These results seem consistent with the findings of the earlier studies in the UAE conducted by Nour (2005), the UAE University (1994; 1997), Gray (1999) and Abdelkaraim and Haan (2002). For instance, the UAE Education Assessment Report (1994) shows that both technical and vocational education and training provision are unregulated, uncoordinated and unplanned, while the results of the UAE University (1997) show the limited contribution to private sector training provision by both the public and government sectors. Moreover, the findings of Gray (1999) show that only 30% of the respondent firms provide systematic training. The provision of training is selective in most cases – focused on some occupational groups, but not others –

Table 5 - The factors constrained the provision of training in the Sudan, 2010

Factors constrained the provision of training	Offi cial	All firms	Che mical	Food	Meta l	Textil e	Larg e	Med ium	Sma ll
Inadequate planning for training programme	94%	59%	57%	55%	75%	67%	81%	37%	54%
Inadequate assessment of training needs.	92%	65%	65%	65%	63%	67%	86%	47%	54%
Mismatch between training programme and changing technical needs	89%	50%	48%	50%	50%	67%	76%	26%	38%
Mismatch between training programmes and changing skill needs	94%	50%	43%	50%	63%	67%	81%	21%	38%
Low quality of trainers and mentors	94%	50%	46%	50%	78%	0%	76%	33%	31%
Low educational qualifications of workers	89%	67%	67%	70%	63%	67%	81%	55%	62%
Lack of trainers and mentors	97%	60%	58%	55%	88%	33%	76%	40%	62%
Lack of appreciation/ information about training	94%	69%	75%	70%	63%	33%	86%	55%	62%
Lack of specialized training institutions	86%	63%	78%	50%	50%	67%	71%	53%	69%
Lack of full appropriability of the return from training investment.	92%	57%	61%	60%	38%	67%	62%	58%	54%
Lack of interactions between training institutions and firms	94%	61%	61%	60%	63%	67%	67%	47%	77%
Lack of finance to cover the cost of training	97%	69%	74%	60%	63%	100%	76%	68%	54%
Lack of training materials and equipment	97%	64%	71%	55%	63%	67%	86%	35%	69%
High rate of mobility of trainers to move for better paid jobs after training	89%	69%	61%	75%	63%	100%	76%	63%	62%
Lack of a system of training certification of skills acquired	92%	50%	52%	55%	38%	33%	71%	37%	38%
Total response		56	24	20	9	3	21	21	13

Source: Own calculation based on the macro survey (2010) and firm survey (2010).

C. Consequences of the low educational qualifications of unskilled workers at the micro/firm level

From Tables 2-3 above we find that one serious problem in the Sudan is the high share of unskilled workers in total employment. In this section we show that next to the consequences of the deficient educational system at the macro level, the high incidence of unskilled workers also causes several serious implications at the micro/firm level.

a. Low skill level and skills mismatch at the micro/firm level[29]

From the demand perspective, the results of the firm survey can be used to argue that firm demand for low skilled workers leads to an excessive share of low skilled workers. On the other hand, from the supply perspective, our findings from the firm survey show that the excessive share of low skilled workers has direct implications in

and for two-thirds of the respondent firms, the provision of training was limited to on-the-job training. The study concluded that the UAE does not have a training-led employment culture. Employers have become used to bringing in their workers from outside the country with readymade skills and replacing them with similarly skilled workers. There has been little incentive to provide skill upgrading except in response to immediate needs such as the introduction of new technology. The local training industry has suffered from the uncoordinated nature of provision and the very limited contribution by public sector organisations and higher education institutions to this variety of provision. Most of training provision has been in low-investment, low-cost and quick-profit areas such as marketing, public relations, sales, computer awareness and management development. The private sector training is relatively undeveloped and un-coordinated, and has limited market due to both limited demand and limited supply. Moreover, the provision of public sector training is constrained by the inadequate involvement of public education institutions. For instance, the Higher Colleges of Technology (HCTs) had little involvement in the important area of adult technical education, including vocational training and retraining (Gray, 1999: 15, 33-34, 43). Additionally, the findings of Abdelkaraim and Haan (2002) show that the UAE public sector training is still limited due to less attention, awareness and resources (Abdelkaraim and Haan, 2002: 15).

[29] It is convenient in this paper to briefly indicate the consequences with respect to low skill and skills mismatch at the micro level and to discuss this more fully later in Nour (2011). That serves our aim in this chapter to compare and integrate the macro-micro consequences of low skill level. This brief discussion in this chapter also substantiates the third hypothesis in Section 1 above about the interaction between the deficient educational system at the macro level and the high incidence of unskilled workers at the micro level and the serious implications on low skill levels and skills mismatch. It is appropriate to discuss the skills mismatch problem more extensively later in Nour (2011), where we provide a broader, more in-depth and coherent analysis of skill problem and the implications of the prevalence of low-skilled workers at the micro/firm level.

lowering skill levels at the micro/ firm level. For instance, Table 6 and Figure 3 below show that across firms the average percentage share of low skilled workers (66% and 74%) is much higher than that of high-skilled workers (34% and 26%) defined by both educational and occupational classifications respectively. Moreover, Tables 5 and 6 show that the poor educational qualifications of firms workers lead to poor provision of training – see our discussion above – and a serious skills mismatch across firms- see Figure 4 below; see also Nour (2011).[30]

Table 6 – Main technology and skill indicators defined by firm size and industry in the Sudan, 2010

Indicator	All Firms	industry				size		
		Chemical	Food	Metal	Textile	Large	Medium	Small
Skill and skills mismatch indicators								
Share of high skilled (education) (%)	34%	35%	33%	31%	39%	42%	32%	25%
Share of high skilled (occupation) (%)	26%	27%	25%	21%	32%	25%	26%	29%
Share of low skilled (education) (%)	66%	65%	67%	69%	61%	58%	68%	75%
Share of low skilled (occupation) (%)	74%	73%	75%	79%	68%	75%	74%	71%
Share of firm conducting R&D (%)	20%	23%	13%	17%	40%	29%	10%	19%
high skilled wages /low skilled wages	3.5	3.7	3.45	2.96	3.6	4.2	3.1	2.98
Share of firm with skills mismatch (%)								
The high skilled group (%)	40%	38%	44%	22%	60%	58%	36%	17%
The medium skilled group (%)	31%	24%	38%	44%	20%	30%	40%	13%
The low skilled group (%)	45%	39%	39%	71%	60%	43%	53%	38%
Technology indicators								
Share of R&D expenditure/total output (sales value) (%)	0.17	0.12	0.36	0.01	0.11	0.19	0.05	0.225
Average R&D expenditure (x 1 million Sudanese Pound)	0.5	0.65	0.5	0.5	0.1	0.6	0.002	0.5
Number of R&D employees (R)	1≤R≥11	1≤R≥11	1≤R≥11	1≤R≤10	2≤R≥11	1≤R≥11	1≤R≤10	1≤R≥11
Number of full time R&D employees	1≤R≥11	1≤R≤10	1≤R≤10	0	2≤R≥11	1≤R≥11	1≤R≤10	1≤R≤10
Number of full time R&D employees	1-11	1-10	1-10	0	2-11	1-11	1-10	1-10
Number of part time R&D employees	1≤R≥11	1≤R≥11	1≤R≥11	1≤R≤10	0	1≤R≥11	1≤R≤10	1≤R≥11
Number of part time R&D employees	1-11	1-11	1-11	1-10	0	1-11	1-10	2-11
Share of firm applying for patents (%)	6%	8%	3%	8%	0%	6%	8%	5%
Share of firm in total spending on ICT (%)	100%	50%	30%	11%	9%	37%	33%	30%
Share of firm in total spending on ICT training (%)	100%	13%	63%	13%	13%	50%	25%	25%
Share of firm in total spending on ICT (%)	62%	71%	52%	46%	100%	57%	62%	76%
Share of firm with spending on ICT training (%)	9%	3%	16%	8%	20%	11%	7%	10%
Average Spending on training (x 1 million Sudanese Pound	14.42	21.28	2.65	2.00	5.01	18.38	1.06	10.00
Number of training employees	5.77	2.25	2.33	0	25	7	2.5	3.5
The degree of automation/use of sophisticated technologies[31] (%)	54%	35%	67%	61%	80%	68%	55%	35%
Dependence on foreign technology[32] (%)-q18	49%	49%	58%	25%	60%	51%	38%	63%
Dependence on foreign technology-q-19(%)	100%	100%	100%	100%	100%	100%	100%	100%
Share of firm providing training (%)	27%	34%	15%	27%	40%	34%	26%	17%
Incidence of external schooling effect (%)	77%	72%	74%	91%	100%	81%	74%	74%
Dependence on foreign technology- 1- q-21	56%	58%	56%	46%	57%	57%	48%	62%
Dependence on foreign technology-2-q22	45%	35%	46%	65%	51%	45%	53%	31%
Factors constrained the contribution of R&D unit to adaptation of imported technologies								
(a) Shortage of finance	78%	71%	83%	83%	75%	82%	81%	65%
(b) Shortage of human resources skilled & qualified workers	74%	68%	80%	75%	75%	81%	67%	70%

Source: Own calculation based on the firm survey (2010).

[30] We define the mismatch as the differences between the required and actual education. Actual education refers to high (university and above), medium (secondary) and low (below secondary) levels of attained years of education that represent the supply of skills. We define the required education by the required qualifications for each of the occupational classes translated into average years of schooling that represent the demand for skills. We observe that the inconsistency between the required and actual education implies inconsistency between demand for and supply of skills, which we interpreted as skills mismatch - cf. the detailed discussion in Nour (2011).

[31] We measure the degree of automation/ sophisticated technologies qualitatively, we asked firms about their own appreciation or evaluation of the level of technologies they are using in their production.

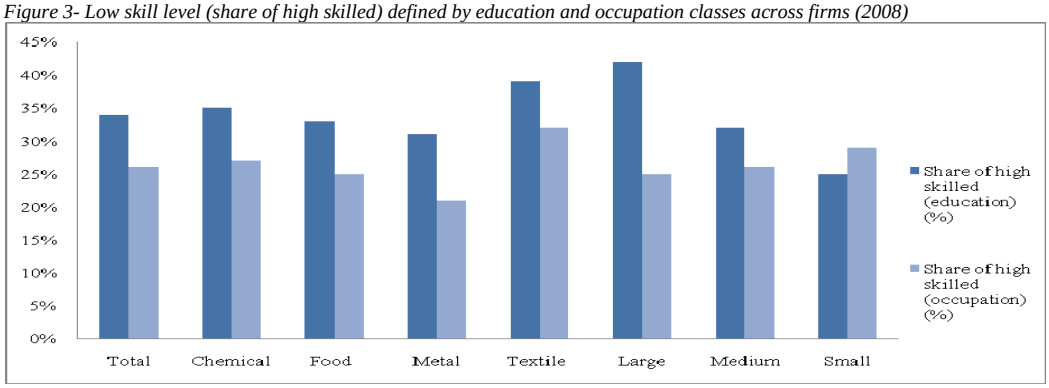
[32] We measure the dependence on foreign technologies qualitatively, we asked firms if they have an adequate capacity/ability to produce and develop local technologies and if they have purchased equipment, machines and techniques from abroad. Our definition also includes quantitative measurement of the value of imported capital equipment to total capital equipment, the percentage value of capital equipment to total capital equipment that has been built by foreign companies. Finally technology transfer is also an indicator of dependence on foreign technologies- see Table 9 below.

Table 7– Weak Technology indicators and dependence on foreign technologies (%) in Sudan (1999-2008)

Year	Total researcher[a]	Total gross domestic expenditure on R&D (GERD)[a]				Patent applications (non resident and residents)[b]	% of population accessing the Internet (per 100 population)[b]	Dependence on foriegn technologies[c]
		GERD by sector of performance (%)[a]						
		R&D (% GDP)[a]	Business enterprise[a]	Government[a]	Higher education[a]			
1999	9100	0.53%	31.5%	38.5%	30.1%	6	0	60
2000	900	0.47%	31.5%	38.9%	29.5%	22	0	64
2001	9340	0.44%	31.5%	39.3%	29.2%	14	0	67
2002	11208	0.39%	31.8%	39.0%	29.2%	22	0	67
2003	7300	0.34%	31.9%	39.0%	29.1%	17	1	72
2004	7500	0.29%	33.6%	38.3%	28.1%	21	1	77
2005	7850	0.28%	33.7%	39.2%	27.1%	22	1	78
2006	7850	0.28%	33.7%	39.2%	27.1%	16	8	80
2007	7850	0.28%	33.7%	39.2%	27.1%	16	9	82
2008	7850	0.28%	33.7%	39.2%	27.1%	16	9	82

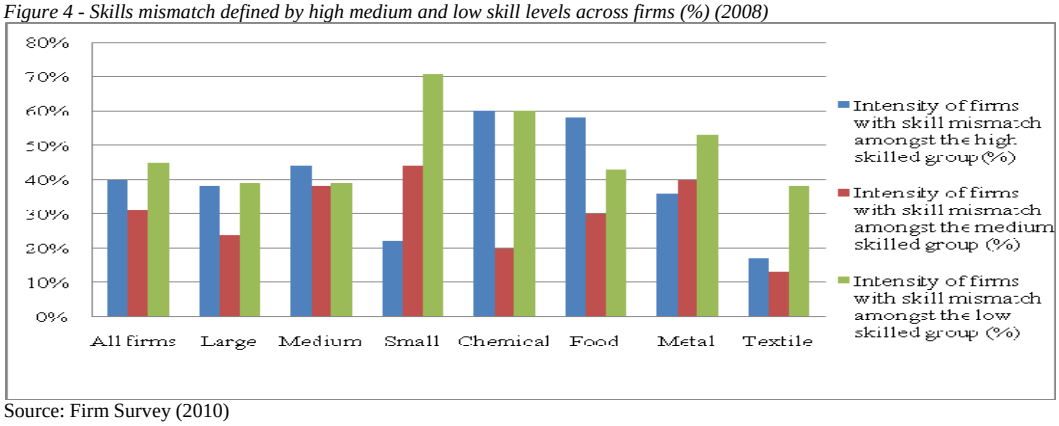
Sources: (a) UNESCO R&D Statistics (2006), (b) World Development Indicators database (2011); (c) The dependence on foreign technology is calculated from the Sudan Ministry of Foreign Trade and Central Bank of Sudan Annual Foreign Trade Statistical Digest various issues (1992-2010)[33]

Figure 3- Low skill level (share of high skilled) defined by education and occupation classes across firms (2008)



Sources: Firm Survey (2010)

Figure 4 - Skills mismatch defined by high medium and low skill levels across firms (%) (2008)



Source: Firm Survey (2010)

b. weak technology indicators

From the demand perspective, the results of the firm survey can be used to argue that weak technology indicators lead firms to demand and rely heavily on low skilled workers. On the other hand, from the supply perspective, the excessive share of unskilled workers leads to weak technology input-output indicators across firms. From Table 6 above, we observe that a weak R&D indicator appears from the following: (a)

[33] The dependence on foreign technology is defined the share of chemicals, manufactured goods, machinery and equipment, transport equipment in total imports.

The limited R&D activities/efforts performed continuously or occasionally amongst only 20% of all the respondents firms; (b) The limited R&D activities and expenditures particularly devoted/aimed at improving firm product and to produce a new product; (c) The low R&D expenditures and R&D expenditures as percentage of total output expenditures. For instance, amongst all the respondent firms, average R&D expenditure was around 0.5 million Sudanese pounds,[34] while the average R&D expenditures as a percentage of total output (sales value) amongst all the respondents firms accounted for only 0.2%; (d) The low number of both full time and part time R&D employees. For instance, a large majority (91% and 89%) of the respondents firms with R&D activities have no or a low number (1-3) of full time research employees and/or part time research employees respectively. Only few (9% and 11%) of total firms have more than three full and part-time research employees respectively. Only few firms have more than eleven full and part-time research employees.[35] Only few firms have (6-10) full and part time research employees.[36] Moreover, the contribution of research units in adapting the imported technologies is constrained by a shortage of skilled and qualified workers amongst 74%, 68%, 80%, 75% and 75%, 81%, 67% and 70% of all firms, chemical, food, metal, textile, large, medium and small firms respectively- see Table 8 below.[37] In addition, the contribution of research units in adapting the imported technologies is constrained by a shortage of finance amongst 78%, 71%, 83%, 83% and 75%, 82%, 82% and 65% of all firms, chemical, food, metal, textile, large, medium and small firms respectively. Moreover, the follow-up interviews with the officials and firms managers revealed that R&D activities are constrained by several factors such as high costs and low public and private spending, lack of information systems, and the absence of a R&D culture due to inadequate awareness and concern. Further constraint relates to a lack of entrepreneur perspective. Additional constraints relate to the poor coordination between the institutions engaging in R&D activities, either due to the absence of explicit government policy or the ineffective role of a central body (e.g. government) to coordinate and promote R&D efforts and motivate collaborative research efforts between the firms sector and

[34] The value is measured in the Sudan local currency: Sudanese Pounds, which equalled US$ 2.50 Dollars when the survey was held (2010).
[35] As reported by 5%, 3% 7%, 20%, 9% and 5% of the all firms, chemical, food, textile, large and small respondent firms respectively.
[36] As reported by 15%, 22%, 10%, 17%, 20%, 14% and 10% of the all firms, chemical, food, metal, large, medium and small respondent firms respectively.
[37] We measured the contribution of a research unit to adapt the imported technologies qualitatively, by asking firms how the research unit contributed to adapting imported technologies. In addition to a lack of qualified workers, there may also be other

university sector. In addition to weak network systems, R&D efforts, in particular, are limited across firms because of a lack of entrepreneur perspective and weak contact and collaboration with the university sector; this is probably attributable to the fact that the university sector is lacking resources or concern and interest to conduct joint research with the firms sector.[38] Moreover, Table 6 above shows the weak technology output indicator as measured by patent applications.[39] For instance, in the year 2008, only 6% of all respondent firms applied for a patent; the low degree of patenting may be attributable to low R&D efforts. These results confirm our second hypothesis in Section 1 above that the major causes of low level of local technology are low/ a lack of R&D activities due to a lack of skills, entrepreneur perspective, transfer of knowledge, networks and collaborations between universities and industry/firms.

Our results regarding the poor technology indicators (R&D and patent) and heavy dependence on foreign technologies at the micro level are consistent with the results reported in Table 7 above at the macro level, the observations from the general literature (UNDP, 2001) and results in the Sudanese literature at the macro level (Nour, 2010) which imply the poor technology indicators (R&D and patent) and heavy dependence on foreign technologies at the macro level in Sudan-see Table 7 above. Our findings concerning the low levels and problems hindering R&D at the micro level are also consistent with the results in the Sudanese literature at the macro level (Nour, 2010) which imply that the low level of R&D and the main problems hindering R&D at the macro level include lack of finance from public sector; lack of management and organization ability; lack of coordination and weak relationship, network, consistency and cooperation between universities and higher education institutions and productive

factors such as a lack of incentives or pressure to adapt or master imported technologies as firms can always opt to buy the required technologies or techniques.

[38] This can also be interpreted as a lack of demand-pull since firms can buy all technologies or techniques. Our findings are consistent in some respects with the findings in the UAE as discussed in Nour (2005) and Haan (1999), who notes" R&D capacity in the UAE is presently very limited. While some research is taking place at the University and other institutes of higher education, it is -as usual in such institutions- more geared towards pure science and tends to have only limited relevance for the productive sector. While the Higher Colleges of Technology place emphasis on more practical training, hardly any R&D takes place, only as a by-product of the training. Within the private sector in the UAE likewise very few R&D activities are going on. Most manufacturing and other firms tend to rely on imported technologies (both in terms of hardware and software), as well as imported materials and even expatriate manpower. There is very little interest in carrying out research, and the R&D activities are small-scale in nature and mostly only concern -minor- adaptations to the companies' own products. In all it is estimated that less than 1% of turnover is used for this purpose. The parastatel sector, in which a number of large basic industries are operating, will do better. There is also some agricultural research ongoing. Without such R&D facilities and efforts, the UAE is almost completely dependent on imported technologies. And without the necessary adaptations to local conditions (e.g. temperatures, effects of dust and sand winds, special cultural aspects, the country's socio-political system, etc.), even these technologies cannot be optimally applied. Moreover, a genuine technology culture to motivate the involvement in R&D and promotion of local technology is now absent in the UAE. The UAE society is geared more predominantly to non-technical education, training and employment. Technical qualifications and occupations are not rated very high by its social values and cultural traditions. The UAE only has a limited industrial tradition (e.g. trade), and lacks explicit policies to stimulate and direct technological development" (Haan, 1999: 37-38).

sector (agriculture, industry, services), lack of R&D culture, lack of finance from private sector, lack of favorable conditions and necessary facilities; lack of awareness and appreciation of the economic values of R&D, lack of human resources (researchers and qualified workers in R&D fields) respectively.

In addition, a lack of R&D efforts may hinder innovative activities across firms. The increasing uses of technology has encouraged the incidence of product and process innovations, in particular, the incidence of incremental product innovation, namely, improvement of product quality amongst 59% of all respondent firms. It has also encouraged the incidence of new product, new organizational method, new combination of old output, new method of production, and new process.[40] It has also encouraged the incidence of considerable effect on increasing total sales and total profits, but it has only slight effect on reducing total costs– see Table 8 below.[41]

Table 8 - The effects of increasing use of technology product and process innovations across firms in the Sudan, 2006-2009

Product / process innovation (2006-2009)	**All firms**	**Firm industry**				**Firm size**		
		Chemical	Food	Metal	Textile	Large	Medium	Small
Improvement of product quality.	59%	69%	55%	33%	60%	68%	50%	53%
Production of a new method of production.	40%	44%	30%	42%	60%	49%	25%	47%
Production of a new combination of old output.	43%	50%	38%	25%	60%	59%	29%	37%
Production of a new process.	35%	22%	40%	33%	100%	46%	18%	37%
Production of a new product.	66%	50%	73%	83%	100%	60%	68%	74%
Production of new organizational method.	44%	56%	31%	33%	60%	53%	32%	42%
Improvement of training within the firm.	52%	57%	45%	42%	80%	59%	46%	44%
Improvement of communication within the firm.	57%	66%	52%	42%	60%	65%	54%	44%
Production of more output with low cost.	57%	61%	50%	50%	80%	74%	43%	42%
Production of the same output with low cost.	37%	44%	38%	25%	0%	38%	36%	32%
Open of a new market.	50%	58%	52%	25%	40%	62%	50%	32%
Production of a new service.	28%	33%	21%	17%	60%	35%	25%	21%
Improvement of process of personal selection.	38%	40%	38%	25%	60%	50%	21%	39%
Total response	83	36	30	12	5	35	28	19
Reduction in per unit material costs.	21%	22%	19%	29%	25%	24%	14%	28%
Reduction in per unit energy costs.	28%	36%	21%	17%	20%	20%	25%	46%
Reduction in total cost.	35%	37%	29%	50%	25%	25%	37%	46%
Increase in total sales.	85%	92%	68%	100%	100%	87%	78%	93%
Increase in total profit.	81%	86%	76%	72%	100%	85%	76%	85%
Total response	64	28	24	7	5	26	24	14

Source: Own calculation based on the firm survey (2010).

c. dependence on foreign technology

From the demand perspective, the results of the firm survey can be used to argue that the dependency on foreign technology leads firms to demand and rely heavily on low skilled workers. On the other hand, from the supply perspective, the deficient educational and training system and a high supply of low skilled workers lead to low skill levels, lack of knowledge transfer and low capability to build and promote the

[39] As reported by 6%, 8%, 3%, 8%, 6%, 7% and 5% of the all firms, chemical, food, metal, large, medium and small respondent firms respectively. This includes five firms: one small chemical, one medium chemical, one medium metal, two large chemical and one large food firms applied for patent.

[40] As reported by 66%, 44%, 43%, 40% and 35% of all respondent firms respectively.

local technology. The results of the firm survey show that this condition leads to weak technology indicators and dependence on imported technology that appears from the following: (1) The high dependence on the imported equipment, machines and techniques among all of the respondent firms (100%). (2) The high percentage value of capital equipment to total capital equipment that has been built by foreign companies (56%) among the respondent firms. (3) The considerable percentage value of imported capital equipment to total capital (45%) among the respondent firms in the year 2008. (4) The short run plan for 92% of the respondent firms is based/ depends on imported technology.[42] The main reasons for the dependence on foreign technology are the lack of local technology from local suppliers, better quality and better price of foreign technology in that order.[43] Despite the high dependency on imported technologies, it is somewhat surprising that the level of technology used is below to international standards amongst majority of the respondent firms (53%) and a high level of technology used similar to international standards is limited only within 47% of all the respondent firms. Moreover, somewhat surprising a high degree of automation through the use of sophisticated and advanced technology is limited only within 54% of all the respondent firms- see Table 6 above. The degree of automation/ sophisticated use of advanced technologies is determined by both firm size and industry/activity.[44]

The dependence on foreign technologies also appears from the reported information on the transfer of foreign technology that is made through different channels. For instance, Table 9 below illustrates that hiring foreign skills/ technologically advanced workers/ consultants and FDI are more common channels of technology transfer, while strategic alliances, technology licensing and joint ventures are less preferred channels. The transfer of technology, mainly the transfer of technologically advanced workers/consultants, has induced important effects in enhancing firm production but has slight less effect in enhancing the capacity to develop the local technologies.[45]

[41] The terms new product and new process refers to new products and processes intended even just for local firm or for local market and not necessarily for the international market.
[42] Short, medium and long run refers to next three years, next three to five years and next ten years respectively.
[43] As reported by 71%, 42% and 14% of the respondent firms respectively.
[44] These results are consistent with the findings in the UAE as indicated by Nour (2005) and El Sabaa (1997), who notes "The adoption of different approaches in transferring technology differs according to certain criteria, such as: the scale of industry and its activity. Large size and some specific sectors, namely chemical and petrochemicals industries have better use of sophisticated advanced technologies" (El Sabaa, 1997: 21-22).
[45] These results are consistent in some respects but differ in others with the findings in the UAE as indicated by Nour (2005), El-Sabaa (1997) and Haan (1999) respectively. "The major channels of technology transfer are: joint ventures, and industrial foreign projects, the latter accounts for the first source of technology transfer. The turn-key projects are preferred channel of technology transfer in the Gulf region mainly because of the keenness to avoid defects of execution and to guarantee the maximum consistency of the project's design, lines of production, quality of the products, facilities of training, etc. But it has very limited

Table 9- The channels of technology transfer and their effects on firm production and development of local technology across firms in the Sudan, 2010

(a) Channels of technology transfer (2005-2009)	All firms	Chemical	Food	Metal	Textile	Large	Medium	Small
Hiring foreign skills/technologically advanced workers/ consultants	48%	56%	35%	62%	40%	57%	39%	50%
FDI	31%	28%	32%	31%	40%	40%	29%	20%
Strategic alliance	18%	22%	20%	8%	0%	21%	11%	25%
Licensing	15%	19%	13%	8%	20%	18%	21%	5%
Joint ventures	7%	8%	7%	0%	20%	9%	7%	5%
Others (e.g. in house technology development by hiring technologically advanced persons)								
Total response (2005-2009)	85	36	31	13	5	35	28	20
(b) The effects of technology transfer in (2005-2009)	All firms	Chemical	Food	Metal	Textile	Large	Medium	Small
Enhancing firm production	96%	95%	96%	100%	100%	100%	97%	90%
Enhancing the capacity to develop the local technologies	85%	90%	73%	93%	100%	92%	82%	75%
Total response (2005-2009)	85	37	30	13	5	35	29	20
(c) The effects of technologically advanced workers in	All firms	Chemical	Food	Metal	Textile	Large	Medium	Small
Enhancing firm production	91%	95%	90%	85%	100%	91%	93%	90%
Enhancing the capacity to develop the local technologies	81%	89%	70%	85%	80%	92%	75%	70%
Total response (2005-2009)	84	36	30	13	5	35	28	20

Source: Own calculation based on the firm survey (2010).

In the firm survey questionnaire the question on the channels of technology transfer allows for multiple answers, assuming that firms may choose more than one channel to transfer technology.[46] Our results indicate that the all respondent firms are less interested in transferring technologies through formal licenses. These may not be often requested, probably because of more liberalized and open market policies that led to considerable presence of foreign capital investment and allowed for foreign and mixed ownership – cf. Nour (2011).[47]

role in transferring technology to local industry, because it is confined to their plants, with no minimum leakage allowed. Thus they contribute nothing to implant advanced technologies in the country. Technology transfer to the UAE has obviously contributed to accelerating industrial and economic growth, elevating the standard of national products both quality- wise and quantity-wise. In particular, the transfer of technology contributed to rapid growth of local industrial sector. However, a number of negative factors are still adversely affecting the transfer of technology; the technologies transferred could hardly approach its target of constituting an autonomously developing local technological base, similar to those in the Far East industrial countries. Because of: the inadequate awareness of the end target of technology transfer, the lack of a constitutional framework or comprehensive plan for transferring technology, the insufficient local base of technological data, the lack of qualified local manpower necessary for transferring technology and the contracts of technology transfer" (El Sabaa, 1997: 23-26)."…….The UAE is almost completely dependent on imported technologies. And without the necessary adaptations to local conditions (e.g. temperatures, effects of dust and sand winds, special cultural aspects, the country's socio-political system, etc.), even these technologies cannot be optimally applied" (Haan, 1999: 38).

[46] Our assumption and respective findings are plausible and consistent with the results in the UAE as indicated by Nour (2005) and the results of El-Sabaa (1997), which indicate numerous different channels of technology transfer to the UAE, such as: foreign industrial investments, offset programs, training missions, technological imports, industrialization licenses, patents, technological products, foreign manpower and industrial consulting offices (El Sabaa, 1997: 26).

[47] For instance, according to Sudan Ministry of Investment among the efforts which aim at promoting foreign investment, the government has issued the investment encouragement law which grants encouraging exemptions to investors and indicates that the investor has the right to operate without a Sudanese partner. In addition, in order to promoting foreign investment the government has established free zones which include: Suakin Free Zone and Aljaily Free Zone. The Free Zones and Free Markets Law (1994) represents the legislative framework for the establishment and operation of free zones and markets in Sudan. The rules resultant from this law represents the organizational framework for operating and managing free zones in Sudan. This law provides several advantages of investment in free zones, for instance the industrial, commercial or service investments which are licensed to be established in the free zones enjoy several advantages. This includes the following: exemption of the projects from profits tax for a period of 15 years, renewable for an extra period dependant on the decision made by the concerned minister commencing from the 1 year period of grace which follows the year of commencement of production; salaries of expatriates working in projects within the free zones will be exempted from the personal income tax; exemption of products imported into the free zone or exported abroad from all customs fees and taxes except service fees and any other fee imposed by the board of

These findings on weak technology indicators and dependence on foreign technologies at the micro level are consistent with those at the macro level and the interaction of these findings lead to a large technological gap– see also our results in Table 7 above and Nour (2010). Our results in this paper and Nour (2010) imply that in the short and medium term, the Sudan is unable to rely on local technologies and remain heavily dependent on foreign technologies.

Our findings in this section verify our first hypothesis in Section 1 above that the interaction between the deficient educational system -caused by low quality of education- and the high share of unskilled workers leads to poor provision of training; low skill levels; skills mismatch; low transfer of knowledge/external schooling effect; weak technology indicators and dependence on foreign technologies at the micro level.

Our findings from the firm survey confirm our fourth hypothesis and show that both skill and technology indicators, product and process innovations, the channels of technology transfer and their respective effects vary enormously across firms and seem determined by both firm size and industry level. For instance, Table 6 above shows that skill levels, technology input–output indicators (R&D and patent), the provision of training (upskilling), the dependence on imported technology, the degree of automation and the use of sophisticated and advanced technology vary across firms and increase with firm size and industry level. Moreover, the use of ICT and provision of ICT training increase with firm size, while the transfer of knowledge/ external effects of schooling increase with industry level.

d. Shortage of skilled workers and weak adaptation of imported technologies

From the demand perspective, the results of the firm survey can be used to argue that low supply of skilled workers lead firms to demand and rely heavily on low skilled workers. On the other hand, from the supply perspective, our findings show that the excessive share (supply) of low skilled workers and low supply of high skilled workers lead to some shortage of skilled workers, since firms are experiencing increasing

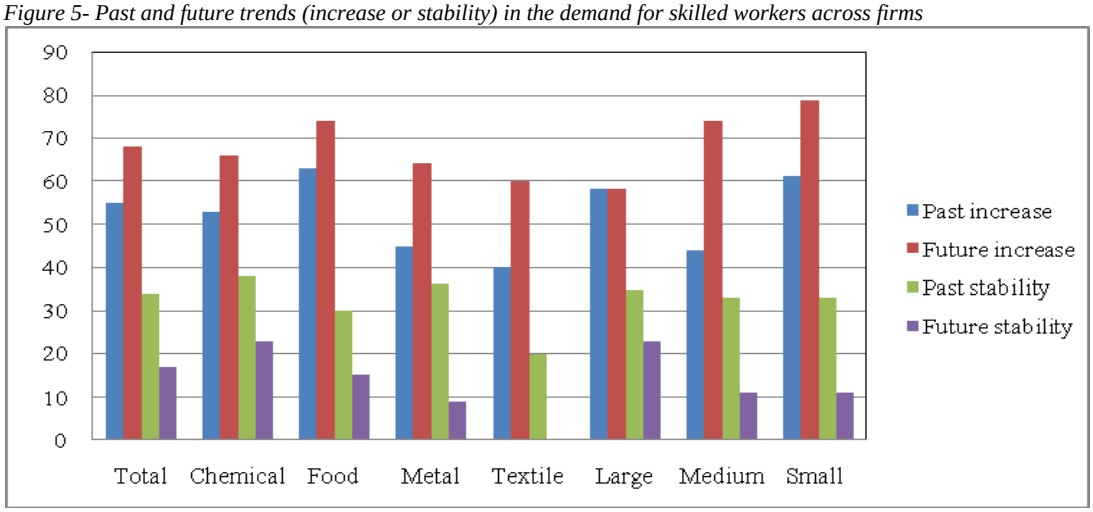
the Sudan Free Zones Company; real estate establishment inside the free zones area are exempted from all taxes and fees; invested capital and profits are transferable from Sudan to abroad through any bank licensed to operate in the free zone and exemption of products of industrial projects established in the free zones from customs fees; depending on materials used and local costs incurred in production, provided that the value be estimated by a committee assigned for this purpose by the board of the Sudanese Free Zones Company- see Sudan Ministry of Investment, accessed on January 30, 2011 " http://www.sudaninvest.org/English/Sudan-Invest-FreeZone.htm " . These results are consistent with the findings in the UAE as indicated in Nour (2005). For instance, Fasano (2002) indicates that other than Abu Dhabi, the emirates have established free zones that allow 100 per cent foreign ownership of companies. These zones are particularly important in Dubai, where they have attracted a large number of foreign companies (Fasano, 2002: 331). El Sabaa (1997) finds that the adoption of open market philosophy, supported by the existence of nine free zones in the seven emirates and the advantage of 100% foreign ownership and control, encourages foreign industrial investors to set up their projects and to promote technology transfer to the UAE (El Sabaa 1997: 23).

demand for skilled workers, see Figure 5 below. We find that the increasing demand for high skilled workers is related to increasing use of new technologies, which has not only raised the demand for these workers in the past few years, but has also encouraged firms to predict a future/long run increase in this demand. For instance, Figure 3 identifies and compares past and future trends of the demand for skilled workers, which vary enormously across firms according to size and industry level. According to 68% of the respondent firms, the interpretations of the predicted long run increase in the demand for skilled workers are related to expansions of production, project plans, increasing R&D activities, implementation of new processes, output technologies, advanced control systems and purchases of new machines and equipment. Additional reasons for the rising demand are the increasing adoption of international standards and enhancement of production, product diversification, market share, turnover, sales, shortage of manpower, competition, increasing motivation to reduce costs, increasing production, achieving high standard precision work and improving productivity and quality of work and demand for more specialized skills in IT. On the other hand, the major explanations for the predicted long run stability in the demand for skilled workers across 17% of all respondent firms is related to the stability in quantity of production, sales, business, demand and market; as well as to the lack of a plan for critical expansion of product operations, potential stability in substituting and replacing the outgoing skilled worker in any field and, the use of automated technology.

We observe that the expected future rise in the demand for high skilled workers across firms is reasonable since increased use of skilled workers in the past has had significant effects. In particular, there has been increase in firm production, improvement in product quality, improvement in the level of competitiveness in the local market, utilization of technology and faster adaptation of foreign technology.[48] On the other hand, our results from the firm survey indicate that the relative shortage of skilled workers amongst 41% of the respondent firms leads to serious delay, slight abolishment/cancellation of project implementation and constrains the R&D units in adapting imported technologies – see Table 10 below.[49]

[48] As indicated by 83%, 81%, 73%, 73% and 65% of the respondent firms respectively
[49] As indicated by 31%, 24% and 74% of the respondent firms respectively.

Figure 5- Past and future trends (increase or stability) in the demand for skilled workers across firms



Source: Firm survey (2010)

Table 10 - The shortage of skilled workers and effects across firms in the Sudan, (2006-2009)

Shortage of skilled workers and effects on firm projects	All firms	Chemical	Food	Metal	Textile	Large	Medium	Small
Shortage of skilled workers	41%	44%	43%	36%	20%	47%	39%	37%
Effects of shortage of skilled workers on firm projects								
Serious delay of firm project	31%	39%	21%	45%	0%	31%	25%	42%
Abolishment/ Cancellation of firm project	24%	23%	21%	9%	0%	22%	22%	16%
Constrained the R&D units to adapt the imported technologies	74%	68%	80%	75%	75%	81%	67%	70%
Total response	82	36	29	12	5	32	28	20

Source: Own calculation based on the firm survey (2010).

Our analysis of the shortage in skilled workers is based on the economic interpretation and definition of 'skilled shortage' as scarcity or lack of sufficient skilled workers needed, mainly because the supply of skills (as shaped by systems of education and training) has not responded fully to the rising demand across firms. However, managers may have a different interpretation and understand this as a lack of sufficient skilled workers in conjunction with wages constraints, due to limitations on their ability to pay higher wages for the high skilled workers they demand. This may constitute a limitation and appropriate caution should be exercised in interpreting our results with respect to skilled shortage, mainly because the firms answered the questionnaires do not really make it very clear how they have perceived the shortage of skilled workers and their further consequences.

3. The impacts of skill upgrading and technological upgrading: Micro-Macro views

In view of the above findings and our results in Nour (2010) on poor skill and technology indicators, it is therefore essential to recommend further incentives to upgrade both skill and technology levels at both micro and macro levels. From that perspective, our results in Table 11 below show that at the micro level the upskilling

plan amongst 54% of the respondent firms induced significant effect in enhancing firm production, facilitating the effective utilization and upgrading of technologies and upskilling national workers in the firm. But it has only relatively a slight less effect on reinforcing the employment of national skills, hiring more skilled national workers and reducing future demand for foreign workers. Moreover, technological upgrading induced significant effects in enhancing firm production and upskilling via raising skill levels and upskilling national workers in the firms, but it has relatively a slight less effect on both reinforcing firm ability to promote the local technology and hiring more skilled national workers.

Table 11 - The effect of upskilling plan and technological upgrading across firms in the Sudan, 2010: Micro view

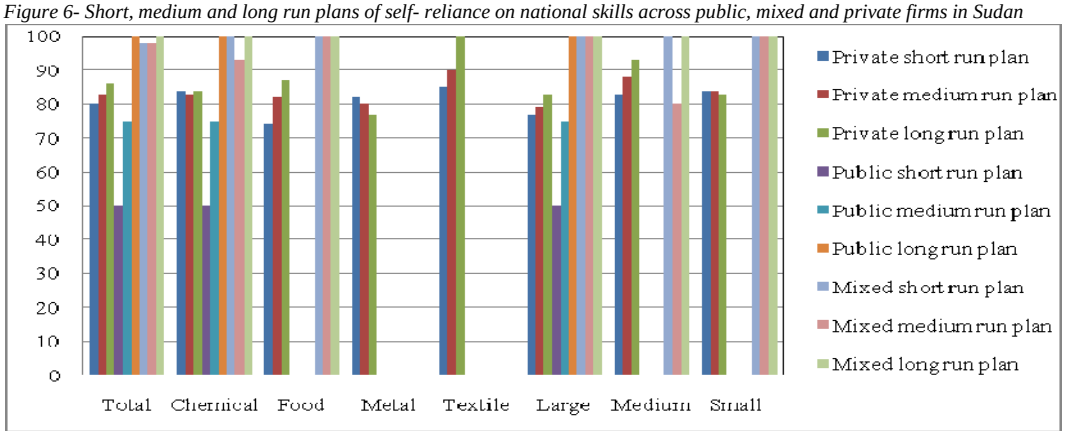
(a) Upskilling plan and its impacts, self-reliance strategy	All firms	Chemical	Food	Metal	Textile	Large	Medium	Small
General Upskilling plan	54%	46%	52%	82%	60%	55%	59%	42%
Self reliance on national skills- adequate availability of national workers	90%	89%	93%	91%	80%	81%	96%	94%
Self reliance on national skills: plan for dependence on national skill even in restricted fields	94%	92%	93%	100%	100%	94%	96%	89%
Self reliance on national skills- in the short, medium and long run	86%	85%	91%	80%	92%	85%	91%	92%
(b)The effect of general upskilling on								
Enhancing firm production	92%	92%	89%	100%	100%	94%	89%	95%
Facilitating effective utilization and upgrading of technologies	95%	97%	89%	100%	100%	97%	100%	82%
Hiring more skilled national workers.	63%	64%	59%	64%	80%	69%	59%	58%
Upskilling national workers in the firm.	89%	89%	81%	100%	100%	94%	78%	95%
Reducing future demand for foreign workers	61%	53%	70%	55%	80%	78%	52%	42%
Reinforcing the employment of Sudanese national skill workers.	79%	88%	67%	73%	100%	81%	78%	76%
(c) The effects of technological upgrading in:								
Enhancing firm production	99%	100%	100%	92%	100%	100%	96%	100%
Raising skill level	94%	92%	100%	83%	100%	91%	93%	100%
Reinforcing firm ability to promote the local technology	83%	89%	80%	83%	60%	80%	89%	80%
Total response	84	37	30	12	5	35	28	20
Upskilling national workers in the firm.	93%	95%	97%	75%	100%	97%	93%	85%
Hiring more national skill workers.	82%	78%	80%	92%	100%	89%	75%	80%
Total response	84	37	30	12	5	35	28	20

Source: Own calculation based on the firm survey (2010).

At the micro level, Figure 6 below compares the plans of public and private firms to depend on national skills. It predicts consistency between private and public firms that appears from the potential strong commitment to completely rely on national skills in the short, medium and long run plans in the large public firm. Moreover, our results from the firm survey and Figure 6 below show that managers of private firms have a somewhat optimistic view regarding the self-reliance on local skills and the potential role of both technological upgrading and upskilling in reinforcing the self- reliance strategy. For instance about 90% of the respondent firms have supported the argument in favor of adequate availability of Sudanese national skilled workers and 94% of the

respondent firms have plans to rely on national skilled workers even in restricted fields. Amongst all the respondent firms the plan for complete depending on the national skills (by 100%) over the long run reached 74% of the total skilled workers.

Figure 6- Short, medium and long run plans of self- reliance on national skills across public, mixed and private firms in Sudan



Source: Firm survey (2010)

In strong consistency and similarity to the above view, the macro survey shows that the respondent policy makers and experts are highly optimistic regarding the interactions between technological upgrading and upskilling and their roles in reinforcing economic growth, self-reliance on local skills and restructuring the labour market at the aggregate/ macro level. For instance, Table 12 below shows that the large majority of all respondent policy makers and experts predict strong linkages between both upgrading of technology and upskilling of labour force to reinforce each other and to have a similar large significant effect on reinforcing the self-reliance strategy and reducing unemployment rate. The official view predicts that the effect of upskilling is stronger than the effect of technological upgrading in both reinforcing economic growth and solving the mismatch and imbalances in the labour market and so reducing the potential future demand for foreign skilled workers. These results support our fifth hypothesis on the consistency of upskilling plans at the macro-micro levels.

Table 12 – The effects of technological upgrading, skill upgrading at the aggregate level in the Sudan2010: Macro view

The effects of technological upgrading	%	**The effects of skill upgrading**	%
Enhancing / accelerating upskilling.	94%	Enhancing/accelerating technological upgrading	100%
Increasing/reinforcing economic growth.	97%	Increasing/reinforcing economic growth.	100%
Reinforcing self-reliance strategy.	97%	Reinforcing self-reliance strategy.	94%
Reducing the future demand for foreign skilled workers.	92%	Reducing the future demand for foreign skilled workers.	94%
Reducing unemployment rate.	94%	Reducing unemployment rate.	94%
Solving the mismatch problem in the labour market: by increasing the match between educational and training output to match with the needs in labour market	97%	Solving the mismatch problem in the labour market: by increasing the match between educational and training output to match with the needs in labour market	100%

Source: Own calculation based on the macro survey (2010)

This consistency in optimistic views at the macro and micro levels, regarding the self-reliance on local skills and the role of both technology and upskilling in reinforcing it, imply that the self-reliance strategy is probably not only a preferred government strategy, but also probably favoured by firms. This is consistent with the observation that 92% of the respondent firms are private firms dominated by low skilled workers and probably realized the negative consequences of the lack the incentives/interests to rely on upskilling workers, mainly due to high costs of training and high salary requirements for high skilled workers. The respondents firms probably confronted with the challenges to initiate and maintain upskilling efforts. For instance, our findings from the firm survey indicate that the lack of finance to cover the high cost of training is mentioned by 69% of all the respondent firms and a lack of entrepreneur perspective, are among the important factors hindering the provision of training and hence upskilling of workers across firms at the micro level- see Table 5 above. The respondent firms, which are costs minimizers/profits maximizers, are probably willing to continue hiring cheap readymade skilled workers instead of incurring expensive costs by hiring, training and upskilling unskilled workers.

4. Conclusions

This paper uses the results of the macro and firm surveys to show the interaction between the deficient educational system and the high incidence of unskilled workers and their implications.

Our results in Section 2 above confirm that in the short and medium term, the Sudan is unable to rely on local technologies and remain heavily dependent on foreign technologies at the micro level. The major reasons are low levels of both skill and technology due to the deficient educational system and the high incidence of unskilled workers and their implications.

On the one hand, from the demand perspective, the results of the firm survey can be used to argue that firm demand for low skilled workers, weak technology indicators and dependency on foreign technology led firms to demand and rely heavily on low skilled workers. On the other hand, from the supply perspective, our findings in Section 2 show that the deficient educational system – due to low quality of education – and the excessive share of unskilled workers led to low skill levels, poor provision of training, serious skills mismatch, weak linkages, lack of a networks and hindered the transfer of knowledge. These factors interacted with each other and led to poor

technology indicators, poor indigenous capability to build the local technology and a heavy dependence on foreign technology. These results prove our first hypothesis in Section 1 above concerning the low skill and technology indicators at the micro-macro levels: the serious implications of the interaction between the causes and consequences of the deficient educational system and the high use of unskilled workers. We confirm our second hypothesis in Section 1 above that the major causes of low level of local technology are low/ a lack of R&D activities due to a lack of skills, a lack of entrepreneur perspective, transfer of knowledge, networks and collaborations between universities and industry/firms. We confirm our fourth hypothesis that skill and technology indicators are significantly determined by firm size and industry.

Our results show one surprising contradicting macro-micro view. Notably, contradicting optimistic-pessimistic micro and macro views regarding the incidence and success of knowledge transfer/ external schooling effect implies that, probably, the transfer of knowledge/ the external effects of schooling is successful within firms but is unsuccessful within society at large. This is probably because the transfer of knowledge is hindered by: low quality of education; the weak linkages and lack of networks between universities, colleges, technical and training institutes and the productive sectors; and the mismatch imbalanced structure of the labour market. We show that the major cause behind the low transfer of knowledge/external schooling effect is low educational qualifications, and deficient educational and training systems. The major consequences are the lack of networks and collaboration between universities and firms, low R&D efforts and low technology indicators. These results verify our third hypothesis in Section 1 above about the relative success of the transfer of knowledge/external schooling effect at the micro level, and the failure and factors hindering the transfer of knowledge/external schooling effect at the macro level.

Our observation from Section 2 implies consistency and similarity optimistic macro and micro views concerning the self-reliance on local skills, and the role of both technological upgrading and upskilling in reinforcing it, implies that the self-reliance strategy is probably not only a preferred government strategy, but probably is also one followed by private firms. Though driven by profit-maximizing considerations, private firms are likely to continue in hiring cheap readymade skilled workers rather than in hiring, training and upskilling workers with expensive costs. From these observations, our results accept our fifth hypothesis in Section 1 above about the consistency of upskilling plans at the macro-micro levels.

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