Human Capital and Systems of Innovation in African Development

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Abstract: In this paper we propose that historically generated institutions and persistent pattern of human capital formation condition the emergent systems of innovation in Africa. These factors determine the development path of the region. We advance the notion of dynamic and non-dynamic systems of innovation, the latter describing the African condition. We combine the strands of literature on institutions and their persistence in shaping development with evolutionary theory and systems of innovation. Evidence is presented on the colonial origins of skewed schooling enrolment, at variance with the industrialization objective of modern economies. Employing simple statistical tests, the persistence of initial human capital (school enrolment) reflects in the significant correlation among the three levels of schooling enrolments, and correlation of enrolment in 1970 with per capita income in 2000, a periodicity of some three decades. This outcome is consistent with the literature on countries at early stages of development. Path-dependency is partially proved even though we did not attempt to investigate all variables making up the system of innovation. This is a first tentative attempt to explore long-run development in Africa within the systems of innovation framework.

Résumé: Dans cet article, nous proposons que les institutions historiques et le schéma constant de formation du capital humain soient utilisés pour influer sur les systèmes émergents d'innovation en Afrique. Ces facteurs déterminent le chemin du développement de la région. Nous avançons la notion de systèmes d'innovation dynamiques et non dynamiques, ce dernier type décrivant la situation africaine. Nous avons combiné la tendance des publications sur les institutions et leur persistance à concevoir le développement selon la théorie évolutive et les systèmes d'innovation. Des preuves sont fournies sur l'origine coloniale de l'asymétrie de la scolarisation, ce qui est en porte-à-faux avec l'objectif d'industrialisation des économies modernes. Sur la base de tests

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statistiques simples, on constate que la persistance du type de capital humain initial (scolarisation) se reflète dans l'étroite corrélation entre les trois niveaux d'enseignement, et dans la corrélation entre la scolarisation en 1970 et le revenu par habitant de 2000, soit une périodicité de trois décennies. Ce constat est en phase avec les publications sur les pays dans les premières phases du développement. La dépendance par rapportau chemin déjà tracé est partiellement prouvée, même si notre objectif n'était pas d'analyser toutes les variables qui forment le système d'innovation. Il s'agit d'un tout premier essai visant à explorer le développement à long terme de l'Afrique dans le cadre des systèmes d'innovation.

1. Introduction

This paper explores the human capital root of the slow pace of development in Africa within the system of innovation (SI) framework. We propose that historically generated institutions and persistent pattern of human capital formation condition emergent systems of innovation, and effectively determine the development trajectory of African countries. As Rodrik (1998, p. 5) observed, 'the way to reverse the trend (poor growth) is not to target the region's trade volume per se, but to raise overall growth rate'. For the relatively well performing African countries, Rodrik like others identified human resources and institutions as important predictors of growth.[1] We therefore argue that a fruitful way of understanding the African condition is an exploration of these growth predictors within the evolutionary technological change tradition pioneered and elaborated on by researchers including Freeman (1987), Nelson and Winter (1982), Rosenberg (1986) and Dosi *et al.* (1988).

Several explanations have been advanced to explain Africa's dismal economic performance. They range from policy-related issues (e.g., World Bank, 1981); structural and institutional factors (e.g., Easterly and Levine, 1997; Sachs and Warner, 1997); the paucity of technological and managerial capabilities which result in the failure to effectively transfer technology and the under-utilization of human and physical resources (Enos, 1992; Lall, 1992, 1993); and the long-term effects of historical factors (Engerman and Sokoloff, 2000). While these factors explain parts of Africa's growth problems, a systemic explanation of the nature of institutions in long-run development is still lacking. Africa is far from having uniform initial conditions and varies widely in economic and political governance systems. Thus, cross-country analysis tends to hide the considerable intra-regional variations, particularly the significant influences of specific national systems. This paper therefore calls attention to the role of institutions

broadly, and specifically, systems of innovation supporting technological advance in long-term industrialization. In doing this, we combine the strand of literature on institutions and their persistence in shaping development with the literature on evolutionary theory and systems of innovation. The role of initial conditions such as levels of literacy and natural endowment, the structure of industry, as well as resource endowment have been emphasized (Sandberg, 1982; Abramovitz and David, 1994).

Considerable work has been done on the role of human capital in economic growth, from classical writers (Schultz, 1961; Denison, 1985); to others who link technological progress to human capital (Romer, 1990; Lucas, 1990). According to Lucas (1990), poor technology flow to poor countries is a result of poor human capital endowment. A number of scholars have also examined other dimensions of human capital, particularly the educational rates of return for a host of countries (Mincer, 1998; Cohn and Addison, 1998; Psacharopoulos, 1994). The two broad conclusions from this wealth of empirical studies are that the presence of large stocks of human skills tends to boost economic growth, and investment in schooling is an important prerequisite for effective human capital. This kind of emphasis on the explicit link between human capital and economic growth is lacking in the SI framework. Given its pivotal importance, the question is why there has been so little consideration of the issue.

The unique contribution of this paper is its emphasis on human capital and institutions in shaping the evolution of the systems of innovation in Africa. This first tentative attempt to explore long-run development in Africa within the SI framework therefore follows the line of inquiry suggested by Lundvall *et al.* (2002). According to the authors, 'a principal task for future research based on the concept of national systems of innovation is to adapt it in such a way that its application in less developed countries... helps to stimulate policy learning. We will argue that a major step in this direction is to broaden and deepen the concept and make it more dynamic' (p. 225).

The paper is organized as follows. The next section reviews the role of education and human capital in development, and the institutional origins of Africa's present systems of innovation. Section 3 analyses the formation of human capital over time in Africa. Section 4 presents empirical tests of the link between human capital and elements of systems of innovation, followed by a concluding section.

2. Education, Human Capital and Economic Development

Schooling, according to human capital theory, is viewed as an investment that directly enhances the productivity of workers (Wolff, 2001). However, an educated workforce without the necessary prerequisites of

investment, training, research and development (R&D) and, 'a receptive political structure and low population growth may not lead to growth'.[2] Wolff (2001, p. 736) ascribes the relatively weak performance of less developed countries to their 'failure to keep up with, absorb and utilize new technological and product information, and to benefit from international dissemination of technology'. In other words, underdeveloped areas perform poorly as a result of underdeveloped systems of innovation, which fail to absorb, diffuse and adapt by imitation, available process and product innovation.

Several scholars (Easterlin, 1981; Sandberg, 1982) have identified factors that played a critical role on technological change and development of innovation systems. The first is the role of formal schooling. There seems to be a direct correlation between schooling of the appropriate content and a country's ability to master new technologies (e.g., Easterlin, 1981). Empirical justification for this consists of the high literacy rates in Western Europe and North America from 1850, and the virtual absence of mass literacy in countries outside these regions.

Secondly, the combined rate of technology and human capital, the latter transmitted through educational attainment, are seen to be ultimately connected. Thirdly, the pre-existing supply of human capital with a different mix of skills at the onset of the industrialization process is an important prerequisite for rapid growth. As Sandberg (1982, p. 2) notes:

> 'A country with a pre-existing disproportionally large support of human capital can concentrate relatively more heavily on the accumulation of physical capital than a country that started with relatively small supplies of human capital'.

This factor is vitally important for latecomer countries starting from a very low or non-existing base of technical skills and managerial capabilities. The efforts to accumulate both physical technological capitals simultaneously with human capital starting from basic education to industrial skills could be enormous, and may well prove daunting for poor countries. Further, low levels of human capital will tend to slow down the rate of income growth. This is so because in addition to contributing directly to skill formation, high literacy rates tend to be correlated with the growth of financial services and formal banking systems, all of which have important implications for industrialization (Gerschenkron, 1962).

The relevant questions relating to the non-dynamic systems of innovation and limited human capital development in Africa are thus: what explains the relatively difficult process of implanting science and technology institutions in Africa? How do initial conditions pattern the growth of technology in building up national systems in Africa? In what ways do the pattern of educational development influence the evolution of industrialization and in doing so, contribute to the observed structure of the national systems in Africa?

We hypothesize that the initial shallow base of human capital as well as the nature of institutions inherited by African states are responsible for the current level of development of the national system of innovation. We test this hypothesis by taking per capita income growth as indicative of economic progress since a weak system of innovation will be unable to support rapid growth, resulting from dynamic technical change.

2.1 The Systems of Innovation Approach

The 'systems' approach is based on the notion that innovations by enterprises, be they technical or organizational, take place within a complex interaction of actors in a particular national, sectoral or regional context. At a very narrow level, interactions between firms and other support institutions, as well as customers and suppliers, is a requirement for collective learning. At a much broader level, the behaviour of productive actors such as firms, universities and research organizations are shaped by cultural, economic and political factors, that are in turn conditioned by historical forces (Lundvall, 1992). Three key concepts underpin the notion of SI as defined by Lundvall, and they are: interactive learning, organized markets and institutions. He provides a formal definition of SI as follows: 'A system of innovation is constituted by elements and relationships which interact in the production, diffusion, and use of new and economically useful, knowledge . . . a national system encompasses elements and relationships, either located within or rooted inside the borders of a national state' (Lundvall, 1992, p. 2). The SI concept is relevant to the African context because countries have a wide array of knowledge generating institutions (universities, research institutes and so on); they have developed institutions supporting innovations such as patent offices, laws for intellectual property rights (IPRs). More importantly, all societies, no matter how far back on the technological ladder, possess endogenous knowledge systems, a central requirement for innovative activities.

2.2 Institutional Origins of Systems of Innovation

Institutions are conceptualized narrowly or broadly[3] but in both contexts they take on the functions of the management of uncertainty, the provision of information, the management of conflicts, and the promotion of trust among groups (Edquist, 1997; North *et al.*, 1989).[4] Institutions are necessary for innovation for two reasons. First, is the uncertainty that characterizes innovative activities. Institutions act to provide stability and to regulate the actions of agents, and to enforce contractual obligations.

Second, learning and knowledge creation, validation, and distribution are prerequisites of modern economic change mediated by institutions as organizations (R&D laboratories, finance and investment institutions) and as rules, such as intellectual property rights, patent laws and so on. In this study, we employ the broader concept of institutions in addition to locating institutions within a historical context, which admits the evolution of institutions themselves (David, 1994; Zysman, 1994). Coriat and Dosi (1998) called attention to another set of issues in understanding institutional evolution. First, is the origin of the institutions, and the need to explain institutions that preceded them and the mechanisms that led to the transition. Secondly, is what they refer to as the degrees of intentionality of institutional constructions. In other words, whether institution arose out of a *self-organizational* process or derived from a collective *constitutional* process. Third and last is the concern for institutional efficiency. The point is whether institutions are merely 'carriers of history' in the sense of David (1994) and simply 'path-dependently reproducing themselves well beyond the time of their usefulness (if they ever had one)' (Coriat and Dosi, 1998, p. 7). Clark (2000) gave examples of Africa's higher education institutions established at a time for a purpose far different to what the current objectives of Africa's development presently demand. The founding initial objectives persist while the developmental requirements have radically changed and this constrains organizational effectiveness.

3. Path Dependence in Africa's Human Capital Formation

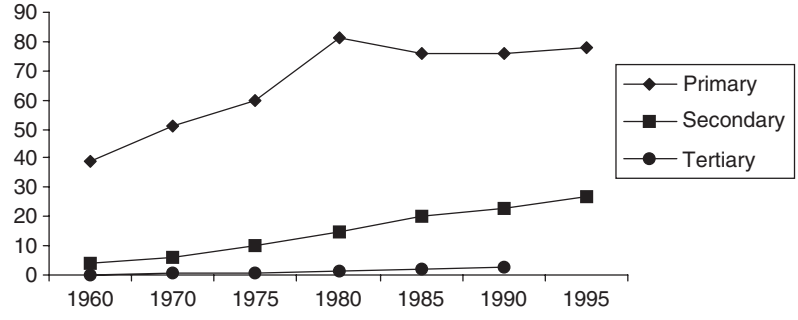
One of the key factors behind the phenomenal economic success of latecomers such as the South-East Asian economies, was their emphasis on human capital formation and a dynamic system of innovation. These countries, employing a mix of selective and functional policies, developed an education structure that effectively provided the requisite skills for their industrialization initiative. Public spending was concentrated on primary and secondary education while the demand for tertiary education was primarily financed by the private sector. Public spending at the tertiary level focused on science and technology education, while the humanities and social sciences were privately funded. The governments, to varying degrees, intervened in curriculum development to ensure that it was compatible with the needs of their evolving industrial policy. To this end, they *inter alia* encouraged private sector involvement in universities. Additionally, some countries, notably Singapore, imported expatriate skills where domestic capabilities were limited (e.g., Lall, 1992; Page, 1994).

By contrast, the current educational structure in Africa has been described as being 'unsuitable for industrialization' (quoted in Lall, 1992, p. 119). Several reasons have been advanced to explain this. First, some researchers argue that the present education system in Africa is a legacy of colonialism (e.g., Blakemore and Cooksey, 1982). It seems that the metropolitan powers implemented a highly academic, subject-centred curriculum in Africa. This curriculum, with its focus on producing an academic elite, was largely irrelevant to Africa's development needs. The colonial governments also unsuccessfully attempted to introduce technical and vocational schools. However, African societies, partly influenced by the colonial elite, regarded academic education as the sole means of social and economic mobility.

Only a privileged minority benefited from this elite education. In 1960, the gross primary enrolment in all of sub-Saharan Africa was a mere 36 per cent. This was roughly half the levels found in Latin America (73 per cent) and Asia (67 per cent) (World Bank, 1988). In an attempt at social control, access to education was deliberately limited, particularly secondary education, among the Africans. According to Lord Lugard, the expansion of missionary schools in southern Nigeria 'seems to have produced discontent, impatience of any control and an unjust assumption of self-importance in the individual' (quoted in Blakemore and Cooksey, 1982, p. 37). Indeed, academic education was conceived not as a means of industrializing the countries but rather creating an elite supply of white-collar African workers for the administration of the colonies.

African governments sought to remedy this situation in the post-independence era. As Figure 1 demonstrates, performance has been impressive. Within two decades, the gross primary enrolment ratio[5] tripled from 39 per cent in 1960 to an astounding 81 per cent in 1980. This ratio subsequently declined by 8 per cent in 1999. However, gross

Figure 1: Gross enrolment ratios in Africa, 1960–95

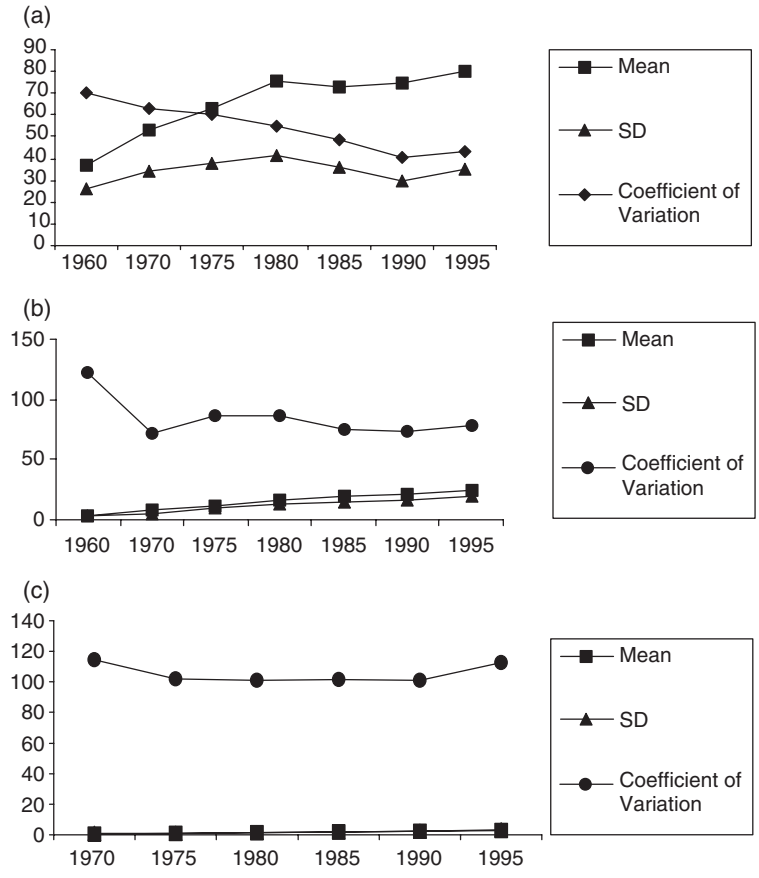


Source: World Development Indicators (CD-ROM)

secondary and tertiary enrolment steadily increased during the period reviewed. Secondary enrolment ratios rose six-fold during the years 1960–95, while tertiary enrolment ratios increased seven-fold during the years 1960–90.

Trends in enrolment are statistically tested by means of *t*-test, standard deviation, and coefficient of variations. The *t*-test is used to test the null hypothesis that the mean value of enrolment does not vary significantly. The hypothesis is rejected if the level of significance is less than 0.10. Standard deviation and coefficient of variation, on the other hand, are measures of dispersion. Enrolment levels vary considerably at the three levels, with the largest variation found at the tertiary level and smallest at the primary level. Figure 2 shows the mean, standard deviation and the

Figure 2: Mean, standard deviation and coefficient of variation for (a) primary education; (b) secondary education; (c) tertiary education



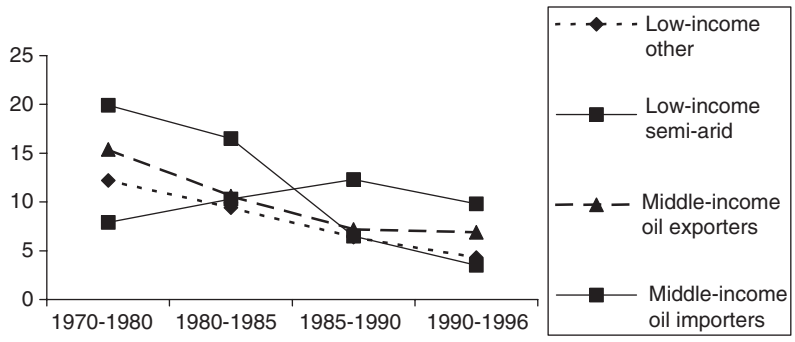
coefficient of variation of the enrolment ratios at the primary, secondary and tertiary levels. The last variable, the coefficient of variation, is a relative measure of variation and can thus be expressed in percentages or ratios. The analysis of the data for primary education reveals that the standard deviation rose for the period 1960–80, declined over the next ten years before rising again, while the coefficient of variation declined over the period 1960–90, showing a tendency of a rising mean enrolment. For both secondary and tertiary enrolment, standard deviation rose over the whole period, with the coefficient of variation for secondary enrolment first declining sharply in the first ten years, then rising and assuming a steady but slight decline between 1970 and 1990, again showing a steady rise in mean enrolment. Changes at the tertiary level were not as significant, however.

The average annual growth rates in school enrolment vary widely among different groups of African countries. The rate in primary education declined in the post-1990 period for only the middle-income, oil exporting countries such as Angola and Cameroon, and the middle-income, oil importers including Botswana and Senegal. The former group saw average annual growth rates slip from 19 per cent in 1985 to 1990, to 0.1 per cent in 1990 to 1996. Moreover, it was only these two groups that experienced a decline in the average annual growth rates in secondary education. The middle-income oil importers saw average annual growth rates in secondary education decline from 7.2 per cent in 1985 to 1990, to 5.2 per cent in 1990 to 1996. However, all of these countries experienced sharp falls in the average annual growth rates of tertiary education (see Figure 3).

This period also witnessed considerable fluctuations in public expenditure on education. This variable slightly declined during 1970 to 1975, recovered in 1980, but dropped dramatically to half of its 1970 value in 1996 (see Figure 4). Data on public education expenditure reveals wide variations among African countries. For example, low-income countries such as Benin, Ghana and Kenya, experienced the greatest decline in public expenditure on education: government expenditure on education as a proportion of total expenditure precipitously fell in two decades from 16 per cent in 1970 to 12 per cent in 1990. It was only in 1995 that government spending on education was restored to 1970 levels. Other groups of African countries also experienced fluctuations in public expenditure on education. Most experienced steep declines in spending in 1985 with some recovery in 1995.

Since education is generally publicly financed in Africa, it is subject to the availability of government revenues, many of which are heavily dependent on primary commodity exports. Nonetheless, the severe economic decline experienced in Africa in the 1980s adversely affected

Figure 3: Average annual growth rate (%) in tertiary education

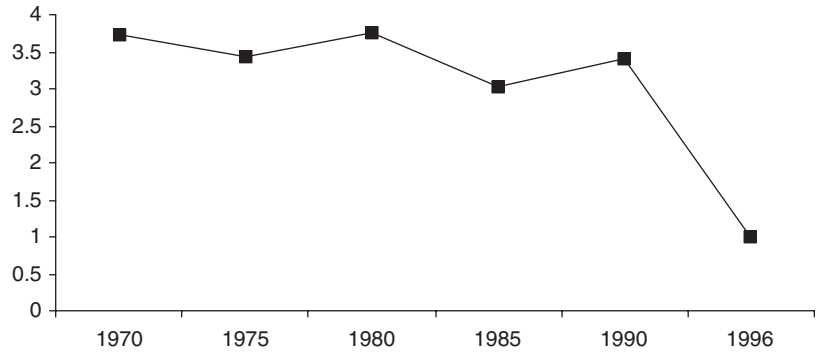


Notes: 'Low-income, other' countries inlude Benin, Burundi, Central African Republic, Comoros, the Democratic Republic of Congo, Equatorial Guinea, Eritrea, Ethiopia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mozambique, Nigeria, Rwanda, Sao Tome, Sierra Leone, Sudan, Tanzania, Togo, Uganda, Zambia.
'Low-income, semi-arid' countries include Burkina Faso, Chad, Gambia, Mail, Mauritania, Niger, Somalia.
'Middle-income oil exporters' include Angola, Cameroon, Congo, Gabon.
'Middle-income oil importers' include Botswana, Cape Verde, Côte d'Ivoire, Djibouti, Mauritius, Namibia, Senegal, Seychelles, South Africa, Swaziland, Zimbabwe
Source: ADEA, Statistical Profile of Education in Sub-Saharan Africa, 1999

government spending on education. The interaction between economic decline and the continued high rates of population growth in Africa has negatively affected primary school enrolment. It seems that the resources available for primary education were unable to keep up with the population growth. It was difficult for governments to provide the number of school places that was needed to maintain enrolment rates at past levels. Declining household income and a possible reduction in the demand for education also compounded the situation by some households (World Bank, 1988; Colclough and Al-Samarrai, 2000).

While African governments have recorded substantial progress in educational attainment, however, they have made very little changes in the structure of the education system from what had existed during the colonial era. King (1991) suggests that African policymakers had very little influence over the development of their education systems. The education system, specifically at tertiary level, produces an inappropriate mix of skills. African institutions of higher education presently enrol 60 per cent of students in the arts and humanities, and 40 per cent in science and engineering. Enrolment in technical subjects presently lags behind that of other regions. While in 1995, only 0.04 per cent of persons as a percentage of the population were enrolled in technical subjects such as engineering and mathematics, the figure for the four Asian Tigers was

Figure 4: Public expenditure on education as a percentage of GDP, 1970–96

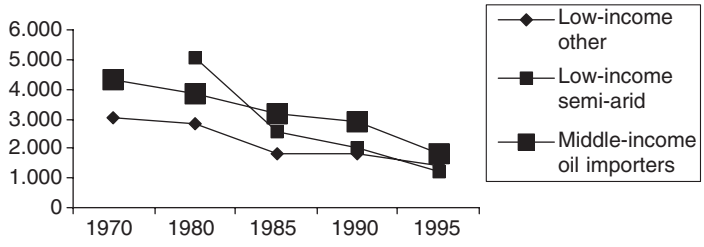


Source: ADEA, Statistical Profile of Education in Sub-Saharan African, 1999

1.34 per cent (Lall, 2001). In a set of technical enrolment indexes constructed by Harbison_Myers,[6] while Norway ranked first with 73.52, South Africa, the most industrialized country in sub-Saharan Africa (SSA) had a total of 23.61, Nigeria, 5.85 (less than 9 per cent of the Norwegian figure), while most SSA countries ranged from 1 to 5. However, this skill mix has remained unchanged for the past four decades despite the declining demand for arts and humanities graduates, and the rising and unfulfilled demand for science and engineering graduates (World Bank, 1988; Fabayo, 1996).

The situation is compounded by the quality of education offered in Africa, which is said to be well below world standards. Education standards are increasingly becoming poor with the gap in achievement between African students and those in industrialized countries 'widening to unbridgeable proportions' (Clark, 2000, p. 82). Over time, the student/teacher ratios at the primary and secondary schools have steadily increased in the post-1990 period especially for low-income, semi-arid countries such as Gambia and Chad, as well as middle-income, oil importers such as Botswana and Zimbabwe. In addition, there has been a drastic decline in the quality of physical inputs (e.g., African staff, especially at the senior levels, and learning resources and facilities) that are essential for the successful operations of knowledge institutes. The declining quality of education is largely a result of constant budget cuts (since 1980) together with rapid increases in enrolment rates. Expenditure on tertiary education fared no better: spending per student dropped from US$5,054 in 1980 to US$1,185 in 1990 (see Figure 5).

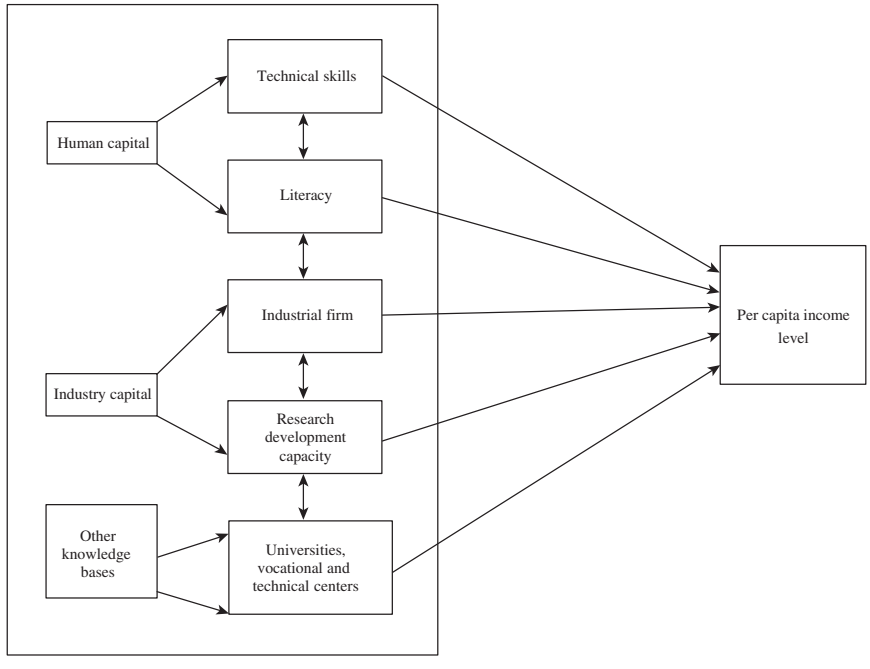
Figure 5: Government expenditure on tertiary education per student (constant 1990 US$)



Source: ADEA, Statistical Profile of Education in Sub-Saharan Africa, 1999

Moreover, firm-level training, which builds on knowledge acquired in the education system, is weak in Africa. Enterprises, with the exception of the major multinationals, invest very little in training. The apprenticeship system that exists in Africa is more geared to the development of traditional skills, which are of a very low level of technological sophistication (Lall, 1995).

Figure 6: Human capital variables in the system of innovation



4. Empirical Analysis of Systems of Innovation and Human Capital

In this section, we carry out statistical tests of human capital and systems of innovation using the variables identified in the study as being particularly strong predictors of national economic development. Figure 6 provides a simple diagrammatic representation for the test. While we employ enrolment rates, we are aware of their limitations in explaining growth of per capita income.[7] There is a generation lag between investment in education and economic growth, which we take account of in this exercise by using enrolment variables with a 20- and 30-year time lag.

4.1 Statistical Analysis of the Variables

Table 1 presents the descriptive statistics showing the mean and standard deviation for all the variables. The equation represented by Figure 1 is hypothesized to be in the following form:

$$\text{Log of per capita income } (LOGPCAP) = \text{f}(PRI70 + SEC70 + TERT70 + AGL90 + ILA90 + TECHSUB + RD96).$$

For other years tested we simply substitute the dates.

To obtain an overall picture of industrial capability, we divided the SSA countries into two groups (low and medium) using a median value of per capita income. Table 2 shows the mean values as well as the *t*-values and the *F*-statistic of performance variables for all the countries

Table 1: Descriptive statistics

	Mean	Standard Deviation
LOGPCAP	6.3970	0.9851
*PRI*70	57.2818	32.0868
*SEC*70	7.5182	4.6089
*TERT*70	0.4364	0.2976
*AGL*90	65.4545	23.0927
*ILA*90	11.0000	8.6487
TECHSUB	5.373E-02	4.675E-02
*RD*96	0.2622	0.4406

Notes: *PRI*70: Primary education gross enrolment ratio in 1970.
*SEC*70: Secondary education gross enrolment ratio in 1970.
*TERT*70: Tertiary education gross enrolment ratio in 1970.
*AGL*90: Percentage of labour force working in agriculture.
*ILA*90: Percentage of labour force working in industry.
TECHSUB: Technical subjects enrolments as a percentage of population in 1996.
*RD*96: Total R&D personnel per million in 1996.

Table 2: Mean values of variables in the 'low' and 'middle' income SSA countries

Variable	Mean (all)	Mean (Low)	Mean (Middle)	*t*-value	DF	*F*-statistic	Significance level
Per capita 2000	688.42 (972.15)	218.95 (64.54)	1157.90 (1213.8)	3.3672	36	11.3383	0.0018
*AGL*90	70.432 (19.292)	80.32 (11.82)	60.00 (20.40)	3.7325	35	13.9318	0.0007
*ILA*90	9.108 (8.306)	5.26 (3.33)	13.17 (10.02)	3.2559	35	10.6015	0.0025
*PRI*70	53.464 (33.214)	44.64 (24.49)	62.29 (38.81)	1.6316	34	2.6622	0.1120
*SEC*70	7.714 (5.696)	6.46 (3.77)	8.96 (7.07)	1.3676	36	1.8705	0.1799
TECHSUB	0.0336 (0.3333)	0.0159 (0.4179)	0.01513 (0.037)	3.837	36	14.7201	0.0005
*TERT*70	0.7541 (0.8557)	0.5797 (0.4179)	0.9290 (1.132)	1.0821	26	1.1709	0.2892

Note: Standard deviation in parentheses.

as well as that of the two groups of countries. Significance levels show the considerable differences between the two groups except for tertiary level enrolment in 1970, which shows no difference between low and middle-income countries. High levels of percentage of labour force working in agriculture tend to be associated with low per capita income, while Manufacturing value added (MVA) values show almost no association, implying little contribution to wealth except for a few countries, notably South Africa and Mauritius. Confirming our hypothesis, enrolment in primary education 30 years earlier is correlated with per capita income. Further tests are carried out employing Ordinary Least Squares (OLS).

We have preferred to use a standard production function form of regression model. As can be seen from Table 4, R^2 in all the models is very low. That explains the fact that education level is not the only factor that influenced income levels of respondents. And it is not possible to include other variables because of high correlation among independent variables. All variables were included in the first model, and two additional models were tested. The correlation matrix presented in Table 3 and Table 4 is a pooled regression of the education enrolments. There is high correlation among the variables, as shown in Table 3. From the table, *PRI*70, *ILA*90 display significant positive correlation with the dependent variable at 1 per cent and 5 per cent levels of significance. *SEC*70, and *TERT* display negative but non-significant correlation while *AGL*90 shows negative and significant correlation.

Table 3: Correlation of the three levels of enrolment

	Variables	*PRI*60	*PRI*70	*PRI*75	*PRI*85	*SEC*60	*SEC*70	*SEC*85	*TERT*75	*TERT*85	*TERT*95
Spearman's rho	*PRI*60	1.000									
		36									
	*PRI*70	0.872**	1.000								
		35	38								
	*PRI*75	0.835**	0.916**	1.000							
		35	37	38							
	*PRI*85	0.734**	0.859**	0.867**	1.000						
		32	35	34	35						
	*SEC*60	0.117	0.149	0.106	0.150	1.000					
		36	38	38	35	41					
	*SEC*70	−0.020	−0.223	−0.163	−0.210	0.371*	1.000				
		36	38	38	35	41	41				
	*SEC*85	0.620**	0.670**	0.709**	0.745**	0.123	−0.116	1.000			
		32	35	34	34	35	35	35			
	*TERT*75	0.595**	0.551**	0.499**	0.420*	0.242	0.216	0.715**	1.000		
		31	33	33	32	35	35	32	35		
	*TERT*85	0.422*	0.424*	0.387*	0.421*	0.112	0.169	0.736**	0.872**	1.000	
		29	31	30	30	32	32	30	31	32	
	*TERT*95	0.578**	0.593**	0.449*	0.515*	0.039	−0.184	0.759**	0.745**	0.798**	1.000
		23	25	25	23	27	27	23	24	23	27

** 1% level of significance (2-tailed).
* 5% level of significance (2-tailed).

Table 4: Pooled regression of the three levels of enrolment

Source	SS	Df	MS			
I.1 Tertiary						
Model residual	8.79785787	1	8.79785787	Number of obs = 61		
	48.0313897	59	0.81409135	F (1,59) = 10.81 Prob > F = 0.0017		
Total	56.8292475	60	0.947154126	R-squared = 0.1548		
				Adj. R-squared = 0.1405		
				Root MSE = 0.90227		
Logcap	Coefficient	Std. Err.	t	P > /t/	95% confidence interval	
Tertiary constant	0.1980261	0.060238	3.287	0.002	0.774901	0.318562
	5.512774	0.1746936	31.557	0.000	5.163212	5.862335
I.2 Primary						
Model residual	18.3359971	1	18.3359971	Number of obs = 72		
	40.6152439	70	0.58021777	F (1,70) = 31.60 Prob > F = 0.0000		
Total	58.951241	71	0.830299169	R-squared = 0.3110		
				Adj. R-squared = 0.3012		
				Root MSE = 0.76172		
Logcap	Coefficient	Std. Err.	t	P > /t/	95% confidence interval	
Primary constant	0.0045066	0.0008017	5.622	0.000	0.0029077	0.0061054
	5.109552	0.1745699	29.269	0.000	4.761383	5.457721
I.3 Secondary						
Model residual	12.8812523	1	12.8812523	Number of obs = 72		
	46.0699887	70	0.658142696	F (1,70) = 19.57 Prob > F = 0.0000		
Total	58.951241	71	0.830299169	R-squared = 0.2185		
				Adj. R-squared = 0.2073		
				Root MSE = 0.81126		
Logcap	Coefficient	Std. Err.	t	P > /t/	95% confidence interval	
Secondary constant	0.15553	0.0035156	4.424	0.000	0.0085414	0.225645
	5.492399	0.1410547	38.938	0.000	5.211075	5.773724

4.2 Correlation of the Three Levels of Enrolment

Correlation coefficients indicate tendencies rather than causation. In this exercise we examine the relationship of the three levels of enrolment. Additional enrolment variables eliminated by the model were used in the correlation. As Table 3 demonstrates, correlation coefficients are as high as 0.873 between *SEC*85 and *TERT*90, and also between *PRI*60 and *SEC*75, *SEC*85, and also between the like variables. One way of interpreting this might be that the higher the primary enrolment, the greater the demand for and provision of secondary education and as the latter increases, the pressure on tertiary enrolment increases. The reverse tendency may be said to hold, that is, the lower the primary enrolment rates, the less the tendency for secondary education provision and less so the pressure for university education. This finding implies that: *a low initial schools enrolment, and for that reason, a low level of initial human capital in African countries will tend to perpetuate a condition of illiteracy and beyond that, a level of human capital that is unable to sustain rapid accumulation of technological capability*. The persistence of initial human capital conditions may well be partially proved by this correlation, conditions which we suggest are likely to have a widespread impact throughout the system of innovation, thereby leading to the non-dynamic system of innovation that is pervasive throughout the region.

4.3 OLS Regression of Human Capital and Per Capita Income

Due to high correlation among some of the variables and the incidence of collinearity, we tested several models using the backward function on SPSS. Further, we separated the variables and used pooled regression for the enrolment data, since the data is both time series and cross-sectional. Table 4 shows the regression outputs.

The re-estimation resulted in models 2 to 3. Table 4 shows the pooled regression output with the three levels of enrolment as independent variables and per capita income, our indicator for economic development, as the dependent variable. Parameters of the models assume that enrolment in primary, secondary and tertiary education in 1960, 1970 and 1975 will be positively associated with per capita income in 1996 and that the three enrolment levels in 1960, 1970, 1975 and 1980 will influence per capita income in 2000. All these data have been included in our pooled regression estimations shown in Table 4. As Table 3 shows, these variables are highly correlated and cannot be used in a single model as explanatory variables.

This finding is consistent with Mironov (1990) and Sandberg (1982) that economic development is significantly correlated with society's human capital in a time lag of 20–30 years. Mironov suggests a periodicity of 20 years when there are no wars, and a longer period when society endures a war, leading to delayed development of about a decade. Our findings show that a time lag of 25–35 years exists between the initial investment in primary and secondary education. Tertiary level enrolment is also significant. They all appear in the pooled regression models.

We also performed OLS regression without the enrolment variables. *TECHSUB*, the percentage of the population enrolled in technical subjects (including engineering and technical subjects) turns out significant as a predictor of development, but the total R&D personnel was not significant. This means that development is positively associated with the growth of technical personnel while personnel in R&D make no contribution to income growth. This is intuitively correct as very little local R&D is carried out in Africa. However, technical personnel may be fully engaged in production, and maintenance functions but not with R&D. Firms within the SI in Africa are engaged in imitative product innovation that requires marginal investment in formal research other than quality assurance. On industrial skills, we equally found statistical significance with labour force in industrial but non-significance with agriculture labour force. This variable is indicative of a country's level of development. However, one may not read too much into this finding as the variable might have been subsumed by the other skills factors such as *TECHSUB* but it may also find consistency with the continuing poor contribution of agriculture to wealth creation in African economies. Read in conjunction with the contribution of technical personnel, our interpretation is that the economies of SSA do benefit from significant local but relatively low-level technological regime. Conversely, it may be argued that the lack of significance found for research and development personnel might be reflective of the immaturity of the region's industrialization initiatives, which cannot yet fully utilize the skills of tertiary graduates in research. This is symptomatic of the dissonance between the education system and the stage of industrialization in the region.

5. Conclusions

In this paper we advanced the proposition that the slow growth and development of African economies could be explained in part by poor human capital endowment. First, we have found that poor human capital formation could explain the lack of dynamism of the region's systems of innovation, institutions that underlie the adoption, diffusion and adapta-

tion of innovation. Secondly, institutions possess path-dependent characteristics influencing the growth rate of per capita incomes, our proxy for development. Thirdly, we conjecture that these path-dependent variables, codified loosely into the concept of systems of innovation, have institutional origins that have persistently had an impact on the evolution of African development. These variables include, among others, human capital, R&D system and industrial capacity. Fourthly, we follow the evolutionary technological change school in the notion that innovation is fundamentally shaped by social, historical, economic and political processes, outside the narrow domain of the firm, and the R&D system. In explaining human capital we used enrolments at several levels as proxies.

For these reasons, the nature of the state and its institutions (which are 'carriers of history') determine whether dynamic or non-dynamic learning systems of innovation emerge. We suggest that the colonial origin, and pattern of schools enrolment at the primary, secondary and tertiary levels gave form to the current low technological base of African industry. We provide evidence of the origin of skewed schooling enrolment that is at variance with industrialization objectives.

We did not attempt to test all variables pertinent to the SI due to poor systematic data over time. We have also not assumed undue causation as correlations simply imply tendencies. While we tested several models in arriving at these findings, we do not discount the possibility of finding other outcomes, particularly at lower levels of data disaggregation. We confine ourselves to one very important set of variables, school enrolment at the three levels over the last 40 years (1960–2000), as well as technical enrolment, labour force in agriculture and industry, and R&D as a percentage of population. We find statistical significance of the schooling variables, a very significant correlation of the three levels of schooling, suggesting a persistence of the initial enrolment and as such, its impact on the national system thenceforth. We also confirm the correlation of enrolment with per capita income (1960, 1970 and 1995 respectively) with a periodicity of some 25–35 years, consistent with the findings in the literature, with regions starting from low levels of technological development. This means that investment in education has an impact on national wealth, after a generation of some two decades or more. Path-dependence and persistence of initial condition may well be implied, as failure to invest in basic primary and secondary education at the minimum would foreclose the development of modern industry exemplified in the system of innovation. The specific form for individual countries is not indicated and our data relates largely to the aggregate of SSA countries.

However, considerable work remains in understanding the systemic origin of Africa's non-dynamic innovation systems, and research may

take several forms. First, we need to understand more specifically which are the key elements of SI that are the most influential and how much they contribute to building the SI. Secondly, we should seek an understanding of the nature of interactions, not only within the narrow domain specified for firms and industry, but also at a wider socio-economic level. For instance, how do we intensify interactions of economic actors and make them more effective? Thirdly, research should explore the specific ways in which the institutional origins of the SI influence development and what policies can mitigate the negative impacts that persist. Lastly, in a globalizing economy, research and policies would do well to understand better the disruptive influences of global agreements while accommodating latecomer countries in sub-Saharan Africa. African countries face the dilemma of integrating into a world economy of the 21st century with states and institutions that have changed little over time. Institutions developing human capital for both industry and the bureaucracy may need to be transformed to fulfil the needs of modernizing economies. The SI approach suggests that the skills and knowledge bases of seemingly unrelated components can be fruitfully brought together to promote development. Capacities outside the productive firm, for instance, may well be as crucial for firm growth as the capacities within. *As institutions and policies demonstrate persistent characteristics, African policymakers need to take a long-term view. Getting the institutions right is certainly more crucial than getting the prices right.*

Notes

1. See Easterly and Levine (1995, 1997) and Sachs and Warner (1997) among others. However, none of these studies work within the SI framework and none situate their analysis within the evolutionary technological change theory where emphasis is placed on institutions supporting innovative activities.
2. Studies by Griliches (1970), cited in Wolff (2001) estimated that increased school attainment contributed one-third of the Solow residual. Denison (1979) also estimated that 20 per cent of the growth in US national income per person between 1948 and 1973 is attributable to the educational levels of the labour force.
3. In a narrow sense, institutions correspond to organizations such as universities, technological service organizations, while in broad terms, it includes political context governed by constitutions and the rules regulating innovation activities.

4. Coriat and Dosi (1998) refer to the broad meaning of institutions as having three components which are: (a) formal organizations (ranging from firms to technical societies, trade unions, universities, and state agencies); (b) patterns of behaviour that are collectively shared (from routines to social conventions to ethical codes); and (c) negative norms and constraints (from moral prescriptions to formal laws).
5. Enrolment ratio is defined as the ratio of the number of persons enrolled in school to the population of the corresponding age group by educational level.
6. See Lall (2001). Technical enrolment index is tertiary enrolment (times 1000) plus tertiary enrolment in technical subjects (times 5000), both as a percentage of population.
7. Formal schooling is a superior measure of human capital stock compared to literacy, as Sandberg observes, due to the additional advantage of numeracy training in formal schooling, which may be missing from education outside the school system. In addition to Sandberg's evidence, we have other studies that found a good correlation between schooling and per capita income levels, for example, see Mironov (1990) and Nunez (1990). While Sandberg (1982) conclusively establish a strong correlation for literacy-on-income causation in a period of 120 years, the other studies show the strongest association in one generation, about 20–30 years.

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