Chapter 8
The Importance (Impacts) of Knowledge at the Macro–Micro Levels

Abstract This chapter uses the firm survey (2010) data at the micro level and secondary data at the macro level to examine hypothesis 7 in Chap. 1 above concerning the importance/impacts of tacit and codified sources of knowledge at the micro and macro levels respectively in Sudan. Our results prove this hypothesis and show that at the macro level tacit knowledge and codified sources of knowledge are positively and significantly correlated with both schooling years and GDP growth (economic growth rate). At the aggregate level and macro level codified knowledge and the number of FTER show positive correlations with technology (patents) and imply a significant positive complementary relationship between tacit knowledge (measured by the number of FTER) and codified knowledge. At the micro (firm) level, we illustrate the importance of tacit knowledge, which shows positive significant correlations with technology (expenditures on ICT) and upskilling (expenditures on training), output (defined by total sale value), output diversification, productivity and profit. At the micro (firm) level, tacit and codified knowledge show positive significant correlations with total investment, capital, and firm size. This can be interpreted that higher levels of total investment, capital and firm size would correspond to more tacit and codified sources of knowledge across firms.

8.1 Introduction

Our earlier findings in Chap. 5 indicate that the transfer of knowledge is successful within firms, but is somewhat doubtful between firms and universities and within society at large. Our analysis shows that within society at large, the transfer of knowledge is hindered by low skill levels, deficient educational and training systems and the lack of incentives. The transfer of knowledge between universities and firms is hindered by the lack of incentives such as subsidies, and the lack of a networks, information systems, cooperation and interest in conducting joint research between universities and firms and matching the relevance of universities' research to firms needs.

S. Mohamed Nour, *Technological Change and Skill Development in Sudan*,
DOI 10.1007/978-3-642-32811-4_8,

One implication of our earlier analysis is that Sudan needs to stimulate the incidence and transfer of knowledge at the aggregate level by providing more incentives, for example through subsidies, to education and training to upgrade skill levels, and also by raising spending on R&D and ICT, organisation, coordination and cooperation. Further incentives, such as subsidies, should be provided to stimulate the transfer of knowledge between universities and firms that requires a good knowledge base within firms and further incentives, for example subsidies to education and training to enhance skill levels, and subsidies to R&D, networks organisation, information, coordination and cooperation. In this Chapter we extend our earlier analysis and explain the importance (impacts) of knowledge at both micro and macro levels in Sudan in more detail. In addition, we show the factors contributing to improve the tacit knowledge within firms. Due to the lack of relevant data to assess the transfer of knowledge amongst firms and between firms and universities, we focus only on the impacts of knowledge within the firms and at the aggregate/macro level.

The rest of this chapter is organised as follows: Sect. 8.2 briefly shows the importance and sources of knowledge in the growth literature; Sect. 8.3 presents hypothesis 7 in Chap. 1 above to test some stylised facts about the importance of knowledge and explains the data used to test them; Sect. 8.4 discusses the main findings; and Sect. 8.5 provides the conclusions.

8.2 Definition, Importance, Sources and Measurement of Knowledge in the Growth Literature

Endogenous growth literature recognised the importance of knowledge and its accumulation as a unique source of endogenous technological progress, innovation and economic growth. For instance, in the Lucas (1988) model, knowledge accumulation is vital for the growth process, for knowledge creation, accumulation and acceleration, contribution to scientific and technological progress, innovation, economic growth performance and development.[1]

In defining ‘knowledge’ the literature makes a distinction between codified and tacit knowledge (Dasgupta and David 1994). “Codified knowledge implies that knowledge is transformed into information which can either be embodied in new material goods (machines, new consumer goods) or easily transmitted through information infrastructure. While, the tacit knowledge refers to that which cannot easily transferred because it has not been stated or measured in an explicit form, skill is an important kind of tacit knowledge”[2] (cf. Freeman and Soete 1997: 404, 405).

In addition, the definition of codified knowledge in the literature is closely related with investment in public spending on education, training, R&D and ICT.

[1] The OECD (1997) confirm that Access to scientific and technological knowledge and the ability to exploit it are becoming increasingly strategic and decisive for the economic performance of countries and regions in the competitive globalized economy.

[2] Disembodied flows of knowledge can be transmitted through movement of people, publications, etc.

Several studies perceive knowledge as a public good, produced through R&D activities that generate spillover and thereby increasing returns (Romer 1994; Grossman and Helpman 1994). Other studies use broader terms to interpret knowledge created and embodied in institutions (cf. Langlois 2001). For instance, Nelson (1993) and Lundvall (1992) emphasise the importance of institutions for the flows of knowledge and information to innovative capability. According to Smith (2002): "R&D is but one component of knowledge and innovation expenditures, and by no means the largest. Because, R&D data tend to either overemphasize the discovery of new scientific or technical innovations, or to exclude a wide range of activities that involve the creation or use of new knowledge in innovation. Thus, innovation rests not only on discovery and R&D but also on learning, external environment (network) of the firm, non-R&D expenditures such as training, market research, design, trail production and tooling up and IPR costs. In addition to capital expenditure, which is a key mode of 'embodied' knowledge spillover from the capital good sector to using industries" (Smith 2002: 14–18).

Moreover, the evolutionary framework developed by Nelson and Winter (1982) makes the nature of knowledge and firms' investment in it a central factor in explaining the size, structure and dynamics of industries. Recent empirical literature (cf. Loof and Heshmati 2002) shows that knowledge capital (defined as the ratio of innovation sales to total sales) is found to be a significant factor contributing to performance heterogeneity and a firm's innovative level. Knowledge capital rises with innovation input, the firm's internal knowledge for innovation and cooperation with domestic universities on matters of innovation. Some empirical studies indicate that survival and growth amongst firms is determined by/or at least influenced by differential rates of investment in knowledge (such as R&D) (cf. Klepper and Simon 1997) or intersectoral differences in the size and R&D intensity of firm (cf. Levin et al. 1985). In addition, Brusoni et al. (2002) and David and Foray (1995) show that an increasing codification of knowledge stock would increase a firm's innovative performance.

In addition, differential in the productivity and growth of different countries is significantly related to improvement in the quality of human capital, technical progress, factors of production and the capacity to create new knowledge and ideas and incorporate them in equipment and people. "Recent growth literature show increasing evidences of the growing relative importance of intangible capital in total productive wealth and the rising relative share of GDP attributable to intangible capital (Abramovitz and David 1996, 1998). Intangible capital largely falls into two main categories: on the one hand, investment geared to the production and dissemination of knowledge (i.e. training, education, R&D, information and coordination); on the other hand, investment geared to sustaining the physical state of human capital (health expenditures). In the US, the current value of the stock of intangible capital (devoted to knowledge creation and human capital) began to outweigh that of tangible capital (physical infrastructure and equipment, inventories, natural resources) at the end of the 1960s. Moreover, since the 1960s annual investment rates in R&D, public education and software have grown steadily at an annual rate of 3 % in the OECD countries" (David and Foray 2001: 1–2).

Furthermore, Drucker (1998: 15) suggests: "knowledge is now becoming the one factor of production, sidelining both capital and labour". In addition, the OECD (1999: 7) has suggested "... the role of knowledge (as compared with natural resources, physical capital and low skill labour) has taken on greater importance".[3] Smith (2002) argues that in recent years, learning and knowledge have attracted increasing attention as a result of the claims that knowledge-intensive industries are now at the core of a growth, knowledge driven economy or even a knowledge society. The role of knowledge as an input to economic processes has fundamentally changed, probably due to rapid technological changes/ advances in ICT; ICT is seen as factor increasing knowledge and increasing the common availability of codified knowledge (David and Foray 1995; Smith 2002). For instance, Van Zon (2001) extends Lucas' (1988) model by incorporating the effects of ICT and capital investment, assuming that ICT has positive influence on growth performance, both by improving the intensity of production and total factor productivity and enhancing the efficiency of knowledge accumulation and learning process.

Moreover, the empirical literature shows that knowledge is positively related to human capital (mainly tacit skill or skill level). For instance, Winter (1987) suggests that tacit and codified knowledge need not be substitutes, but can be seen as complements in the learning process. Brusoni et al. (2002) show a strong positive relationship between the codification of the knowledge base of the industry and its investment in skilled people (high levels of investment in tacit skills) and R&D.

In addition, Cowan et al. (2001: 9) examine knowledge transfer in the services sector "as a process by which knowledge travels from a knowledge holder (a person or organisation possessing the knowledge)" to a knowledge recipient (a person or organisation receiving the knowledge). In their analysis "knowledge holder is important as the "point of departure" of the knowledge being transmitted since they can influence knowledge flows".

Furthermore, the literature indicates a substantial contribution to innovation and therefore to economic growth and public welfare that can be related to an unintended spillover associated with knowledge flows.[4] Distinction has been made between three sources for the flows and transfer of knowledge: for instance, Brusoni et al. (2002) highlight the importance of knowledge sources within the enterprise for innovation among innovative firms in Europe, in particular, the internal divisions (including R&D, design, sales and marketing and senior management). Several other studies have focused on knowledge flows between firms through inter-firm research collaborations (Hagedoorn et al. 2001), user-producer networks (Lundvall 1992), or linkages between competing firms (von Hippel 1988). Yet other studies examine knowledge flows between firms and public research organisations such as universities, public research institutes, government laboratories, and publicly-funded technical institutes (cf. Arundel and Geuna 2001; Mansfield 1991; Mansfield and Lee 1996). At the aggregate level, the transfer of knowledge

[3] See Drucker (1998), p.15 and OECD (1999), p.7 respectively.

[4] Verspagen and Schoenmakers (2000) use patent citations to measure knowledge spillover.

is related to several variables such as the overall quantity of scientific research (publications) and the public research base as measured by the ratio between the total amount of higher education R&D expenditure and the country GDP (cf. Arundel and Geuna 2001: 3, 5).

The notion that knowledge is a public good, produced through education, training and R&D activities that generate spillovers and increasing returns, provides a plausible justification for government intervention to compensate the private sector for the positive externalities they generate and to provide more incentives to support investment and accumulation of knowledge. While Lucas' (1988) model emphasises investment in human capital, it only implicitly allows for a role for public policy through subsidies (Haslinger and Ziesemer 1996: 230). Subsequent studies attempted to fill this gap in Lucas' (1988) model and explicitly indicate a potential role for government intervention and public policies to support the creation and accumulation of knowledge. The main channels are through taxation or subsidisation to the provision of R&D (cf. Romer 1990; Barro and Sala-i-Martin 1992, 1995), public knowledge: basic education and basic scientific research (cf. Ziesemer 1990, 1995) and subsidising training (cf. Chatterji 1995) (see our discussion in Chap. 3 above).

8.3 The Hypothesis, Stylised Facts and Data

Based on the above background, this Section presents hypothesis 7 in Chap. 1 above to test some stylised facts about the importance of knowledge in Sudan and explains the data used to test them.

8.3.1 The Importance (Impacts) of Knowledge at the Micro–Macro Levels in Sudan

In recent times, few studies discuss the status of knowledge in the Arab countries. The UNDP-AHDR (2003), Arab Knowledge report (2009) and Nour (2010) examine the weak status of demand, production and dissemination of knowledge in the Arab states. Aubert and Reiffers (2003) assess the challenges and underline a strategy for the development of knowledge-based economies in the Middle East and North African countries (MENA). All these reports provide significant contribution, but a somewhat general analysis at the aggregate/macro level that refers to all Arab and MENA countries respectively. Since Sudan shows considerable disparity from the other Arab and MENA countries, at least in respect of some indicators such as structure and size of the economy, level of income and structure of labour market, it might be useful to look at it separately. Thus, one obvious advantage of our analysis is that we provide a more specific analysis that focuses only on Sudan as a new case study. Moreover, different from earlier studies, we provide a new empirical investigation of both the importance (impacts) of tacit knowledge at the micro level (see our discussion below) as well as the discrepancy in the transfer of knowledge/external schooling effects at the macro–micro levels (see our discussion in Chap. 5 above).

In this chapter we use the literature presented above to examine hypothesis 7 in Chap. 1 above concerning the importance (impacts) of tacit and codified knowledge at the macro (within society)–micro (inside the firms) levels. In particular, our aim is to test the following stylised facts:

1. At the macro level codified knowledge and tacit knowledge are positively correlated with economic growth (GDP growth rate) and are positively correlated with schooling;
2. At the macro level codified knowledge (the total spending on R&D) and tacit knowledge (the total number of full time equivalent researchers (FTER)) are positively correlated with each other and also with technology (patents);
3. At the micro (firm) level tacit knowledge is positively correlated with technology (ICT), upskilling (training), profit, productivity, output and output diversification;
4. At the micro (firm) level tacit knowledge is positively correlated with market size (firm size; capital; and investment) and firm age.

8.3.2 *Definition of Data and Variables*

We use the broad definition of knowledge found in the new growth literature that highlights both the tacit and codified components of knowledge. In particular, we define tacit knowledge by the percentage share of high skilled workers in total employment at the micro level.[5] In addition, at the macro level we define tacit knowledge by the share of enrolment in tertiary education; moreover, we use the share of high skilled population with tertiary education in total population and the total number of FTER[6] as other indicators of tacit knowledge at the macro level.[7] We define codified knowledge by the embodied knowledge distributed in many indicators, including the share of spending on R&D, education, training and ICT as

[5] As in Chap. 7 above, our definition of high skilled workers refers to workers with post secondary educational attainment: university degree and above (16 years of schooling).

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

[7] The main limitations of our data at the macro/aggregate level are the definition of tacit knowledge by the share/ratios of enrolment in tertiary education (despite their drawback), the adjustment of the variables for different years and the use of unified ratio of education and R&D spending and tacit knowledge and schooling indicators, due to scarcity of data.

percentage of GDP at the macro level.[8] In addition, we use several variables related to knowledge such as patents and schooling years, defined by school life expectancy and mean years of schooling, in Sudan.,[9,10] Table 8.1 below presents the data and variables, which we use in our analysis of the importance (impacts) of knowledge at the macro/aggregate level in Sudan.

As in Chap. 7 above, we obtain our micro/firm data from the firm survey (2010) and use three sets of indicators, including tacit knowledge (technical and non-technical skills), technology and input–output variables. We define tacit knowledge by the share of high skilled/educated workers in total employment; we define codified sources of knowledge by total spending on ICT, R&D and training; we use other definition of codified sources of knowledge, defined by knowledge embodied in machines, defined by total spending on machinery and equipment; we define technology by expenditures on ICT and on machinery and equipment; we define upskilling by expenditure on training; input indicators are labour (employment size) and capital (net worth), output (total sales value), output diversification (sales diversification), productivity and profit.[11]

8.4 The Empirical Results

We use the data presented above and the linear and log linear OLS regression techniques and E-Views and SPSS statistical programmes to test and compare the importance (impacts) of tacit and codified knowledge at the micro and macro levels respectively and compare the relevance of our findings to those in the knowledge literature. Based on Table 8.1 below and Tables 8.2 and 8.3 below we present a panel data analysis reflecting the average for Sudan over the period 1990–2009. Based on data from the firm survey (2010), Tables 8.4, 8.5, 8.6, 8.7, 8.8, and 8.9 reflect the results across firms.

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[8] At the micro level, the definition of codified knowledge by the relative term or the share of these indicators to total output or sales value does not provide relevant results.

[9] *The concept expected years of schooling (of children) is defined by the number of years of schooling that a child of school entrance age can expect to receive if prevailing patterns of age-specific enrolment rates were to stay the same throughout the child's life, see for instance, UNESCO Institute for Statistics (2010a), 'Correspondence on Education Indicators. March 2010. Montreal'.*

[10] *The concept mean years of schooling (of adults) refers to average number of years of education received by people ages 25 and older in their lifetime based on education attainment levels of the population converted into years of schooling based on theoretical durations of each level of education attended, see Barro and Lee (2010), 'A New Data Set of Educational Attainment in the World, 1950–2010', NBER Working Paper No. 15902.*

[11] As in Chap. 7 above, we use the same definitions of educational qualifications, ICT, diversification, output, capital, labour (firm's size) and firm's age (total years in operation) - see our definitions in Chap. 7 above. In addition, we obtained information on investment and labour variables from Sudan Ministry of Industry (2005) 'Comprehensive Industrial Survey (2001)'.

Table 8.1 The determinants of knowledge in the Sudan (1990–2009)

		Tacit knowledge[d, e, f, g, h]		Schooling[e, i, j]		Codified sources of knowledge: public expenditure on education, R&D, ICT and training as % of GDP (%)				
Variable/ year	GDP Growth Rate[a, b, c]	Tertiary[d, e, f,]	Share of high skilled in total population (%)[d, g, h]	School Life Expectancy [i, e,]	Mean years of schooling[j]	Education [k, l, m,]	R&D[n]	ICT[o]	Training[o]	Total spending on education, R&D, ICT and training
1990	5.4	3.0 [d]	0.004 [g]	4.2 [i]	1.5	0.9 [k]	n. a.	n. a.	n. a.	0.9
1991	7.5	3.0 [d]	0.004 [g]	4.2 [i]	1.5	0.6 [l]	n. a.	n. a.	n. a.	0.6
1992	6.5	3.0 [d]	0.004 [g]	4.2 [i]	1.5	0.6 [l]	n. a.	n. a.	n. a.	0.6
1993	4.5	3.0 [d]	0.004 [g]	4.2 [i]	1.5	0.6 [l]	n. a.	n. a.	n. a.	0.6
1994	1	3.0 [d]	0.004 [g]	4.2 [i]	1.5	0.6 [l]	n. a.	n. a.	n. a.	0.6
1995	5.9	3.0 [d]	0.004 [g]	4.2 [i]	1.5	0.6 [l]	n. a.	n. a.	n. a.	0.6
1996	5.9	3.0 [d]	0.004 [g]	4.2 [i]	1.5	0.6 [l]	0.5	n. a.	n. a.	1.1
1997	6.3	3.0 [d]	0.004 [g]	4.2 [i]	1.5	1.4 [m]	0.5	n. a.	n. a.	1.9
1998	6.4	6 [d]	0.004 [g]	4.2 [i]	1.5	1.4 [m]	0.5	n. a.	n. a.	1.9
1999	6.7	6 [d]	0.005 [g]	4.2 [i]	1.5	1.4 [m]	0.53	n. a.	n. a.	1.93
2000	8	6.85 [e]	0.007 [g]	4.4 [i]	2.4	1.4 [m]	0.47	n. a.	n. a.	1.87
2001	6.7	6.85 [e]	0.007 [g]	4.4 [i]	2.4	1.4 [m]	0.44	n. a.	n. a.	1.84
2002	6.5	6.85 [e]	0.007 [g]	4.4 [i]	2.4	1.4 [m]	0.39	n. a.	n. a.	1.79
2003	6	6 [e]	0.007 [g]	4.4 [i]	2.4	1.4 [m]	0.34	n. a.	n. a.	1.74
2004	7.2	6 [e]	0.007 [g]	4.4 [i]	2.4	1.4 [m]	0.29	n. a.	0.0001	1.6901
2005	8	6 [e]	0.007 [g]	4.6 [e]	2.8	1.4 [m]	0.29	n. a.	0.0001	1.6901
2006	10.0	6 [e]	0.007 [g]	4.6 [e]	2.8	1.4 [m]	0.28	n. a.	0.0002	1.6802
2007	10.5	6 [e]	0.007 [g]	4.6 [e]	2.8	1.4 [m]	0.28	0.00039	0.0005	1.68089
2008	7,8	5.9 [f (1)]	0.0532 [h]	4.6 [e]	2.9	1.4 [m]	0.28	0.00018	0.0006	1.68078
2009	6.1	5.9 [f (1)]	0.0532 [h]	4.6 [e]	2.9	1.4 [m]	0.28	n. a.	0.0003	1.6803

Year	Total researcher[n]	Codified sources of knowledge: total public expenditure on R&D, ICT and training (million pounds)				Share in total R&D Expenditure (%)[n]			Patent [p]		
		ICT[o]	Training[o]	R&D[n]	Total R&D, ICT, and training	Business enterprise [n,]	Government [n,]	Higher education [n]	Resident	Non-resident	Total
1995	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
1996	n. a.	n. a.	n. a.	100000	100000	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
1997	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
1998	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
1999	9100	n. a.	n. a.	143000	143000	31.5	38.5	30.1	2	4	6
2000	900	n. a.	n. a.	149000	149000	31.5	38.9	29.5	6	16	22
2001	9340	n. a.	n. a.	152400	152400	31.5	39.3	29.2	1	13	14
2002	11208	n. a.	n. a.	154000	154000	31.8	39.0	29.2	2	20	22
2003	7300	n. a.	n. a.	156500	156500	31.9	39.0	29.1	6	11	17
2004	7500	n. a.	7.3	163730	163737.3	33.6	38.3	28.1	4	17	21
2005	7850	n. a.	4.64	192840	192844.64	33.7	39.2	27.1	6	16	22
2006	n. a.	n. a.	5.56	n. a.	5.56	n. a.	n. a.	n. a.	3	13	16
2007	n. a.	9.341	12.00	n. a.	21.341	n. a.	n. a.	n. a.	3	13	16
2008	n. a.	4,60	15.401	n. a.	15.401	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
2009	n. a.	n. a.	8.559	n. a.	8.559	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.

(1) Data refers to most recent available data between 2001 and 2009). (2) n. a. refers to data not available

Sources: (a) Sudan ministry of Finance and National Economy, (b) Sudan central Bank of Sudan (c) Sudan Central Bureau of Statistics (2009: 39–43), (d) UNDP Human Development Report (HDR) (2002), (e) UNESCO (2011), (f) UNDP HDR (2010), (g) Own calculation from Barro and Lee (2000) and Ali (2006:14), (h) Sudan Central Bureau of Statistics (2010) population census data (2008), (i) UNESCO Institute for Statistics (UIS) (2010a), (j) Barro and Lee (2010), (k) UNDP HDR (2004), (l) UNESCO–UIS (2003), (m) UNESCO–UIS (2000), (n) UNESCO R&D Statistics (2006), (o) Sudan National Council for Strategic Planning- General Secretariat (2010: 493, 497), (p) World Development Indicators database (2011)

Table 8.2 The impacts of tacit and codified sources of knowledge on schooling and GDP in Sudan (1990–2009)

	Coefficient (t-value)						
	Constant	Tacit knowledge (share of enrolment in tertiary education)	Tacit knowledge (Share of high skilled population with tertiary education in total population (%))	Codified knowledge (share of public spending in education, R&D, training and ICT in GDP)	Codified knowledge (share of public spending in education in GDP)	R^2	N
Schooling: school life expectancy	3.994 (43.856)	0.073** (4.113)				0.485	20
	4.283 (109.358)		6.620** (2.977)			0.330	20
	4.110 (43.709)			0.171** (2.731)		0.293	20
	4.014 (41.714)				0.296** (3.669)	0.428	20
Schooling: mean years of schooling	0.690 (2.399)	0.279** (5.006)				0.582	20
	1.830 (13.161)		22.600** (2.866)			0.313	20
	1.142 (3.602)			0.654** (3.092)		0.347	20
	0.806 (2.515)				1.105** (4.115)	0.485	20
Tacit knowledge (share of enrolment in tertiary education)	1.329 (2.284)			2.557** (6.586)		0.707	20
	0.622 (1.035)				3.784** (7.504)	0.758	20
Tacit knowledge (Share of high skilled population with tertiary education in total population (%))	0.001 (0.101)			0.007 (1.043)		0.057	20
	−0.004 (−0.347)				0.012* (1.382)	0.096	20

Growth of GDP	4.108 (3.613)			1.783** (2.334)	0.243	20
	6.559 (11.294)	3.163 (0.073)			0.0003	20
	3.6120 (2.837)		0.609** (2.448)		0.261	20
Codified knowledge (share of public spending on education, R&D, training and ICT in GDP)	0.045 (0.205)	0.276** (6.586)			0.707	20
	1.315 (8.965)		8.677 (1.043)		0.057	20

Correlation is significant * at the 0.05 level (one-tailed), ** at the 0.01 level (one-tailed)

Table 8.3 The impacts of FTER and codified sources of knowledge on each other and patent in the Sudan (1990–2009)

	Coefficient (t-value)							
	Constant	Tacit knowledge (total number of FTER)	Codified knowledge (total public spending on R&D)	R&D (share of government in total R&D spending)	R&D (share of business in total R&D spending)	R&D (share of higher education institutions in total R&D spending)	R^2	N
Tacit knowledge (total number of FTER)	5,392.608 (0.381)		0.014 (0.157)				0.005	8
Codified knowledge (total public spending on R&D)	156,116.6 (8.525)	0.351 (0.157)					0.005	8
	−2,857,670 (−0.828)			39,172.90 (1.093)	31,894.35 (0.941)	16,115.27 (0.478)	0.962	8
Technology (Patents)	−43.323 (−1.283)	0.0008*[(1)] (1.876)					0.779	3
	−13.0895 (−0.585)		0.0002*[(1)] (1.383)				0.277	7

Correlation is significant * at the 0.05 level (one-tailed) ** at the 0.01 level (one-tailed), Notes: N = 6
[1]correlation between tacit knowledge (FTER) codified knowledge (total spending on R&D) and total patent by resident and non-resident

Table 8.4 The significance of tacit knowledge for firms performance across firms, 2010

		Coefficient (t-value)			
All equations for 2008		Constant	Tacit knowledge (share of high skilled in total employment)	R^2	N
Total profit	All firms (log)	15.455 (24.002)	0.211 (0.137)	0.0002	40
Total output (total sales value)	All firms (semi log)	16.867 (26.663)	0.303 (0.194)	0.0003	44
Productivity (total sales value per workers)	All firms (log)	13.003 (21.077)	0.292 (0.813)	0.005	44
Output diversification (sales diversification)	All firms (log)	1.164 (4.190)	0.104 (1.253)	0.035	44
Value added	All firms (linear)	−47,932,040.9 (−0.163)	8,748,233.6 (1.101)	0.092	13
Technology (total expenditures on ICT)	All firms (linear)	31.724 (10.198)	0.0000004** (2.115)	0.052	82
	All firms (linear)	6,270,092.7 (1.412)	53776.9 (0.499)	0.006	44
	Large (linear)	40.404 (6.934)	0.0000003 (1.079)	0.036	32
	Medium (linear)	27.875 (6.103)	0.0000004* (1.953)	0.128	27
	Chemical (linear)	33.111 (7.354)	0.0000003 (1.241)	0.042	36
	Food (linear)	29.619 (5.387)	0.0000002 (1.200)	0.051	28
	Metal (log)	1.282 (5.224)	0.060 (1.202)	0.325	4
	Textile (linear)	19.140 (3.175)	0.000001** (4.773)	0.884	4
Skill upgrading (total expenditure on ICT Training)	All firms (linear)	993,061.5 (0.090)	179433.8 (0.802)	0.177	4
	Large (linear)	43.281 (2.260)	0.000001 (0.576)	0.142	3
	Food (linear)	37.543 (2.109)	0.000002 (0.536)	0.087	4
Skill upgrading (total expenditures on general training)	All firms (log)	14.381 (5.897)	2.726 (1.034)	0.118	9
Skill upgrading (training employees)	All firms (log)	1.917 (3.671)	0.527 (1.022)	0.115	9

Correlation is significant * at the 0.05 level (one-tailed) ** at the 0.01 level (one-tailed)

Tables 8.2, 8.3, 8.4, 8.5, 8.6, 8.7, and 8.8 present our results, which indicate the importance (impacts) of tacit and codified sources of knowledge at the macro (aggregate) and micro (firm) levels respectively. Some of these results are

Table 8.5 The significance of codified sources of knowledge and firms performance across firms, 2010

		Coefficient (t-value)				
All equations for 2008		Constant	Codified knowledge (total spending on R&D, ICT and training)	Codified knowledge (total spending on machinery and equipment)	R^2	N
Total output (total sales value)	All firms (log)	12.733 (6.798)	0.282** (2.062)		0.098	40
	Large (log)	12.808 (3.917)	0.326* (1.568)		0.149	15
	Medium (log)	9.162 (2.482)	0.513* (1.711)		0.226	11
	Chemical (log)	12.619 (6.494)	0.354** (2.350)		0.225	20
	Food (log)	13.965 (2.874)	0.054 (0.150)		0.002	10
	Metal (log)	8.362 (2.237)	0.745** (3.075)		0.825	3
Output diversification (sales diversification)	All firm (log)	0.078 (0.511)	0.017* (1.612)		0.050	50
	Large (log)	0.088 (0.285)	0.018 (0.920)		0.047	18
	Medium (log)	-.178 (−0.701)	0.030* (1.571)		0.150	15
	Small (log)	0.217 (0.773)	0.012 (0.540)		0.020	15
	Chemical (log)	−0.140 (−0.705)	0.038** (2.620)		0.222	25
	Food (log)	−0.093 (−0.352)	0.023* (1.250)		0.115	13
Total profit	All firms (log)	11.042 (6.078)	0.329** (2.479)		0.161	33
	Large (log)	11.293 (2.934)	0.301 (1.215)		0.102	14
	Medium (log)	6.099 (1.644)	0.739** (2.308)		0.432	8
	Small (log)	12.089 (4.625)	0.283* (1.351)		0.186	9
	Chemical (log)	11.111 (4.617)	0.365* (1.985)		0.180	19
	Food (log)	12.404 (4.970)	0.091 (0.474)		0.036	7
	Metal (log)	10.461 (4.873)	0.590** (4.706)		0.957	2

(continued)

Table 8.5 (continued)

All equations for 2008		Coefficient (t-value) Constant	Codified knowledge (total spending on R&D, ICT and training)	Codified knowledge (total spending on machinery and equipment)	R^2	N
Value added	All firms (log)	12.826 (3.331)	0.222 (0.810)		0.062	11
	Large (log)	13.263 (0.825)	0.131 (0.140)		0.010	3
	Medium (log)	−1.074 (−0.429)	1.287** (6.066)		0.948	3
	Small (log)	15.946 (6.592)	0.185 (0.964)		0.317	3
	Chemical (log)	14.728 (2.929)	0.072 (0.200)		0.013	4
	Food (linear)	−114,881,069.48 (−0.341)	17.939** (2.845)		0.730	4
Technology (total expenditures on ICT)	All firms (log)	5.560 (2.060)		0.384** (2.340)	0.142	34
Value added	All firms (linear)	27,460,225.450 (0.738)		0.031** (16.118)	0.956	13
Total profit	All firms (log)	7.682 (2.925)		0.474** (2.945)	0.224	31
Raw materials	All firms (log)	7.161 (2.826)		0.560** (3.614)	0.284	34
Total output (total sales value)	All firms (log)	9.456 (3.436)		0.447** (2.662)	0.172	35
Output diversification (sales diversification)	All firms (linear)	1.485 (17.037)		0.00008 (1.168)	0.039	10

Correlation is significant * at the 0.05 level (one-tailed), ** at the 0.01 level (one-tailed)

consistent with the findings in the literature (cf. Abramovitz and David 1996, 1998; David and Foray 2001; Loof and Heshmati 2002). Our results in Tables 8.2 and 8.3 illustrate the importance of knowledge at the aggregate/macro level. In support of our expectations, the findings in Table 8.2 indicate that at the macro level both codified knowledge (defined by total public spending on education, training, R&D and ICT) and tacit knowledge (defined by tertiary school enrolment ratios and the share of high skilled population with tertiary education in total population) show positive significant correlation with GDP growth rate and positive significant correlation with schooling years (defined by school life expectancy and mean years of schooling). In addition, we find that codified knowledge (defined by the

Table 8.6 The significance of the components of codified sources of knowledge and firm performance across firms, 2010

			Coefficient (t-value)					
All equations for 2008	2008	Constant	Codified knowledge (R&D expenditure)	Codified knowledge (total spending on R&D, ICT and training)	Codified knowledge (general training expenditure	Training employees staff	R^2	N
Total profit	All firms (linear)	−573799690.1 (−1.242)	2.264** (8.181)				0.905	8
Total output (total sales value)	All firms (linear)	1587124792.4 (0.844)	4.493** (3.988)				0.694	8
Codified knowledge (total spending on machinery and equipment)	All firms (linear)	9575800441.6 (0.708)	28.729 (0.258)				0.013	6
Value added	All firms (log)	10.091 (1.118)	0.412 (0.735)				0.350	2
Raw materials	All firms (linear)	879325977.81 (0.596)	3.390 (0.279)				0.015	6
Output diversification (sales diversification)	All firms (linear)	1.676 (8.790)	−0.00007 (−0.584)				0.037	10
Dependence on the import of foreign technology (value of imported capital equipment to total capital equipment (%))	All firms (linear)	0.416 (5.953)	0.00001** (2.468)				0.404	10
	All firm (linear)	0.550 (13.267)		0.000087* (1.449)			0.040	52
Dependence on the import of foreign technology (value of capital equipment to total capital equipment built by foreign companies (%))	All firms (linear)	0.311 (3.052)	0.000001** (2.259)				0.422	8
	All firm (linear)	0.424 (6.905)		0.000001* (1.746)			0.101	28
General Training employees	All firms (linear)	6.146 (1.562)			0.00004 (0.081)		0.001	9
Tacit knowledge (share of high skilled in total employment)	All firms (log)	−1.141 (−3.037)			0.219 (1.022)		0.115	9
	All firms (log)	−1.300 (−2.402)				0.043 (1.034)	0.118	9

Correlation is significant * at the 0.05 level (one-tailed) ** at the 0.01 level (one-tailed)
(1) The logarithm (log) value for all estimated variables is taken. (2) correlation between Codified knowledge (share of R&D expenditure) and labour

Table 8.7 The correlation between tacit and codified sources of knowledge across firms, 2010

			Coefficient (t-value)				
All equations for 2008		Constant	Tacit knowledge (share of high skilled in total employment)	Codified knowledge (spending on R&D, ICT and training)	Codified knowledge (spending on machinery and equipment)	R^2	N
Codified knowledge (total spending on R&D, ICT, training)	All firms	14.290	0.560			0.017	50
	(log)	(13.735)	(0.930)				
	Large	16.804	0.988			0.086	19
	(log)	(12.364)	(1.298)				
	Medium	−3,487,389.092	33,619,426.961*			0.127	27
	(linear)	(−.521)	(1.945)				
	Small	130,726.714	35,922,633.83*			0.089	19
	(linear)	(0.014)	(1.326)				
	Chemical	13.331	0.158			0.002	25
	(log)	(10.035)	(0.224)				
	Food	4,526,245.979	31,159,057.065*			0.071	28
	(linear)	(0.495)	(1.432)				
	Metal	16.324	3.137			0.035	4
	(log)	(1.640)	(0.332)				
	Textile	−22,553,770.978	11,838,6918.5**			0.941	4
	(linear)	(−2.921)	(6.896)				
	Textile	20.030	4.537**			0.712	4
	(log)	(9.936)	(2.721)				
Tacit knowledge	All firms	0.318			0.000003	0.027	35
	(linear)	(7.729)			(0.964)		
	All firms	−1.822		0.031		0.017	50
	(log)	(−3.859)		(0.930)			
	Large	−2.646		0.087		0.086	19
	(log)	(−2.469)		(1.298)			

(continued)

Table 8.7 (continued)

All equations for 2008		Constant	Coefficient (t-value) Tacit knowledge (share of high skilled in total employment)	Codified knowledge (spending on R&D, ICT and training)	Codified knowledge (spending on machinery and equipment)	R^2	N
	Medium	0.279		0.004*		0.127	27
	(log)	(6.103)		(1.945)			
	Small	0.252		0.003*		0.089	19
	(linear)	(5.131)		(1.326)			
	Chemical	−1.622		0.013		0.002	25
	(log)	(−2.001)		(0.224)			
	Food	0.288		0.002*		0.071	28
	(linear)	(5.210)		(1.432)			
	Metal	−1.149		0.011		0.035	4
	(log)	(−2.357)		(0.332)			
	Textile	0.203		0.002**		0.941	4
	(linear)	(4.904)		(6.896)			
	Textile	−3.454		0.157**		0.712	4
	(log)	(−3.890)		(2.721)			
Codified knowledge (total spending on machinery and equipment)	All firms	−148,468,236.04	8,158,430,084.89			0.027	35
	(linear)	(−0.043)	(0.964)				
	All firms	12.231		0.303**		0.123	34
	(log)	(6.528)		(2.154)			
	Large	13.688		0.178		0.051	12
	(log)	(3.995)		(0.769)			
	Medium	13.835		0.070		0.004	9
	(log)	(2.745)		(0.170)			
	Small	9.923		0.617**		0.574	11
	(log)	(4.788)		(3.672)			

	Chemical	13.906	0.159		0.049	19
	(log)	(6.429)	(0.964)			
	Food	9.287	0.513*		0.223	8
	(log)	(1.870)	(1.418)			
	Metal	8.536	0.839**		0.982	2
	(log)	(6.087)	(7.366)			
	Textile	11.491	0.277		0.224	2
	(log)	(1.566)	(0.537)			
Codified knowledge (spending on R&D, ICT and training)	All firms	19,582,066.79		0.001*	0.080	35
	(linear)	(2.163)		(1.721)		
	All firms	6.117		0.406**	0.123	34
	(log)	(1.971)		(2.154)		
Codified knowledge (share of R&D expenditure)	All firms	−5.167		0.112*	0.180	9
	(log)	(−3.505)		(1.326)		
Codified knowledge (total R&D expenditure)	All firms	12.158		0.174	0.037	6
	(log)	(1.763)		(0.439)		

Correlation is significant * at the 0.05 level (one-tailed), ** at the 0.01 level (one-tailed)

Table 8.8 The increased use and effect of skilled workers, scientists and engineers across firms in the Sudan, 2008 (measured in % as indicated by respondents)

The increased use of skilled workers and their effects	All firms	Chemical	Food	Metal	Textile	Large	Medium	Small
(a) Increased use of skilled workers (2006–2008)	50 %	46 %	52 %	55 %	60 %	52 %	41 %	58 %
(b) The effects of increased use of skilled workers								
Increase in firm production	83 %	83 %	78 %	91 %	100 %	87 %	78 %	84 %
Improve product quality	81 %	80 %	78 %	82 %	100 %	77 %	78 %	89 %
Improve the level of competitiveness in the local market	73 %	69 %	74 %	91 %	60 %	65 %	70 %	89 %
Effective utilization of technologies	73 %	80 %	59 %	73 %	100 %	74 %	74 %	68 %
Faster adaptation of technologies	65 %	69 %	52 %	73 %	100 %	74 %	63 %	53 %
Improve the level of competitiveness in the international market	21 %	23 %	19 %	27 %	0 %	32 %	19 %	0 %
Total response	78	35	27	11	5	31	27	19
(c) The effects of scientists and engineers on firm production and acquisition of knowledge								
The effects of scientist and engineers	All firms	Chemical	Food	Metal	Textile	Large	Medium	Small
Shorten development time	89 %	95 %	82 %	91 %	80 %	93 %	89 %	79 %
Add technical, scientific or marketing knowledge to areas where firms already had expertise	80 %	81 %	79 %	82 %	80 %	84 %	78 %	74 %
Add new technical, scientific or marketing knowledge to areas where firms lacked expertise	67 %	69 %	64 %	73 %	60 %	78 %	64 %	52 %
Total response	80	36	28	11	5	32	28	19

Source: Own calculation based on the % as indicated by respondent firms to firm survey (2010)

share of public spending on education as a percentage of GDP) shows positive significant correlation with tacit knowledge (defined by tertiary school enrolment ratios and the share of high skilled population with tertiary education in total population) and with schooling years (defined by school life expectancy and mean years of schooling). These results imply that the enhancement of codified knowledge (defined by increasing public spending on education, training, R&D and ICT) can be used as important mechanism to enhance tacit knowledge (defined by tertiary school enrolment ratios and the share of high skilled population with tertiary education in total population) and to enhance schooling years (defined by school life expectancy and mean years of schooling). In addition, we observe that when excluding the share of public expenditure on training, R&D and ICT relative to GDP from the definition of codified knowledge and limiting the definition of

Table 8.9 The correlations between labour, capital, age, tacit and codified sources of knowledge across firms, 2008

All firms (2005–2008)		Coefficient (t-value)					
Independent variables	Dependent variable	Labour	Capital	Age	Constant	R^2	N
Tacit knowledge (share of high skilled in total employment)	All firms (linear)	1.036 (1.006)			95.529 (2.250)	0.023	44
	All firms (log)		0.006 (0.146)		−1.574 (−2.414)	0.001	35
	All firms (log)			−0.080 (−0.515)	−1.212 (−3.071)	0.006	44
Codified knowledge (total spending on R&D, ICT and training) [1]	All firms (Log)	1.677** (2.372)	0.320** (2.163)		−0.051 (−0.012)	0.210	34
	Large (Log)	1.933 (1.005)	0.634* (1.653)		−6.741 (−0.590)	0.343	10
	Small (Log)	4.227* (1.652)	0.720** (3.461)		−16.684 (−1.792)	0.606	12
	Chemical (Log)	0.723 (0.663)	0.449* (1.513)		1.102 (0.148)	0.148	16
	Food (Log)	3.830** (2.031)	0.226 (1.112)		−6.738 (−0.731)	0.438	8
	Textile (Log)	1.459 (1.013)	0.238 (0.393)		4.184 (0.300)	0.340	4
	All firms (log)	1.864** (2.866)			4.713 (1.623)	0.170	41
	Chemical (Log)	1.393* (1.568)			5.993 (1.471)	0.115	20
	Metal (Log)	4.912 (0.994)			−5.429 (−0.287)	0.248	4
	All firms (log)		0.246* (1.593)		8.273 (3.091)	0.071	34
	Chemical (log)		0.411* (1.439)		4.797 (0.990)	0.121	16
	Metal (Log)		1.138** (7.858)		−9.493 (−3.605)	0.969	3
	All firms (log)			−0.295 (−0.478)	14.245 (8.779)	0.005	51
Codified knowledge (total spending on machinery and equipment)	All firms (log)		0.514** (5.195)		7.631 (4.437)	0.465	32
	All firms (linear)			79661894.8 (0.546)	1133229245.6 (0.349)	0.009	35
Codified knowledge (total R&D expenditure)	All firms (log)	0.357 (0.131)			14.313 (1.047)	0.002	8
	All firms (log)		0.710** (2.064)		2.434 (0.391)	0.516	5

(continued)

Table 8.9 (continued)

All firms (2005–2008)		Coefficient (t-value)					
Independent variables	Dependent variable	Labour	Capital	Age	Constant	R^2	N
	All firms (linear)			−23,181,080 (−0.687)	884908507.6 (1.220)	0.050	10
	All firms (log)		0.040 [2] (0.433)		−3.519 (−2.069)	0.026	8
Codified knowledge and skill upgrading (general total training expenditure)	All firms (linear)	9493.060 (1.049)	0.001** (2.102)		−557534.396 (−0.169)	0.434	8
	All firms (linear)	2125.4 (0.227)			2708644.021 (0.886)	0.006	10
	All firms (linear)		0.001* (1.855)		1945239.301 (0.846)	0.330	8
Codified knowledge and skill upgrading (ICT training expenditure)	All firms (linear)	87806.5** (5.202)			−7,252,877 (−2.033)	0.643	6
	All firms (linear)	115431.1** (5.145)	0. 04* (1.863)		−14,704,554 (−2.592)	0.727	5
Training employees	All firms (linear)	0.021* (1.711)			1.059 (0.266)	0.246	10

Correlation is significant * at the 0.05 level (one-tailed), ** at the 0.01 level (one-tailed)
[1]Log value for all estimated variables: ICT, labour and capital. [1] The logarithm of the variable is taken.
[2]Correlation between Codified knowledge (share of R&D expenditure) and labour.

codified knowledge to include only the share of public spending on education relative to GDP, the coefficient in the regression equation turns more significant. This result is plausible since the public spending on education relative to GDP has high share when compared to the share of public spending on training, R&D and ICT relative to GDP in Sudan. This result can then be used to argue that an increase in public spending on these components would imply an increase in codified knowledge and therefore, GDP in Sudan. From the perspective of the new growth literature, these results would imply that with the assumption of a potential role for public policies, the government could prevent the decline in economic growth and ensure increasing and dynamic economic growth, mainly through improving tacit knowledge and schooling by stimulating investment in education (basic, secondary and tertiary) and by increasing public spending on education, R&D, training and ICT. Moreover, Table 8.3 shows that tacit knowledge (defined by the number of FTER) and codified knowledge (defined by total spending on R&D) show positive correlations with technology (patents). The correlation between tacit knowledge (defined by the number of FTER) and this variable appears more significant than those with codified knowledge (defined by total spending on R&D). When defining the number of FTER as one form of tacit knowledge, we find a positive correlation between the number of FTER and codified knowledge (defined by total spending on R&D), which can be interpreted as complementary relationship between tacit and codified knowledge (cf. Winter 1987; Brusoni et al. 2002). In addition, we observe from Table 8.1 above that total spending on R&D is associated with an increase in the number of FTER. Moreover, Table 8.3 above shows that total spending on R&D is positively correlated with an increase in the share of public (government), private (business) and higher education institutions in total spending on R&D respectively. These results imply the important supporting role of public (government), private (business) and higher education institutions for enhancing and supporting total R&D spending and activities. Moreover, we observe that the correlation between total R&D spending and public (government) spending on R&D appears more significant than the correlations between total spending on R&D and private (business) spending on R&D and higher education institutions spending on R&D. This result is plausible since the share of public (government) spending on R&D is higher than the share of private (business) spending on R&D and the share of higher education institutions spending on R&D. Therefore, these results verify the first and second stylised facts that at the macro/aggregate level knowledge is positively correlated with GDP (economic growth), schooling years and technology (patents).

Table 8.4 verifies the third stylised fact that at the micro/firms level tacit knowledge shows positive correlations with total profit, total output (defined by total sales value), productivity (defined by total sales value per worker), output diversification (defined by sales diversification), value added, technology (total expenditures on ICT) and skill upgrading (total expenditure on ICT training, total expenditures on general training, training employees staff).[12] Notably, tacit knowledge shows positive significant correlations with technology (total expenditures on ICT) for all, medium and textile firms. From the perspective of the new growth literature, the positive correlation between tacit knowledge and output is important to prevent the diminishing returns to scale and to ensure the increasing returns and dynamic growth in the production function. This would imply that with the assumption of a potential role for public policies, the government could prevent the diminishing returns to scale and ensure increasing returns to scale, mainly through improving tacit knowledge by stimulating investment in education (basic, secondary and tertiary).

Table 8.5 verifies the third stylised fact that at the micro/firms level codified sources of knowledge (as measured by total spending on ICT, R&D and training) shows positive correlations with total output (defined by total sales value), output diversification (defined by sales diversification), total profit and value added. Notably, codified sources of knowledge (as measured by total spending on ICT, R&D and training) shows positive significant correlation with total output (defined

[12] There are also positive correlations between tacit knowledge and output, output diversification, productivity and profit that follow the combined correlations of traditional inputs such as labour and capital not reported in Table 8.4; these results are different from the findings in the literature (cf. Drucker 1998; OECD 1999).

by total sales value) (for all, large, medium, chemical and metal firms), output diversification (for all, medium, chemical and food firms), total profit (for all, medium, small, chemical and metal firms) and value added (for medium and food firms). Moreover, codified sources of knowledge (as measured by total spending on machinery and equipment) shows positive significant correlations with technology (total expenditures on ICT), value added, profit, the use of raw materials, total output (defined by total sales value), and positive correlation with output diversification (defined by sales diversification). From the perspective of the new growth literature, the positive correlation between codified sources of knowledge and output is important to prevent the diminishing returns to scale and to ensure the increasing returns and dynamic growth in the production function. This would imply that with the assumption of a potential role for private industrial policies, the industrial firms could prevent the diminishing returns to scale and ensure increasing returns to scale, mainly by improving codified sources of knowledge by stimulating investment in training, R&D, ICT and technology.

Table 8.6 verifies the third stylised fact that at the micro/firms level codified sources of knowledge (as measured by total spending on R&D) shows positive significant correlations with total profit and total output (defined by total sales value). In addition, codified sources of knowledge (as measured by total spending on R&D) shows positive correlation with other codified sources of knowledge (as measured by total spending on machinery and equipment), value added and the use of raw materials but it shows negative correlation with output diversification (defined by sales diversification). Moreover, codified sources of knowledge (as measured by total spending on R&D) and codified sources of knowledge (as measured by total spending on ICT, R&D and training) show positive significant correlations with dependence on the import of foreign technology (as defined by the percentage of value of imported capital equipment to total capital equipment) and the build of foreign technology (as defined by the percentage of value of capital equipment to total capital equipment built by foreign companies). Furthermore, codified sources of knowledge and skill upgrading (measured by total spending on training) show positive correlation with the number of training employees and with tacit knowledge, in addition the number of training employees shows positive significant correlation with tacit knowledge.

Table 8.7 verifies the third stylised fact that at the micro/firms level concerning the positive and complementary correlation between tacit knowledge and codified sources of knowledge as measured by (total expenditures on ICT, R&D and training), the complementary correlation is particularly significant for medium, small, food and textile firms. In addition to positive and complementary correlation between tacit knowledge and codified sources of knowledge as measured by technology (total expenditures on machinery and equipment). In addition to positive and complementary correlation between codified sources of knowledge as measured by (total expenditures on ICT, R&D and training) and codified sources of knowledge as measured by technology (total expenditures on machinery and equipment), the complementary correlation is particularly significant for all, small, food and metal firms. Moreover, codified sources of knowledge as measured by technology (total expenditures on machinery and equipment) shows positive correlation with codified sources of knowledge as measured by both total and share of expenditures on R&D.

Our results from the firm survey (2010) in Table 8.8 bear out the assumption that the increased use of tacit knowledge, defined by skilled workers, scientists and engineers, shows significant effects across firms. In particular, this contributes towards the increase in firm production, improvement in firm product quality, improvement in the level of competitiveness in the local market, effective utilisation of technology and faster adaptation of foreign technology. Moreover, Table 8.8 indicates that the increased use of scientists and engineers would imply the shortening of development time, as well as additions to acquisition of existing knowledge within the firm and acquisition of new knowledge, the latter regarded as of somewhat less importance.[13],[14]

Our findings in Table 8.9 prove part of the fourth stylised fact that at the micro/firm level tacit knowledge is positively correlated with market size: total investment, capital and firm size. Moreover, we find that codified sources of knowledge (as measured by total expenditure on ICT, R&D and training) are positively and significantly correlated with market size: total investment, capital and firm size; the correlation is positive and significant for all, large, small, chemical and food firms. In addition we find that codified sources of knowledge (as measured by total expenditure on R&D, total expenditure on training and total expenditure on machinery and equipment) are positively and significantly correlated with total investment, capital and are positively correlated with market size: firm size. Moreover, we find that codified sources of knowledge and upskilling, as defined by total expenditure on training, are positively and significantly correlated with market size: total capital investment and positively correlated with firm size; and upskilling, as defined by total number of training employees, is significantly and positively correlated with firm size. Therefore, at the micro/firm level an increase in total investment, capital and firm size would coincide with more tacit and codified sources of knowledge and more upskilling. In addition, we find that tacit and codified sources of knowledge are insignificantly and negatively correlated with firm age. This result rejects part of the fourth stylised fact, which implies positive correlation between tacit and codified sources of knowledge and firm age. This result contrasts with our expectation and probably implies that the relative improvement in tacit and codified sources of knowledge has probably been observed more for relatively new and young firms when compared to relatively old firms. This result is somewhat surprising in view of the fact that the accumulation of knowledge and learning often takes or requires more time to develop and improve over time. But we observe positive insignificant correlation between firm age and codified sources of knowledge as measured by spending on technology and machinery and equipment, this implies that total spending on technology and machinery and equipment increases with firm age; improvement in total spending on technology and machinery and equipment has been probably observed more for relatively old firms as compared to young firms.

[13] Knowledge includes technical, scientific or marketing knowledge.

[14] These results are consistent with the findings in the UAE as indicated in Nour (2005).

8.5 Conclusions

In this chapter we use the firm survey (2010) data at the micro level and secondary data at the macro level to examine hypothesis 7 in Chap. 1 above concerning the importance/impacts of tacit and codified sources of knowledge at the micro and macro levels respectively in Sudan. Our results prove this hypothesis and show that at the macro level tacit knowledge and codified sources of knowledge are positively and significantly correlated with both schooling years and GDP growth (economic growth rate). Moreover, we find that at the macro level codified knowledge and the number of FTER show positive correlations with technology (patents). Furthermore, at the aggregate level, our results imply a significant positive complementary relationship between the number of FTER and codified knowledge, which we interpret as a complementary relationship between tacit knowledge and codified knowledge. At the micro (firm) level, we illustrate the importance of tacit knowledge, which shows positive significant correlations with technology (expenditures on ICT) and upskilling (expenditures on training), output (defined by total sale value), output diversification, productivity and profit. Finally, we find that at the micro (firm) level, tacit and codified knowledge show positive significant correlations with total investment, capital, and firm size. This can be interpreted that higher levels of total investment, capital and firm size would correspond to more tacit and codified sources of knowledge across firms. Our results at the micro and macro levels verify the four stylised facts presented in the introduction, which are consistent with the general findings in the knowledge literature. The major implication of our findings is that knowledge shows positive significant correlations with many variables at both the micro and macro levels. Therefore, this would imply that public policy should provide further incentives to improve tacit and codified sources of knowledge at both the macro and micro levels. Another implication is that the positive impact of tacit knowledge also underlines the importance of good education, since tacit knowledge is often embodied in educated people and thus human capital. Moreover, from the perspective of the new growth literature, the positive correlation between tacit knowledge and output is important to prevent the diminishing returns to scale and to ensure the increasing returns and dynamic growth in the production function. This would imply that with the assumption of a potential role for public policies, governments could prevent the diminishing returns to scale and ensure increasing returns to scale, mainly through improving tacit knowledge by stimulating investment in education (basic, secondary and tertiary). In addition, at the aggregate/macro level, the positive correlation between GDP and codified knowledge -the share of public spending on education, R&D, training and ICT relative to GDP - would imply a positive role for public policy to support codified knowledge by increasing spending on education, R&D and ICT. These results are consistent with the literature that substantiate the role of public policies to support the creation and accumulation of knowledge, as we explained in Sect. 3.2 of this chapter and Sect. 3.5 in Chap. 3 above. In addition, at the micro level, our findings on the positive correlation between tacit and codified sources of knowledge, output and firms performance would imply that with the assumption of a potential role for private industrial policies, private industrial firms could prevent the diminishing returns to scale and ensure increasing returns to scale, mainly through improving codified sources of knowledge by stimulating investment in ICT, R&D, training, the use of technology and machinery.

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